ARK-A3001 Design of Structures_Basics

Design with Forces

Toni Kotnik

Professor of Design of Structures

Aalto University
Department of Architecture
Department of Civil Engineering

truss

distribution of forces in space

relation column-plate

structural design thinking

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Force Distribution

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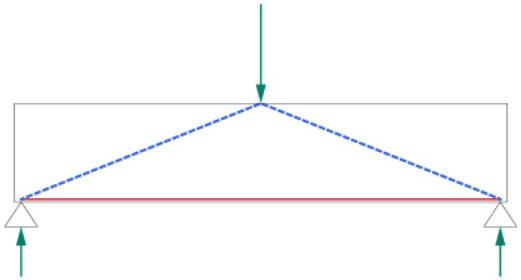
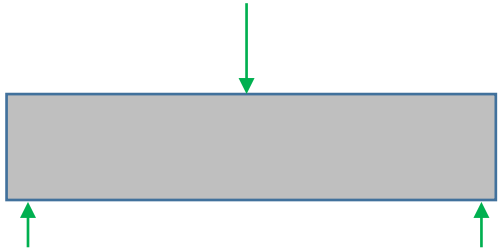
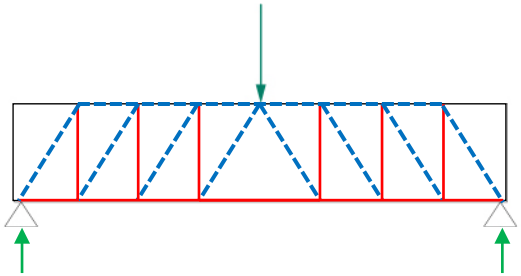
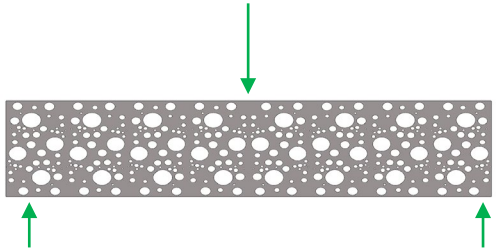
Design Freedom

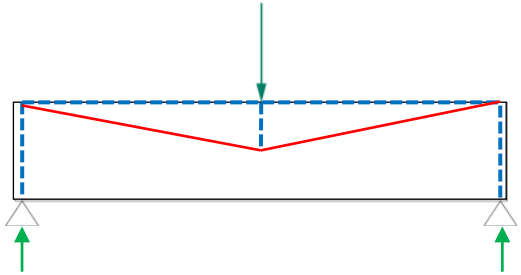


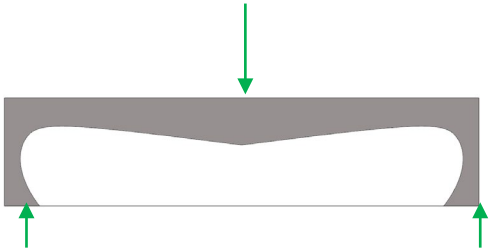


for a load condition many **different** correct **solutions** for the flow of inner forces are possible!









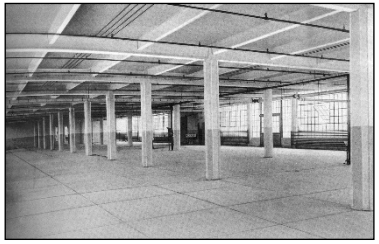
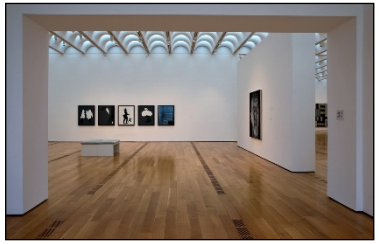
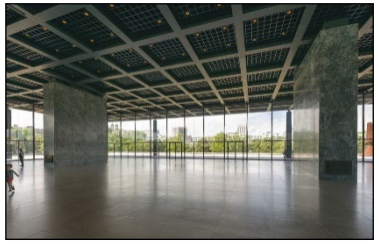
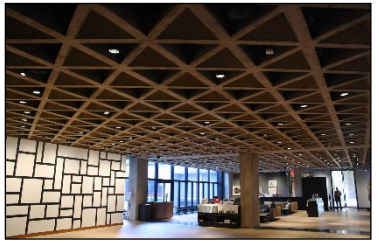
each distribution of inner forces can provoke a different design solution

Design Freedom

How 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

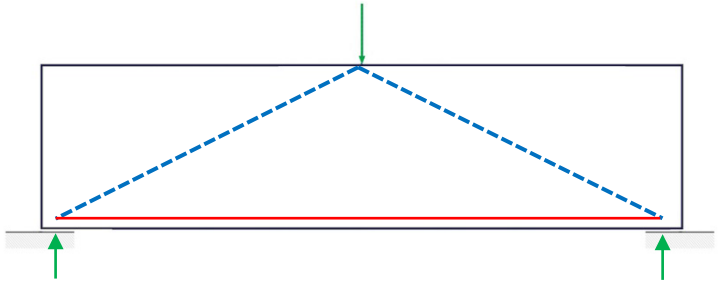
Gerkan, Marg & Partners: Airport
Stuttgart, Germany, 2004

Optimized Truss

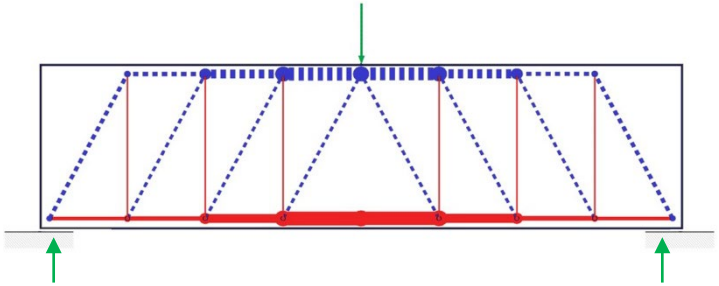
the load is transfered through the material into the support points

inner forces are forces inside the material produced by the load

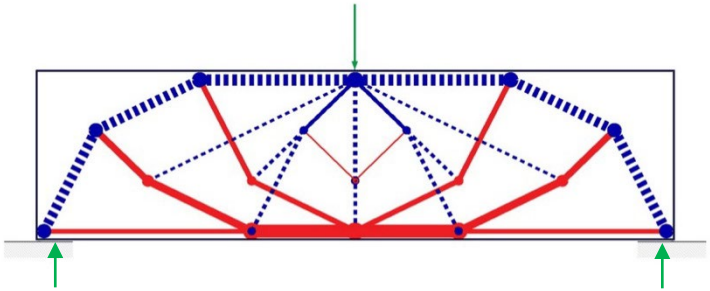
consequence: material is needed only where inner forces are flowing



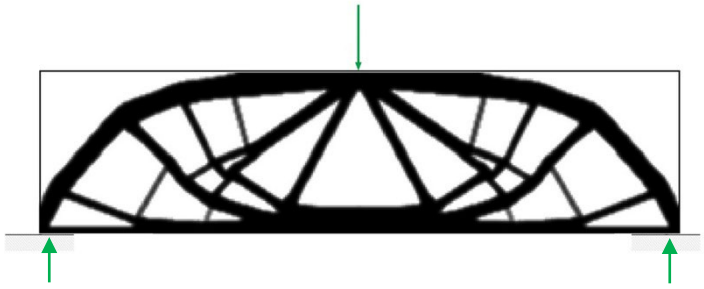
inner flow in beam



inscribed truss



optimized inscribed truss



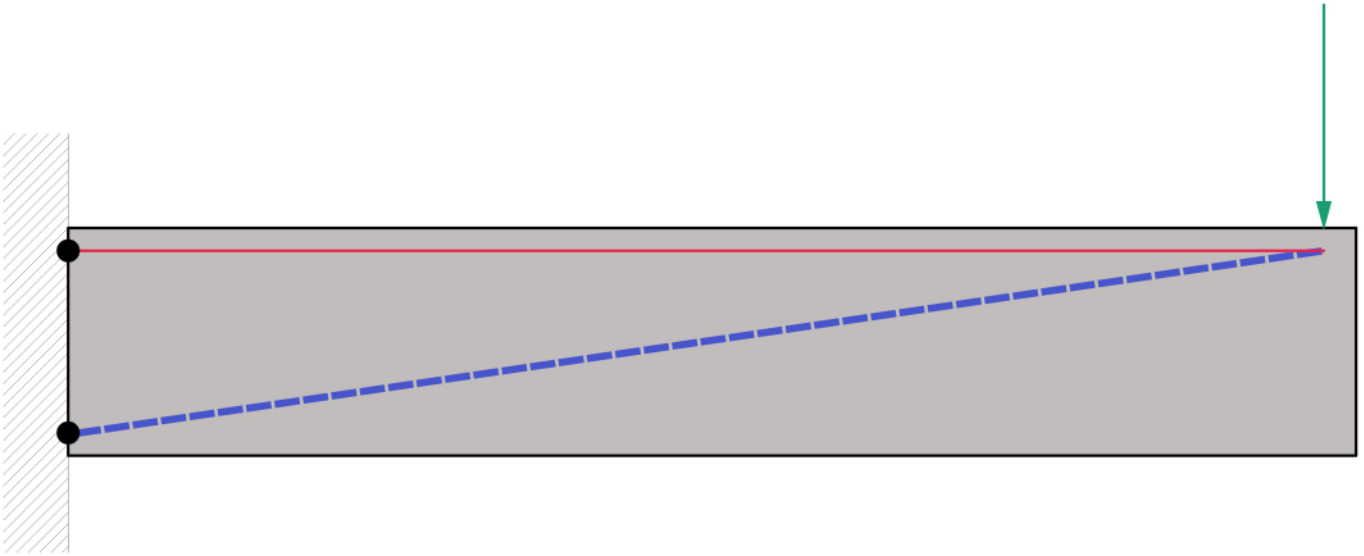
optimized truss structure

topologically optimized anchor point

Shaping of Elements

the load is transfered through the material into the support points

inner forces are forces inside the material produced by the load



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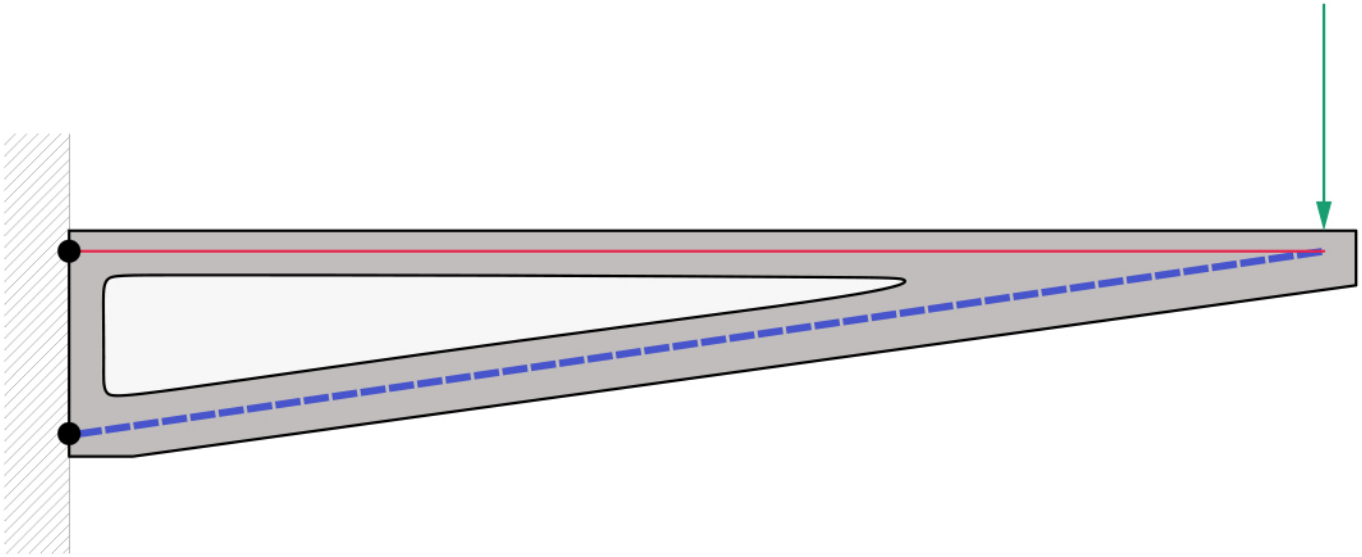
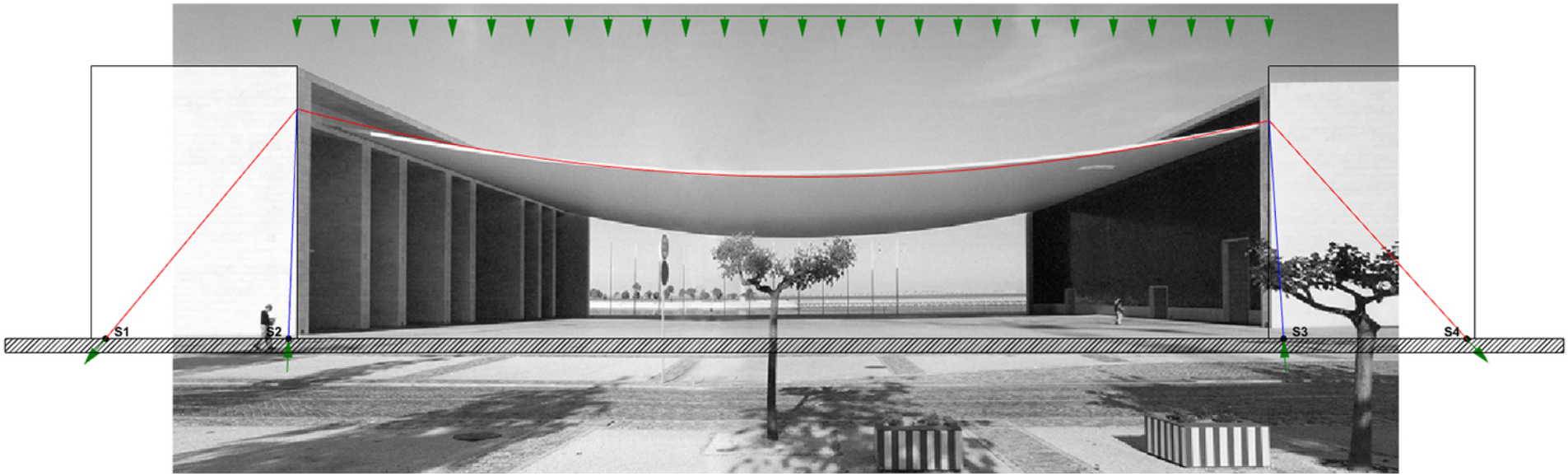


Shaping of Elements

Norman Foster: Maggie's Cancer Center
Manchester, UK, 2016

Shaping of Elements

Shaping of Structures

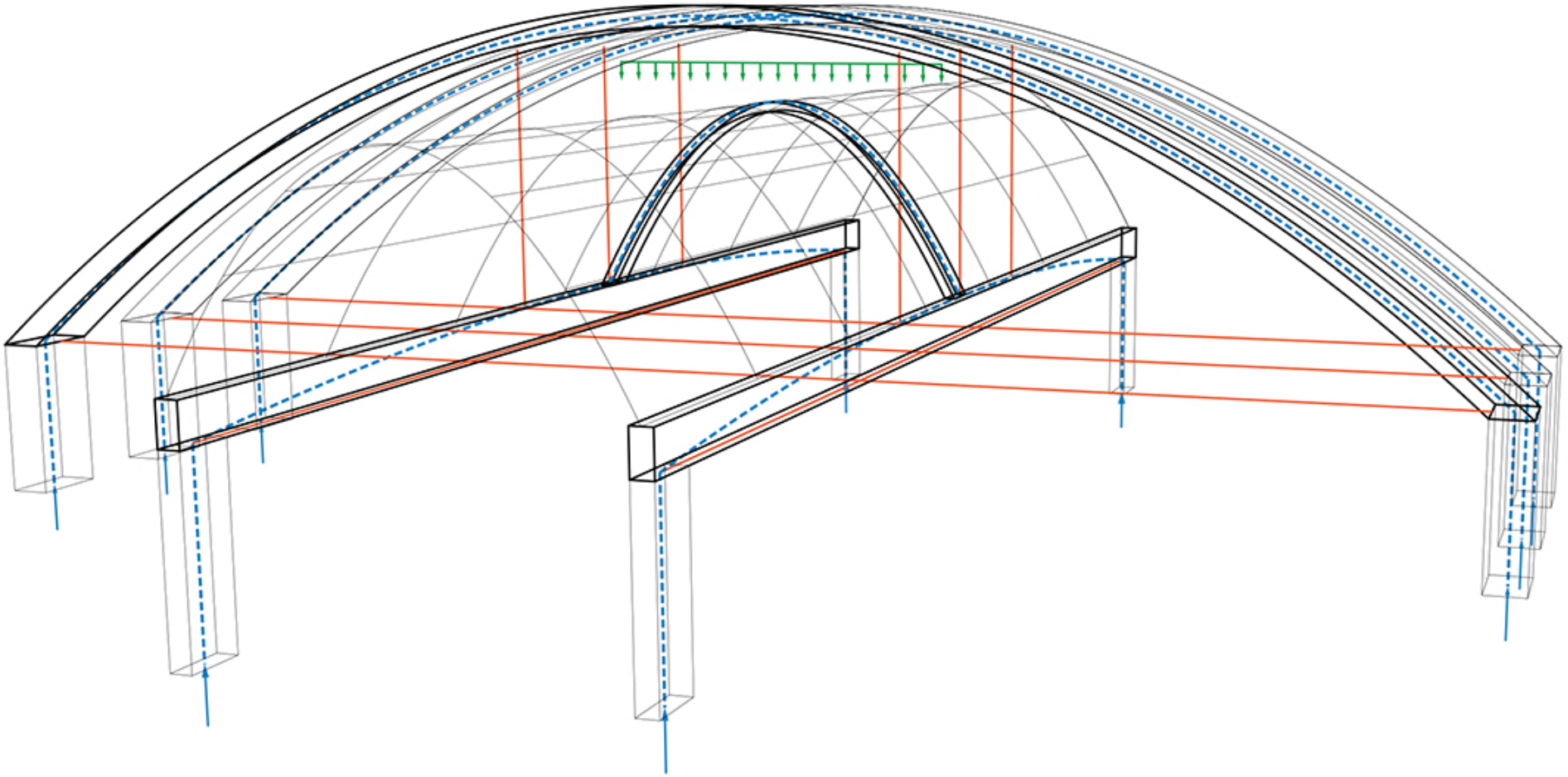


Alvaro Siza: Expo-Pavilion
Lisbon, Portugal, 1998

Shaping of Structures

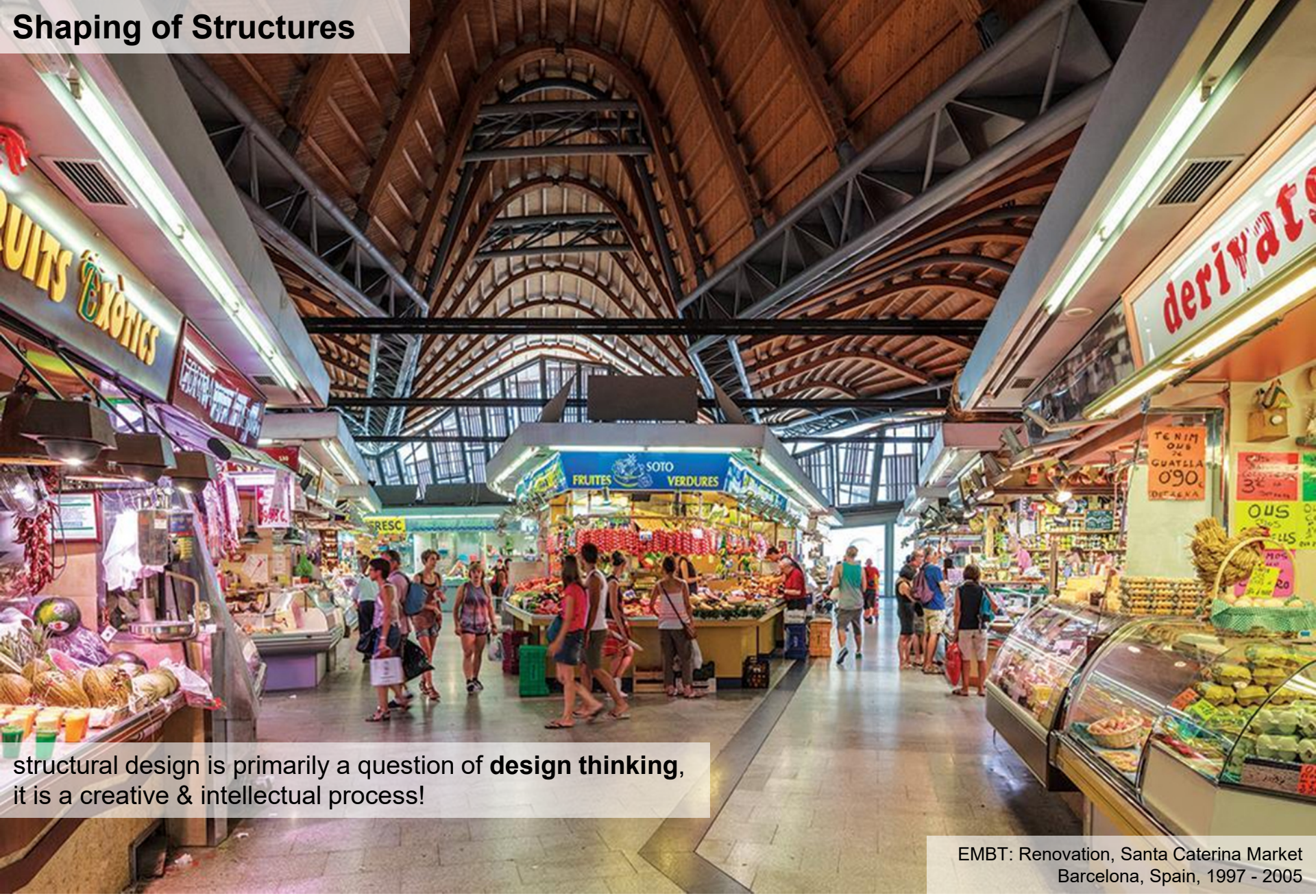
EMBT: Renovation, Santa Caterina Market
Barcelona, Spain, 1997 - 2005

Shaping of Structures



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

Shaping of Structures



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

Sverre Fehn: Nordic Pavilion
Venice, Italy, 1962

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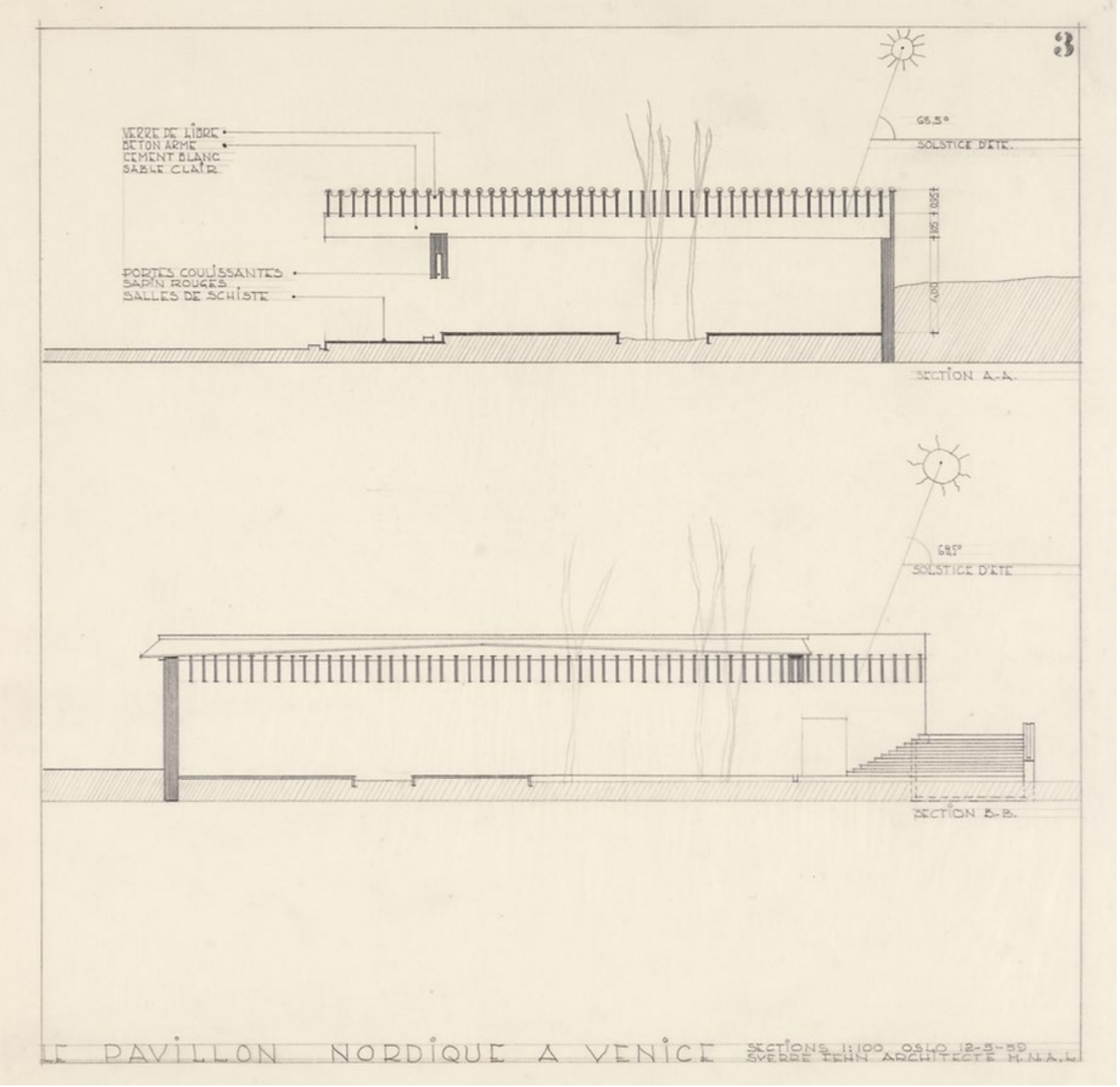
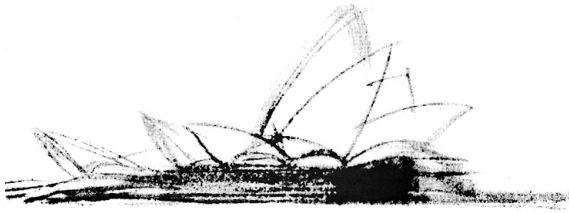


