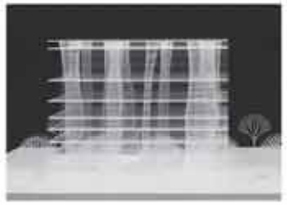
Tragwerksentwurf III

Structural Design III

Joseph Schwartz · Philippe Block



Architektur und Tragwerk

Architecture and Structure

1. Stahl

1. Steel

2. Stahlbeton

2. Reinforced concrete

3. Holz

3. Timber

4. Mauerwerk

4. Masonry

5. Konstruktiondetails

5. Construction details

Tragwerksentwurf III

Structural Design III

Tragwerksentwurf IV

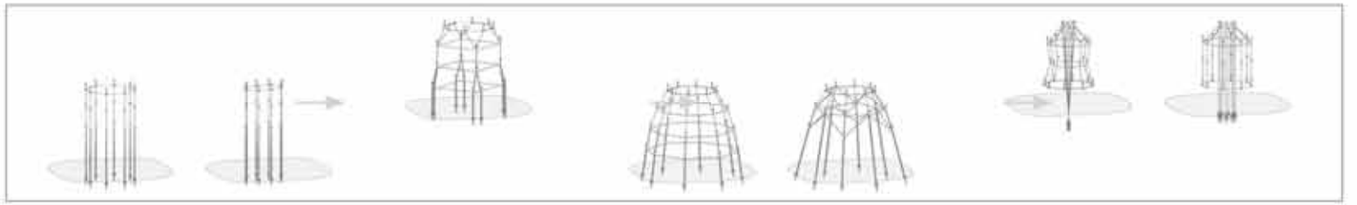
Structural Design IV

Entwerfen von Tragwerken I

Design of structures I

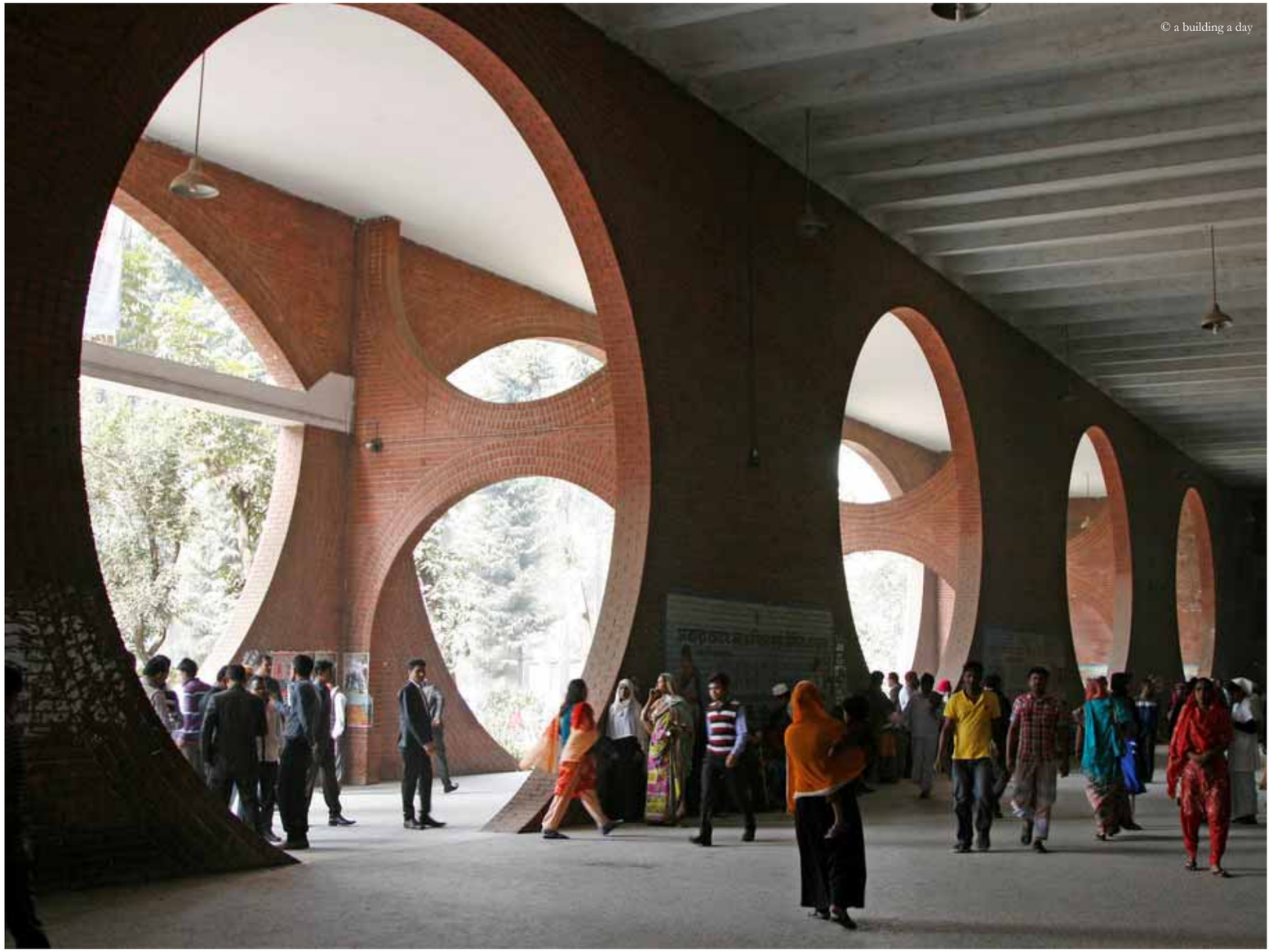
Entwerfen von Tragwerken II

Design of structures II



Entwurfsprojekt

Design project


© a building a day

"Du sagst zu einem Ziegelstein: 'Was willst du, Ziegelstein?' Und der Ziegelstein antwortet: 'Ich möchte einen Bogen. Und du sagst zu Stein: 'Schau, ich will auch einen, aber Bögen sind teuer und ich kann einen Betonsturz verwenden.' Und dann sagst du: 'Was hältst du davon, Ziegelstein?' Der Ziegelstein sagt: 'Ich will einen Bogen.'"

Louis Kahn in einer Diskussion mit seinen Studenten, Penn 1971

Mauerwerk
Masonry

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Masonry

The Great Pyramid of Giza, Cairo, 2560-2490 BC

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Masonry

Parthenon, Athens, 447-438 BC

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Masonry

Colosseum, Rome, 70 AD

Palazzo Barberini, Rome, 1625, arch. Carlo Maderno, Francesco Borromini, Gian Lorenzo Bernini

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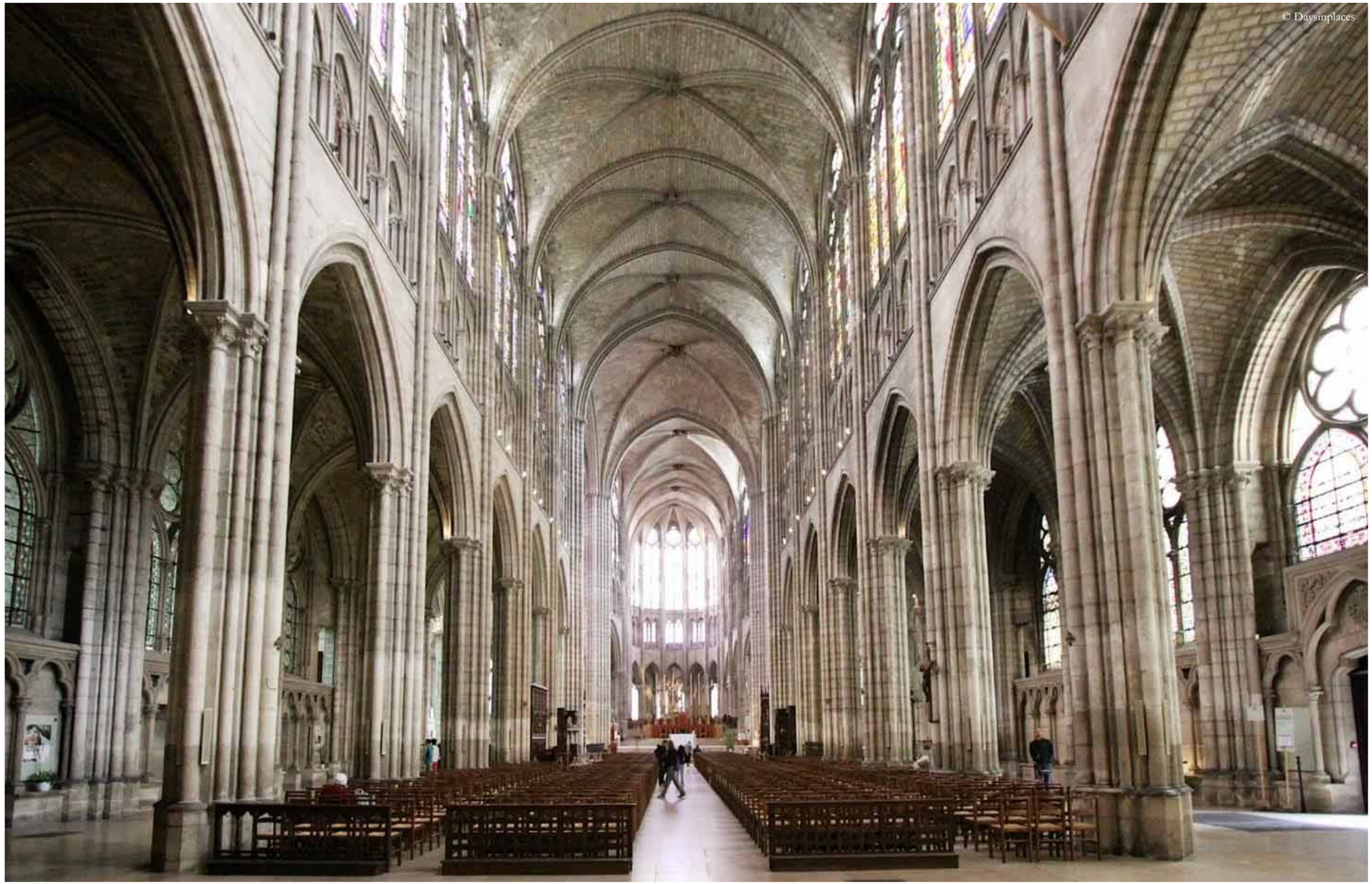

Basilica of Saint-Denis, Paris, 1144

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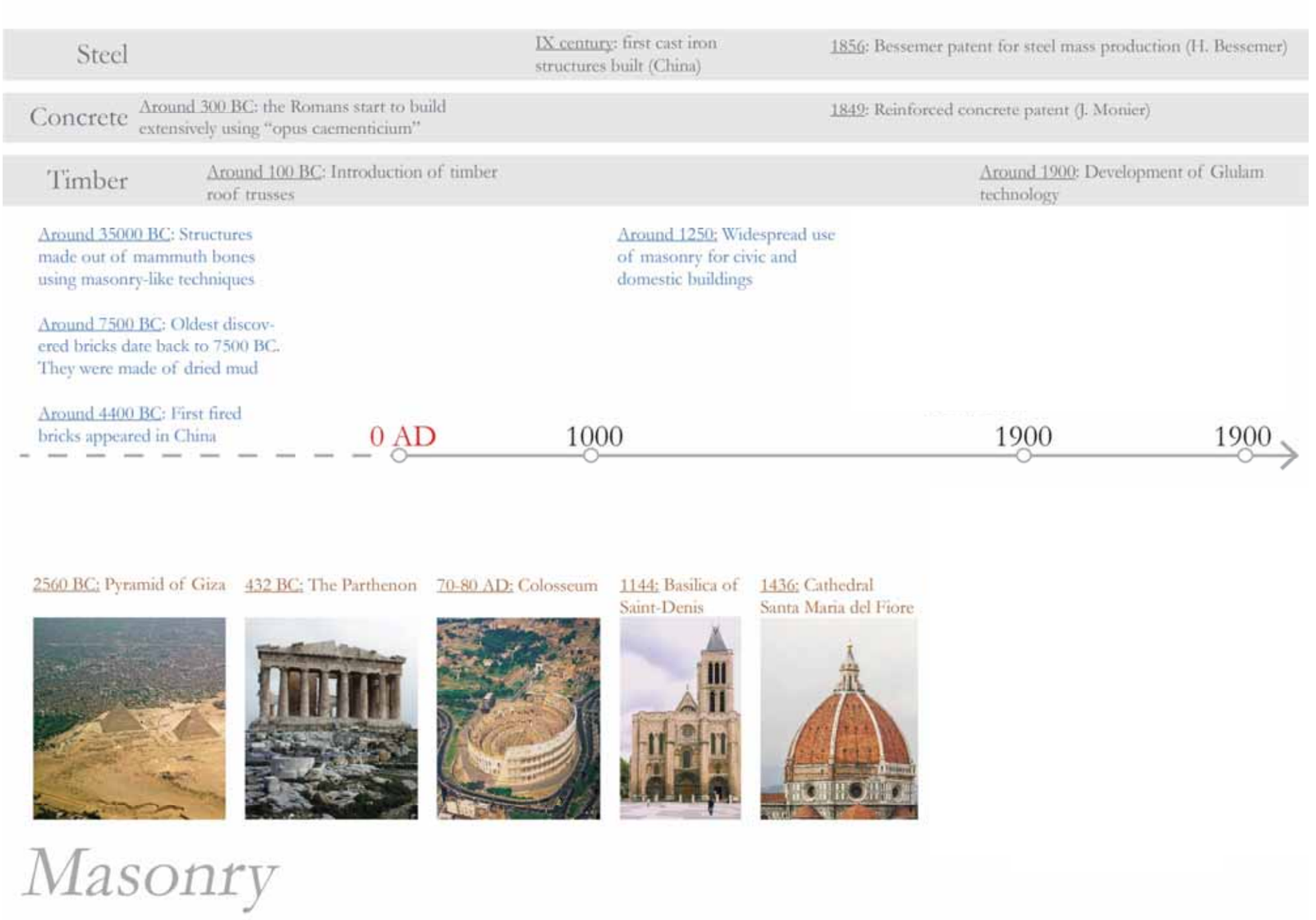
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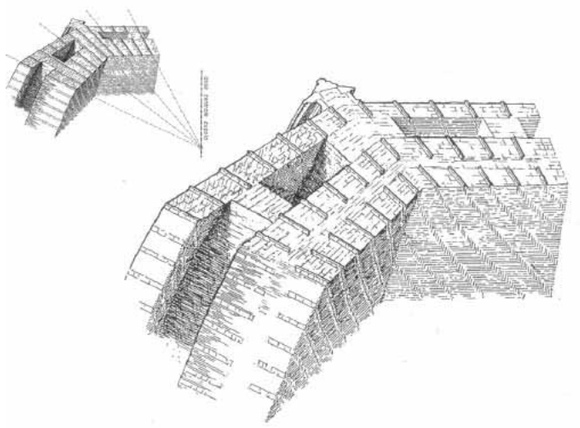