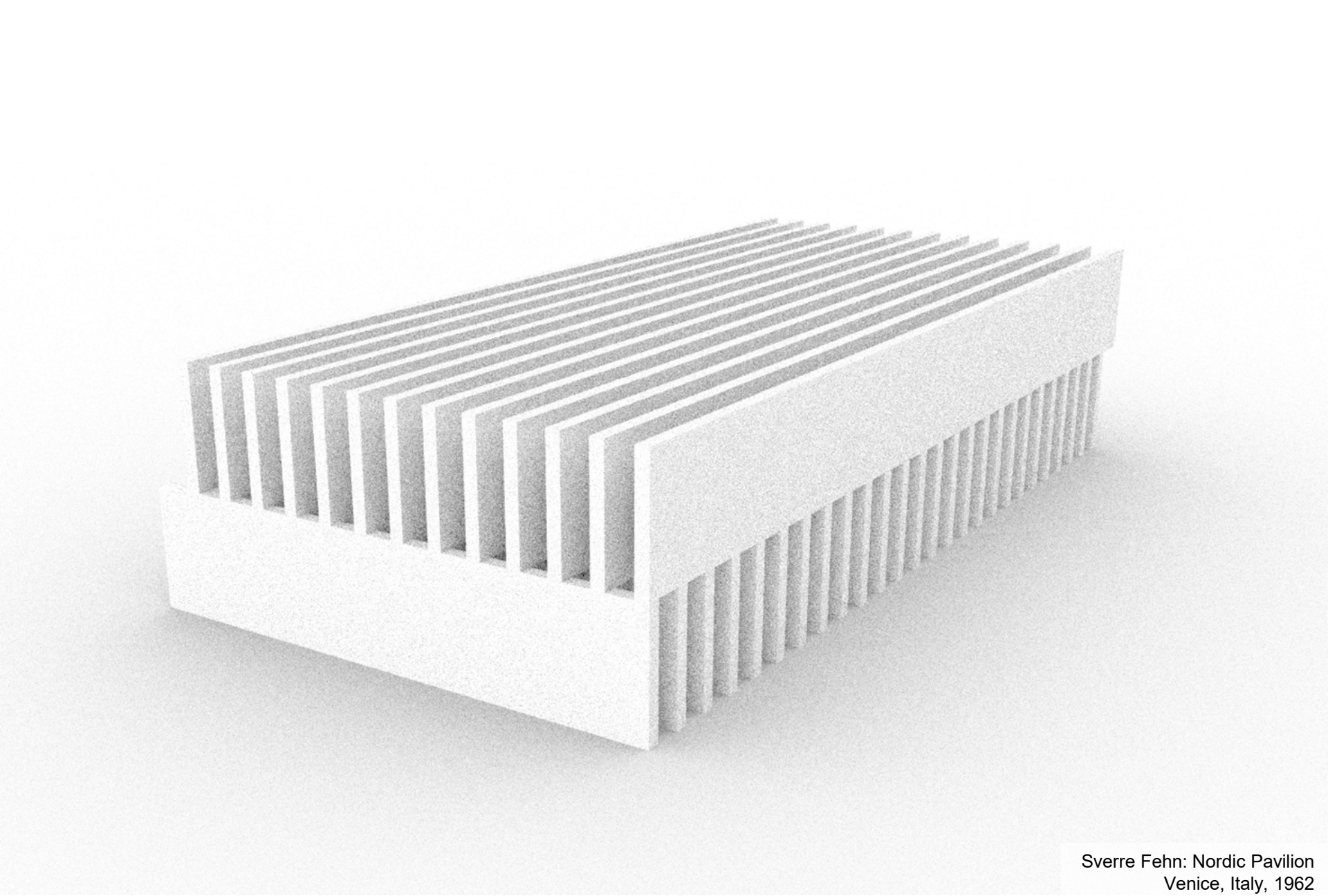
Jørn Utzon: pagoda
sketch, 1962



Jørn Utzon: Sydney Opera
sketch, 1959

Alvar Aalto: Maison Louis Carré
model, 1962

Sverre Fehn: Nordic Pavilion
Venice, Italy, 1962



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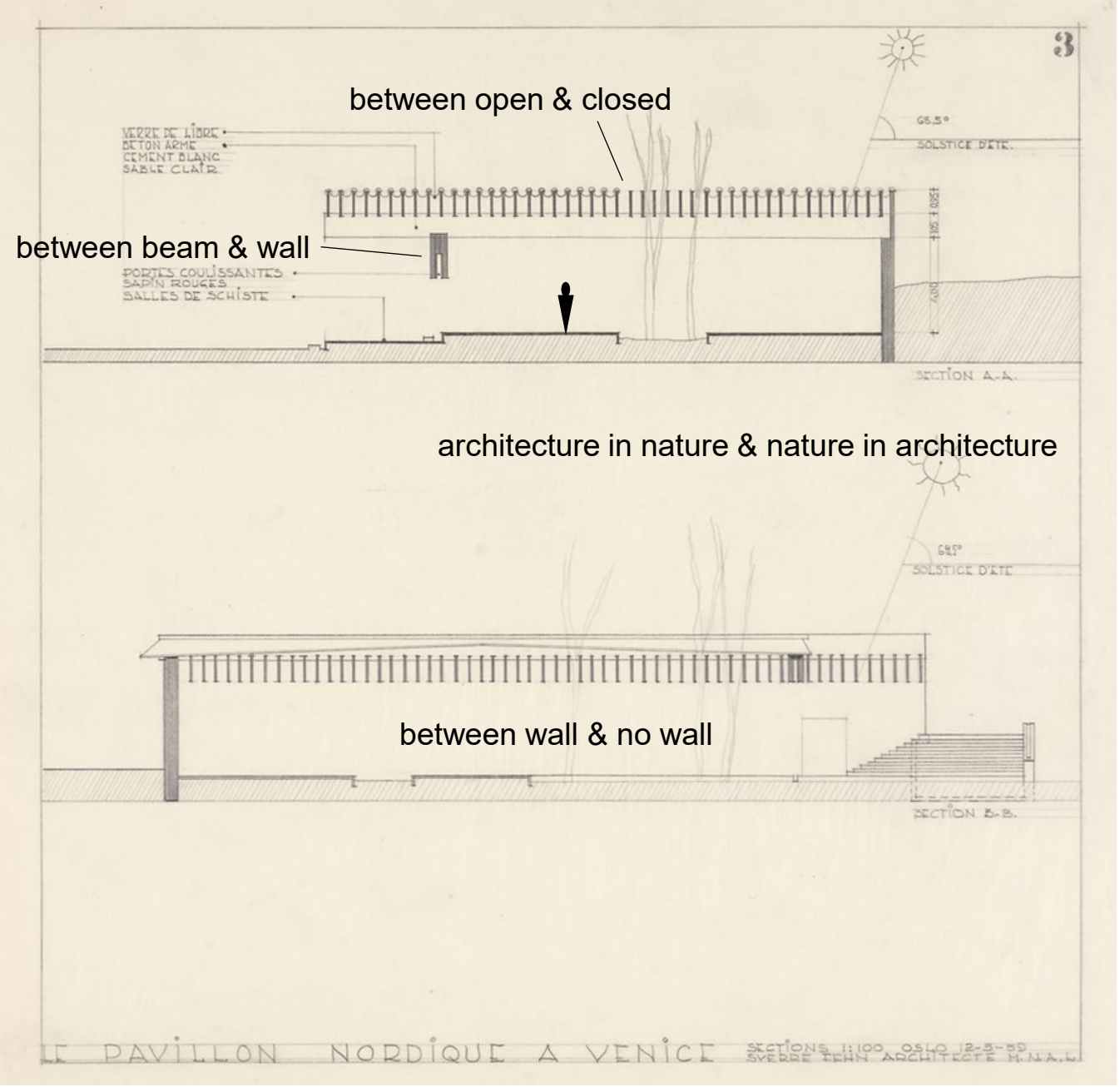


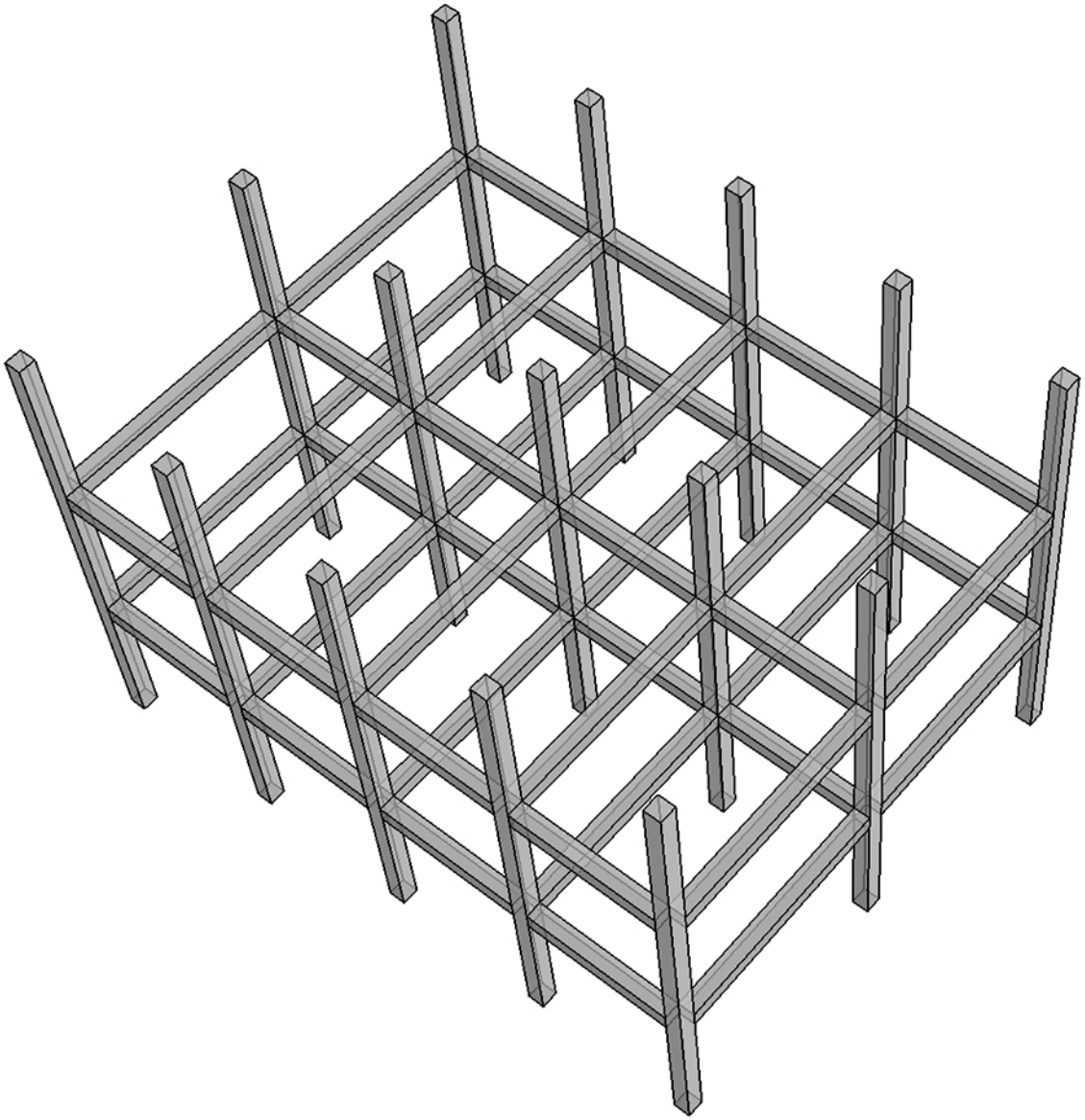
Sverre Fehn: Nordic Pavilion
Venice, Italy, 1962

“No matter how good an architect you are, if you have no chance of expressing your poetic idea in structures, you lack the very foundation of architecture. The structure is a language, a way of expressing yourself, and there should be a balance between thought and language. Every story has a structure.”

Sverre Fehn

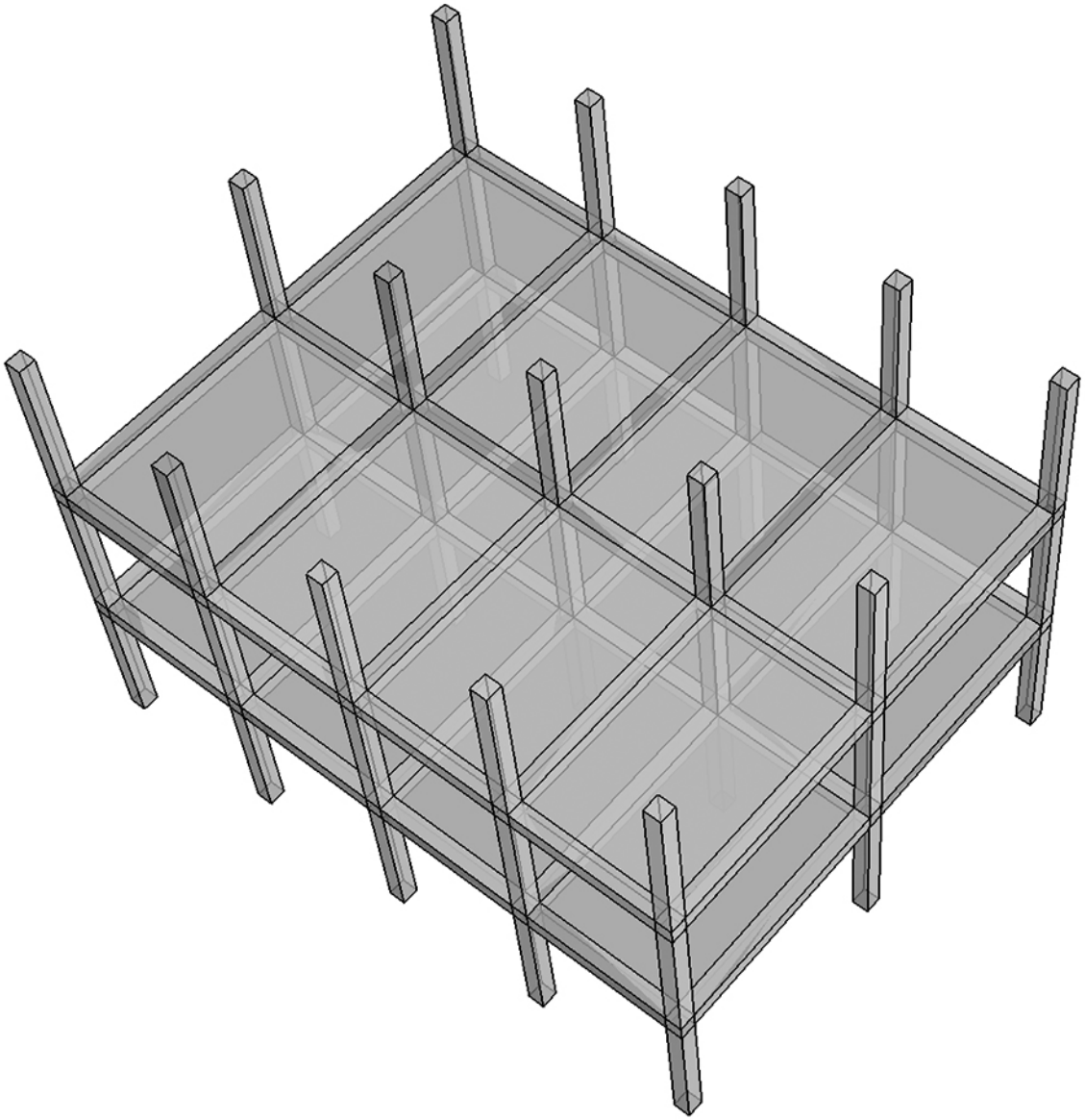
Sverre Fehn: Nordic Pavilion
Venice, Italy, 1962

Generic Structural Concept



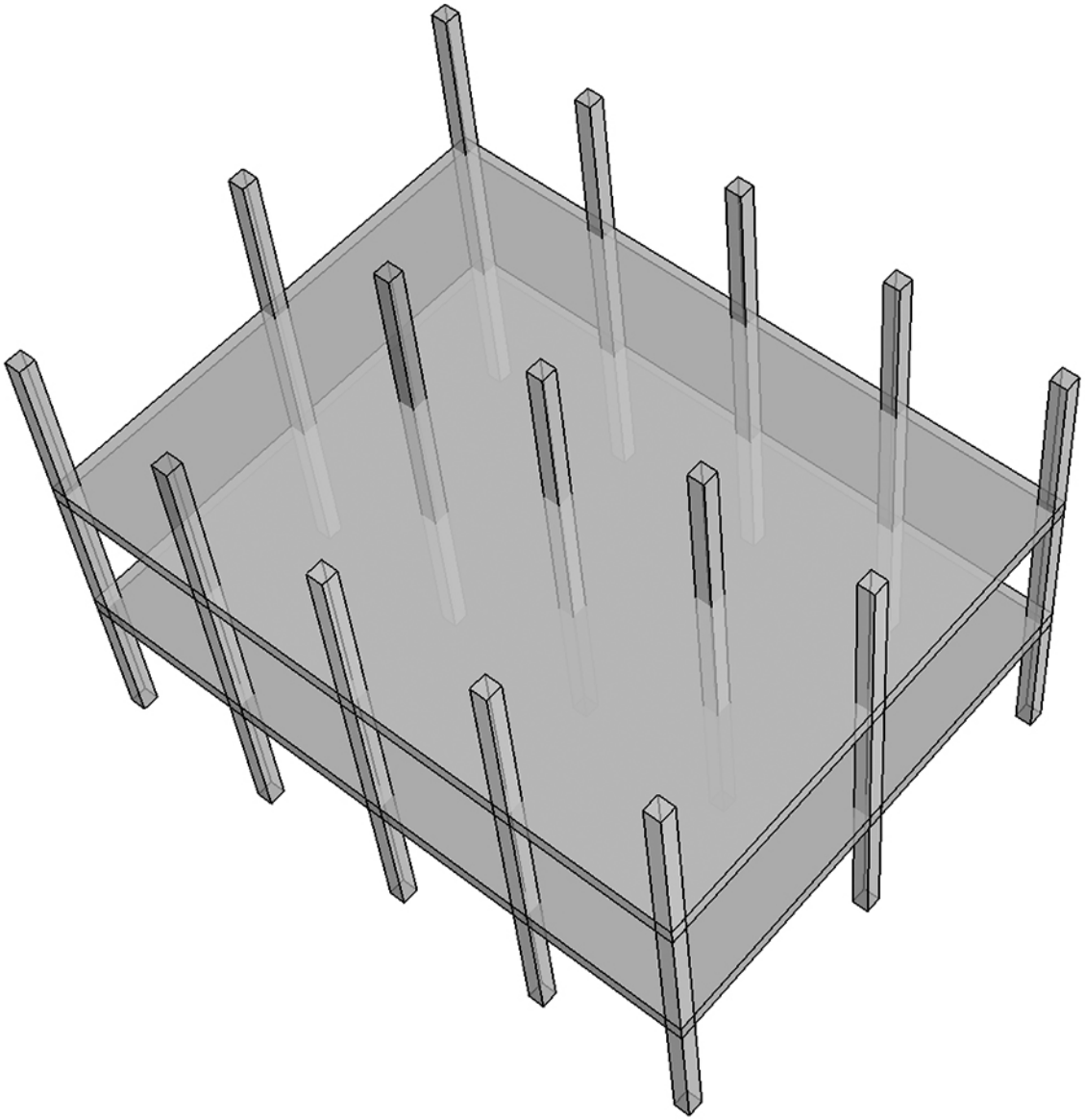
structural grid

Generic Structural Concept



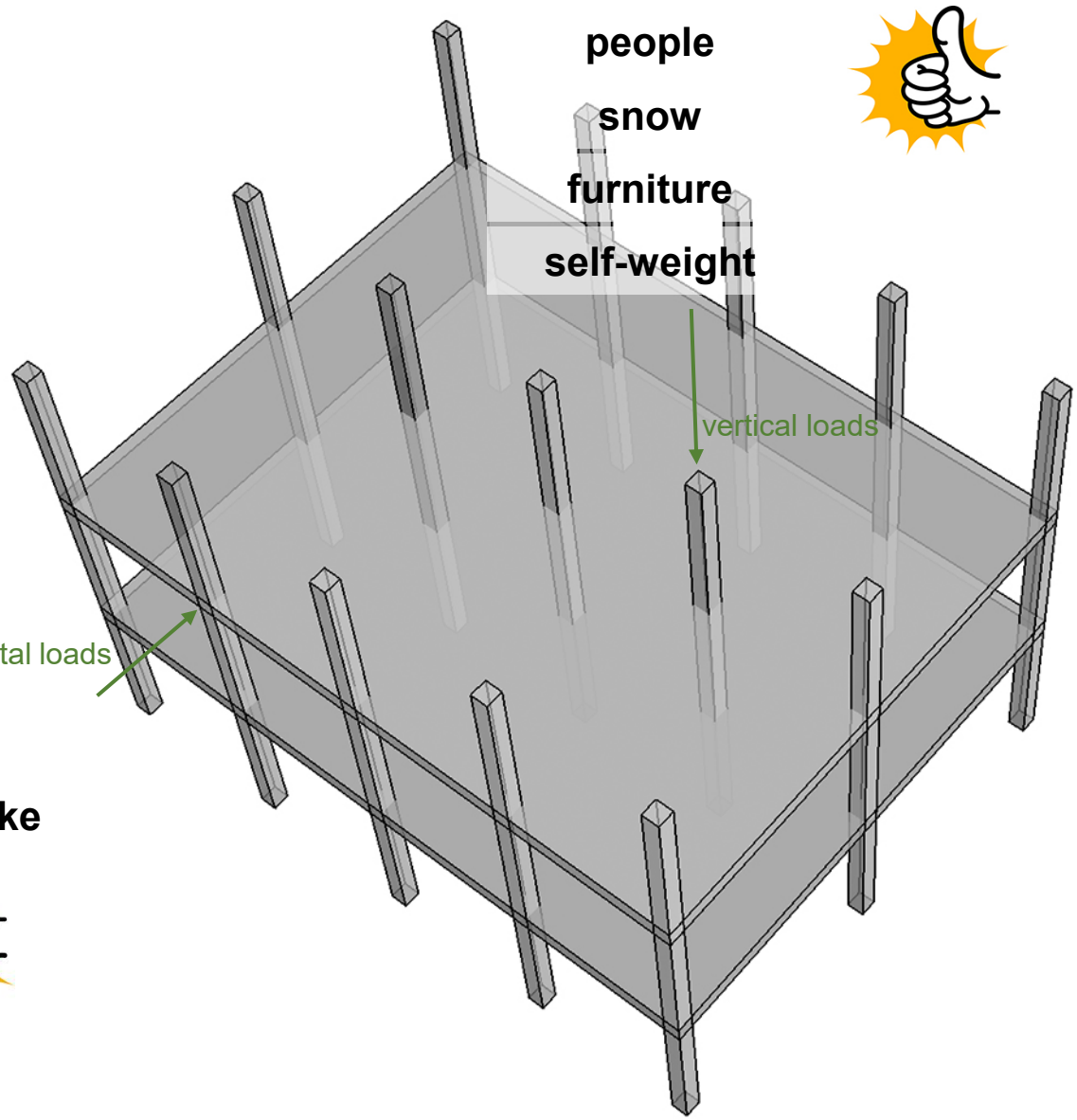
structural grid with infill

Generic Structural Concept



structural grid with infill
as column-plate combination

Generic Structural Concept



structural grid with infill
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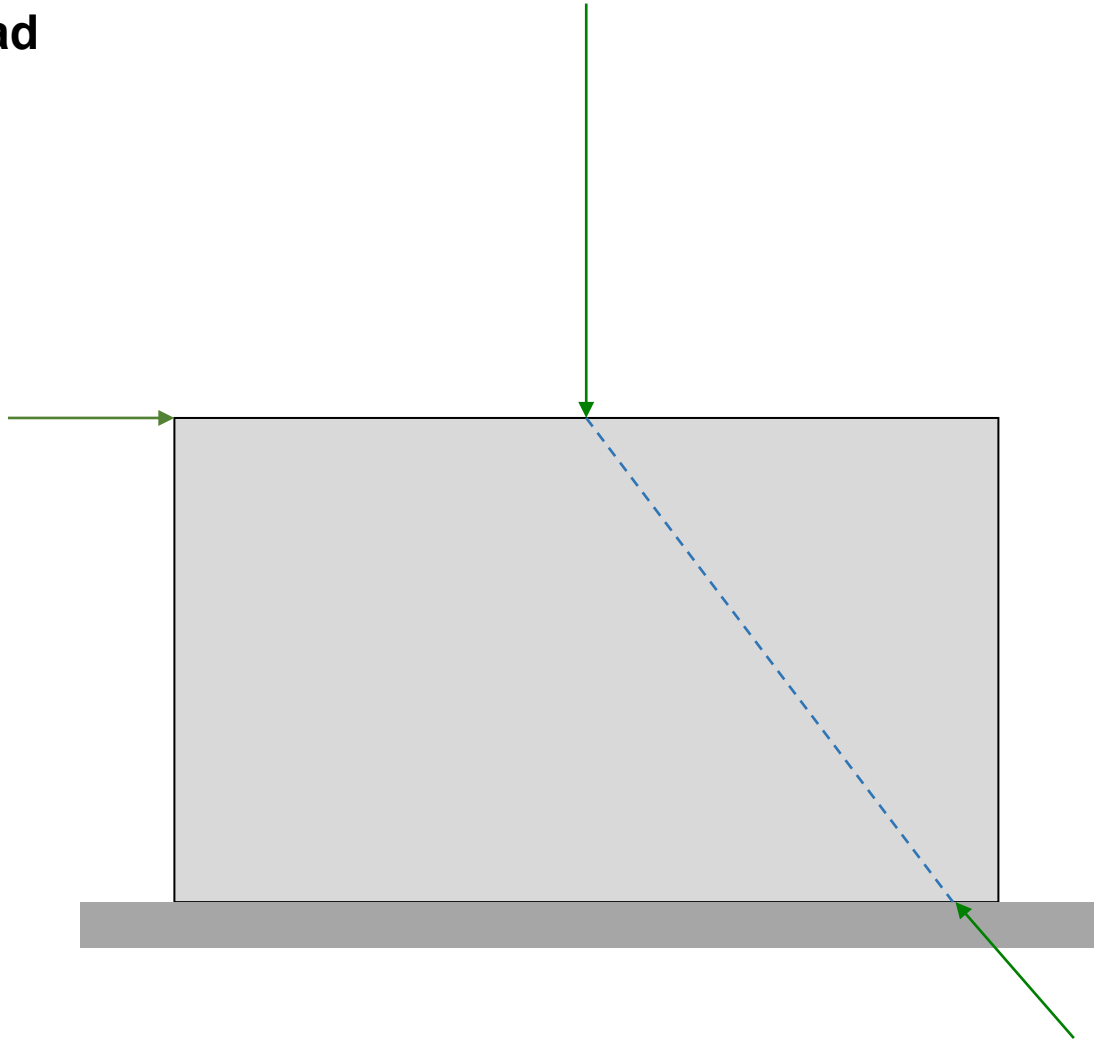
Lateral Load



redirected by self-weight of wall

Lateral Load

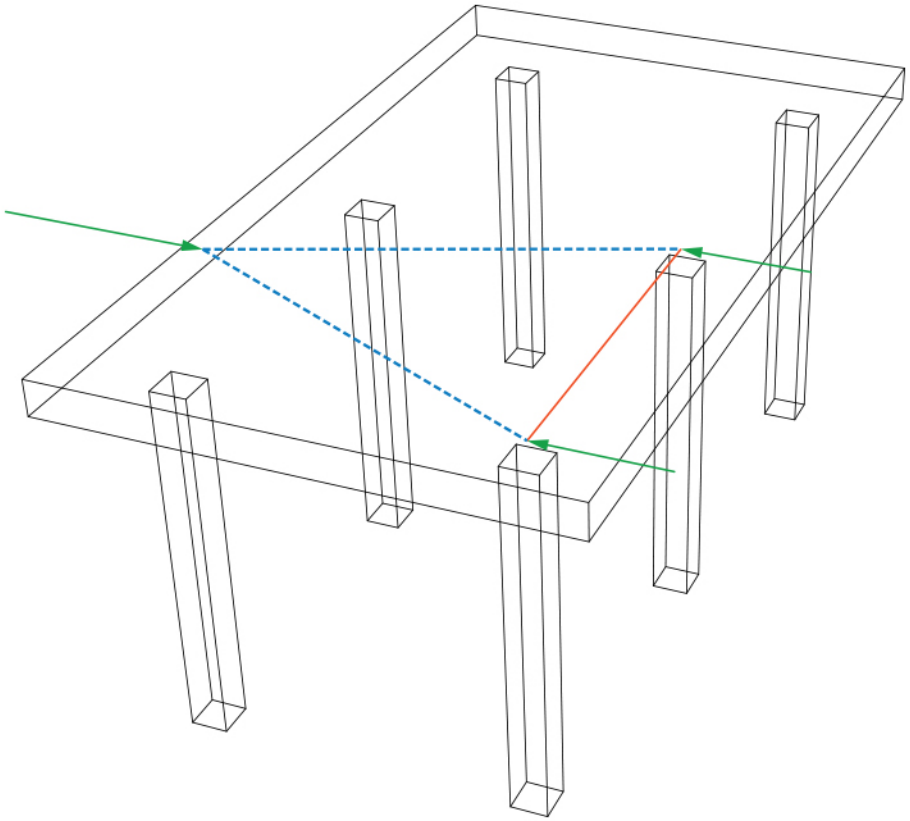
Temple E,Selinunt
Italy, around 460-450 BC

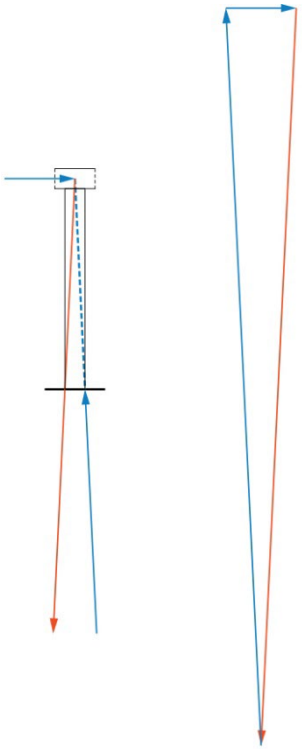
Lateral Load

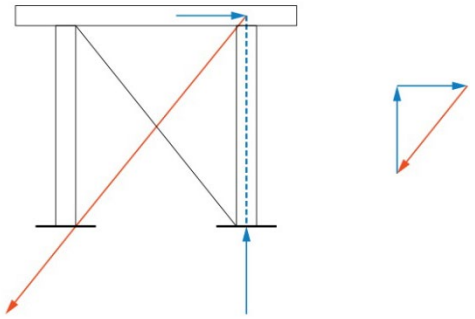
Flying buttress of Church Saint-Pierre
Chartres, France, early 13th century

Lateral Load

wide spreading of forces is required to achieve wall-like behavior

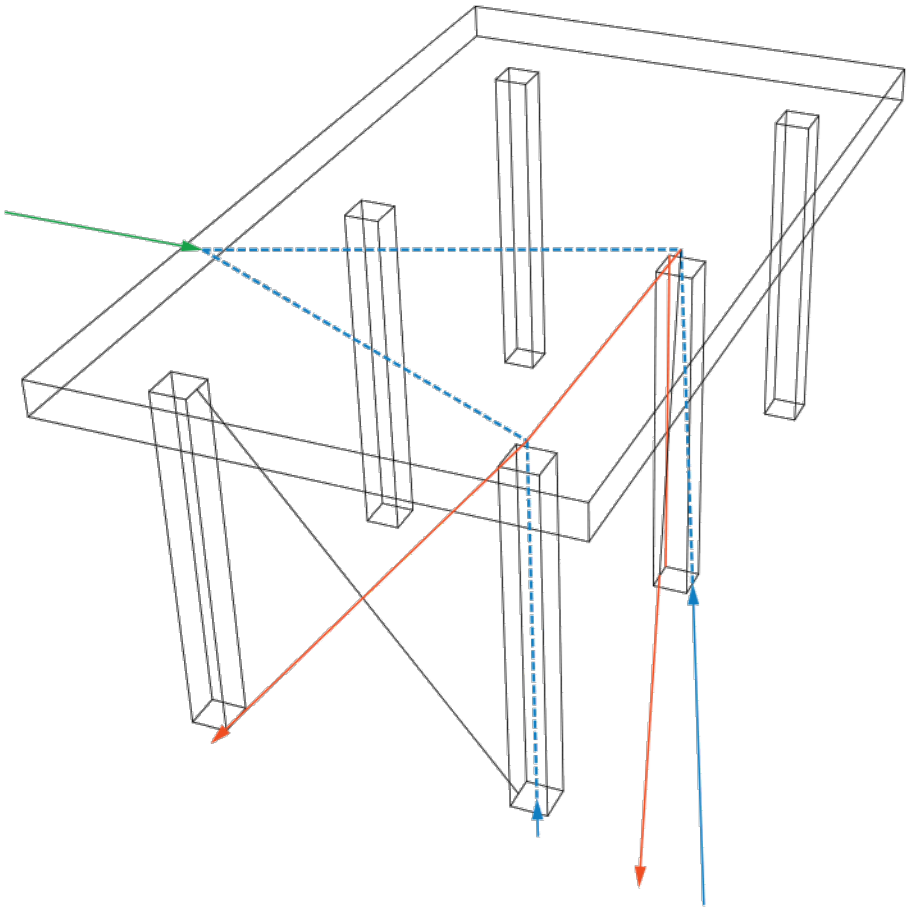


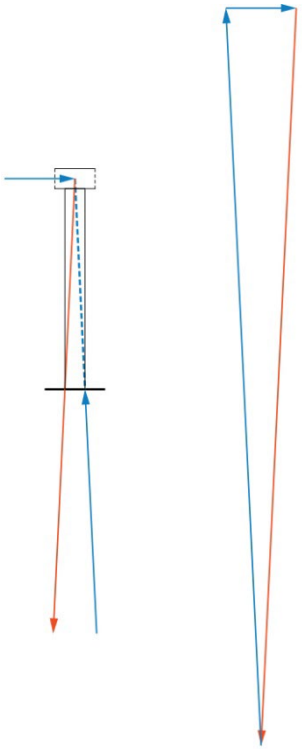




distribution of horizontal forces into space

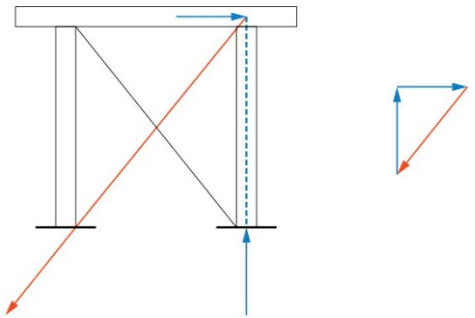
Lateral Load





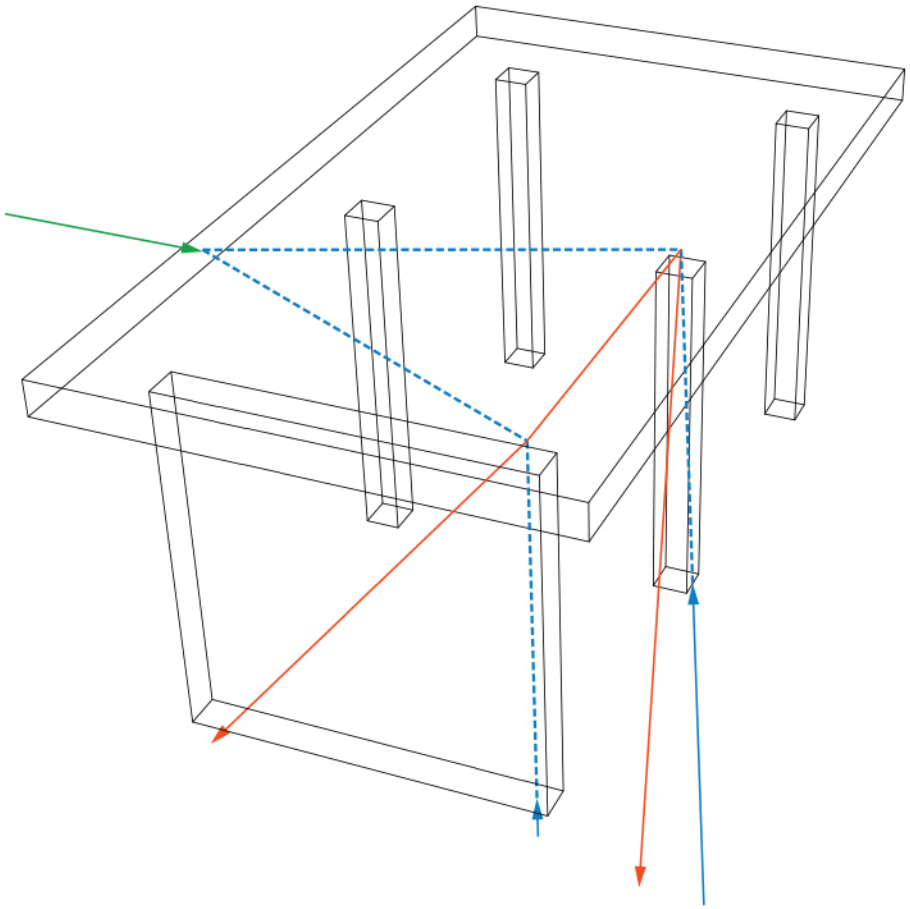
wide spreading of forces is required to achieve wall-like behavior

cross-bracing



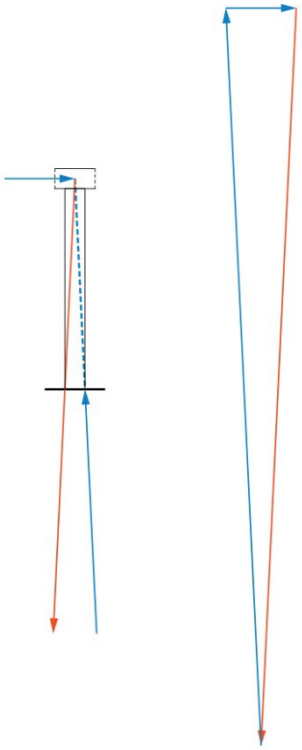
distribution of horizontal forces into space

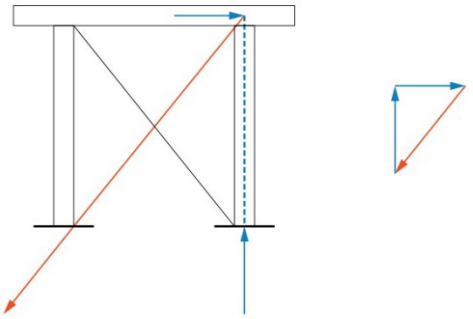
Lateral Load



wide spreading of forces is required to achieve wall-like behavior

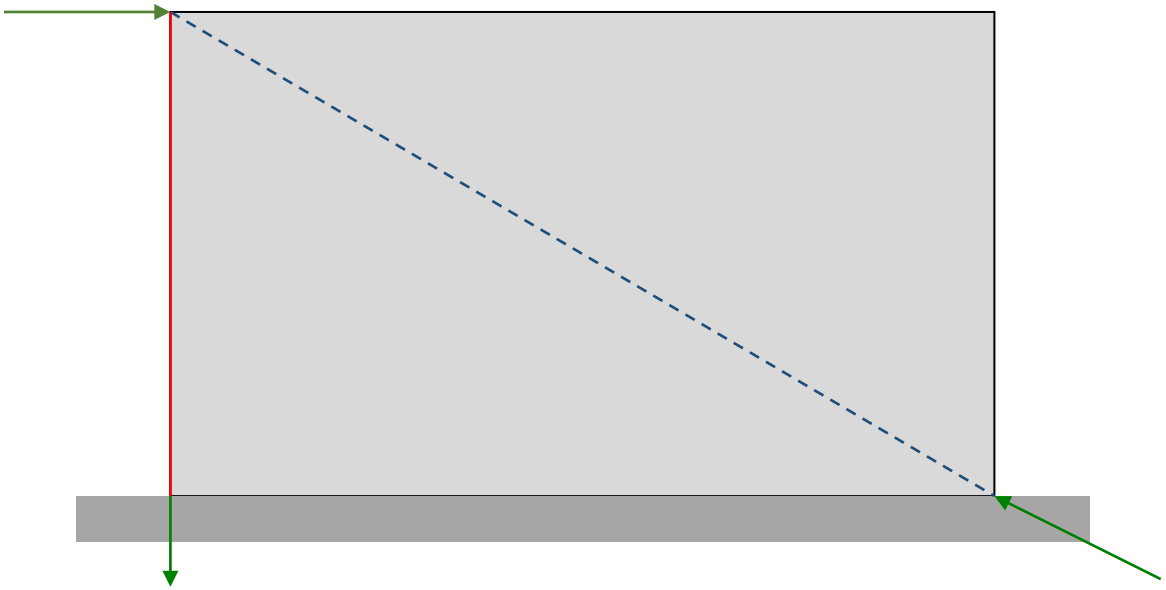
wall





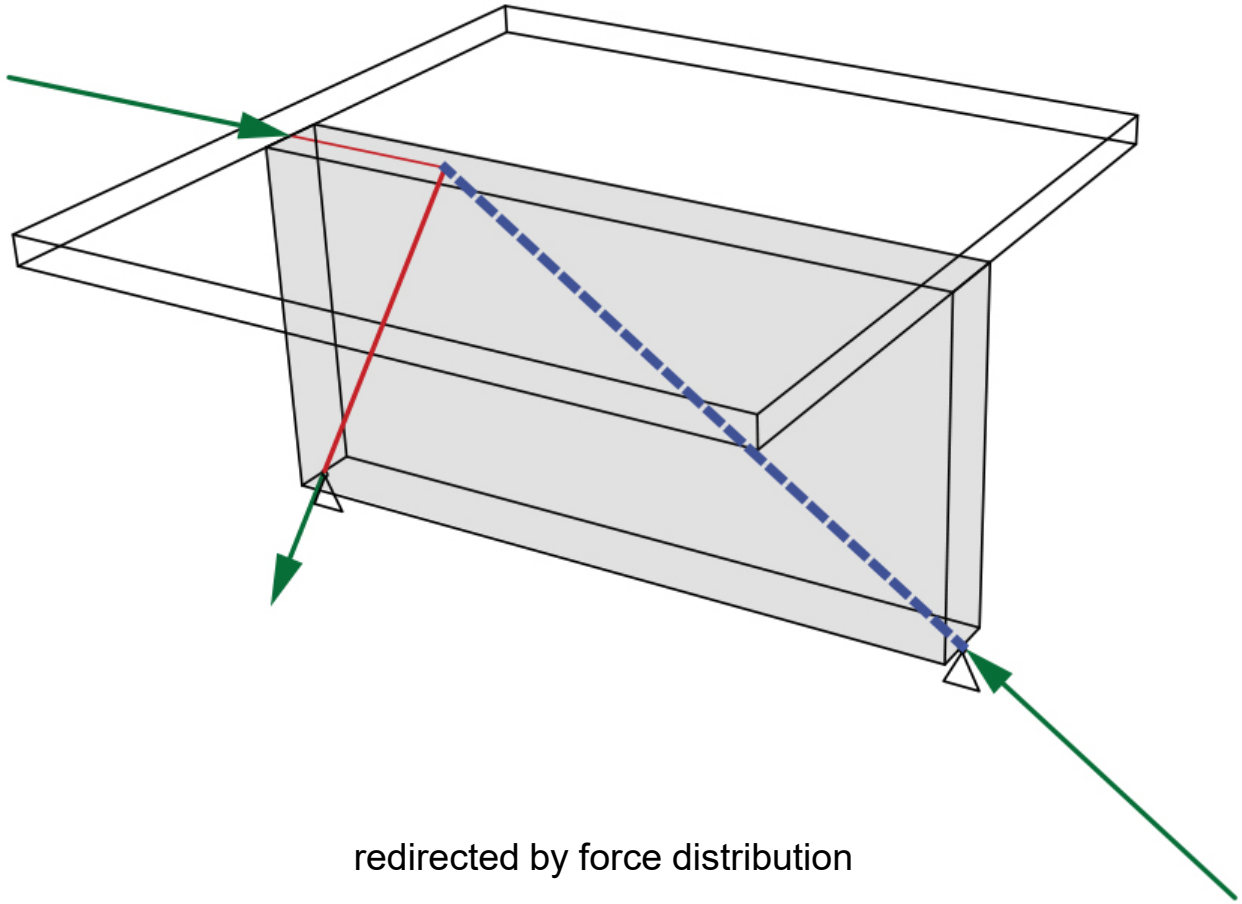
distribution of horizontal forces into space

Lateral Load



redirected by force distribution

Lateral Load



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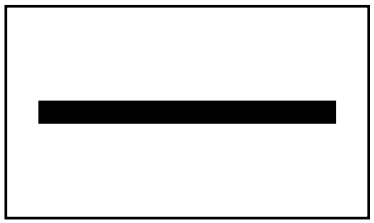
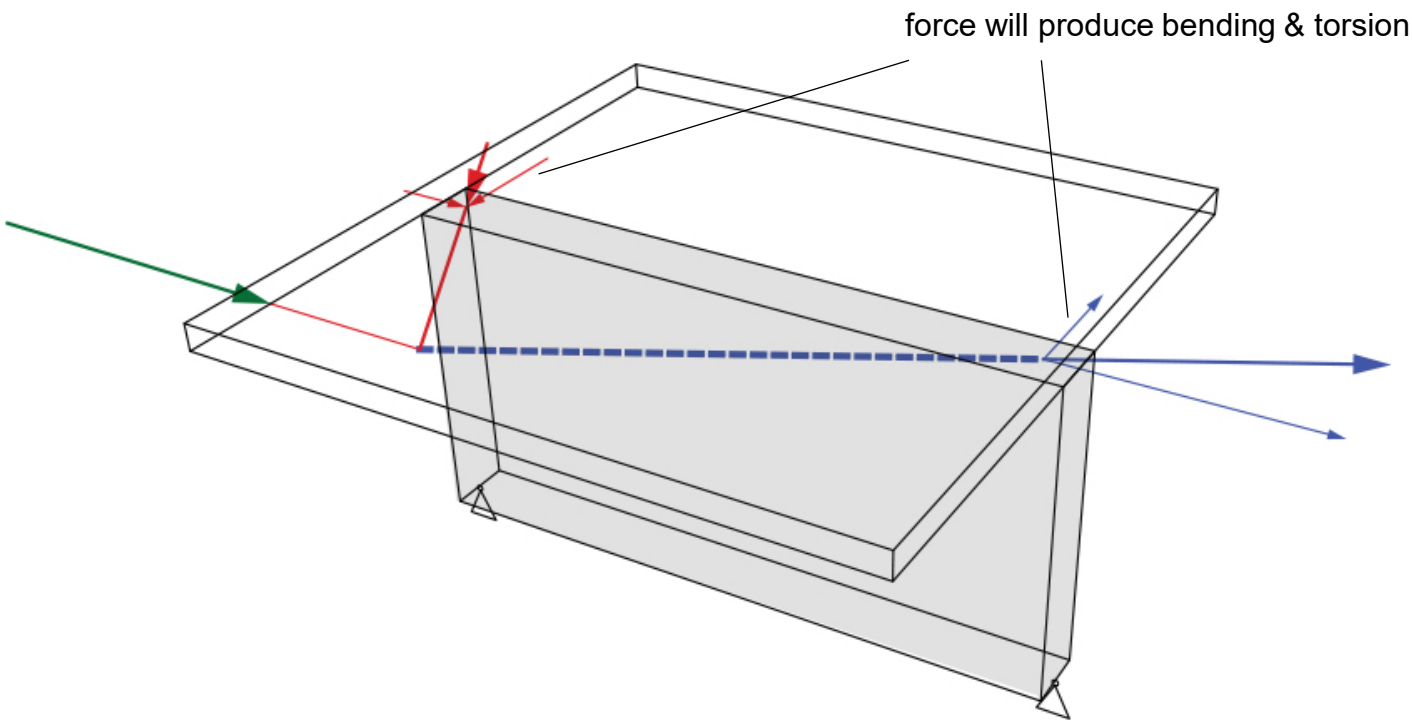
Lateral Load

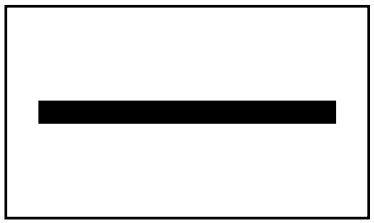


one wall is not enough to ensure equilibrium in the plate



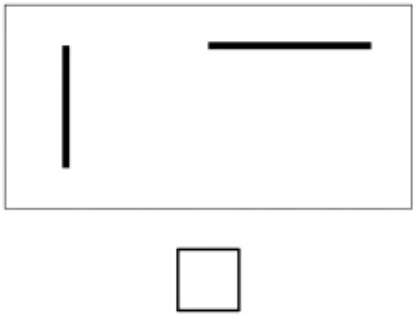
redirected by force distribution
within plate

Lateral Load



one wall is not enough to ensure equilibrium in the plate

how many wall are required to ensure equilibrium in the plate against horizontal loads?