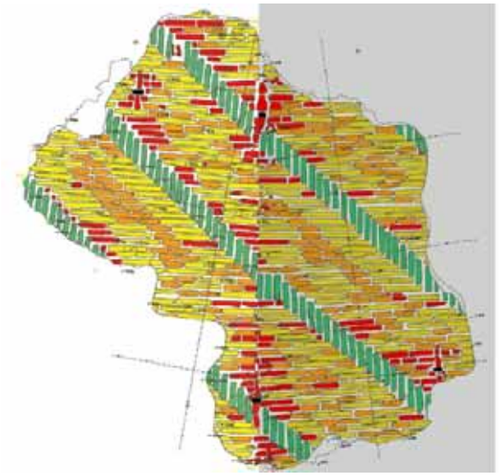

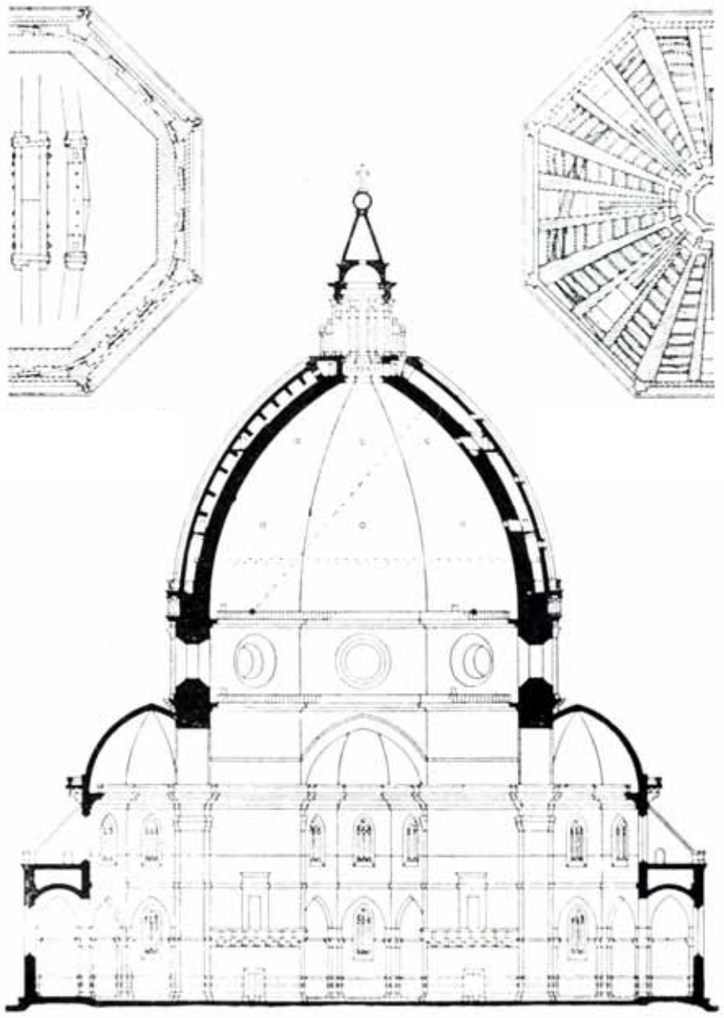

Dome of Santa Maria del Fiore, Florence, 1436, arch. Filippo Brunelleschi

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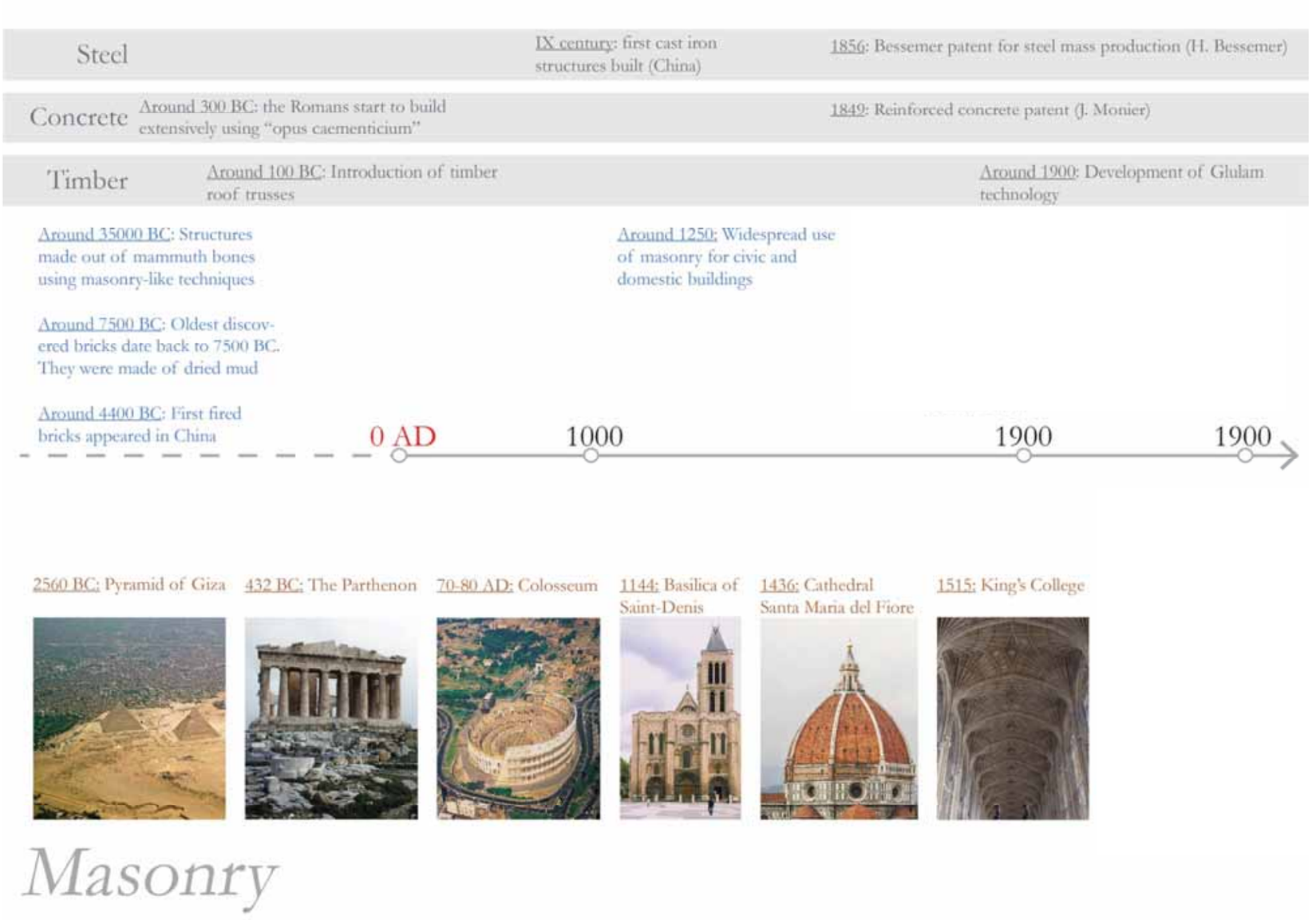
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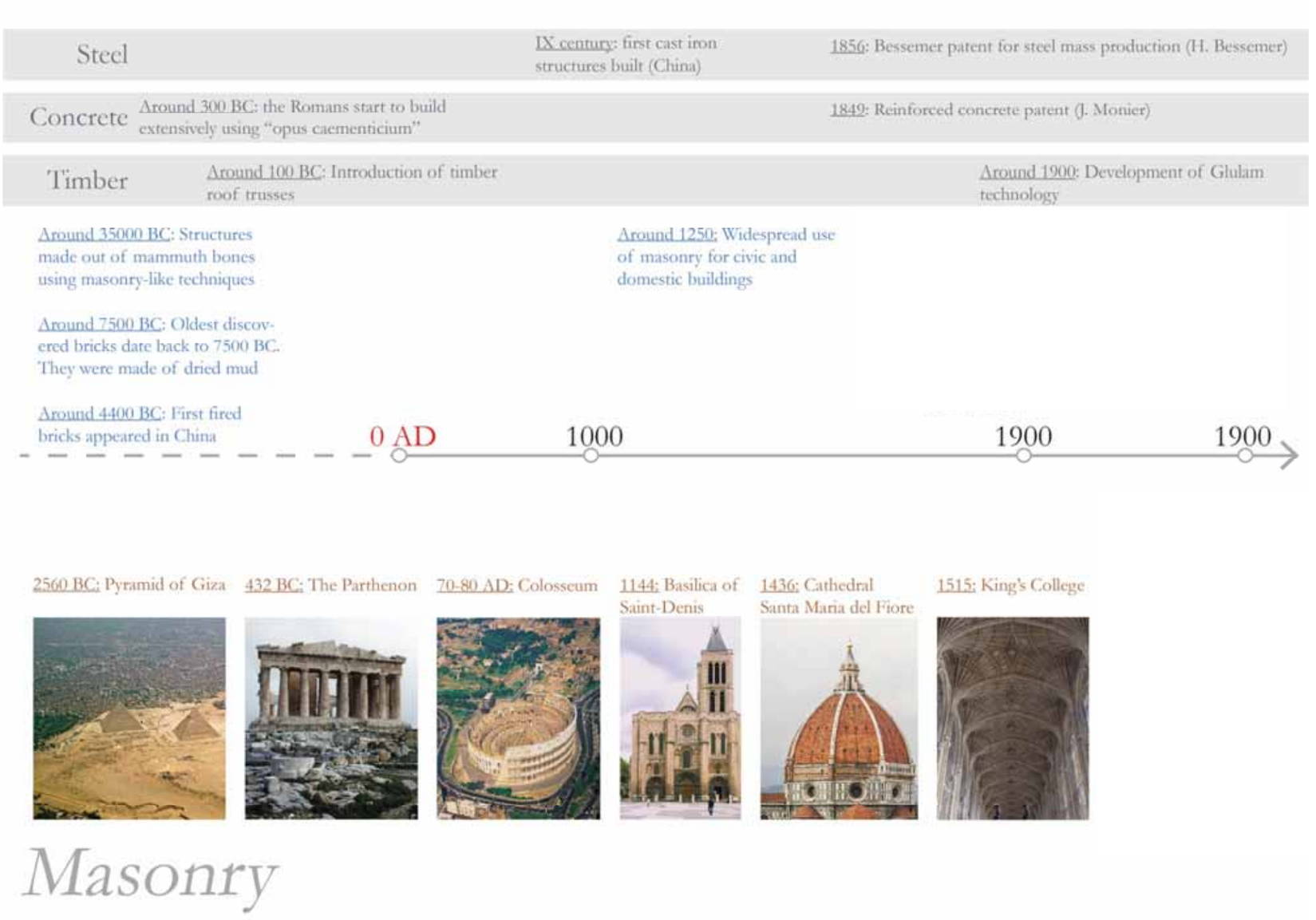
Masonry

King's College, Cambridge, 1515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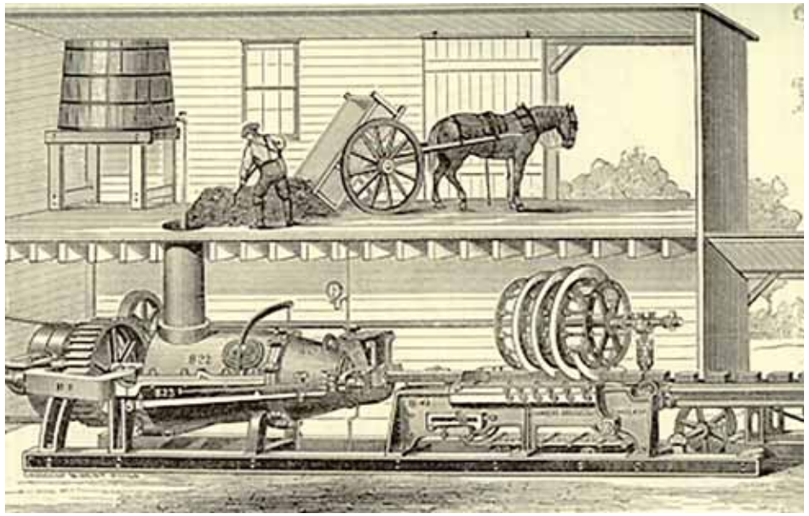