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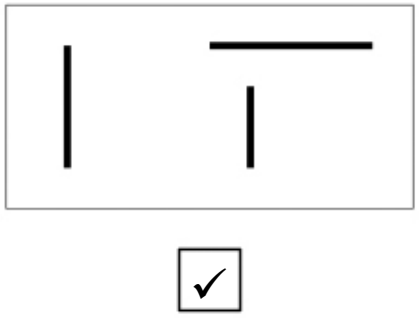

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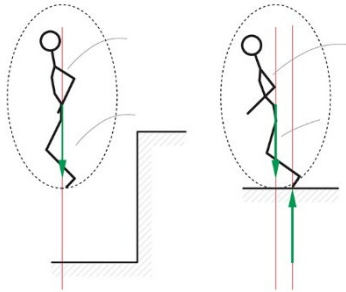
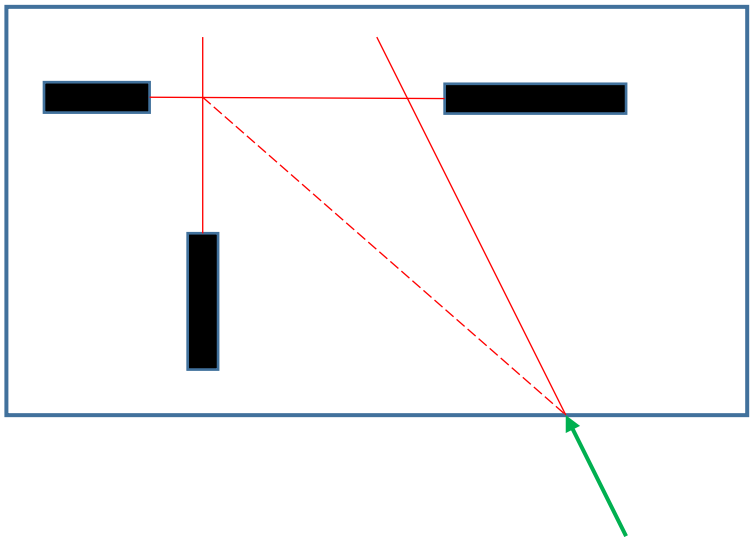
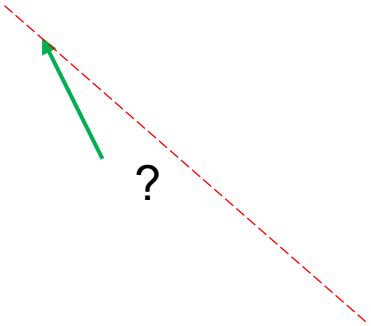
the forces add up to zero
the line of action of the forces intersect in one point



three walls (respectively directions) that do not intersect in one common point are required to ensure equilibrium in the plate

Lateral Load





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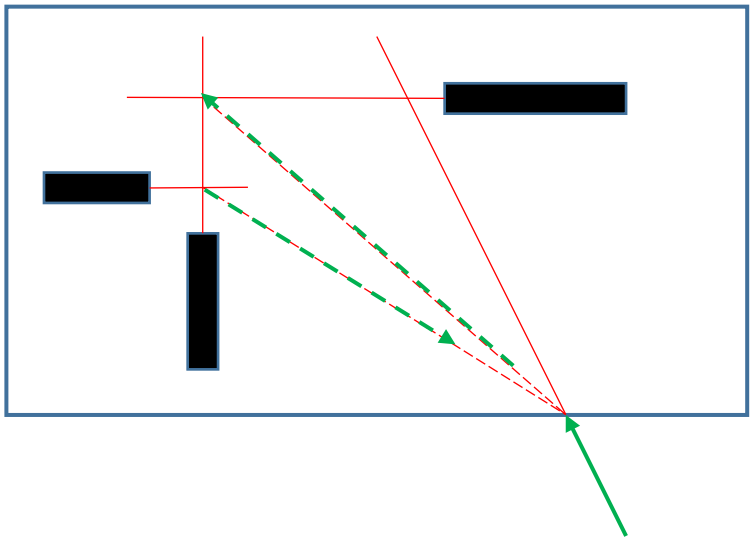
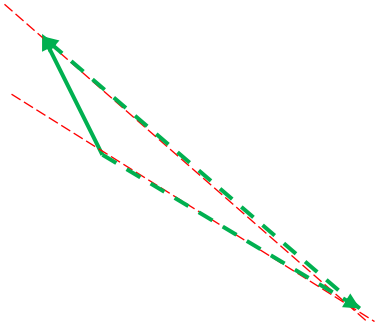
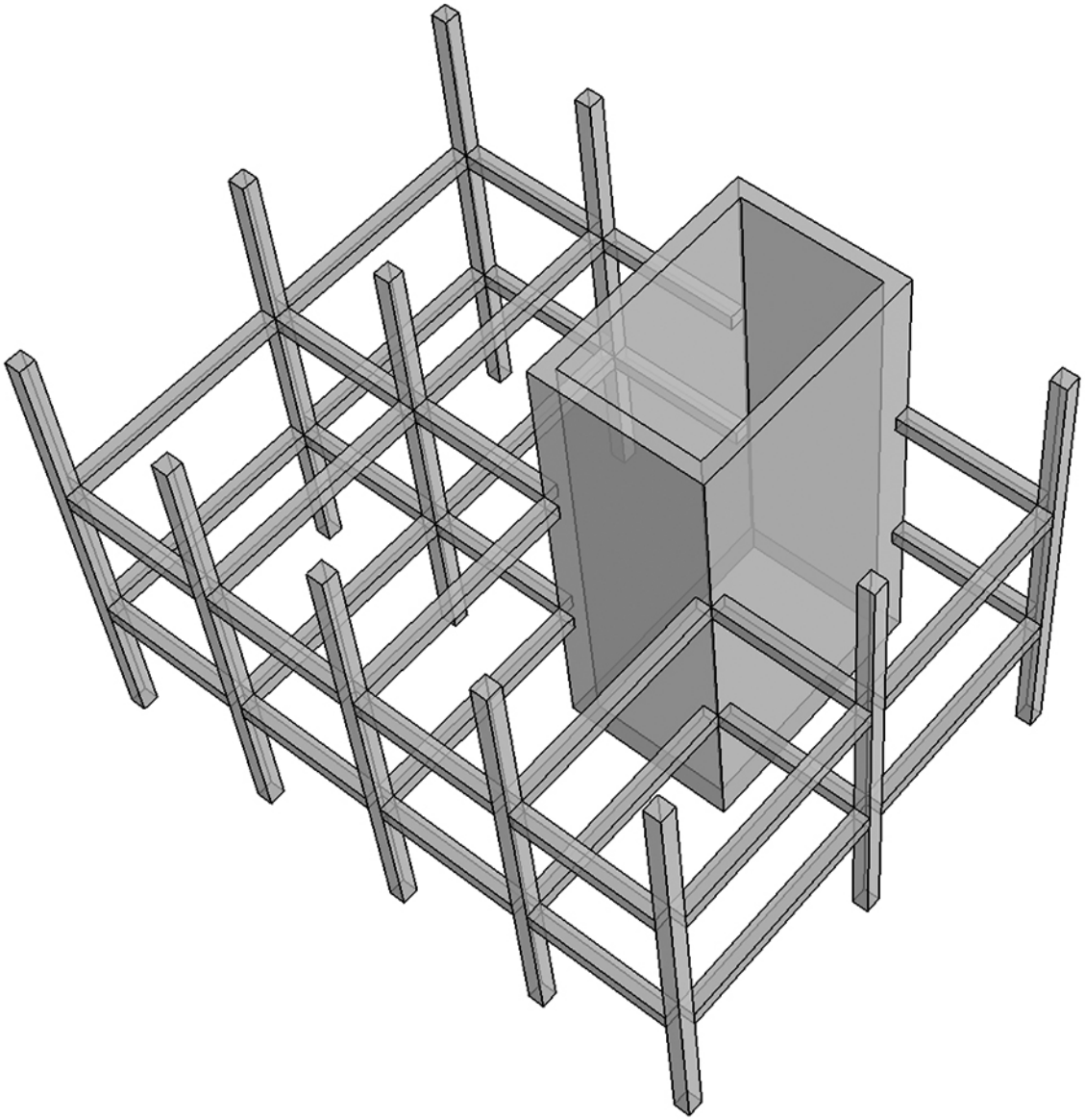


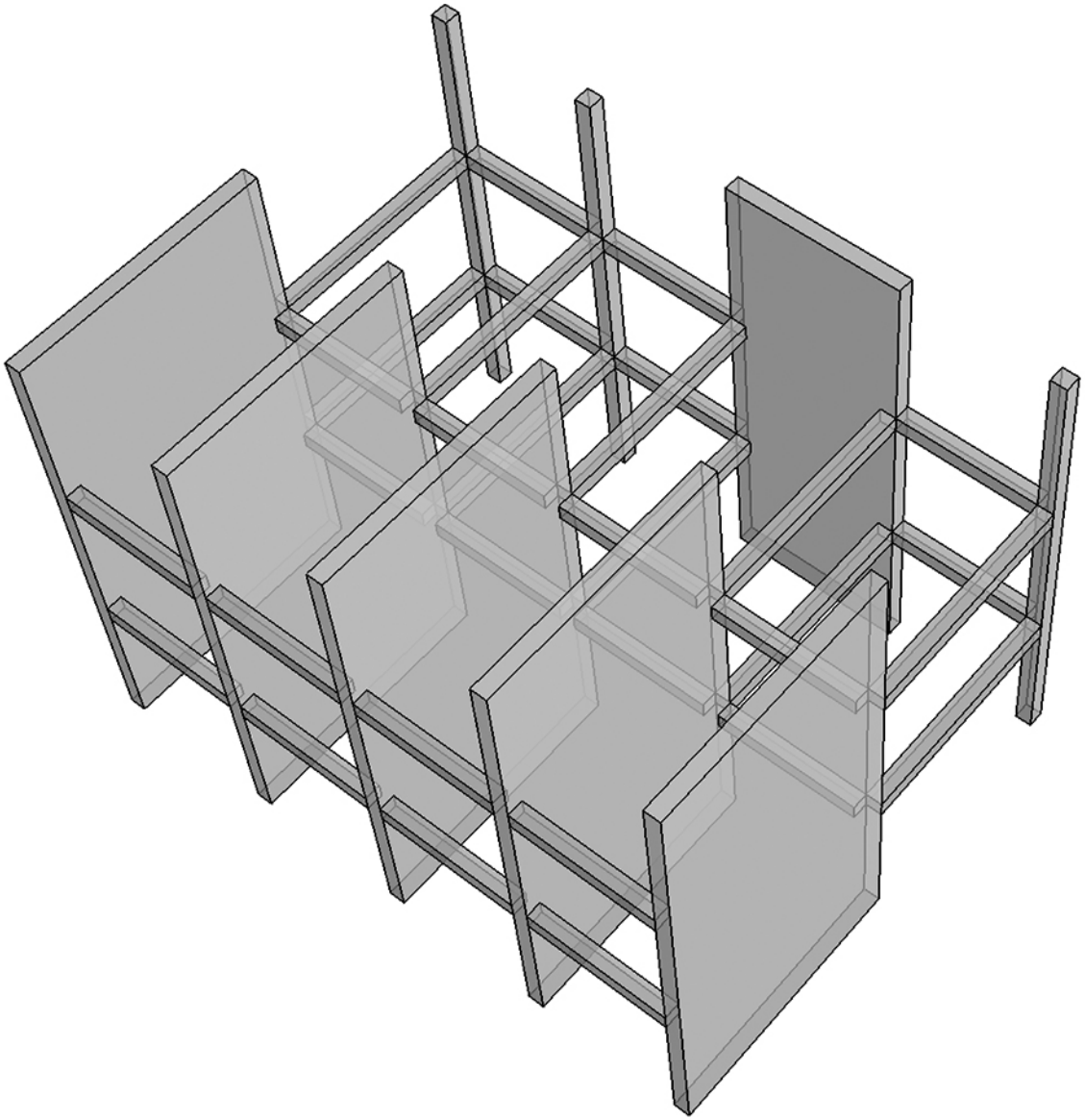


Generic Structural Concept for Lateral Load



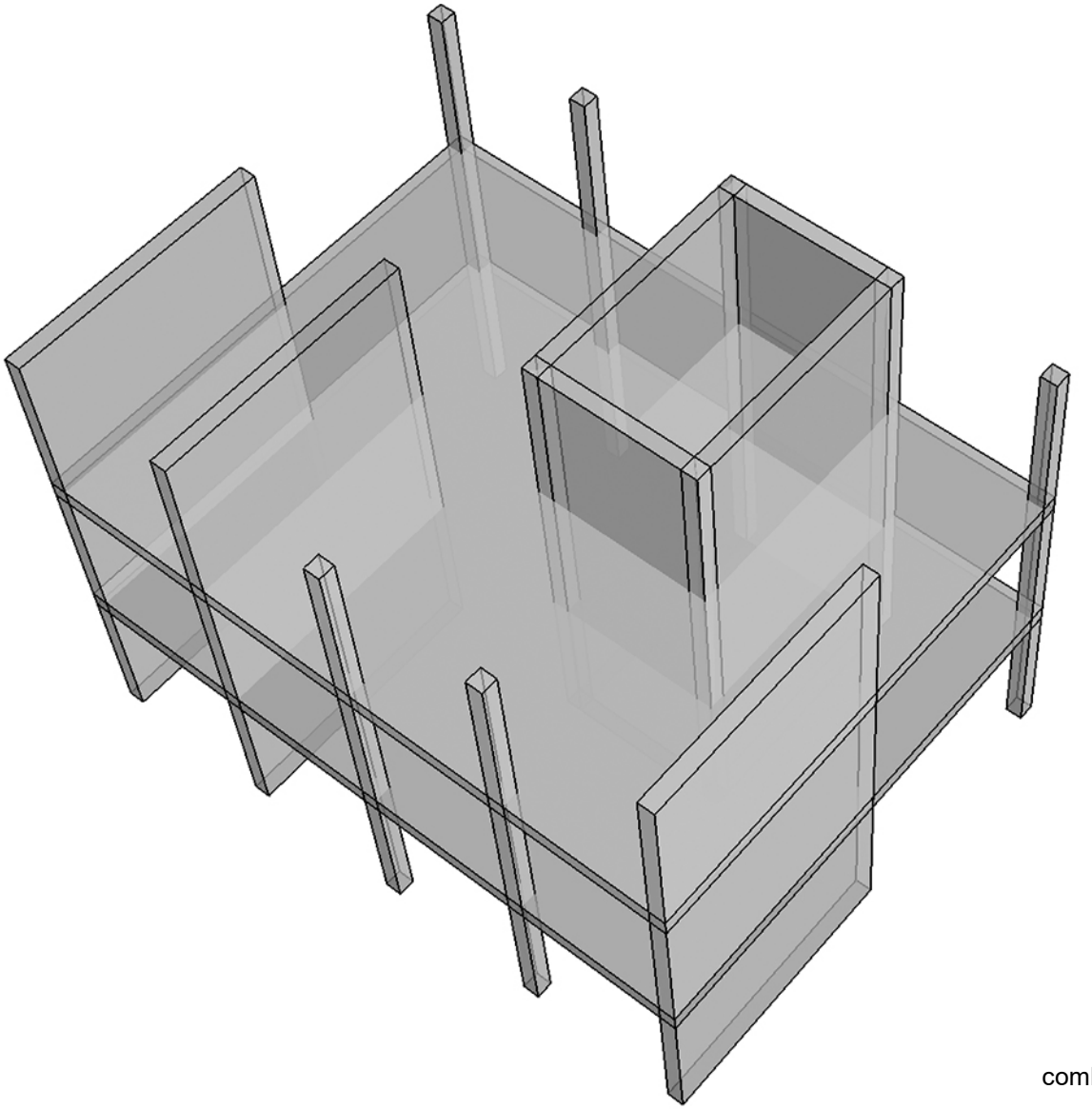
structural grid with core

Generic Structural Concept for Lateral Load



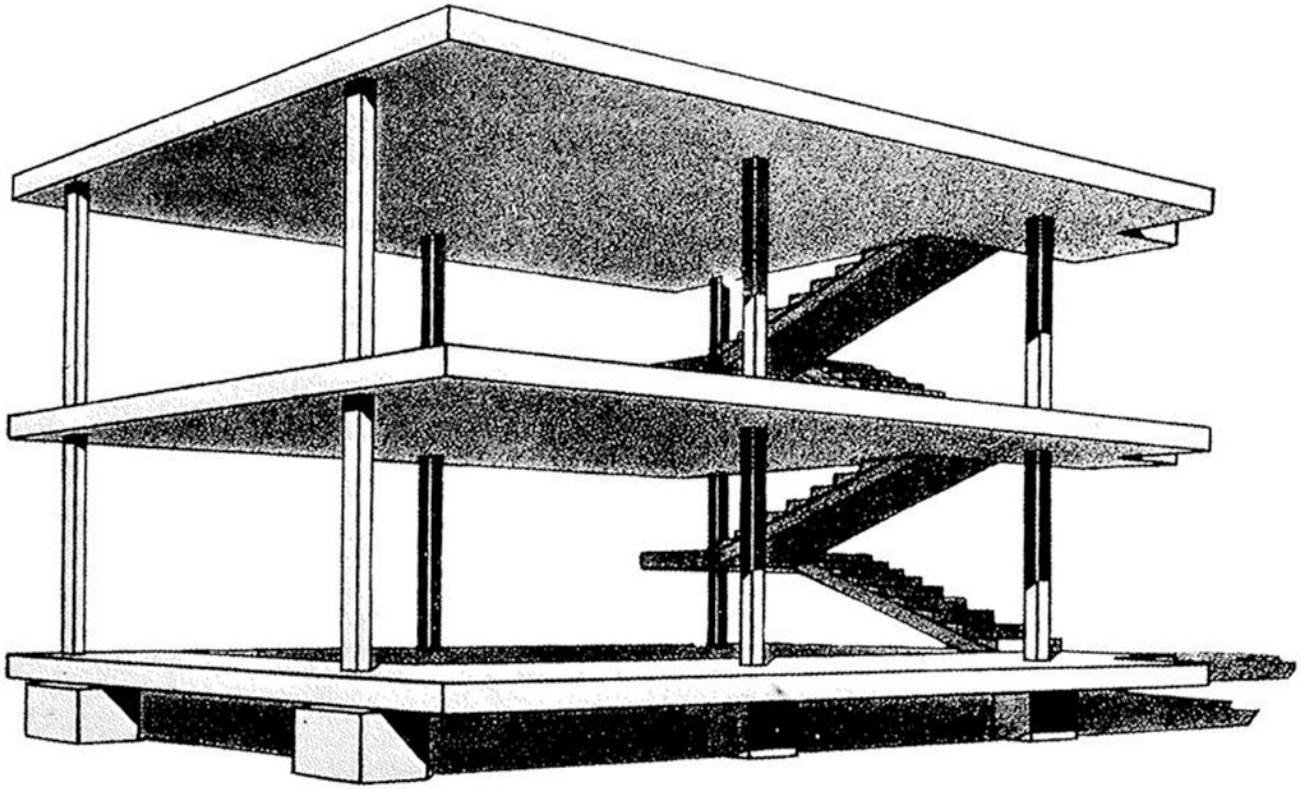
structural grid with shear walls

Generic Structural Concept for Lateral Load



combination of core and shear wall

Generic Structural Concept for Lateral Load



Five Points Towards A New Architecture

Le Corbusier, 1924

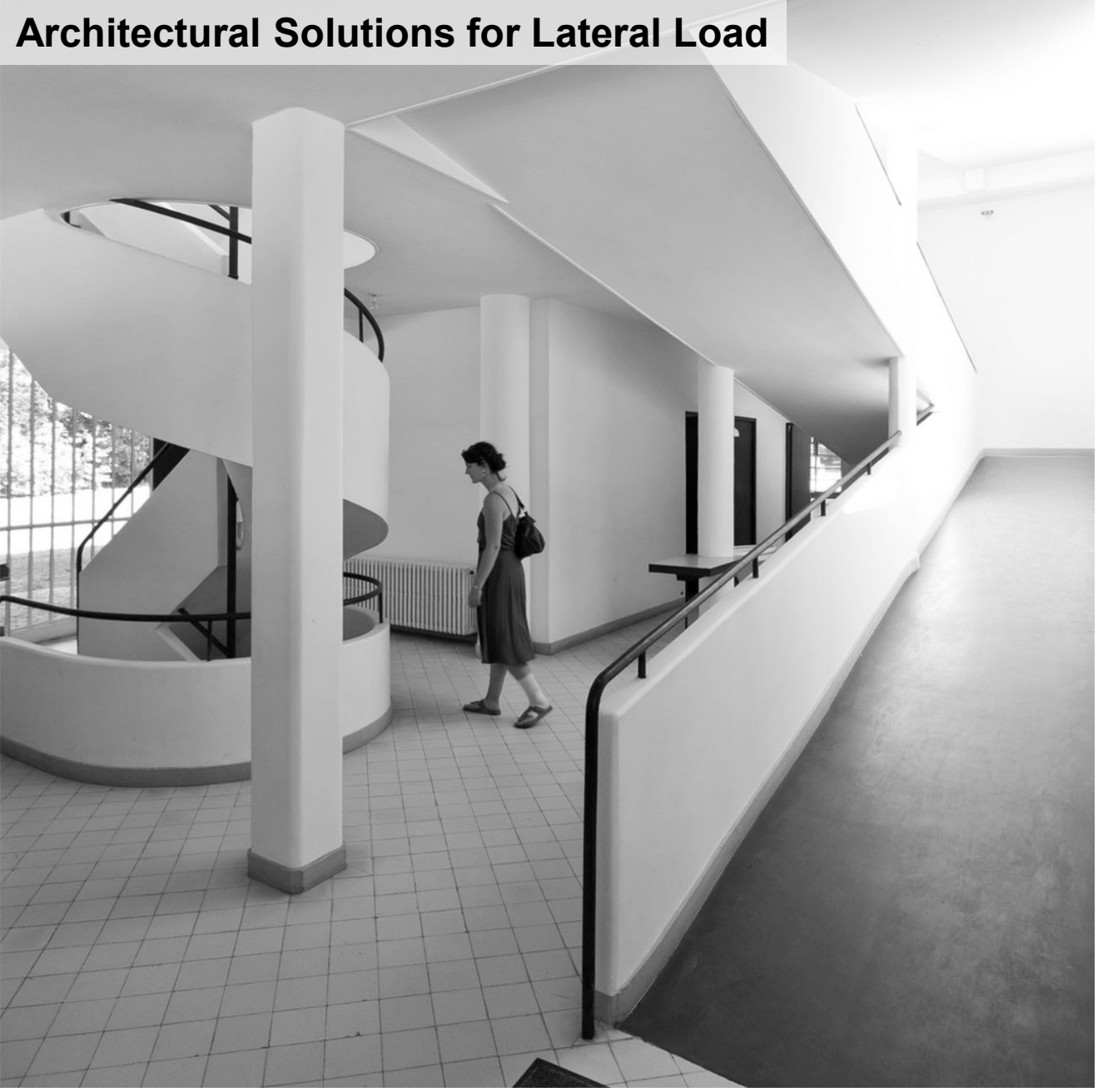
- The supports
- The roof gardens
- The free design of the ground-plan
- The horizontal window
- The free design of the façade

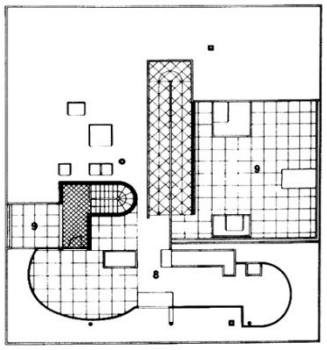
Le Corbusier: Dom-Ino House, prototype, 1914

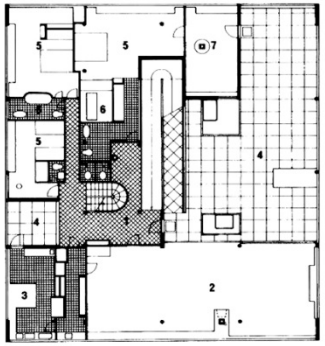
Architectural Solutions for Lateral Load

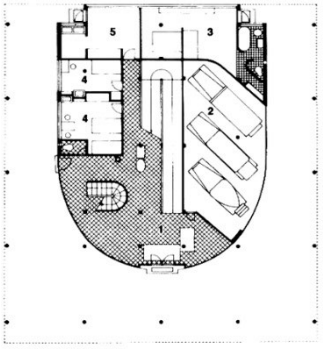
Le Corbusier: Villa Savoye
Poissy, France, 1931

Architectural Solutions for Lateral Load









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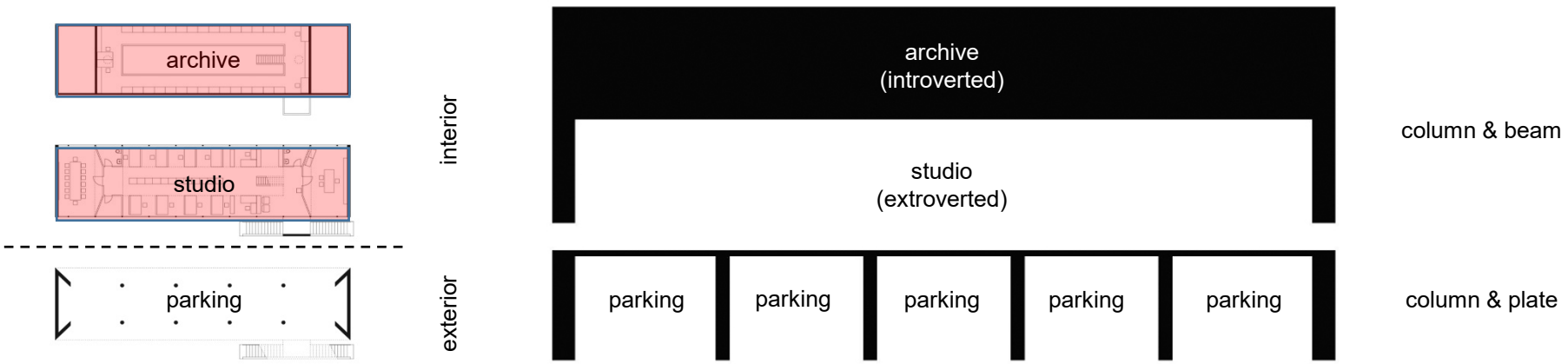
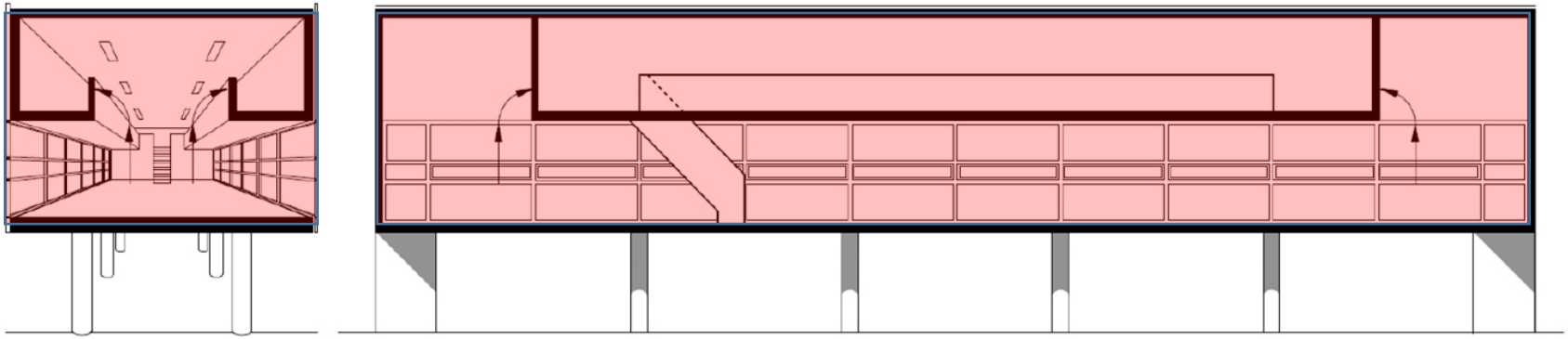
Poissy, France, 1931

Lateral Stability

Livio Vacchini: Office
Locarno, Switzerland, 1985

Lateral Stability





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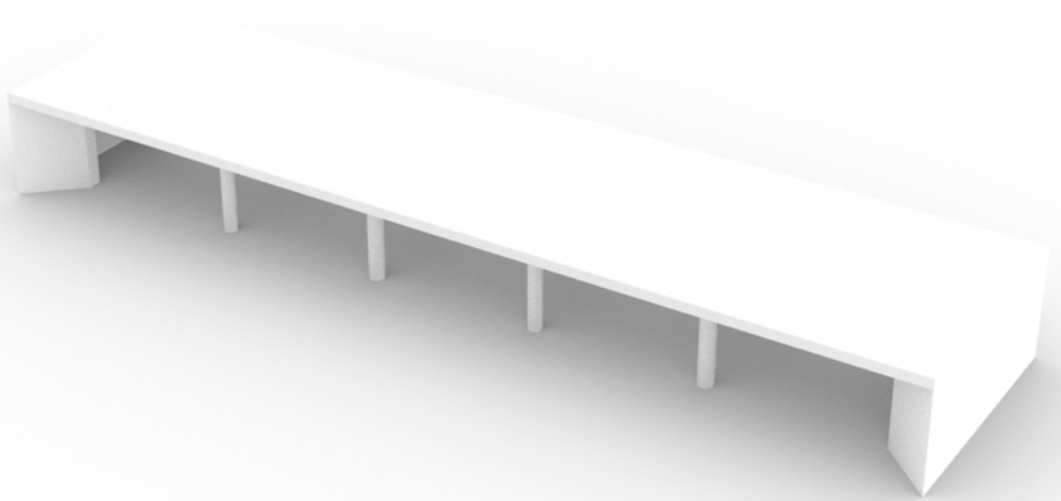

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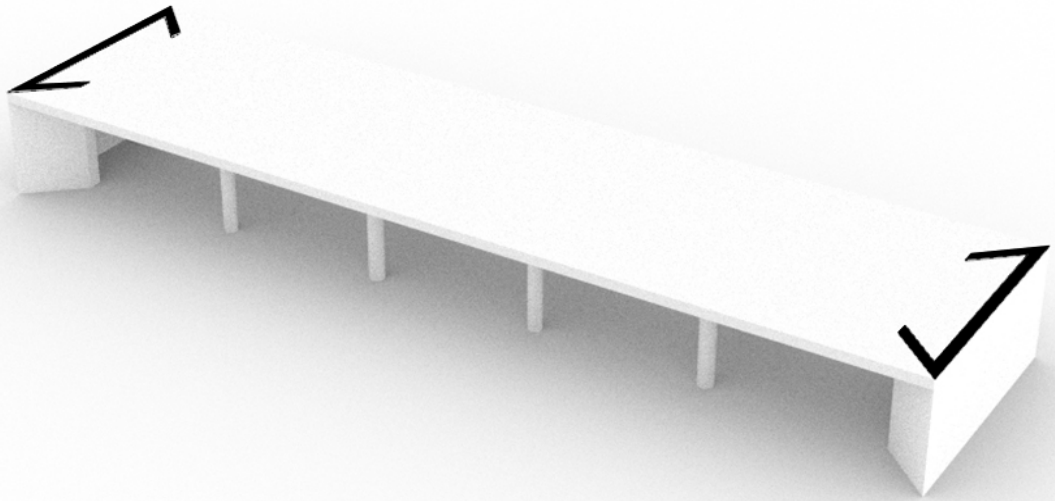

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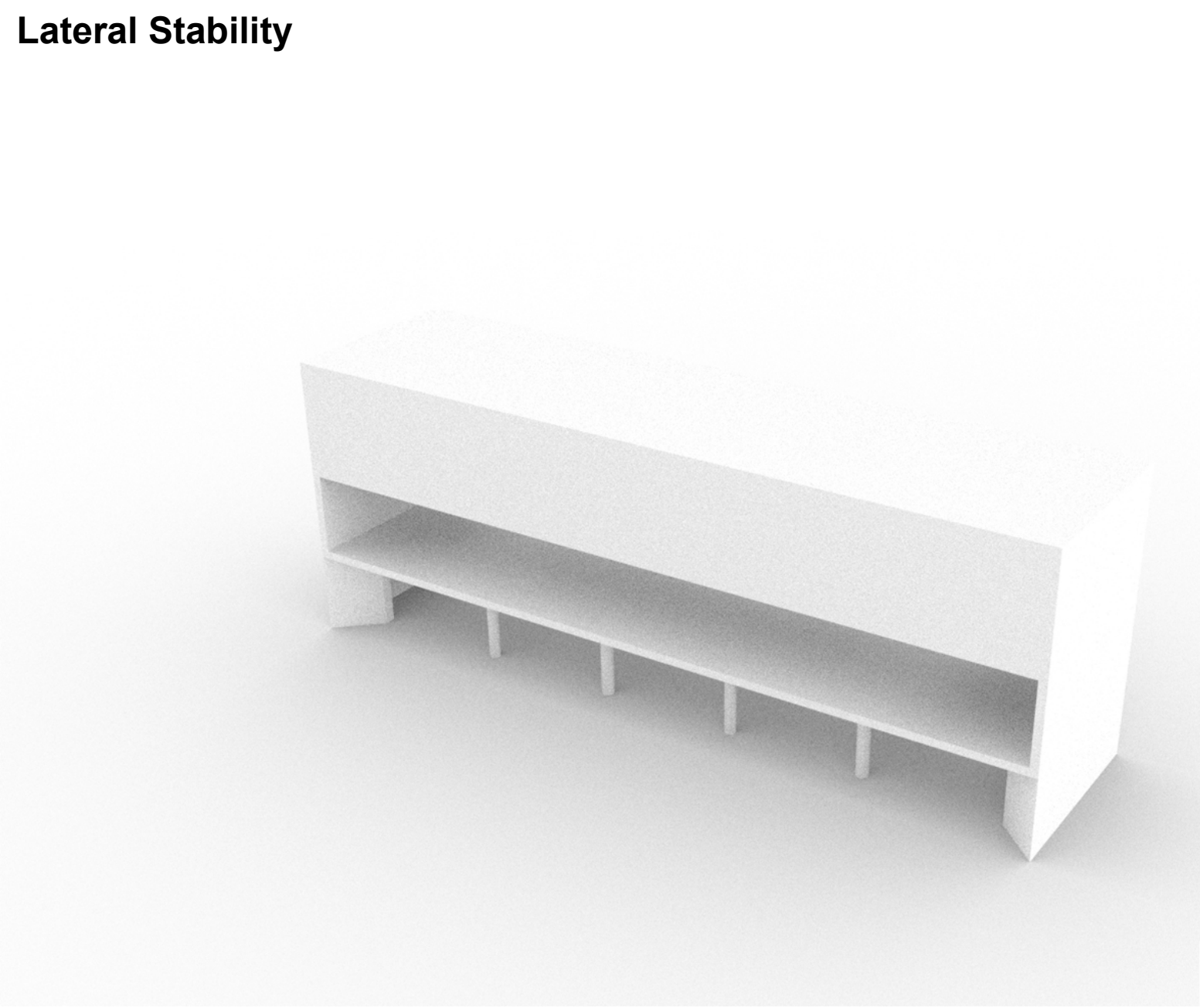

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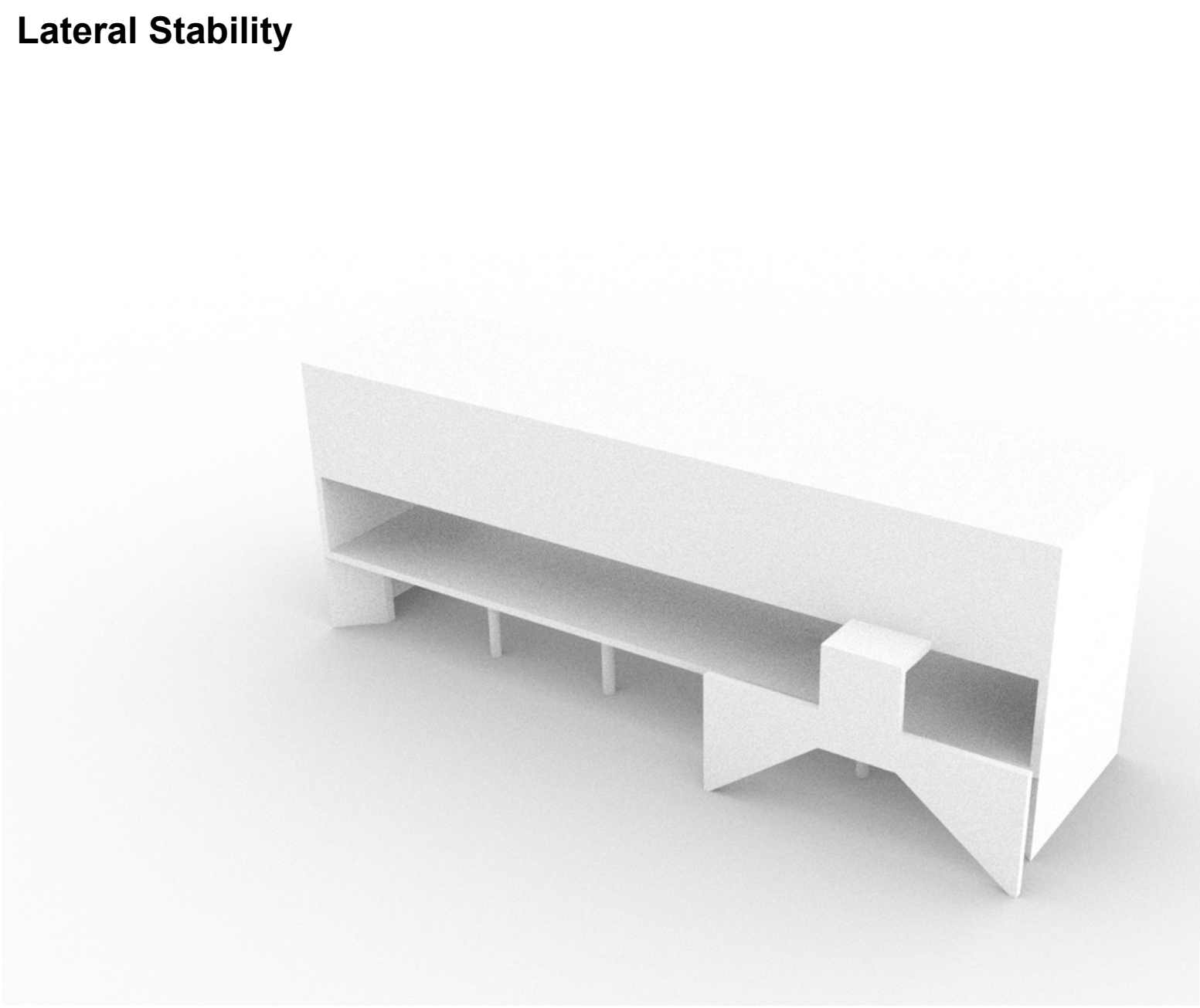

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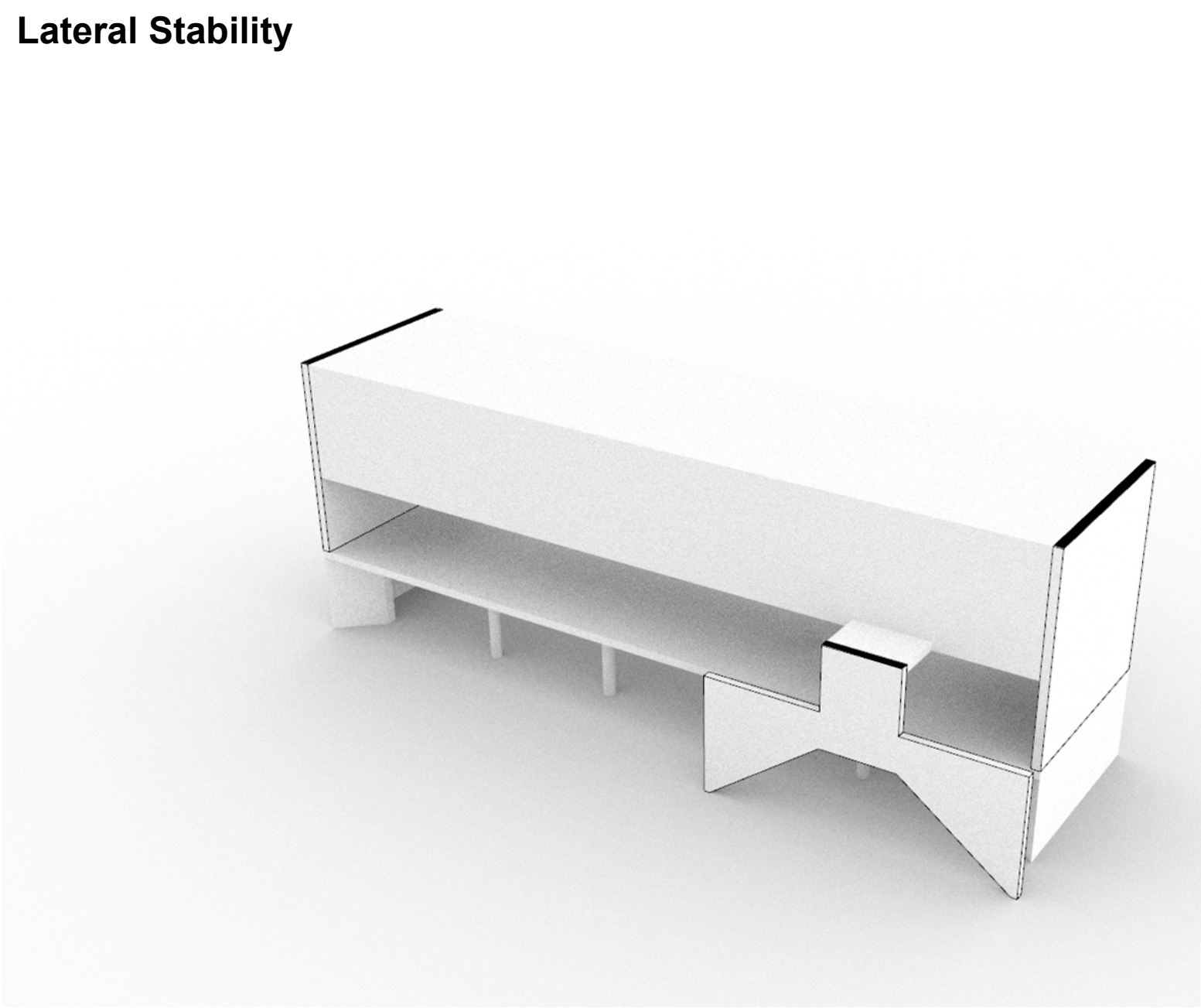

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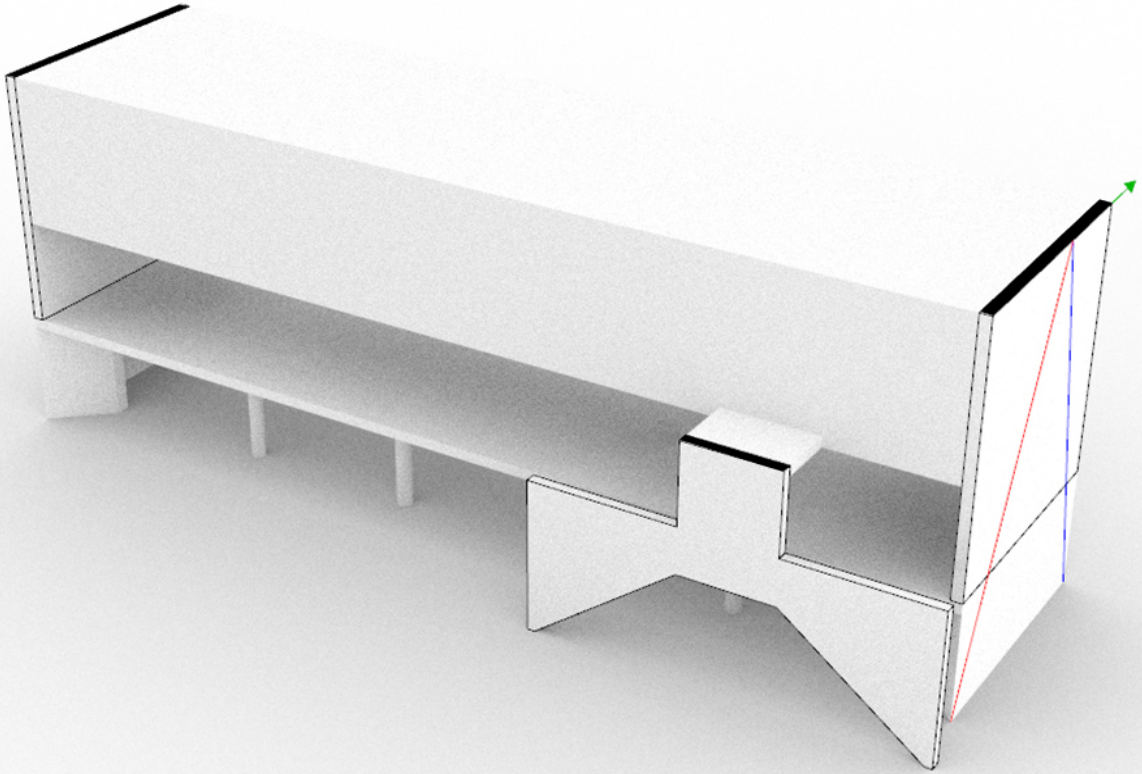

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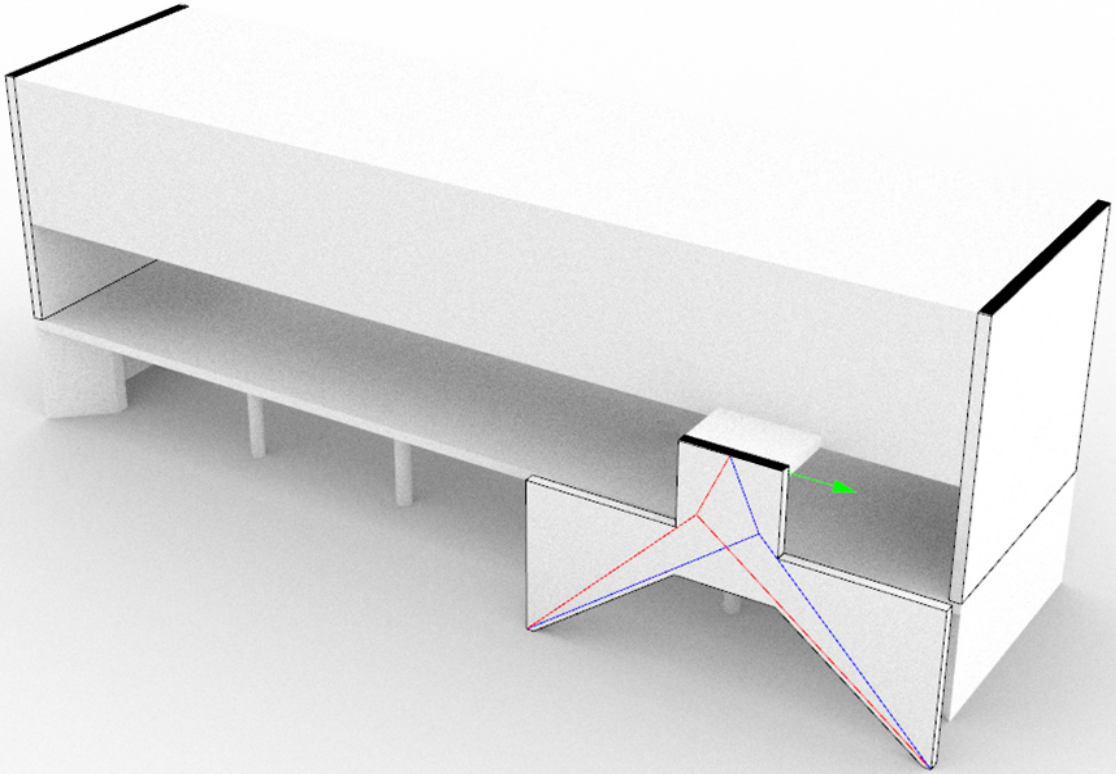

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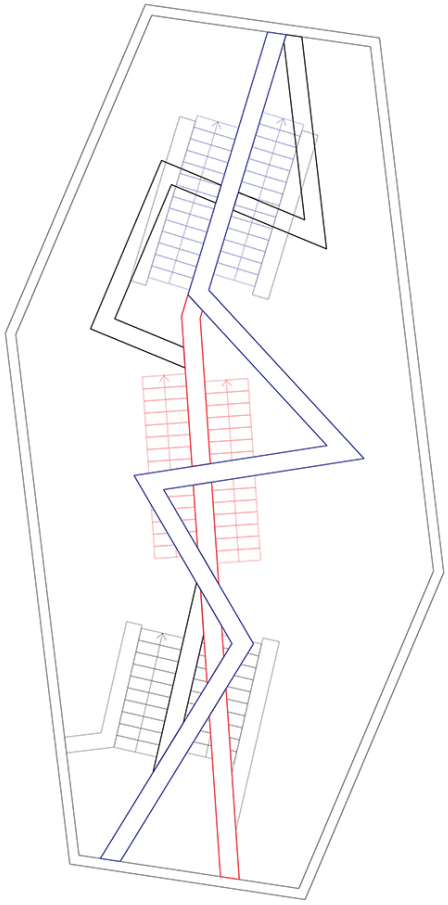
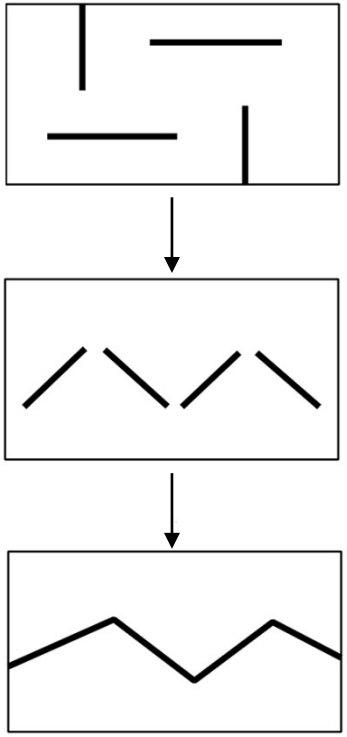
Architectural Solutions for Lateral Load