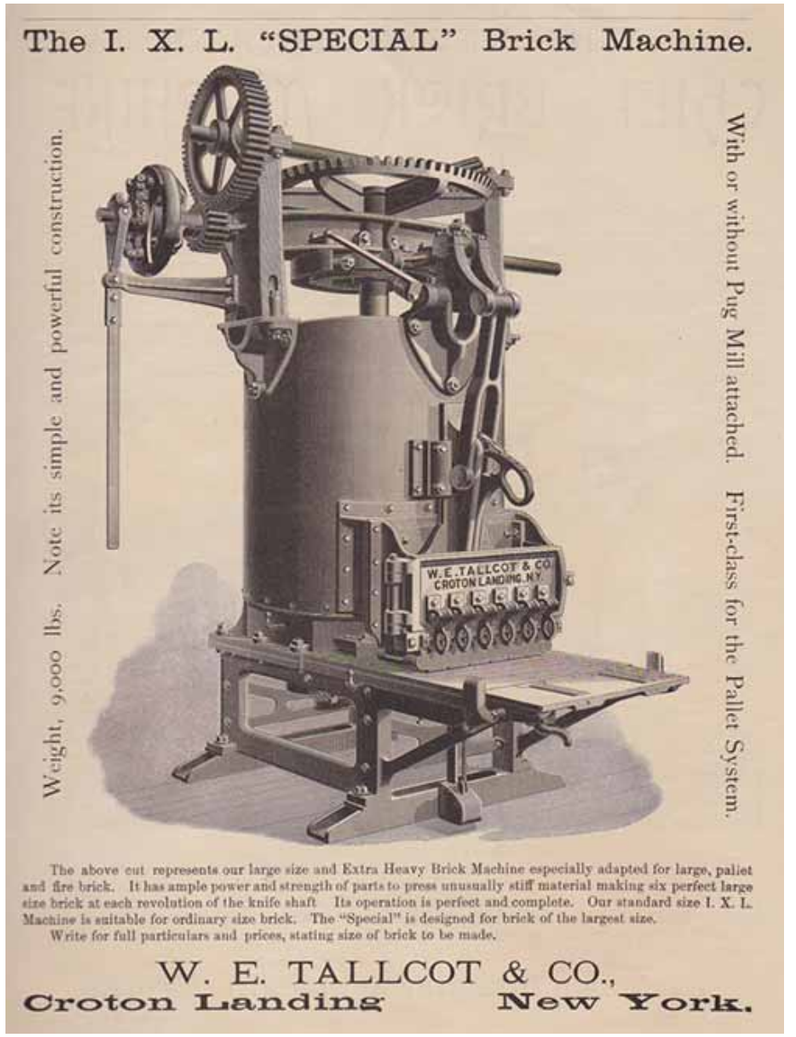

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Monadnock Building, Chicago, 1893, arch. Burnham & Root, Holabird & Roche

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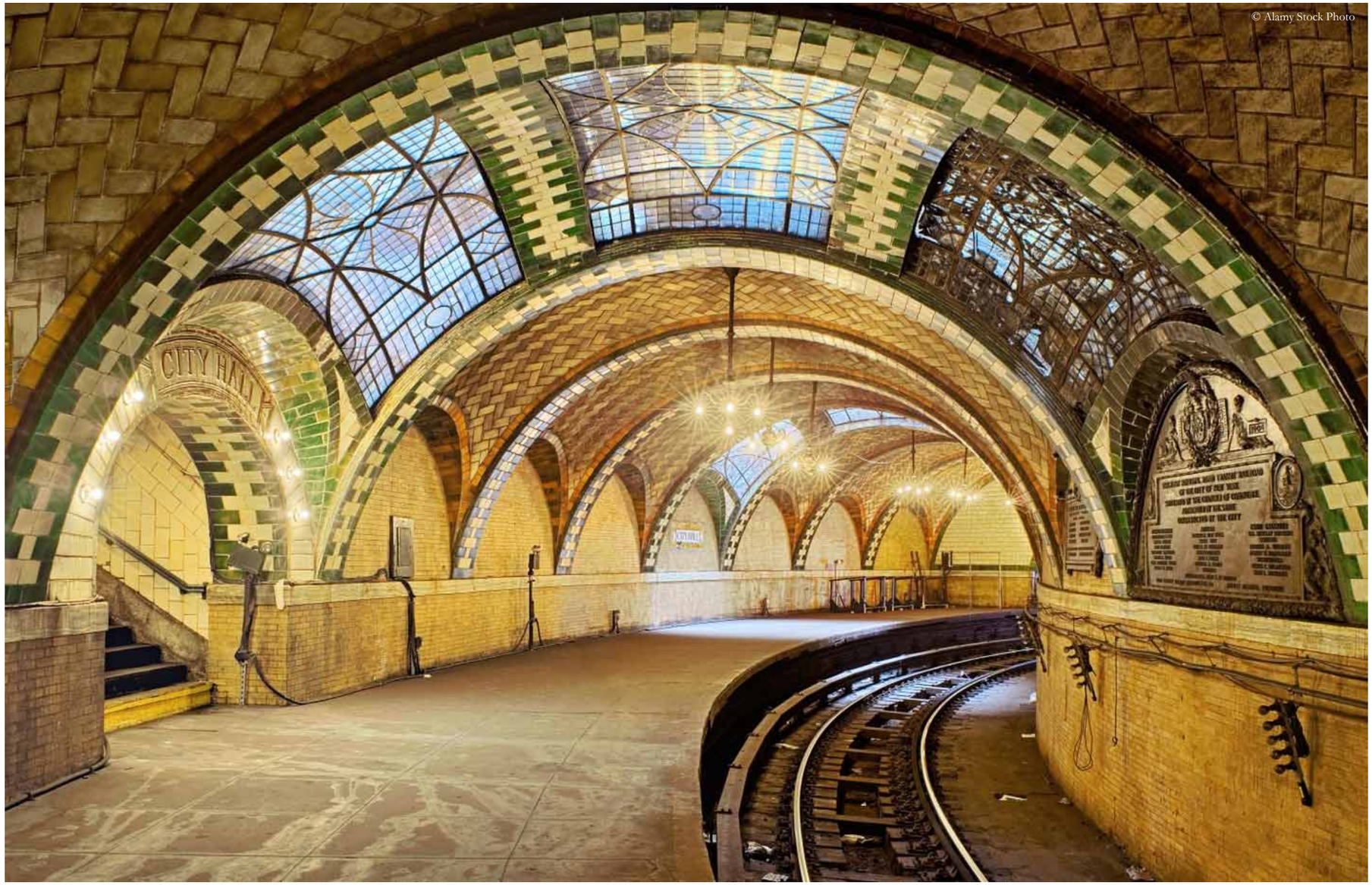
Masonry

1904: City Hall Subway Station
(Heins & LaFarge)

Masonry



City Hall Subway Station, New York, 1904, arch. Heins & LaFarge – Guastavino vault technique

1904: City Hall Subway Station
(Heins & LaFarge)

Masonry

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1900 — 1970 — 1990 — 2010

1910: Robie House
(Wright)

Masonry

1904: City Hall Subway Station
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1932: Maison de Verre
(Chareau)

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Maison de Verre, Paris, 1932, arch. Pierre Chareau, eng. Bernard Bijovet

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Säynätsalo Town Hall, Säynätsalo , 1952, arch. Alvar Aalto

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Cristo Obrero Church, Atlántida, 1960, arch. Eladio Dieste

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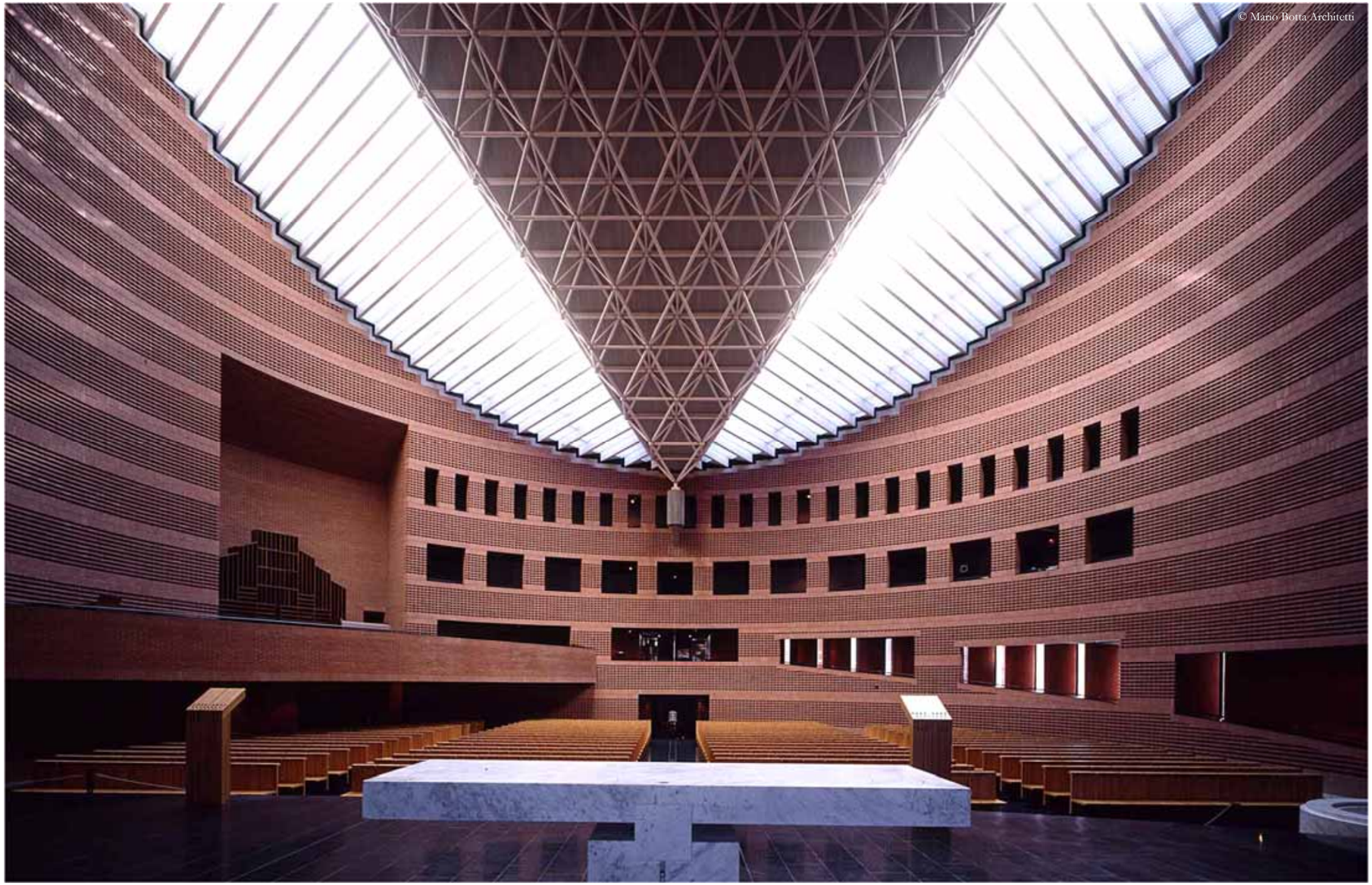

Évry Cathedral, Évry, 1995, arch. Mario Botta

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1900 1970 1990 2010

1910: Robie House
(Wright)

1952: Säynätsalo Town Hall
(Aalto)

1983: National Assembly Building
(Kahn)

2004: Padre Pio Church
(RPBW)

2012: Flight Assembled Architecture
(Gramazio Kohler)

Masonry

Flight Asselmbled Architecture, 2012, Gramazio Kohler, Dr. Raffaello D'Andrea, Jan Carmeliet, Lüchinger & Meyer

1904: City Hall Subway Station
(Heins & LaFarge)

1932: Maison de Verre
(Chareau)

1960: Atlantida Church
(Dieste)

1995: Évry Cathedral
(Botta)

2007: Kolumba Museum
(Zumthor)

1900 1970 1990 2010

1910: Robie House
(Wright)

1952: Säynätsalo Town Hall
(Aalto)

1983: National Assembly Building
(Kahn)

2004: Padre Pio Church
(RPBW)