Christian Kerez: House with one wall
Zurich, Switzerland, 2007

Architectural Solutions for Lateral Load





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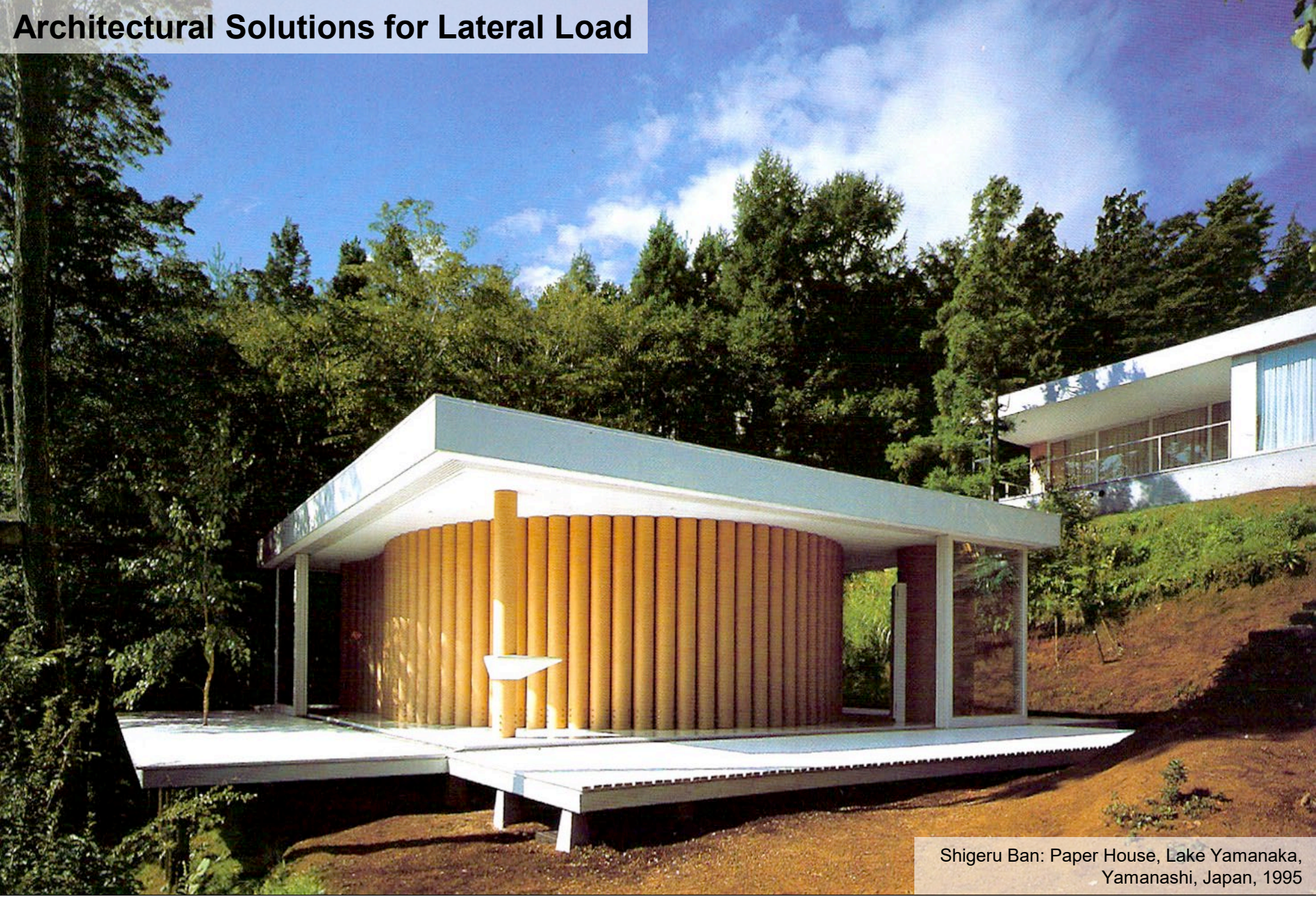

Shigeru Ban: Paper House, Lake Yamanaka, Yamanashi, Japan, 1995

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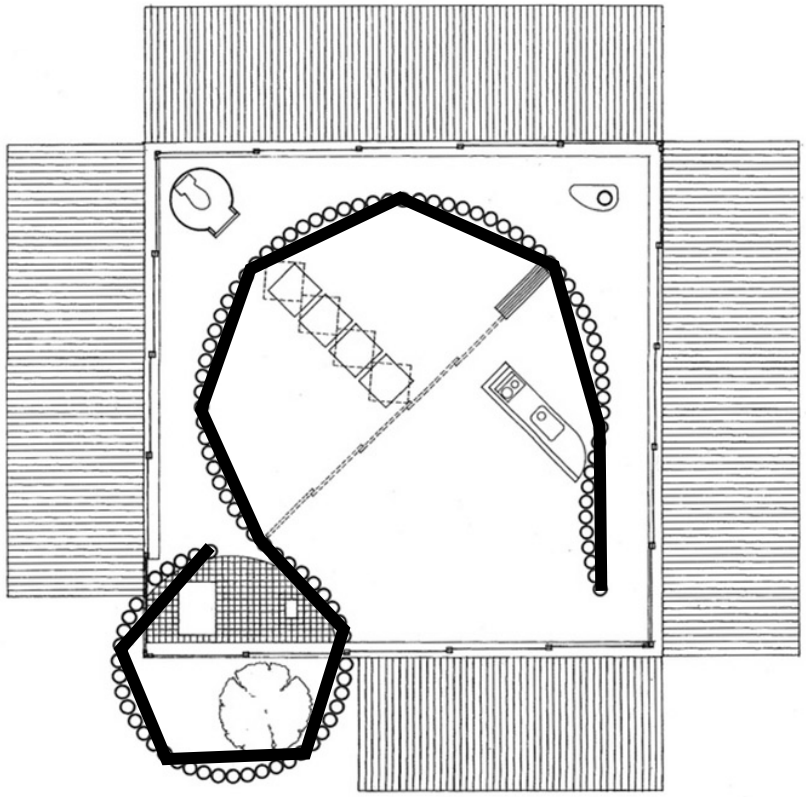

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Architectural Solutions for Lateral Load

Toyo Ito: Mediatheque
Sendai, Japan, 2001

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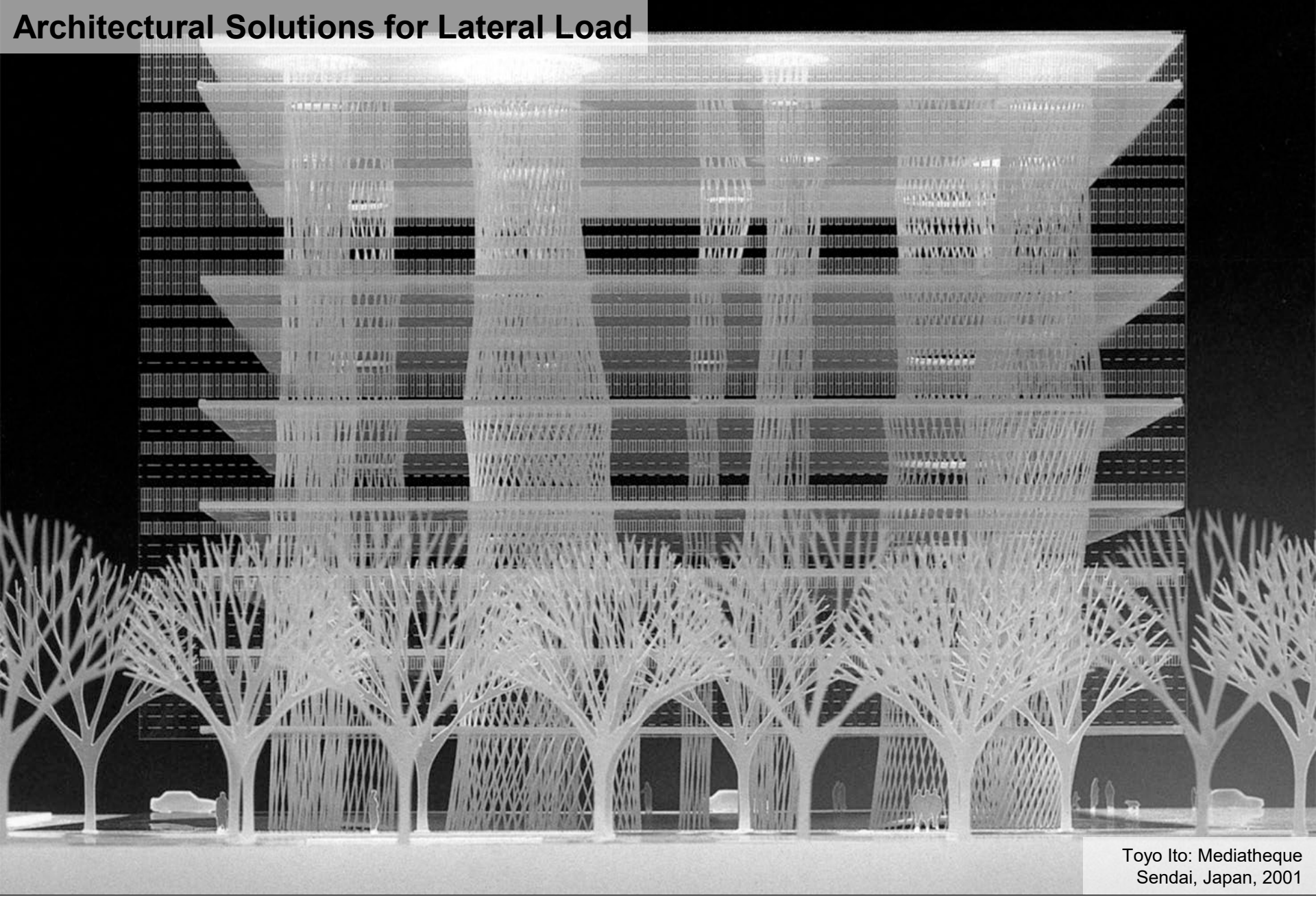

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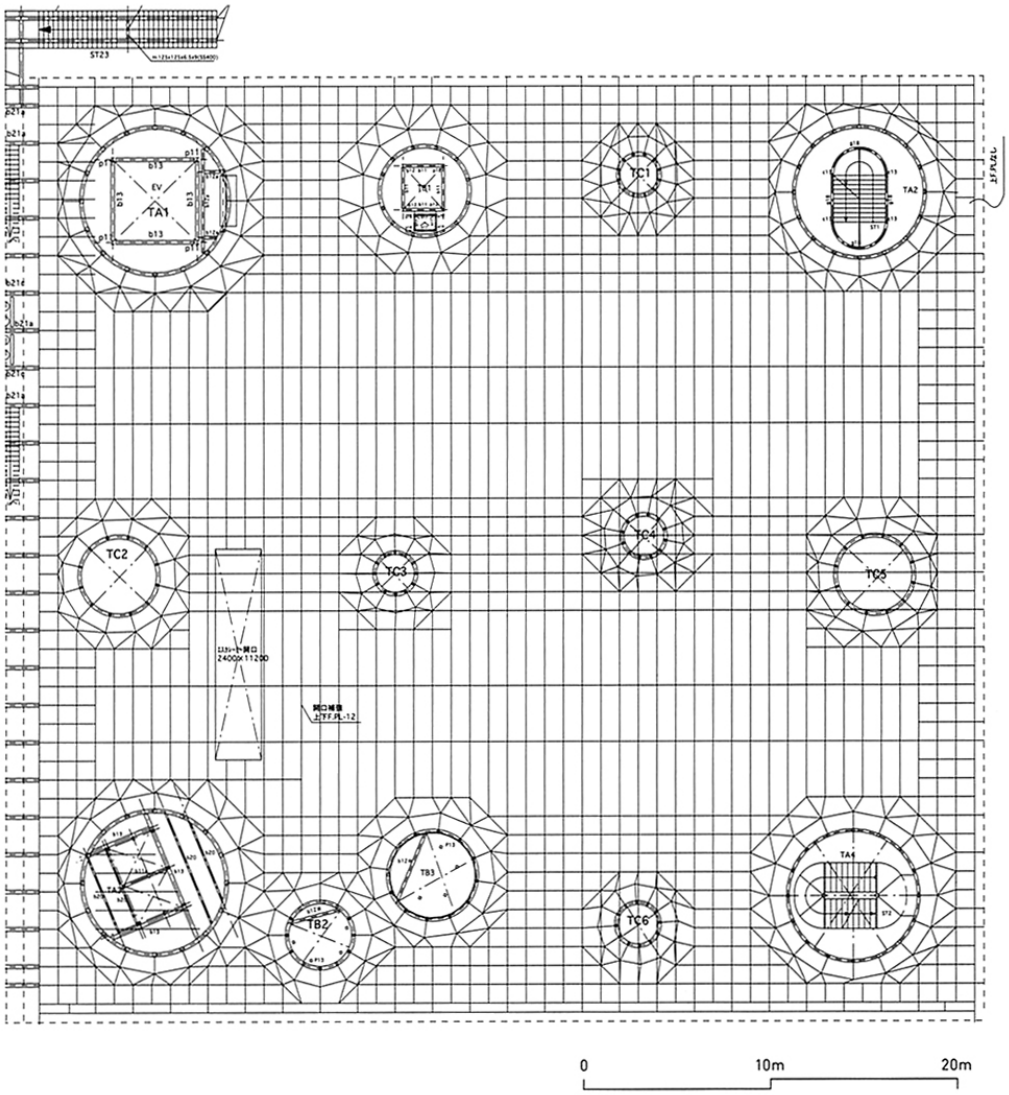

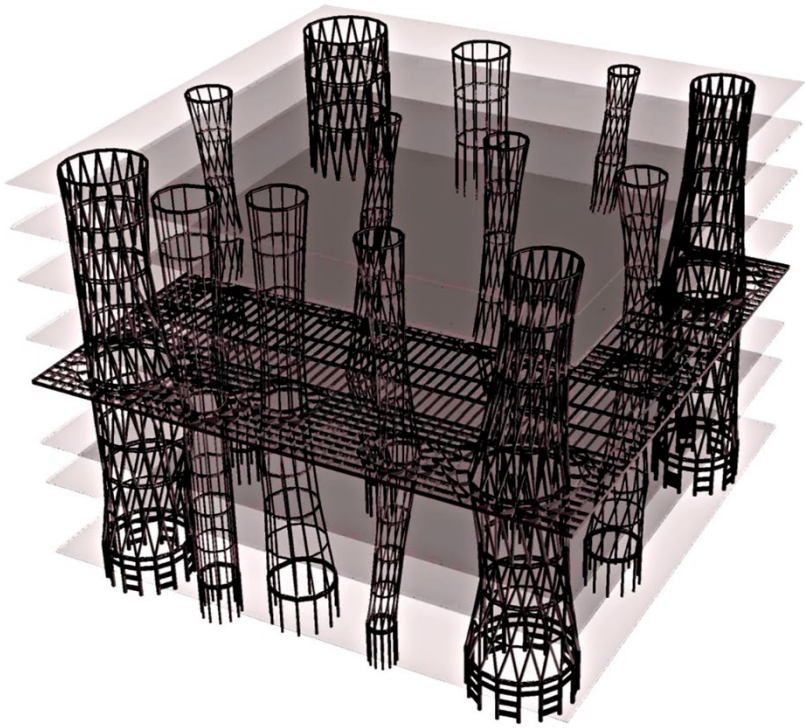

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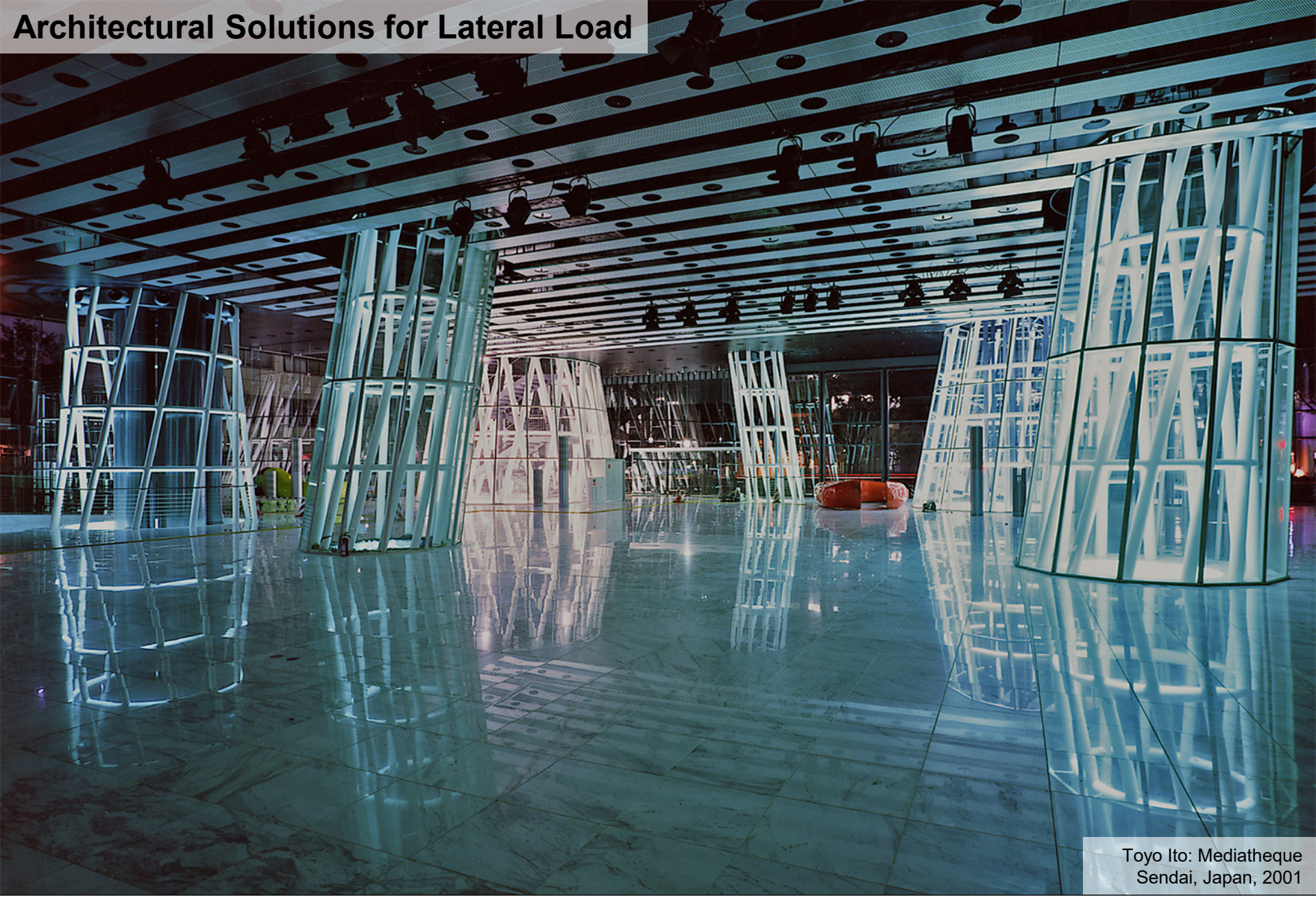

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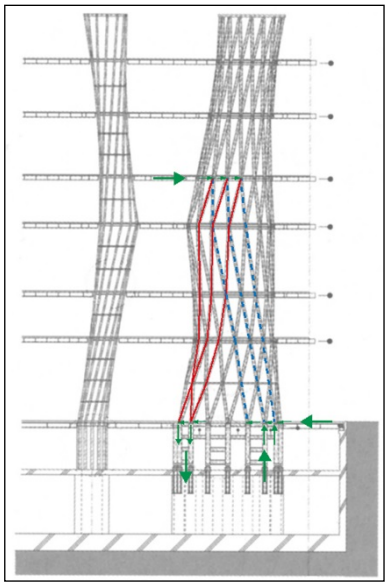

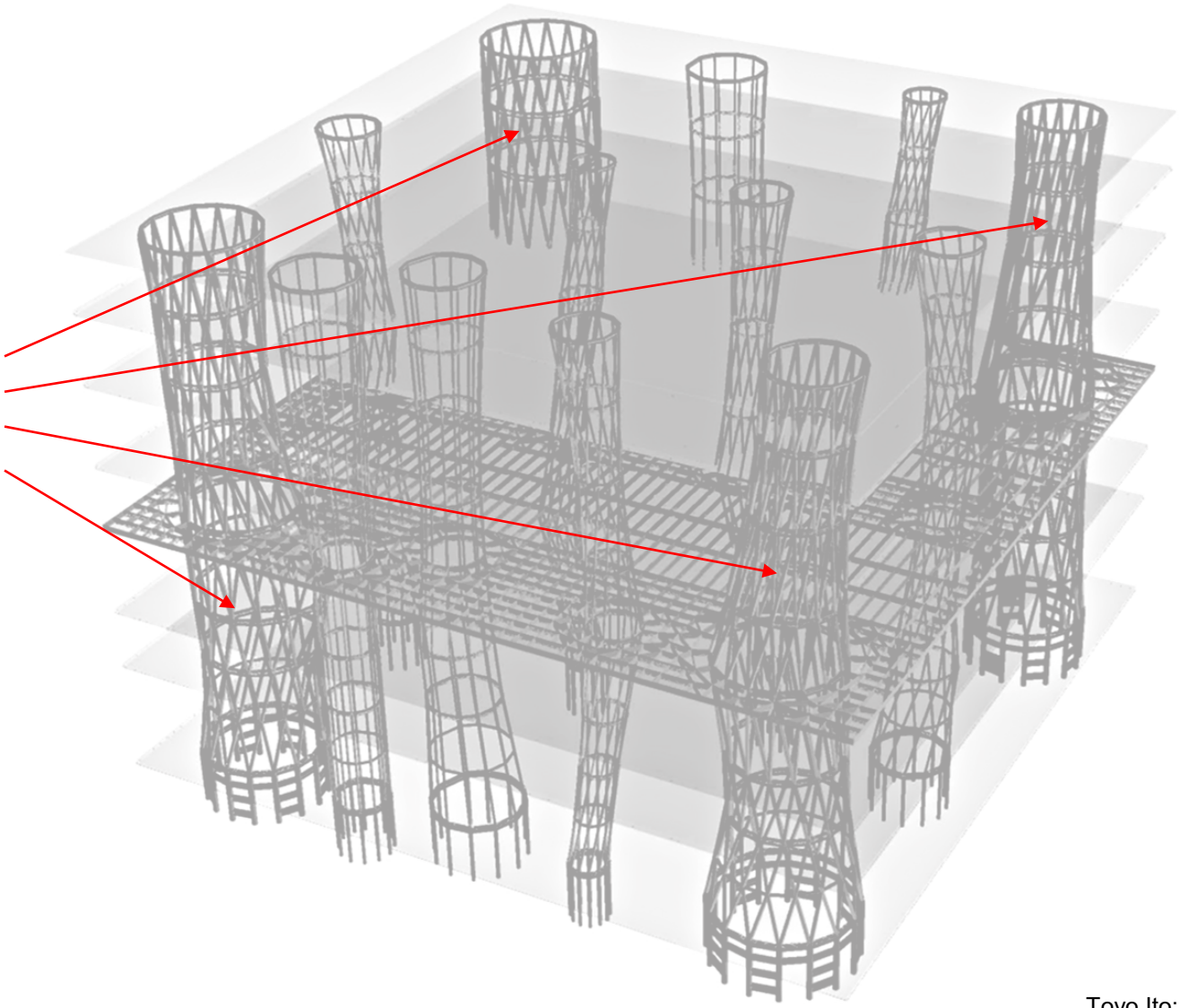

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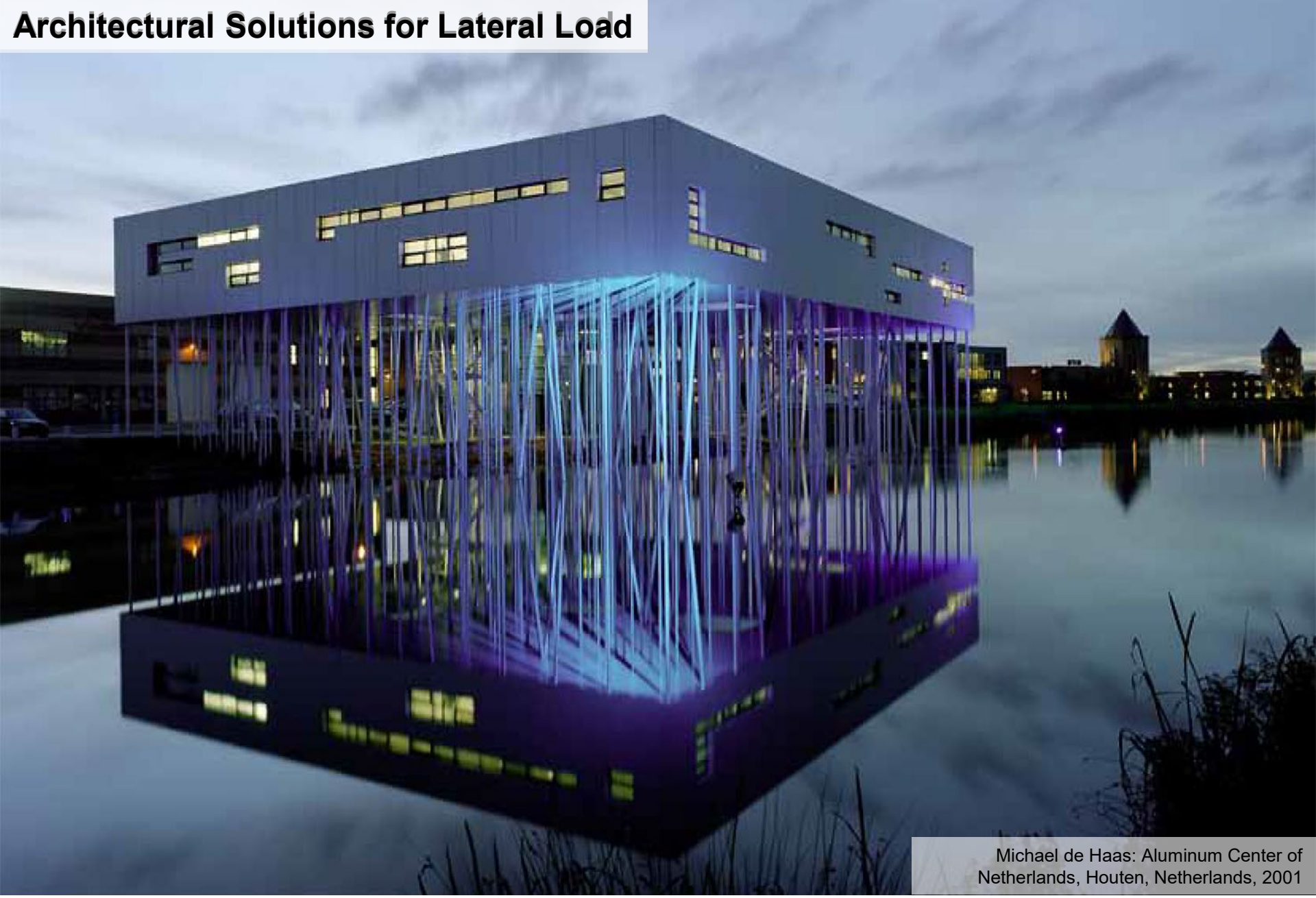