2012: Flight Assembled Architecture
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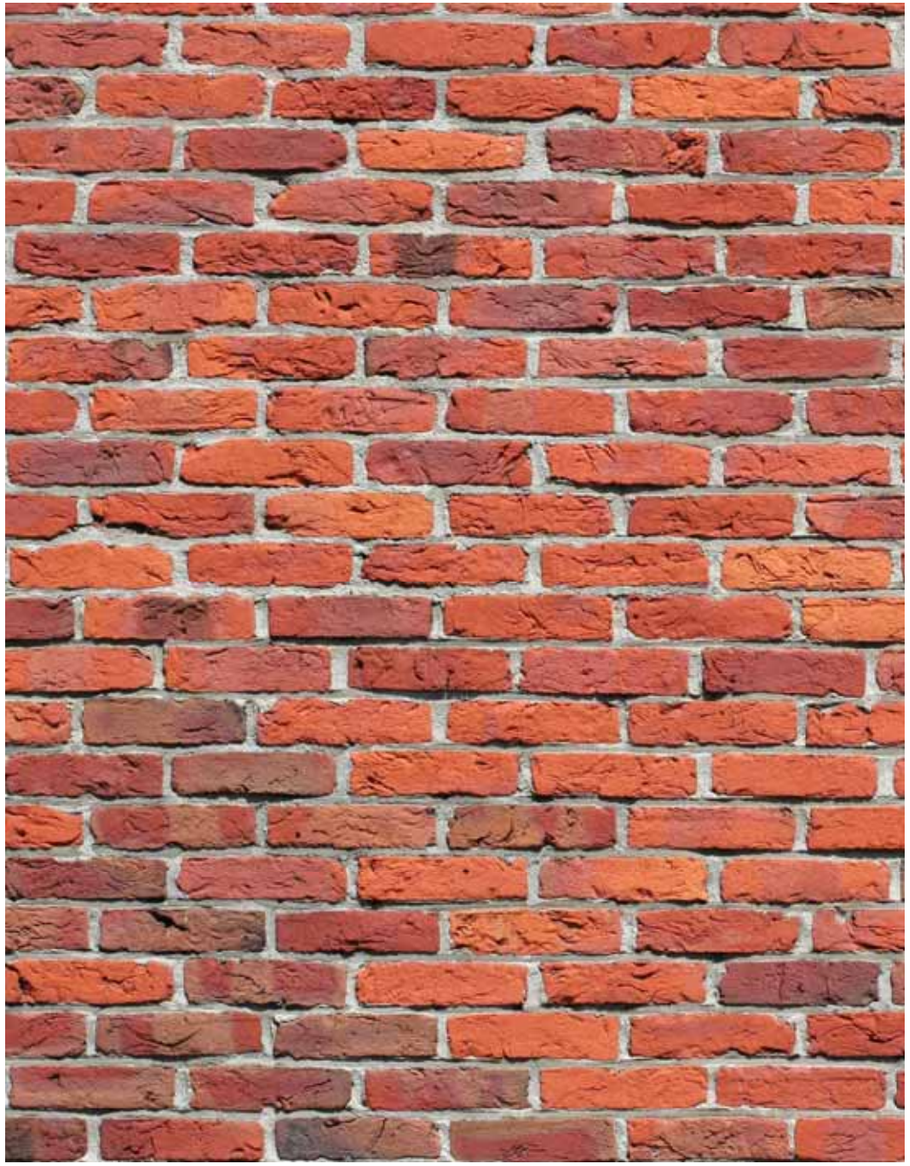
Masonry

Mauerwerk
Masonry

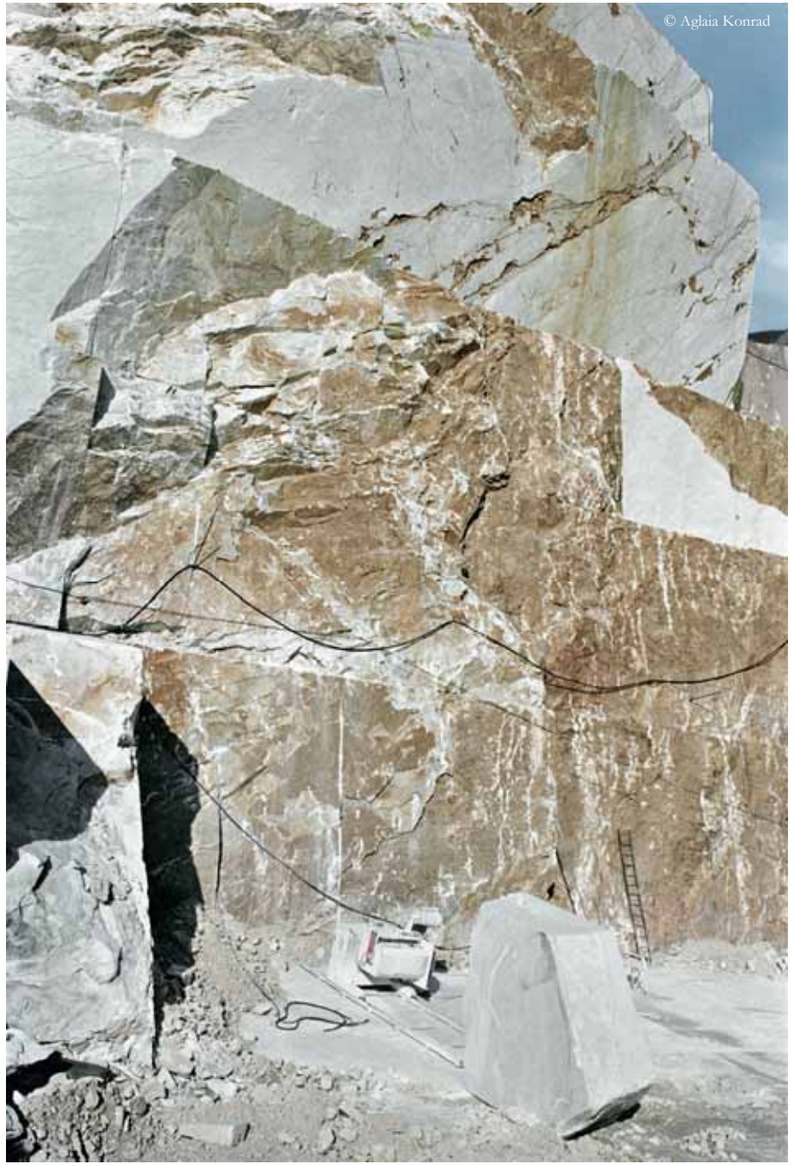
Therme Vals, 1993-1996, Arch. Peter Zumthor