Michael de Haas: Aluminum Center of Netherlands, Houten, Netherlands, 2001

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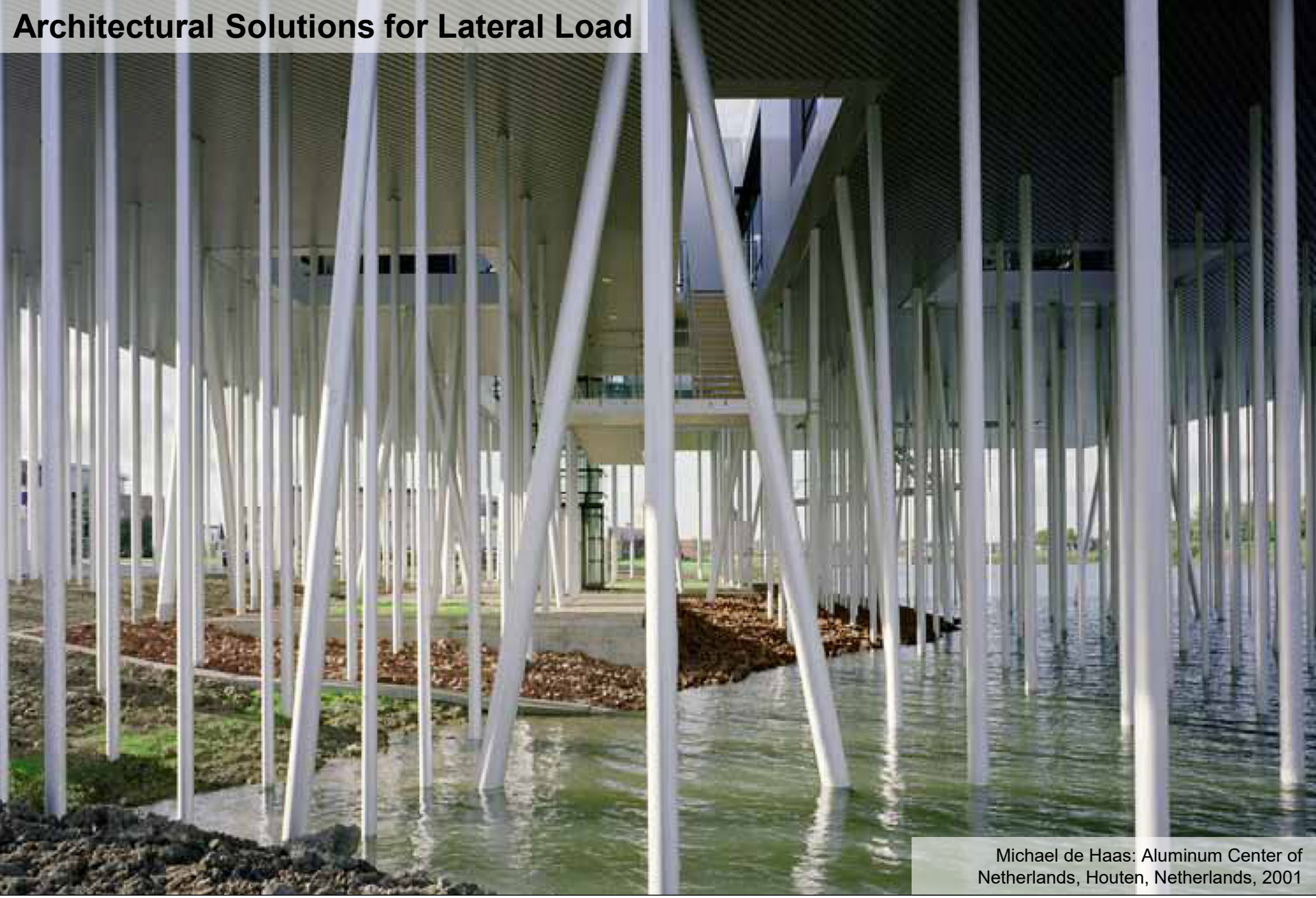

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Architectural Solutions for Lateral Load

Rem Koolhaas: Villa dall'Ava
Saint-Cloud, France, 1991

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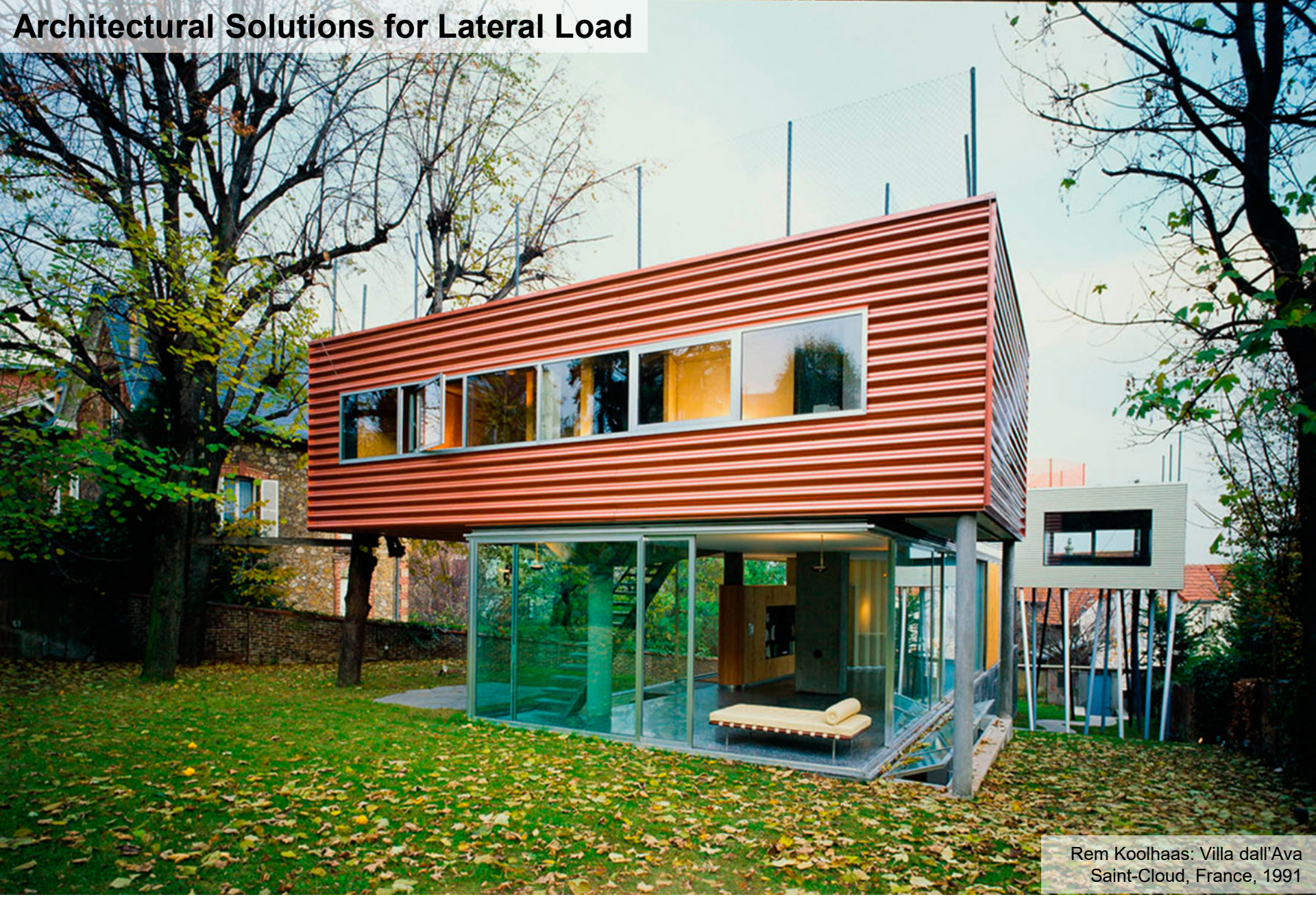

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https://www.youtube.com/watch?v=aFJ71mYYMXI

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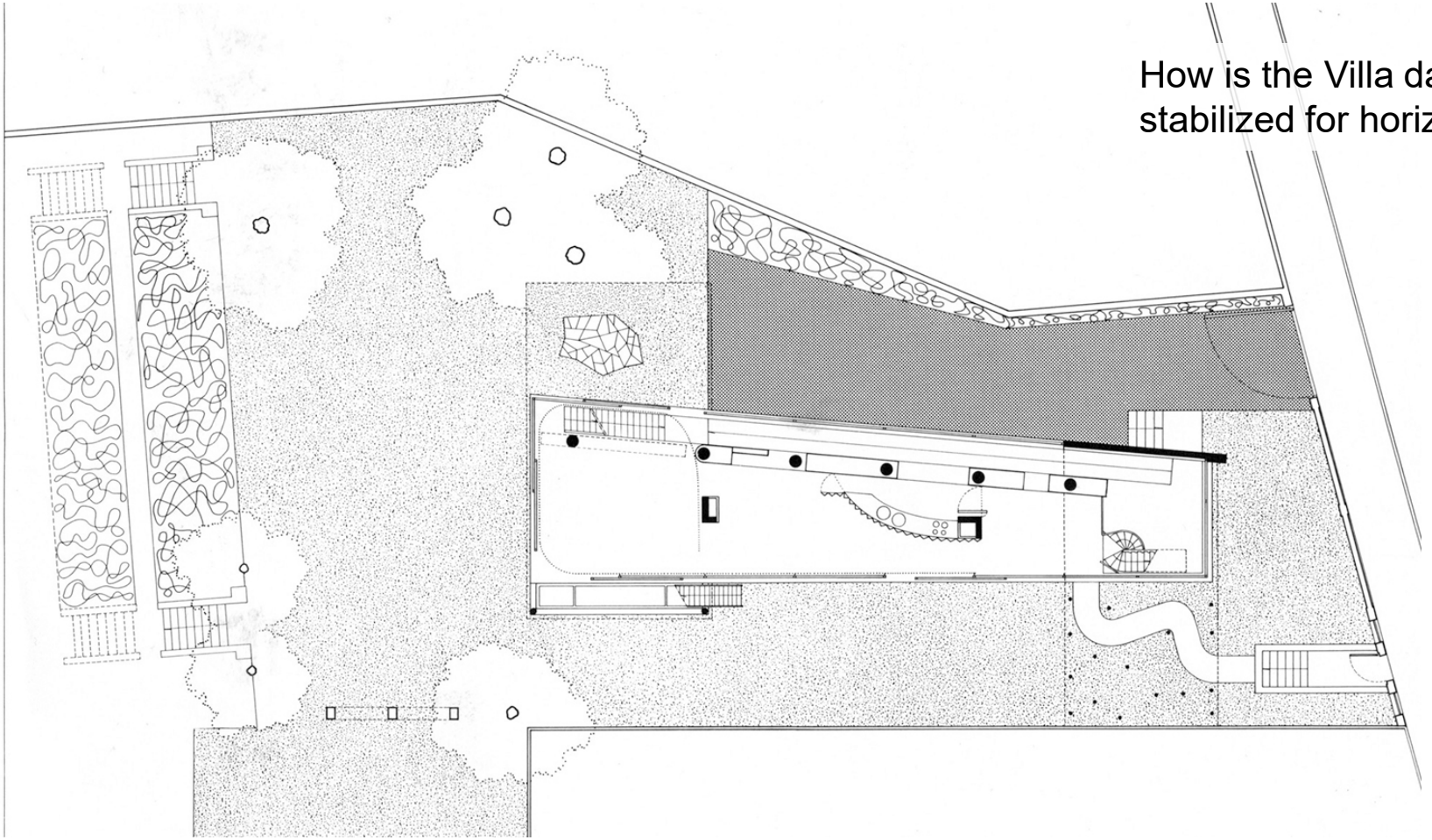
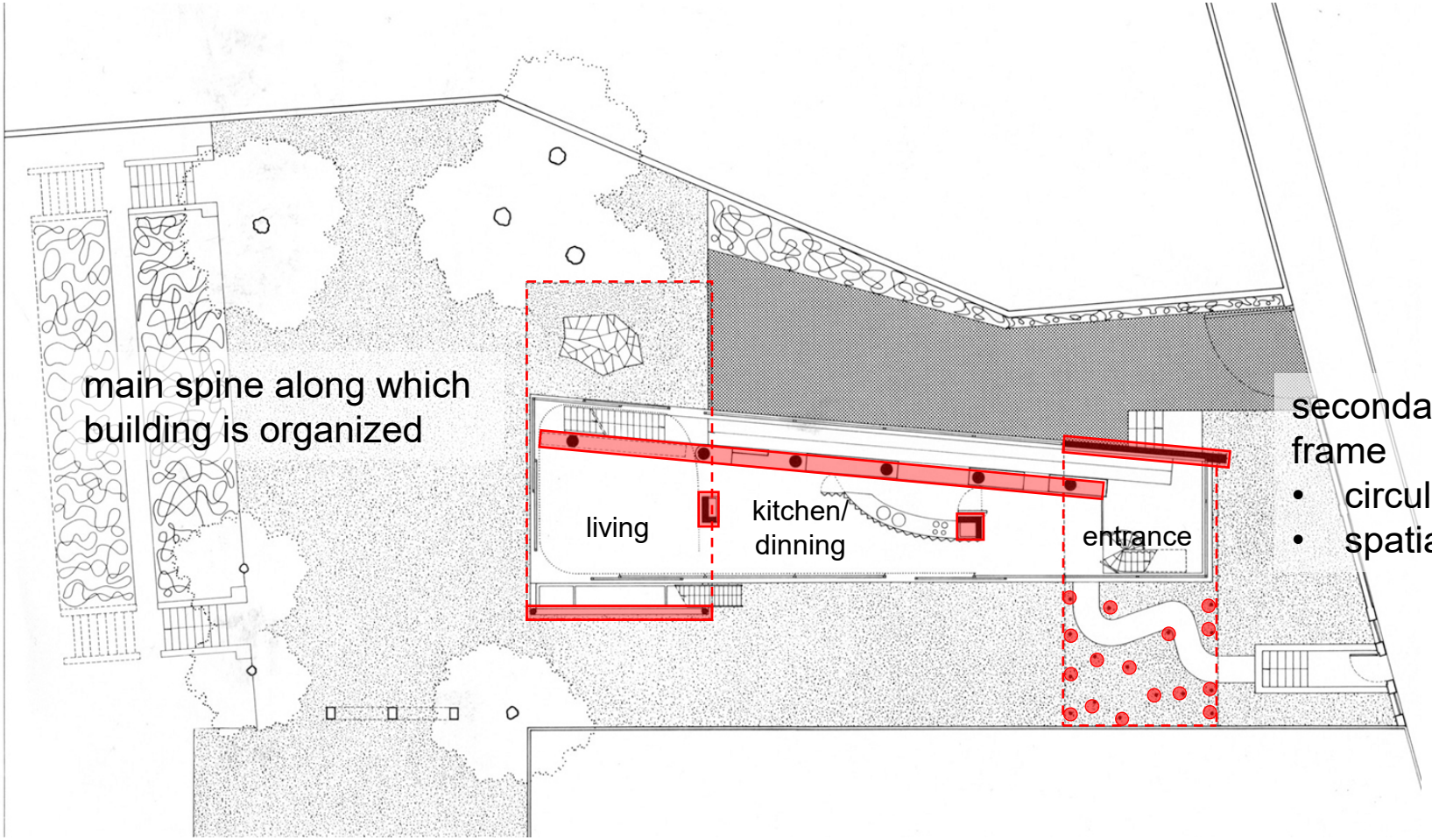


How is the Villa dall'Ava stabilized for horizontal loads?

Rem Koolhaas: Villa dall'Ava
Saint-Cloud, France, 1991

Structure for Spatial Organization



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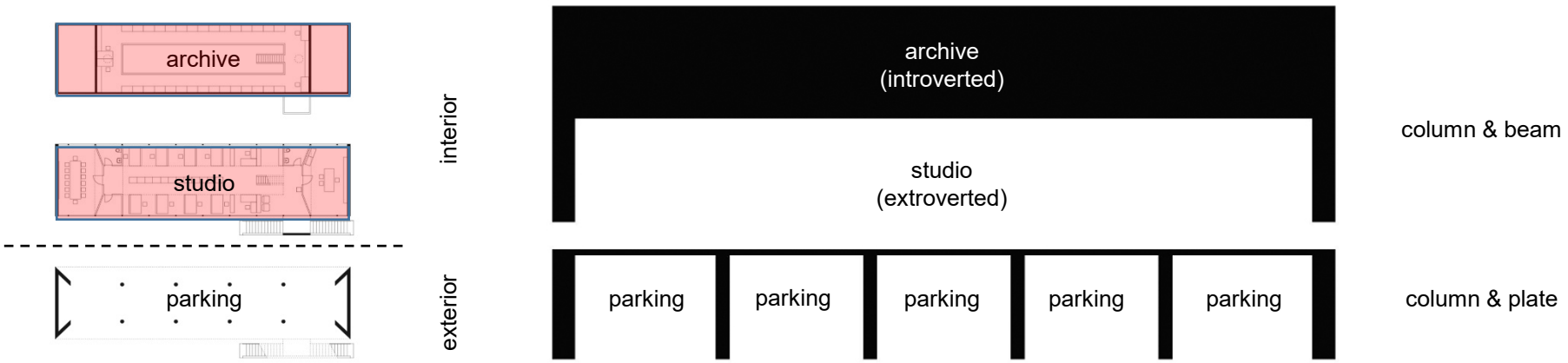

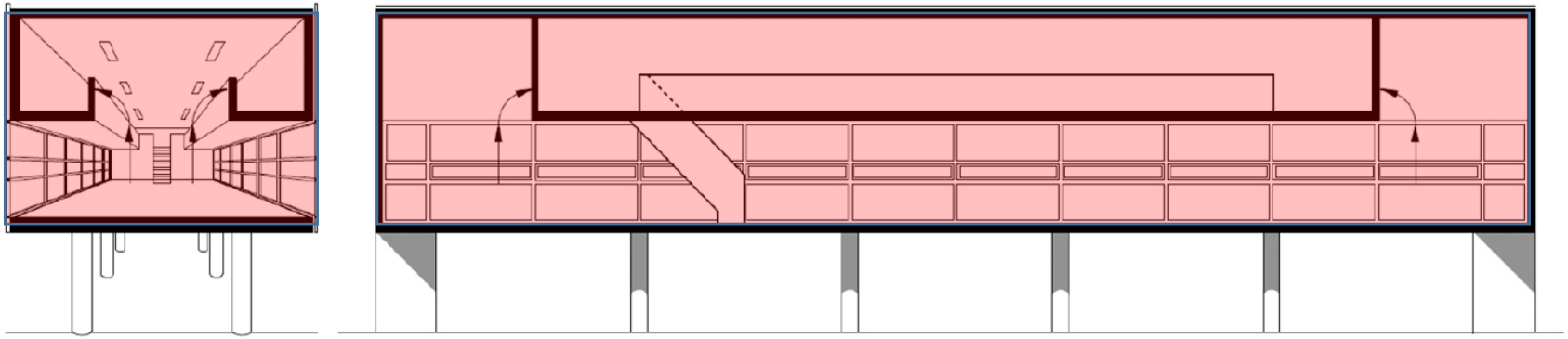

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Structure for Spatial Organization

Christian Kerez: Leutschenbach School
Zurich, Switzerland, 2009

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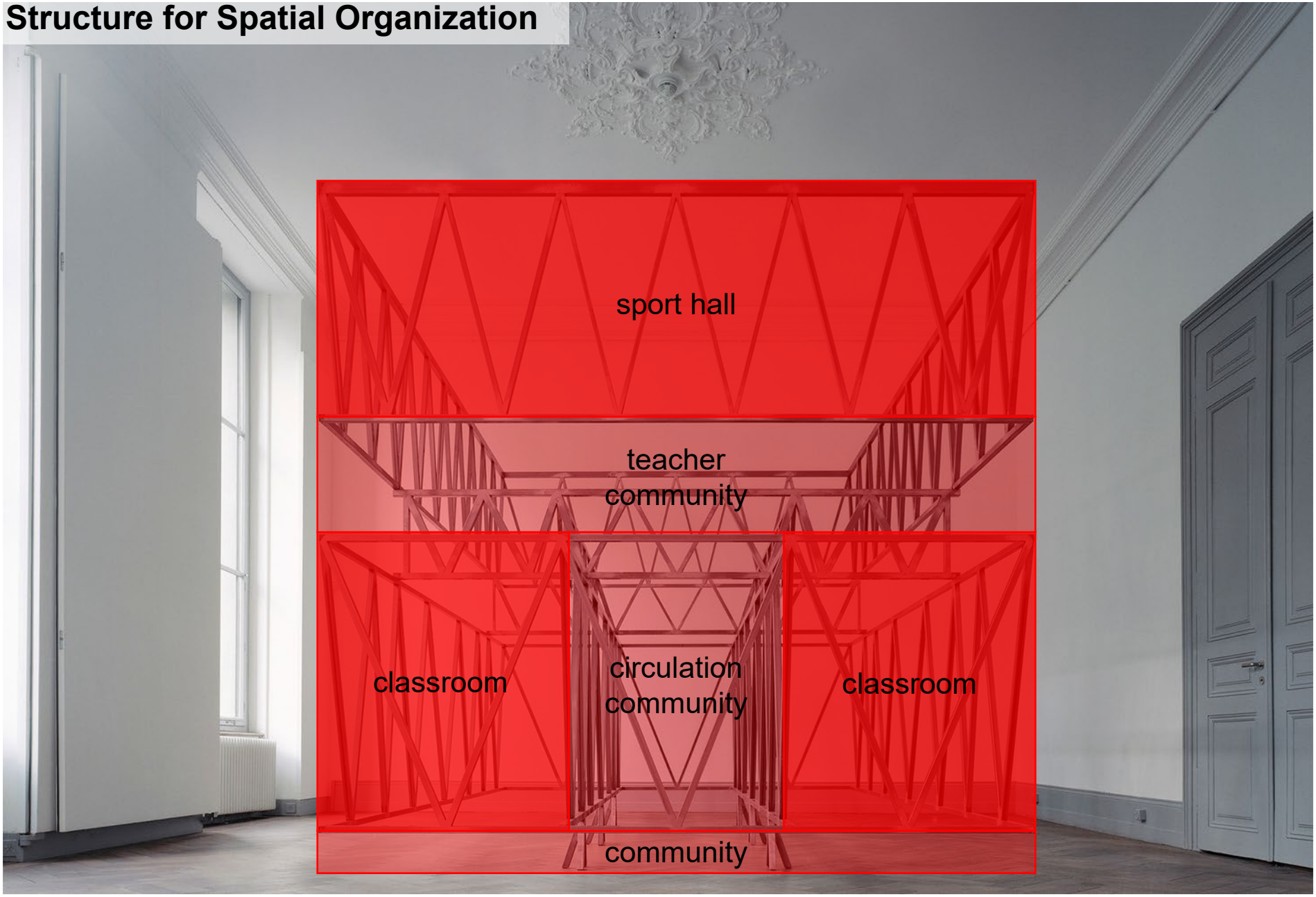

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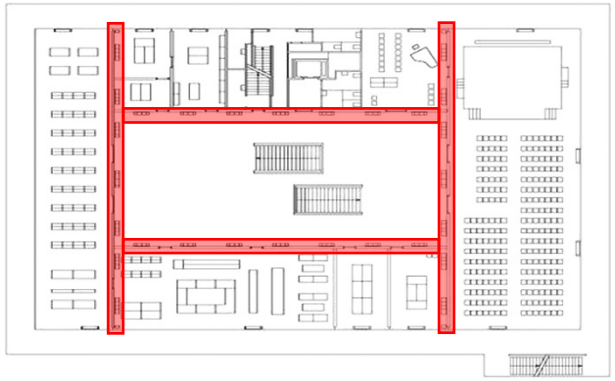