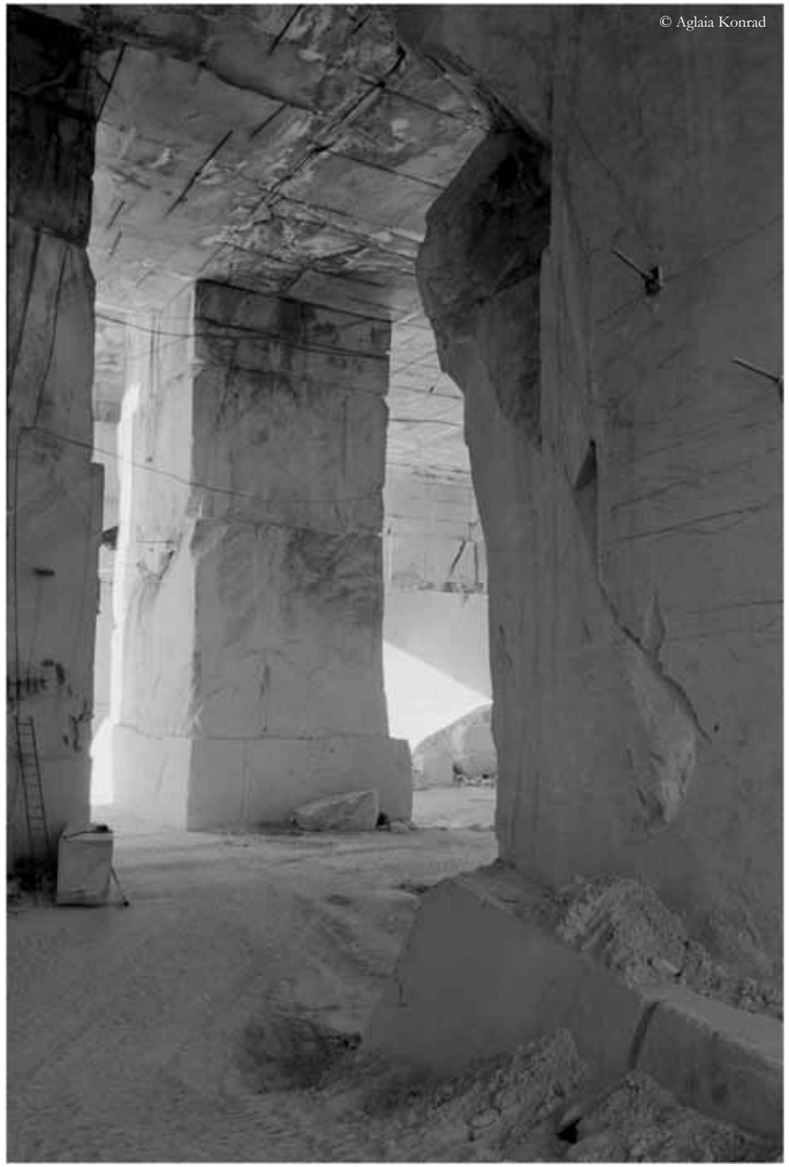
Mauerwerk Steine
Masonry Blocks

Mörtel
Mortar

Mauerwerk
Masonry



Marmorsteinbruch in Carrara
Marble Quarry in Carrara

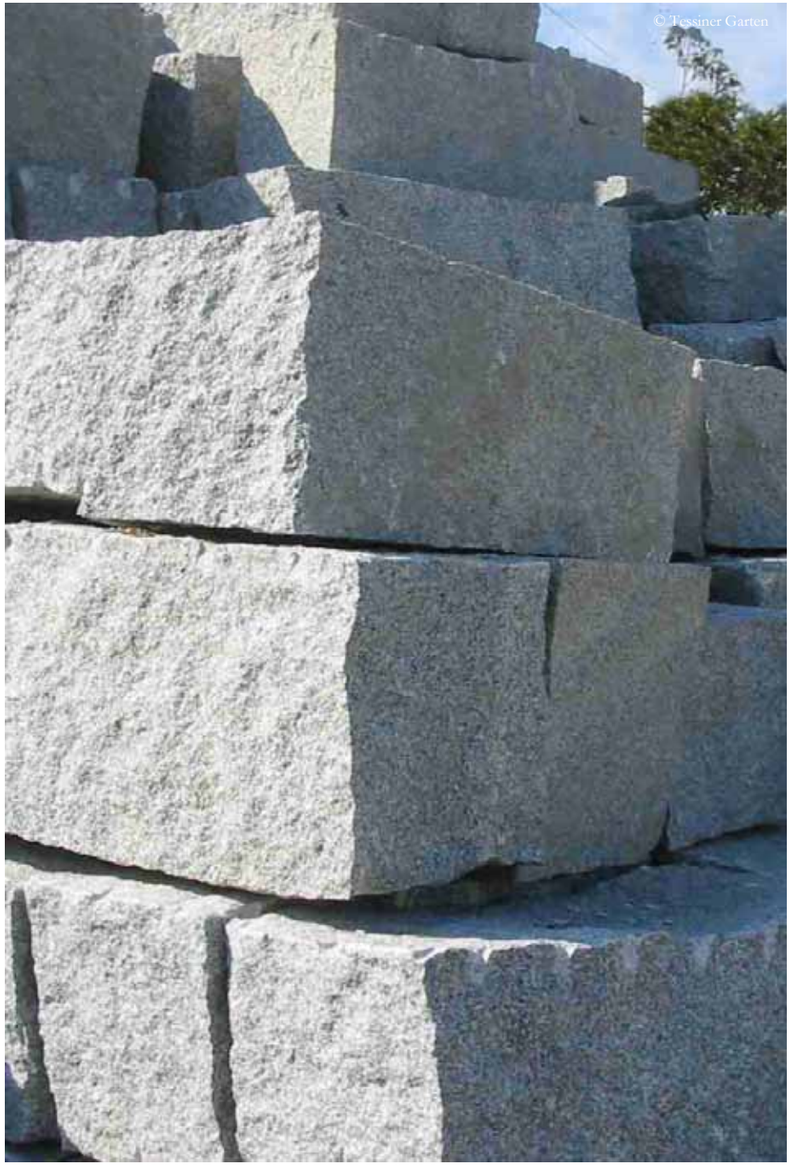


Marmorsteinbruch in Carrara
Marble Quarry in Carrara

Sandsteinbruch in Jodhpur
Sandstone Quarry in Jodhpur

Sandsteinbruch in Jodhpur
Sandstone Quarry in Jodhpur

Gneis Steinbruch in Vals
Gneiss Stone Quarry in Vals



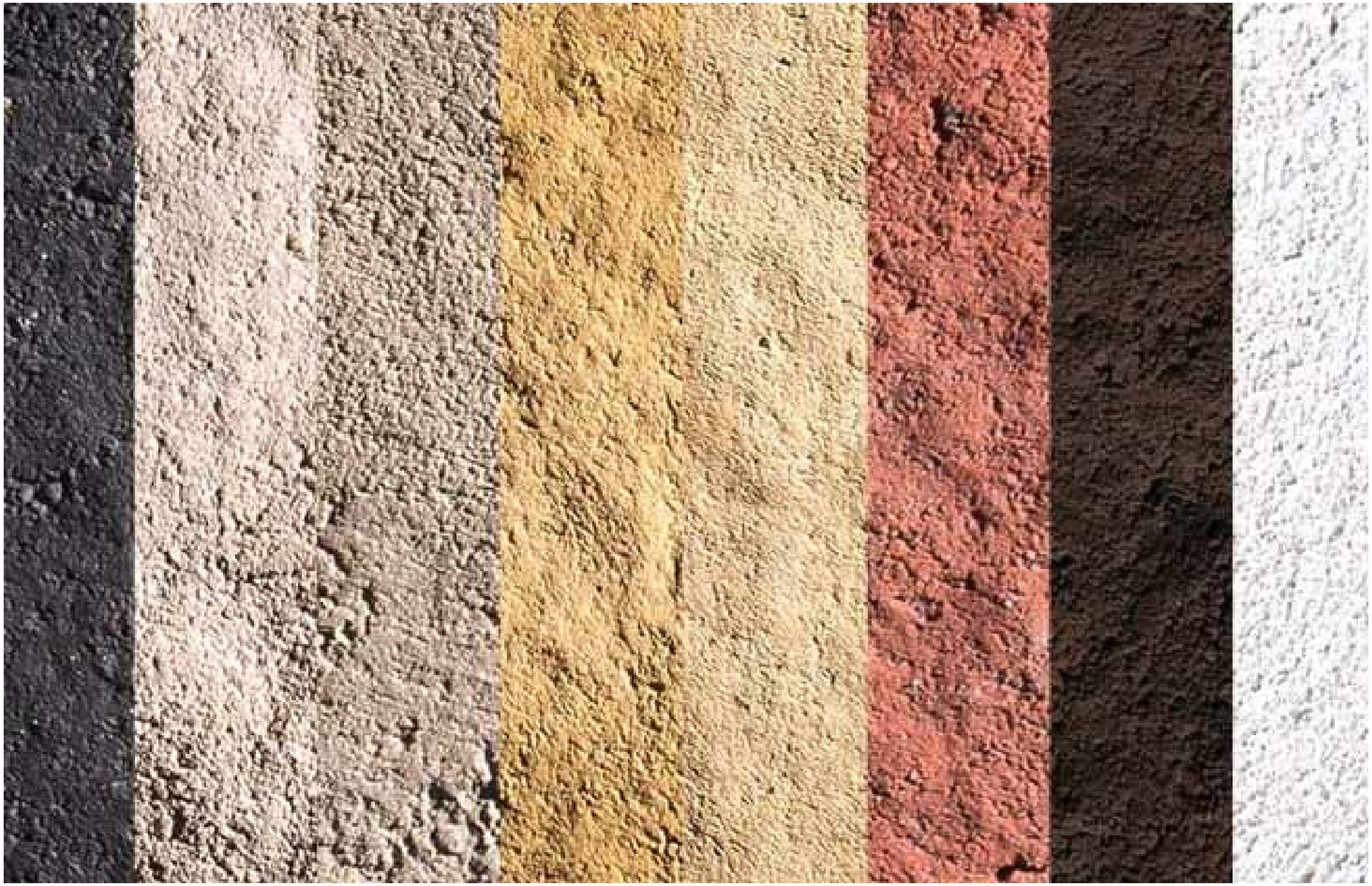
Gneis Steinbruch in Vals
Gneiss Stone Quarry in Vals

Tongrube
Clay pit

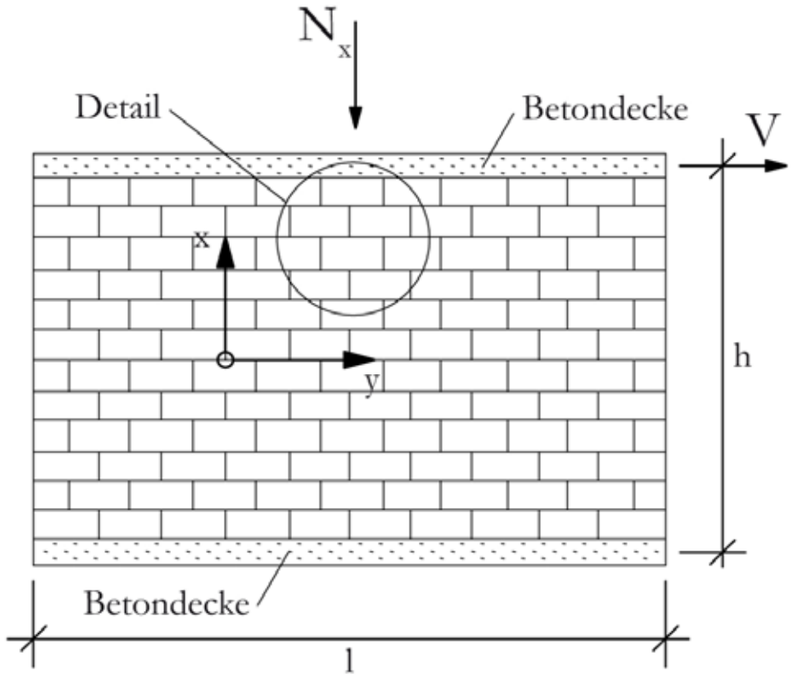
Verschiedene Ziegelarten nach ihrem Mineralgehalt
Different types of brick according to their mineral content

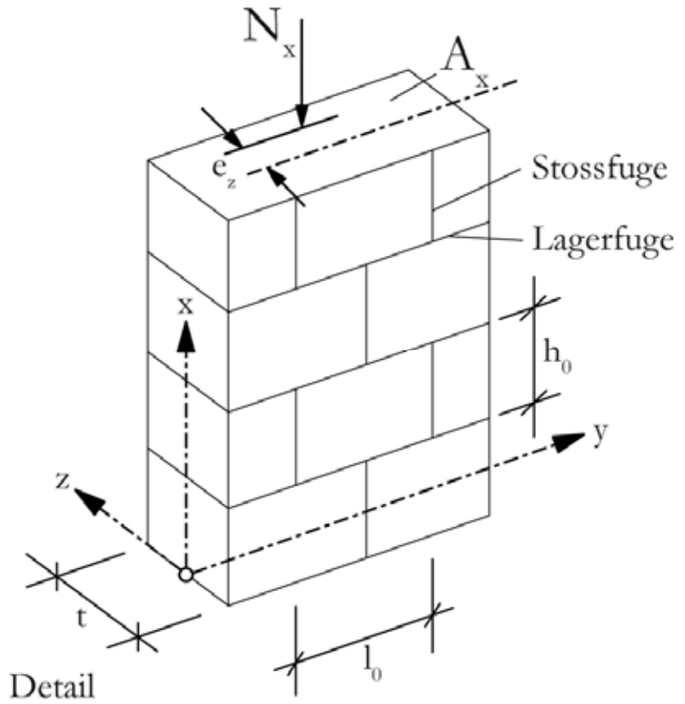
Sand *Sand*	67%
Zement *Cement*	16.5%
Wasser *Water*	16.5%

Zementmörtel
Cement Mortar



Mörtel-Arten
Mortar types

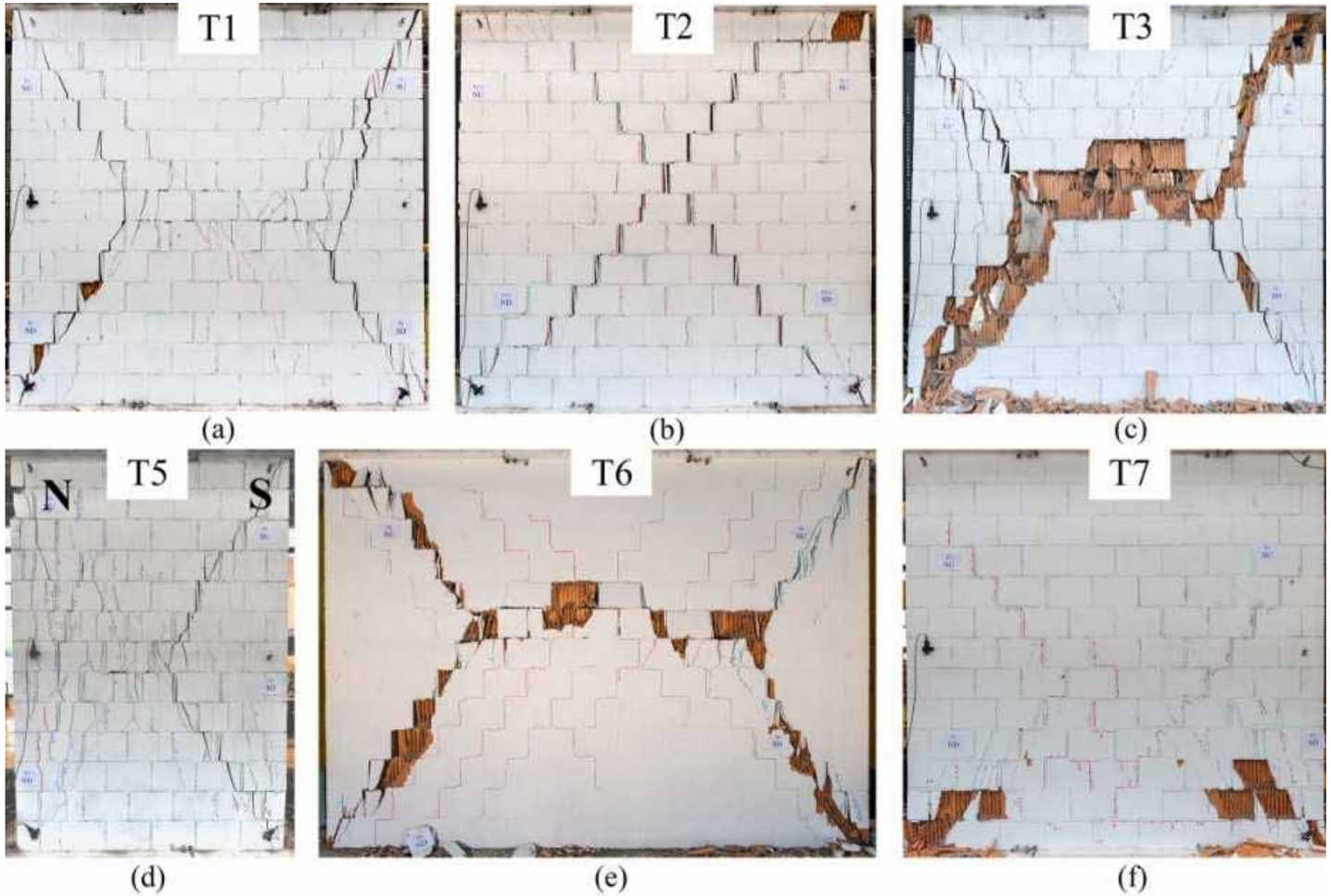


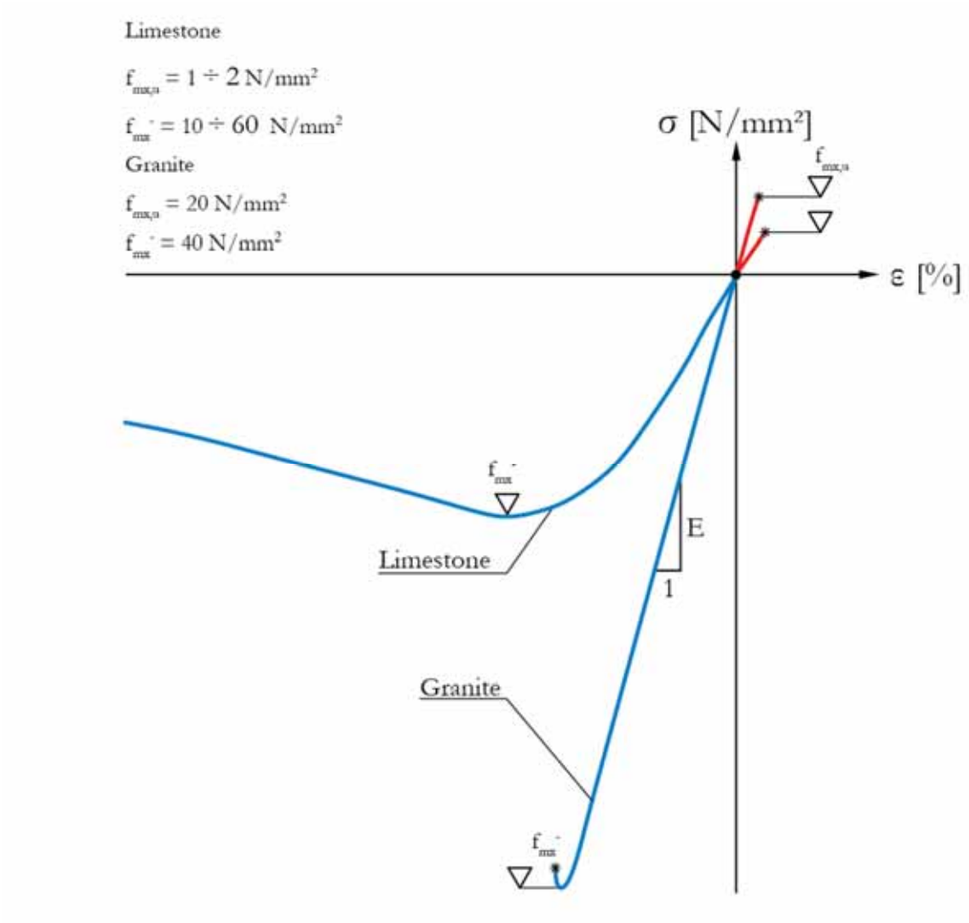


Geometrie des Einsteinmauerwerks
Geometry of a single brick masonry

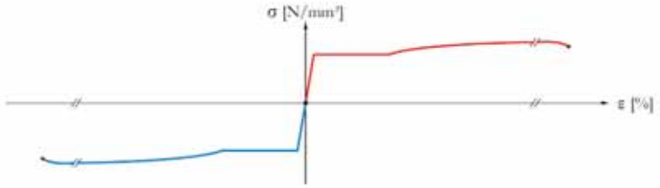
Versagensarten
Breaking patterns


W-05

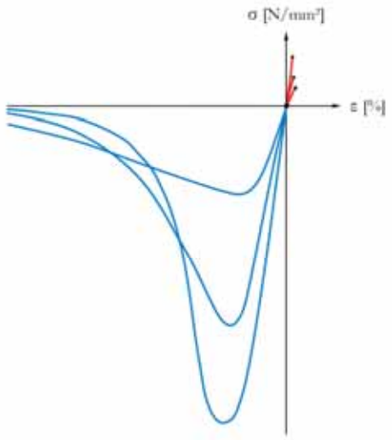

T1
T2
T3
(a)
(b)
(c)
N
T5
S
T6
T7
(d)
(e)
(f)