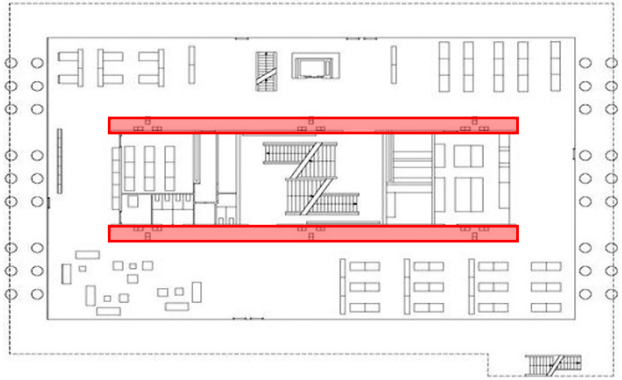

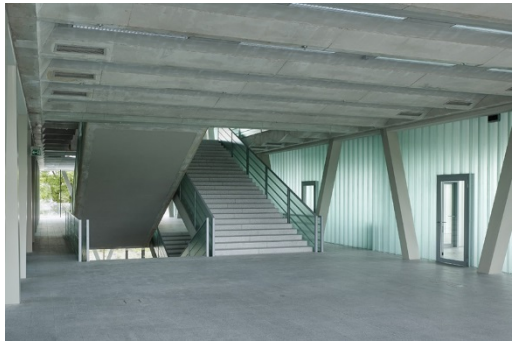

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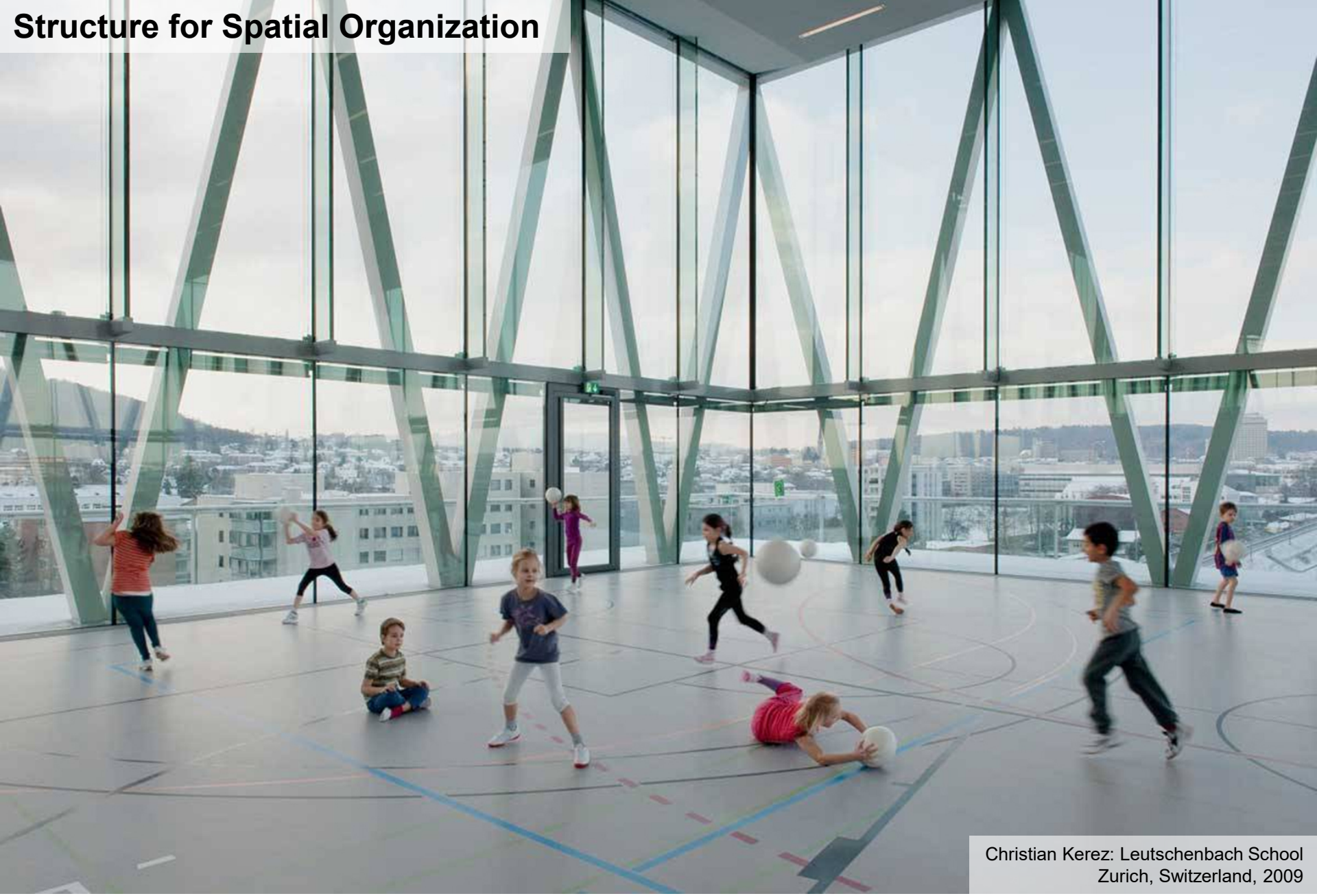

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Shigeru Ban: Picture Window House
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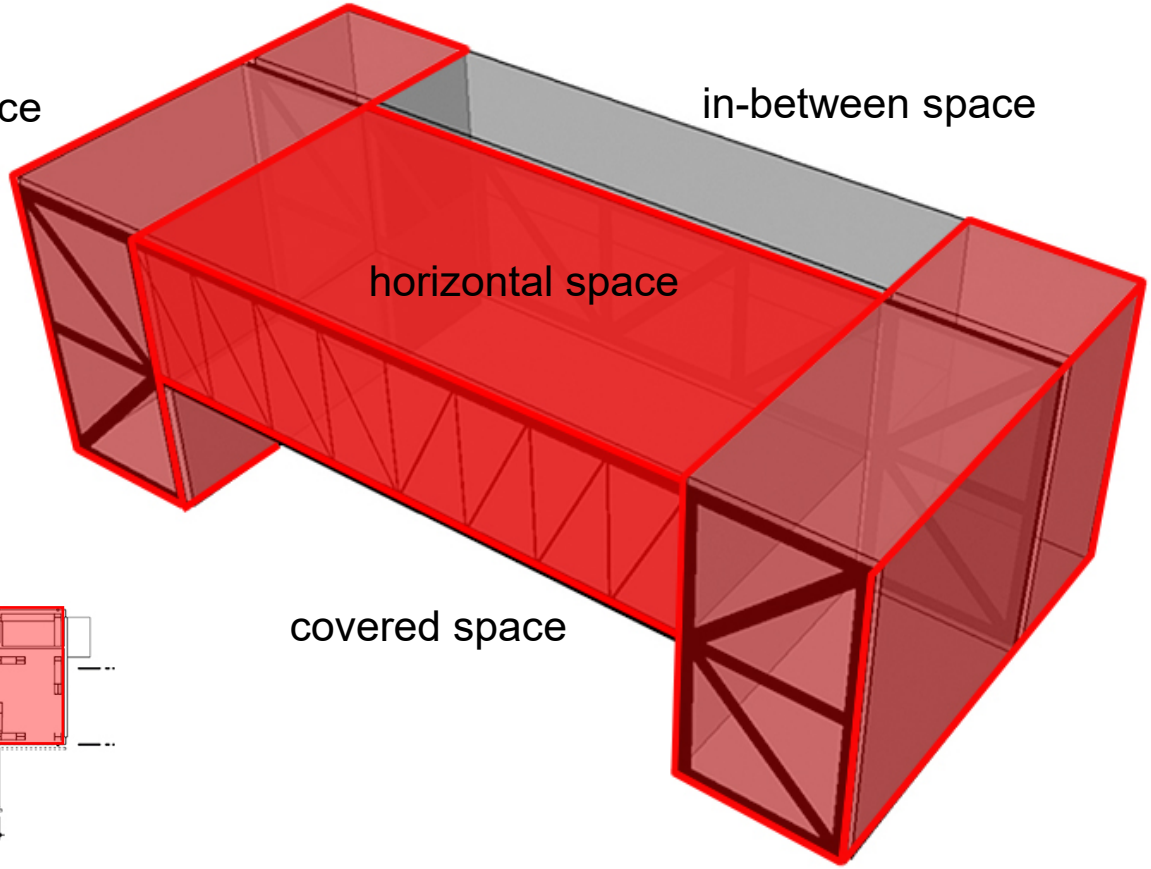

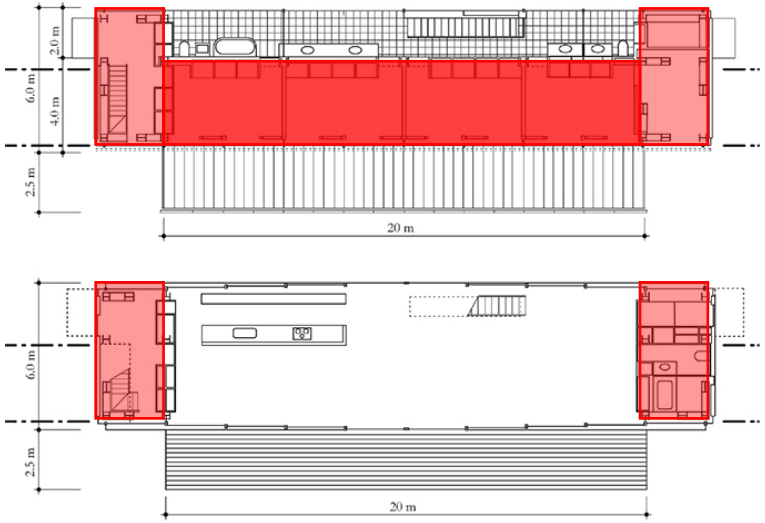

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Structure as Concept

OOPEAA: Kärsämäki Church
Kärsämäki, Finland, 2004

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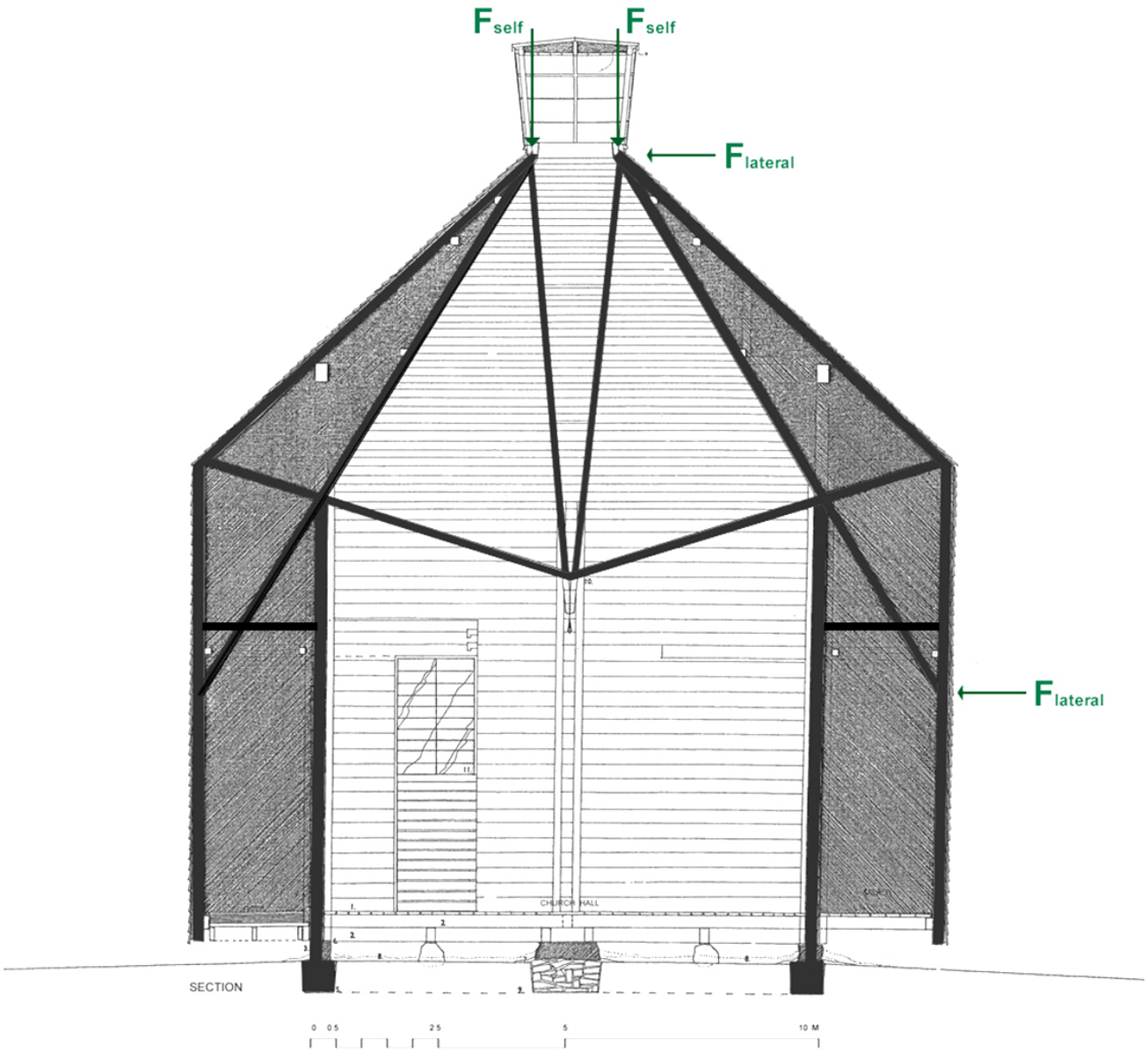

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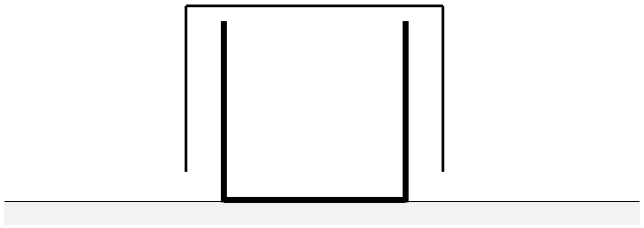

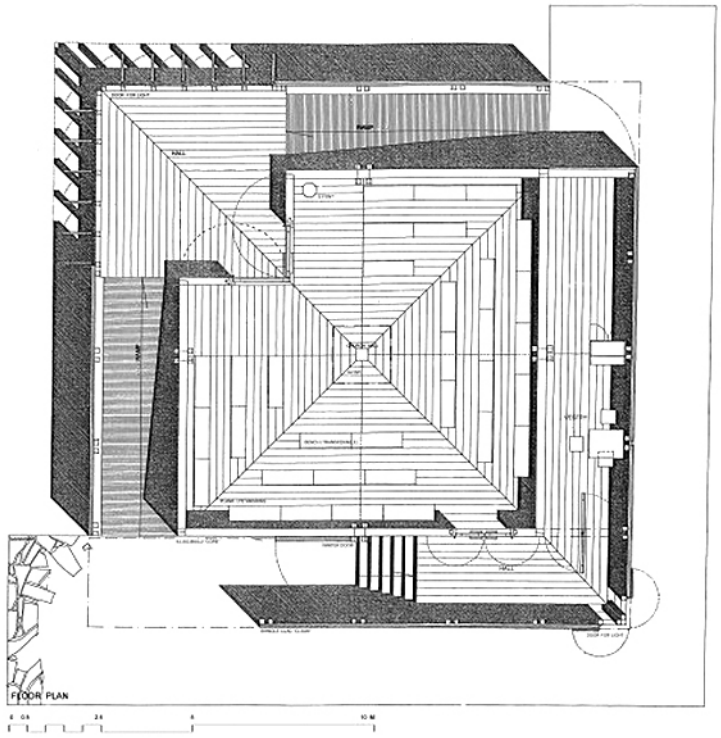

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Kärsämäki, Finland, 2004

Structure and Tectonic

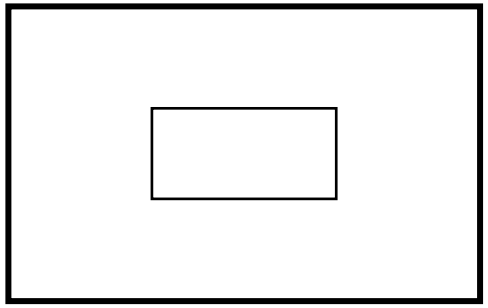
Mies van der Rohe: Farnsworth House
Plano, USA, 1951

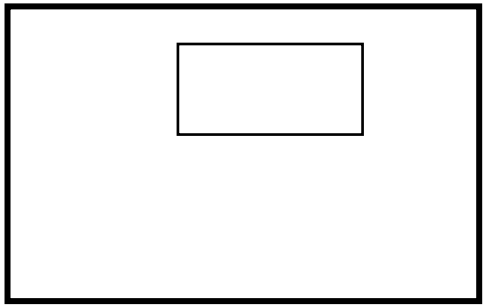
Structure and Tectonic

Mies van der Rohe: Farnsworth House
Plano, USA, 1951

Structure and Tectonic

what is the relation between
two programmatic units?





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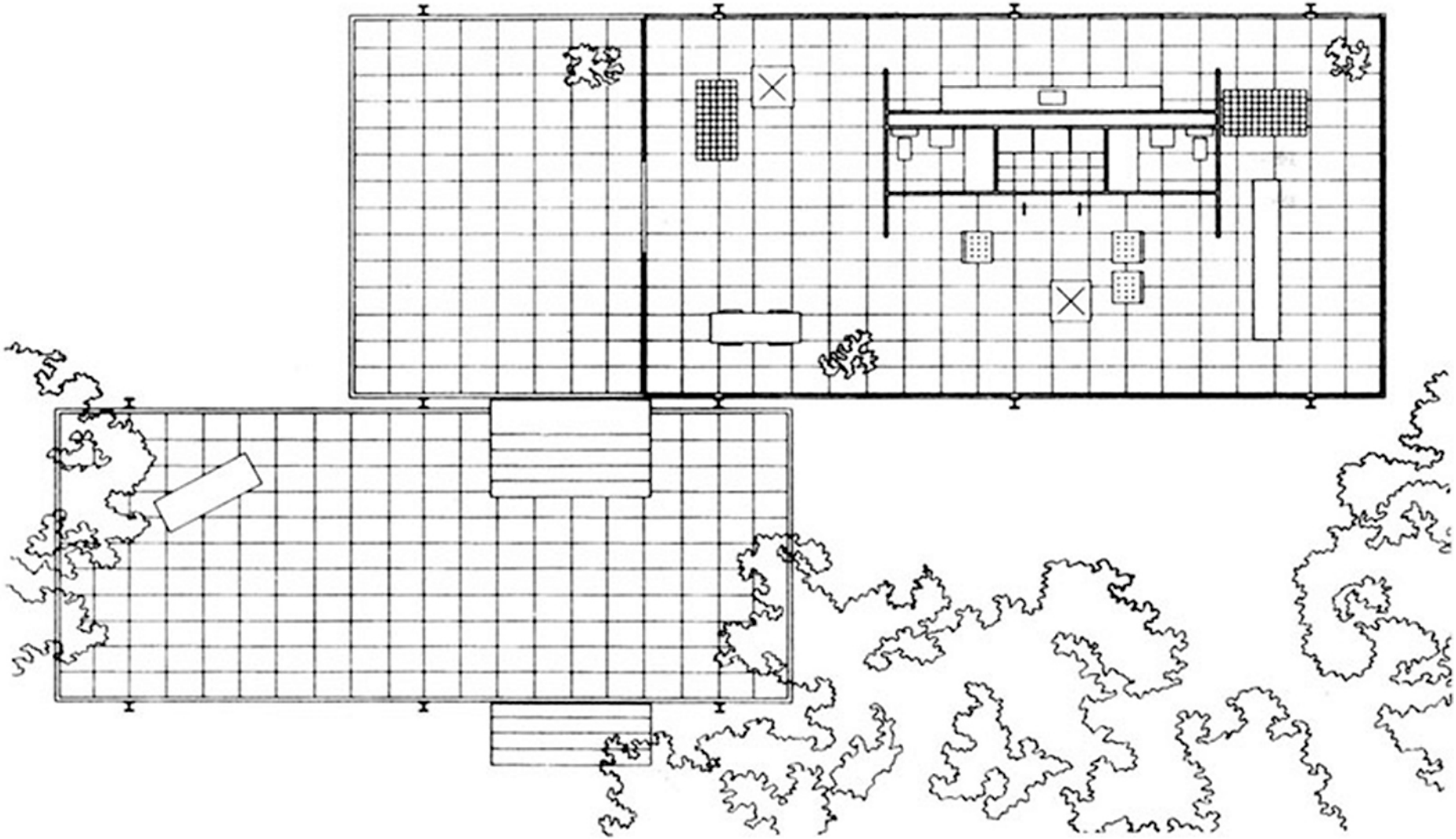

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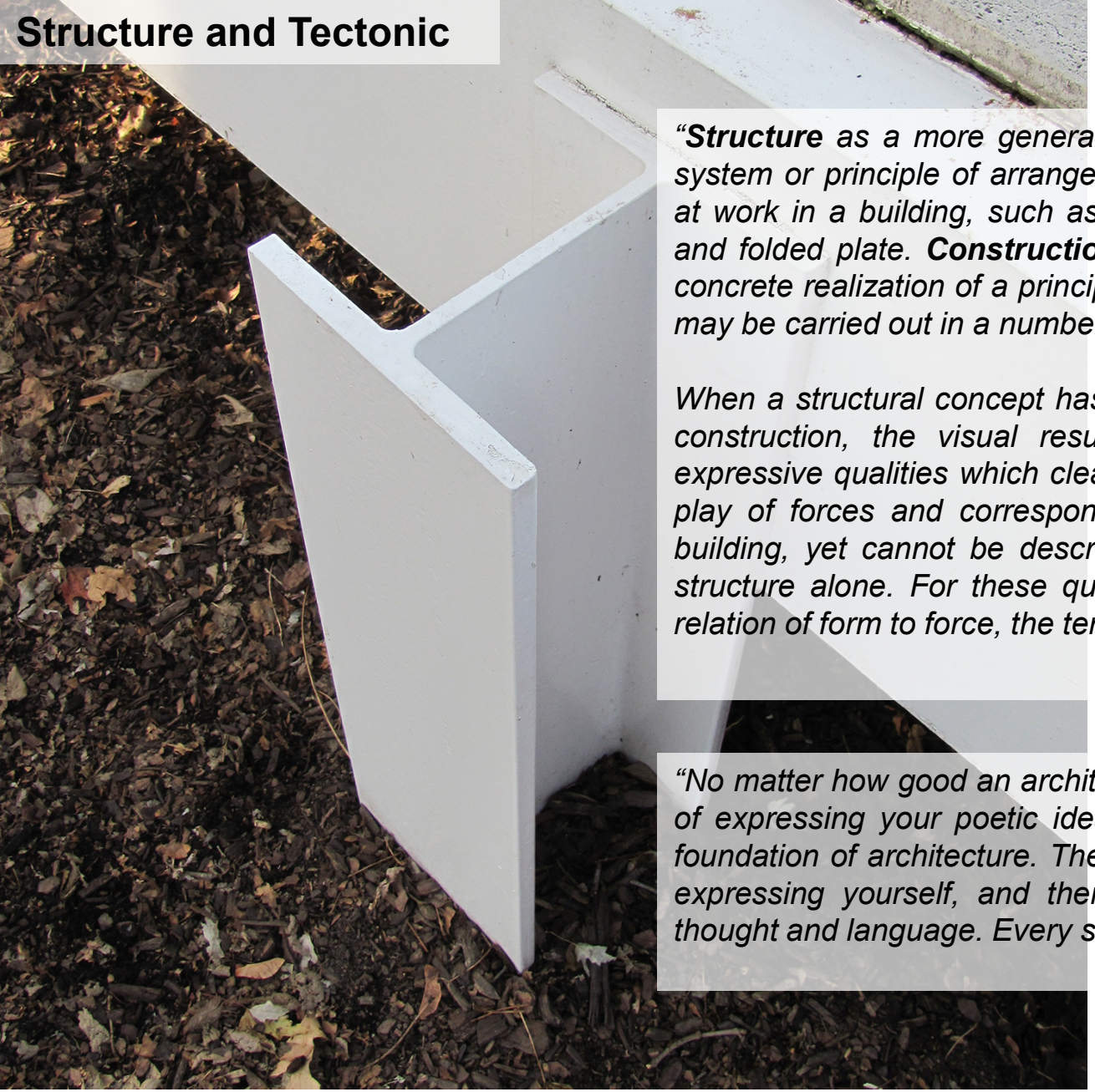

*"**Structure** as a more general and abstract concept refers to a system or principle of arrangement destined to cope with forces at work in a building, such as post-and-lintel, arch, vault, dome and folded plate. **Construction** on the other hand refers to the concrete realization of a principle or system – a realization which may be carried out in a number of materials and ways. …*

*When a structural concept has found its implementation through construction, the visual result will affect us through certain expressive qualities which clearly have something to do with the play of forces and corresponding arrangement of parts in the building, yet cannot be described in terms of construction and structure alone. For these qualities, which are expressive of a relation of form to force, the term **tectonic** should be reserved."*

Eduard Sekler

"No matter how good an architect you are, if you have no chance of expressing your poetic idea in structures, you lack the very foundation of architecture. The structure is a language, a way of expressing yourself, and there should be a balance between thought and language. Every story has a structure."

Sverre Fehn

Mies van der Rohe: Farnsworth House
Plano, USA, 1951

Structure and Tectonic

Peter Zumthor: Chapel
Sogn Benedetg, Switzerland, 1989

Structure and Tectonic

Peter Zumthor: Chapel
Sogn Benedetg, Switzerland, 1989

Structure and Tectonic

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

Peter Zumthor: Chapel
Sogn Benedetg, Switzerland, 1989

three walls for lateral stability

shaping of elements

shaping of structural system

organization of architecture

support architectural concept

structure as architecture

structural tectonics

ARK-A3001 Design of Structures_Basics

Design with Forces

Toni Kotnik

Professor of Design of Structures

Aalto University
Department of Architecture
Department of Civil Engineering

Exercise: Building Analysis