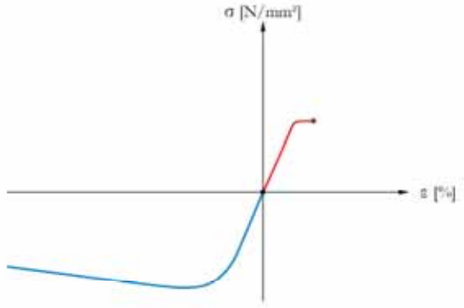
Mauerwerk (Granit, Kalkstein), Spannungs-Dehnungs-Diagramm
Masonry (Granite, Limestone), stress-strain diagram



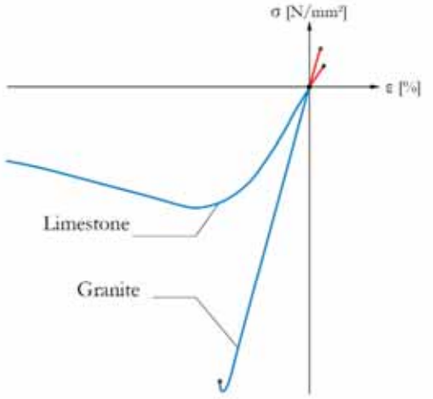
Steel (S235)



Concrete (Different Grades)

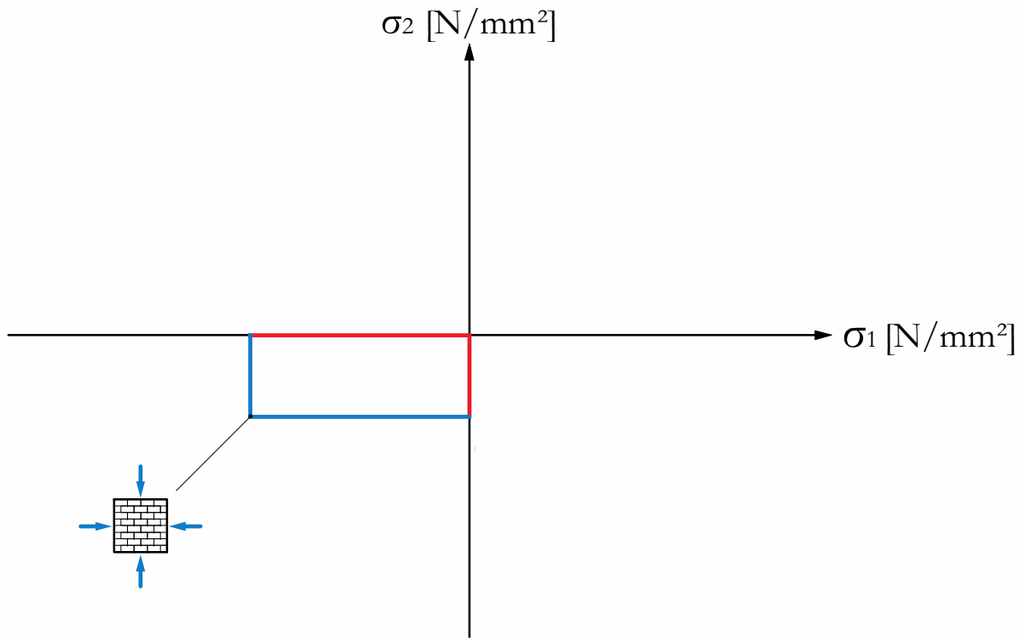


Timber (Fir Wood)

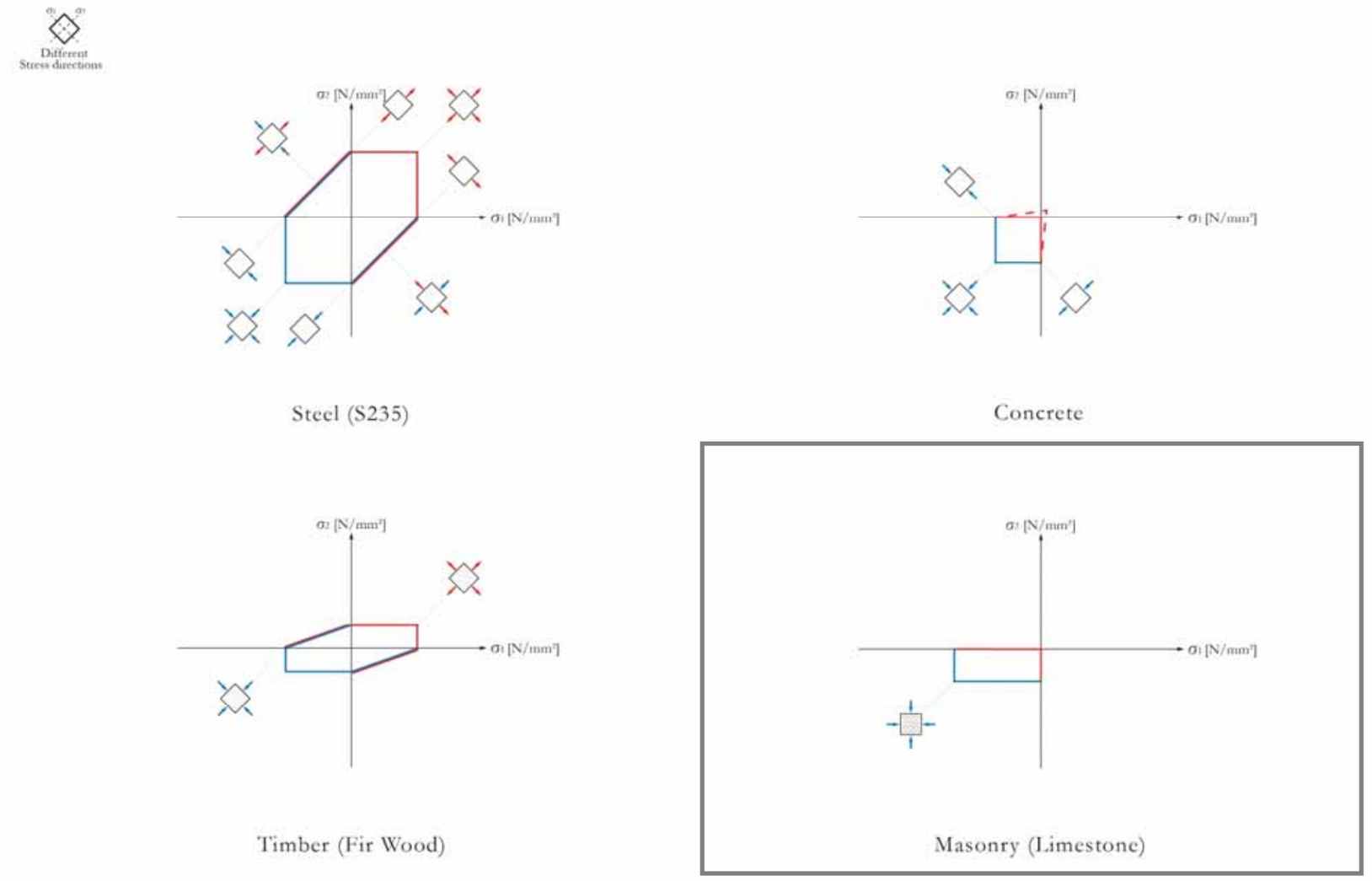


Masonry (Limestone & Granite)

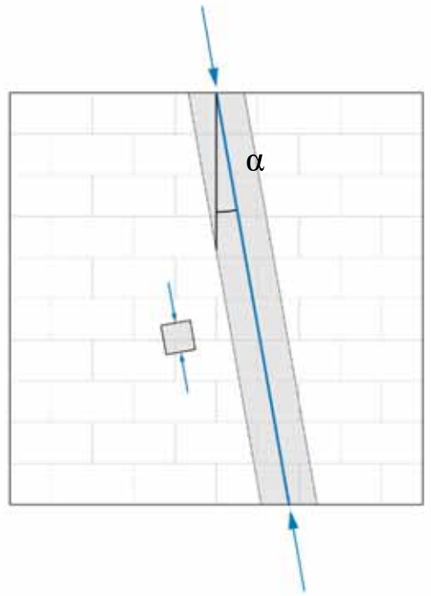
Spannungs-Dehnungs-Diagramme für die wichtigsten Baustoffe
Stress-strain diagrams for the main structural materials

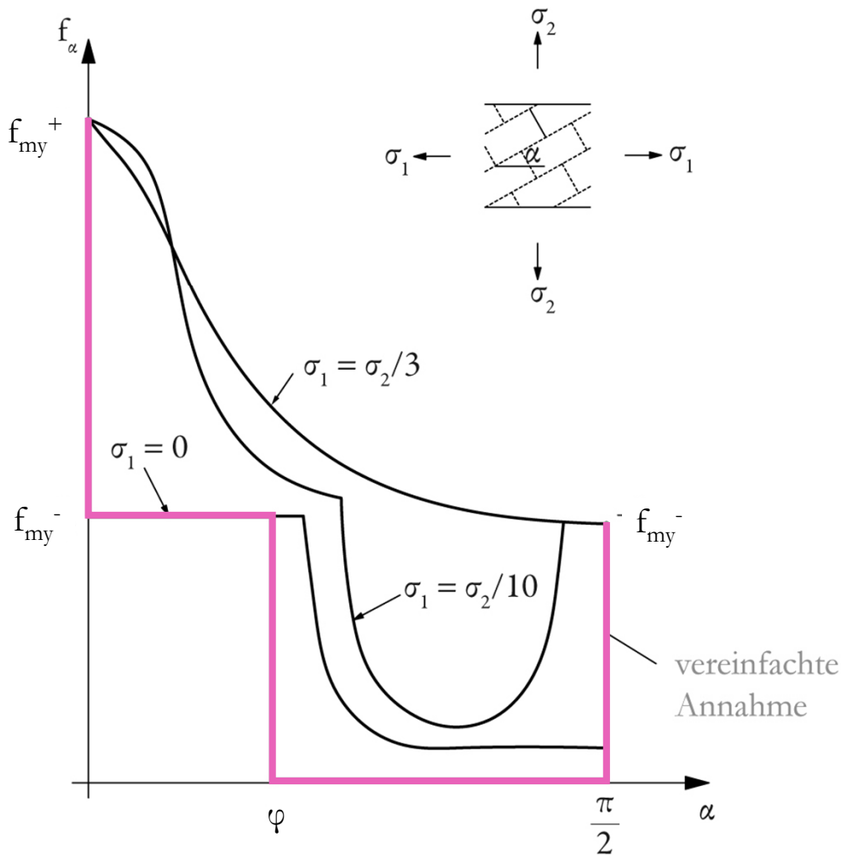


Mauerwerk (Kalkstein), Versagenskriterium in 2D
Masonry (Limestone), failure criterion in 2D

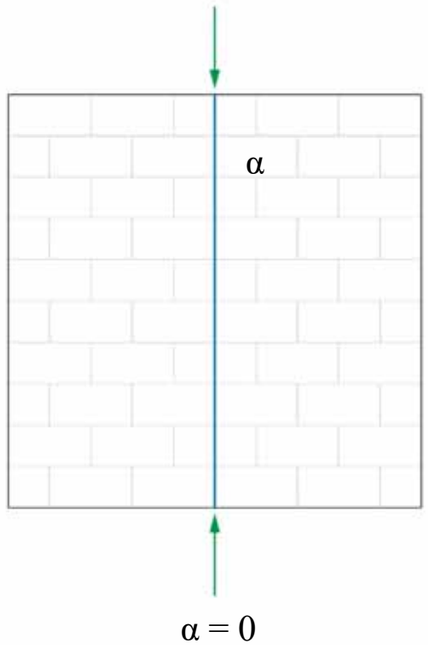


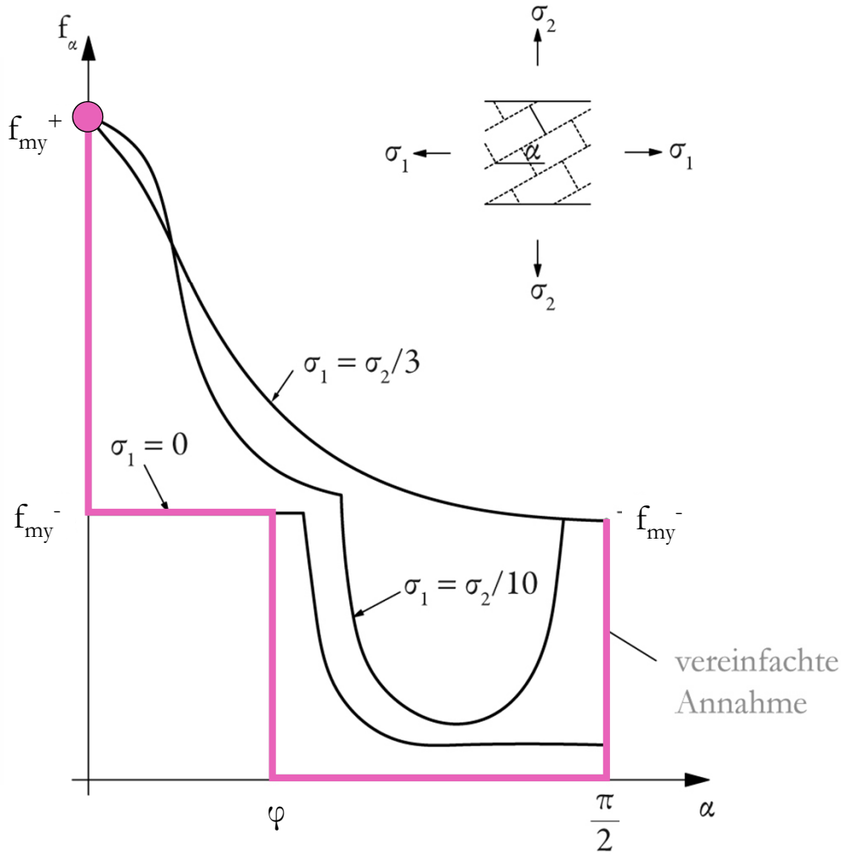
Versagenskriterien für die wichtigsten Baustoffe
Failure criteria for the main structural materials





Druckfestigkeit im Verhältnis zur Neigung der inneren Druckkraft
Strength in relation to the inclination of the internal compression force





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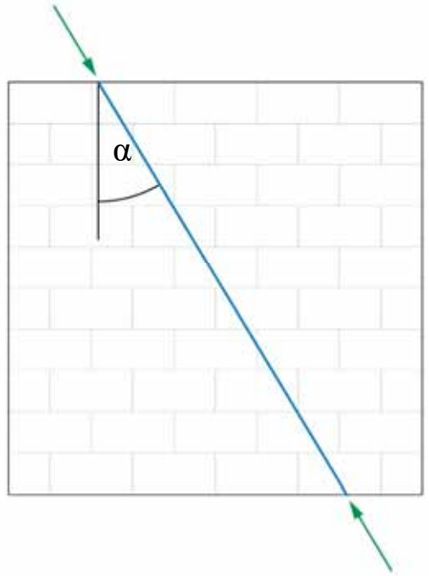
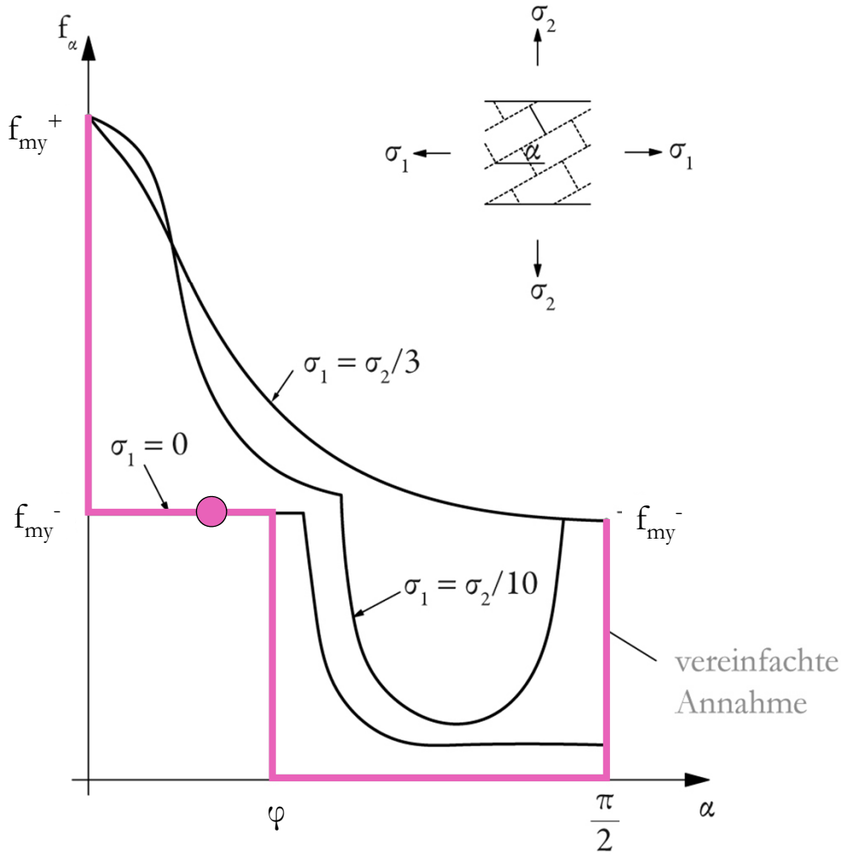
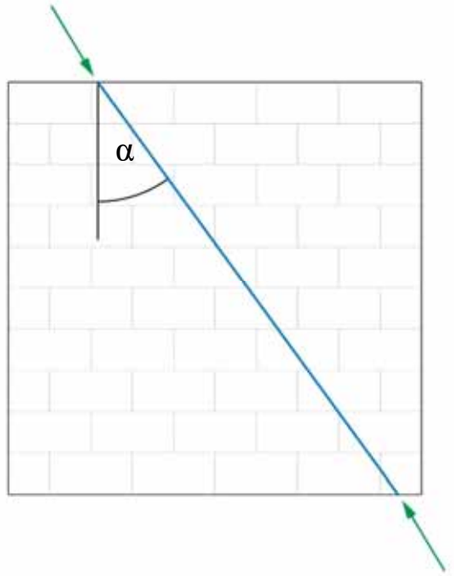
Strength in relation to the inclination of the internal compression force



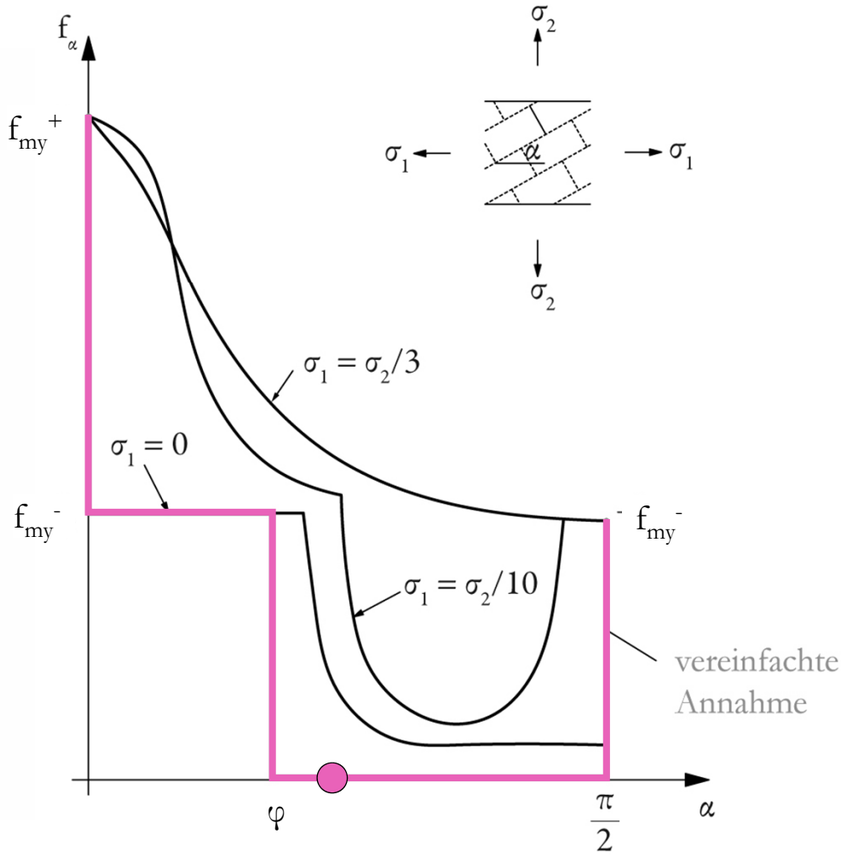
$0 < \alpha < \varphi$



Druckfestigkeit im Verhältnis zur Neigung der inneren Druckkraft
Strength in relation to the inclination of the internal compression force

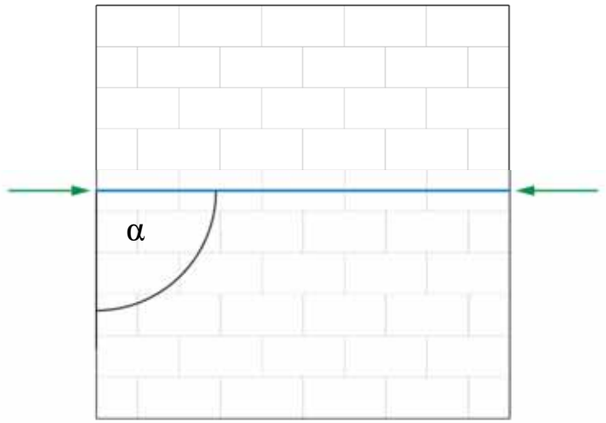


$\varphi < \alpha < \pi/2$

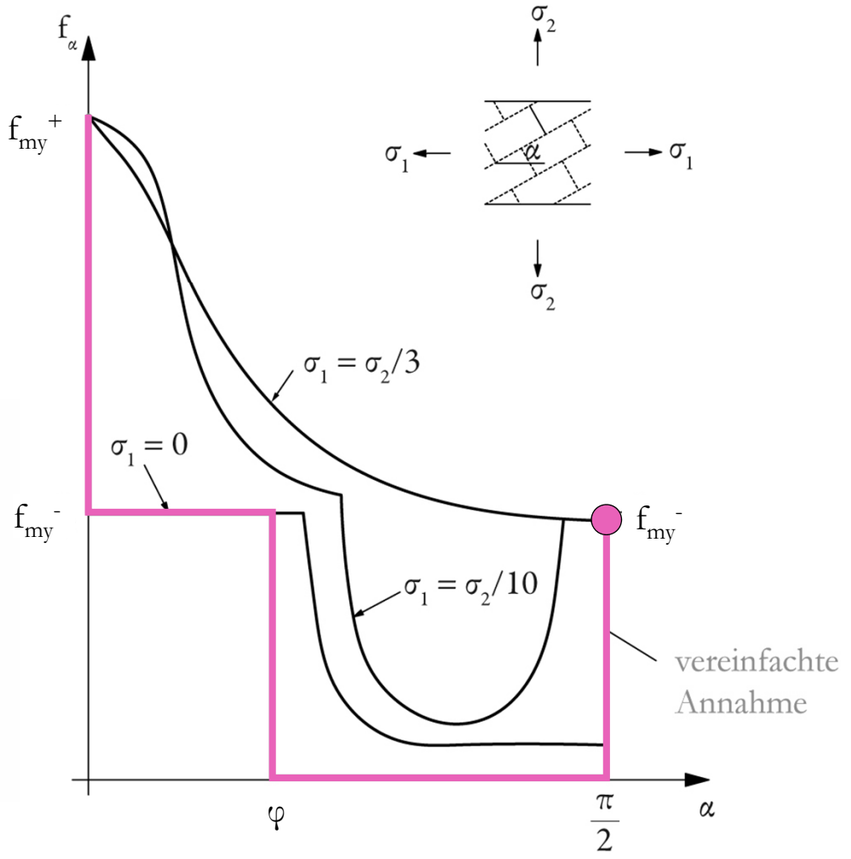


Druckfestigkeit im Verhältnis zur Neigung der inneren Druckkraft

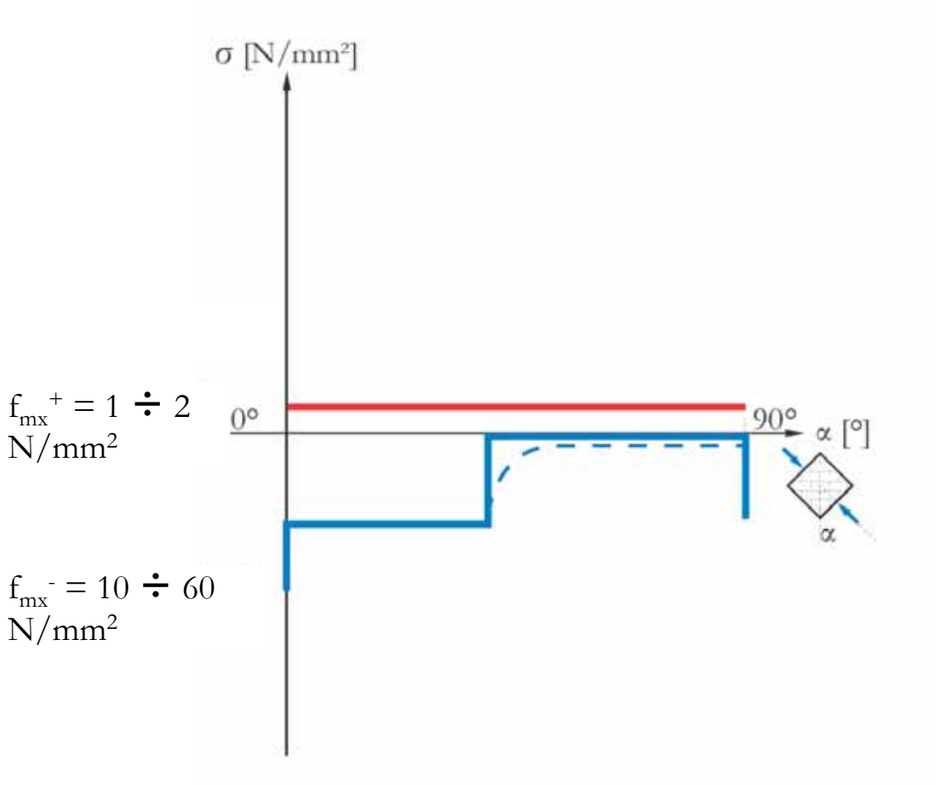
Strength in relation to the inclination of the internal compression force



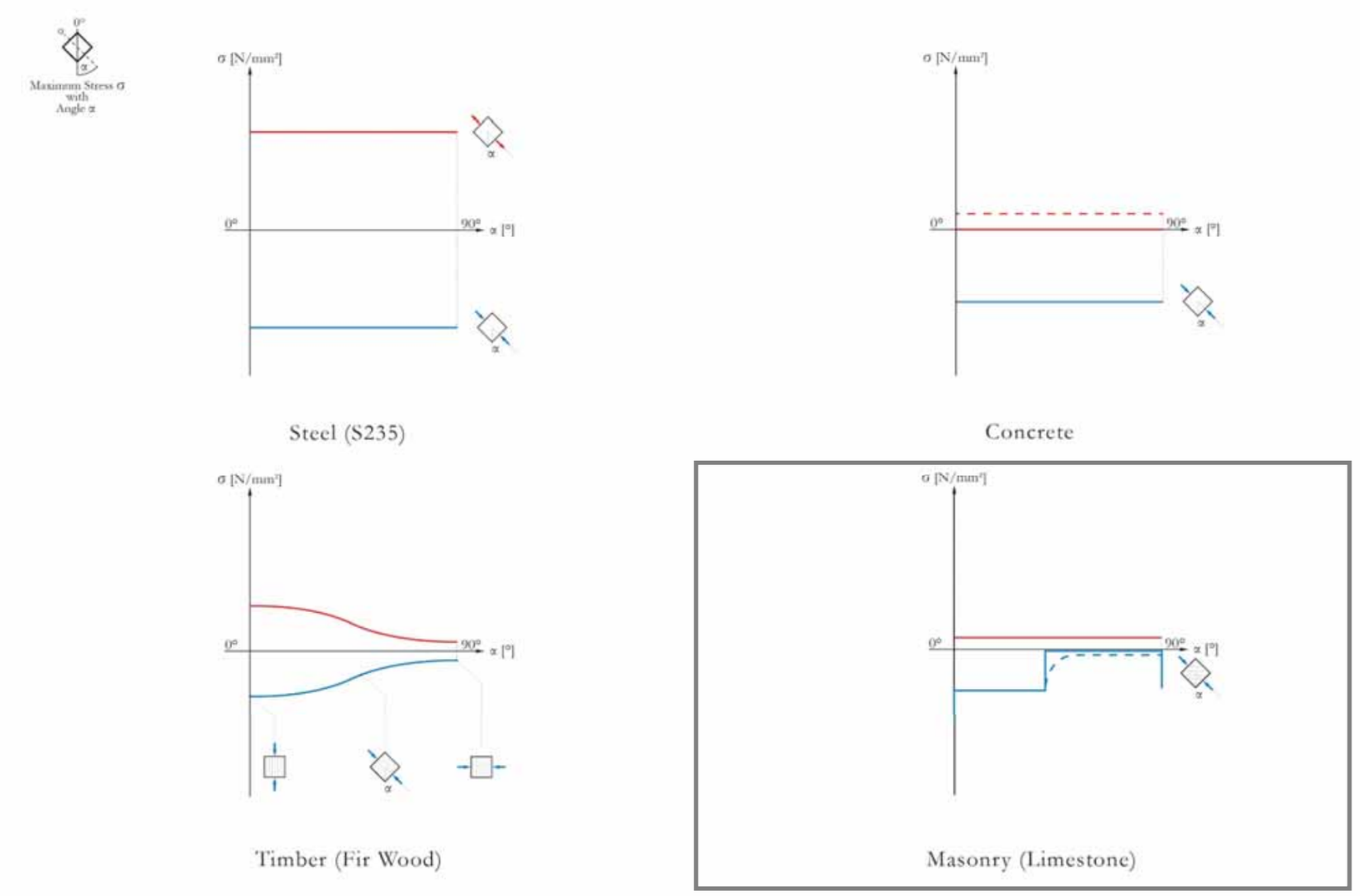
$\alpha = \pi/2$



Druckfestigkeit im Verhältnis zur Neigung der inneren Druckkraft
Strength in relation to the inclination of the internal compression force

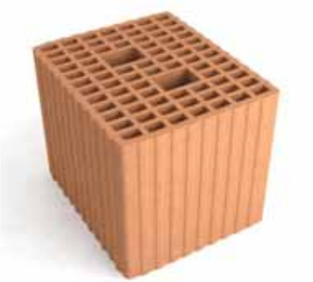


Mauerwerk (Kalkstein), Veränderung der Festigkeit in Abhängigkeit vom Spannungswinkel
Masonry (Limestone), strength variation according to the stress angle



Veränderung der Festigkeit in Abhängigkeit vom Spannungswinkel
Strength variation according to the stress angle

Backstein
Brick (B)



Leichtbackstein
Lightweight Brick (LB)

Betonblock
Concrete Block (C)

Leichtbetonstein
Lightweight Concrete Block (CL)

Kalksandstein
Sand-lime Brick (K)

Porenbetonblock
Aerated Concrete Block (P)

Porenleichtbetonblock
Aerated Lightweight Concrete Block (PL)

Mauerwerk	Bezeichnung	$f_{mx,d}$ [N/mm²]	$f_{my,d}$ [N/mm²]	$E_{mx,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
Backstein	MB	3.5	1.0	3.5	0.6
Backstein leicht	MBL	1.6	0.5	1.6	
Kalksandstein	MK	3.5	1.0	3.5	
Zementstein	MC	3.5	1.7	3.5	
Zementstein leicht	MCL	0.9	0.4	0.9	
Porenbeton	MP	1.6	0.8	1.6	
Porenbeton leicht	MPL	0.9	0.4	0.9	

$\tan \varphi = 0.6$

$\varphi = \tan^{-1}(0.6) = \sim 31°$

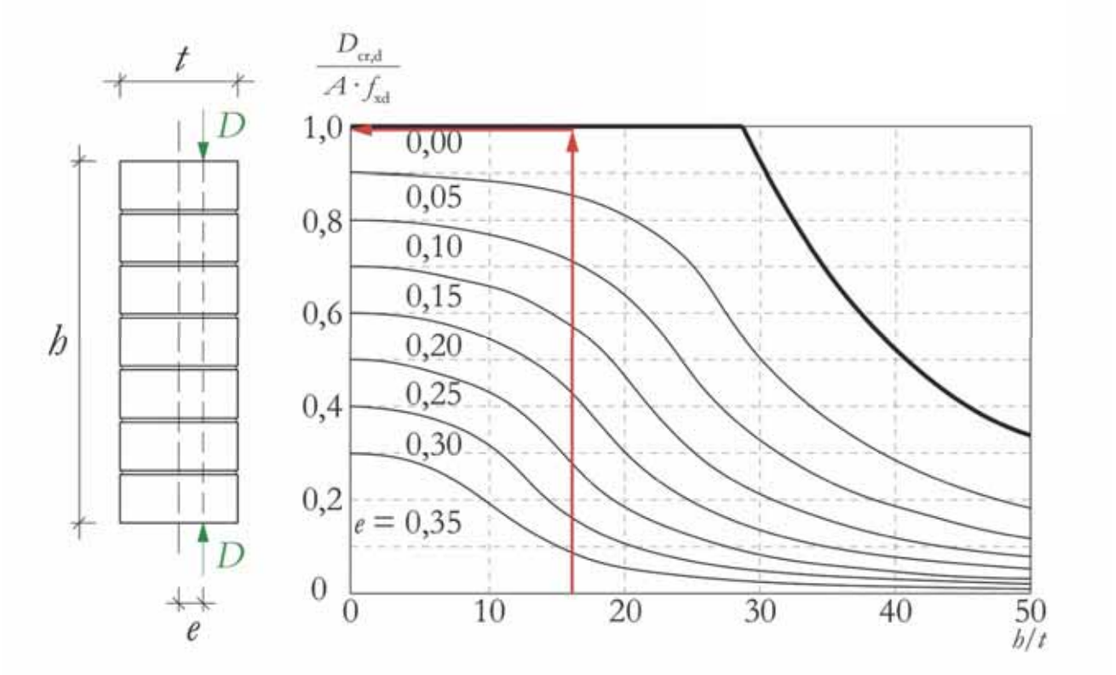
Materialeigenschaften von Standardmauerwerk (Stoßfugen ohne Mörtel)
Material properties of standard masonry (butt joints with no mortar)

Mauerwerk	Bezeichnung	$f_{mx,d}$ [N/mm²]	$f_{my,d}$ [N/mm²]	$E_{mx,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
Backstein	MB	3.5	1.5	3.5	0.6
Backstein leicht	MBL	1.6	0.75	1.6	
Kalksandstein	MK	3.5	1.5	3.5	
Zementstein	MC	3.5	2.55	3.5	
Zementstein leicht	MCL	0.9	0.6	0.9	
Porenbeton	MP	1.6	1.2	1.6	
Porenbeton leicht	MPL	0.9	0.6	0.9	

$\tan \varphi = 0.6$

$\varphi = \tan^{-1}(0.6) = \sim 31°$

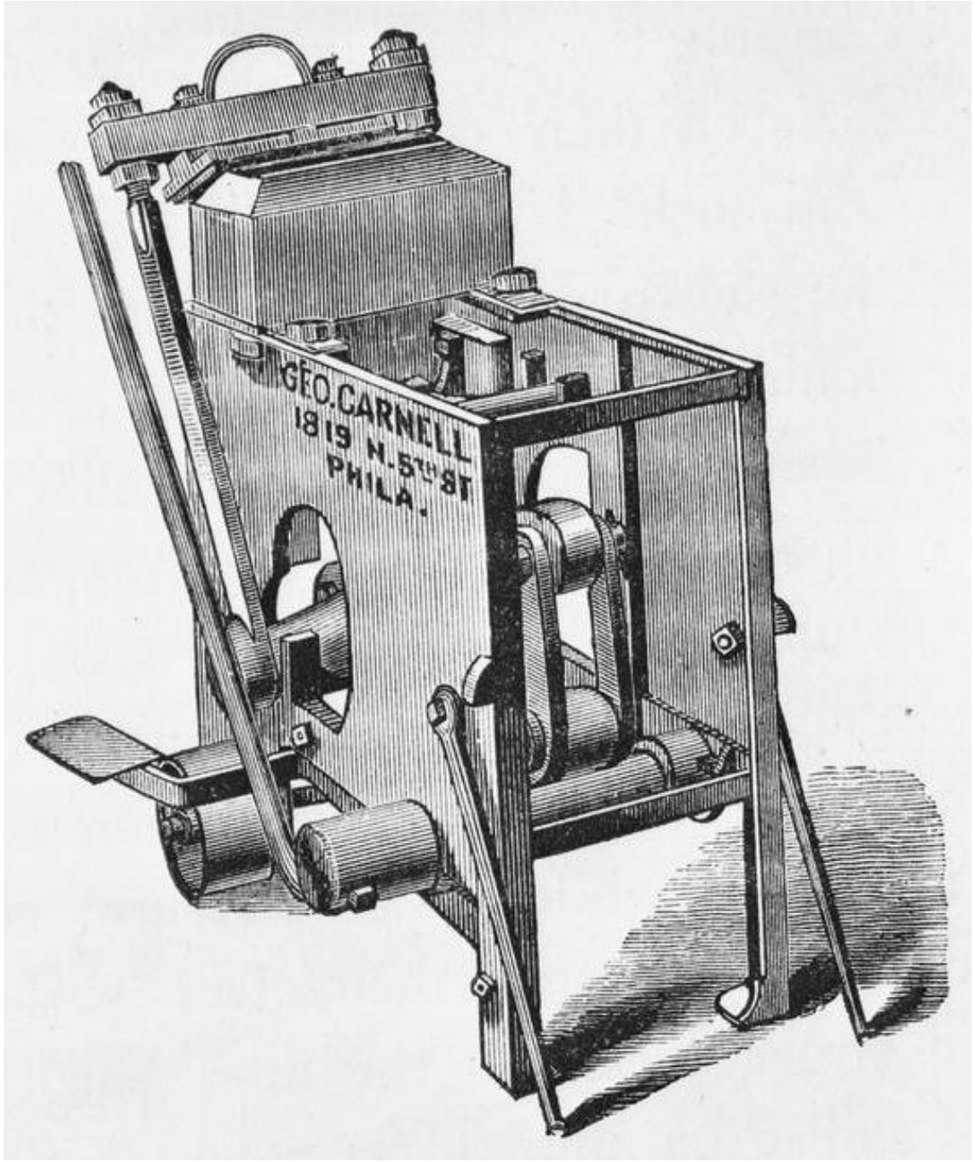
Materialeigenschaften von Standardmauerwerk (Stoßfugen mit Mörtel)
Material properties of standard masonry (butt joints with mortar)



Knickdiagramm für Mauerwerk
Buckling diagram for masonry

Mauerwerk
Masonry


© BigStockPhoto



Backsteinpresse
Brick press

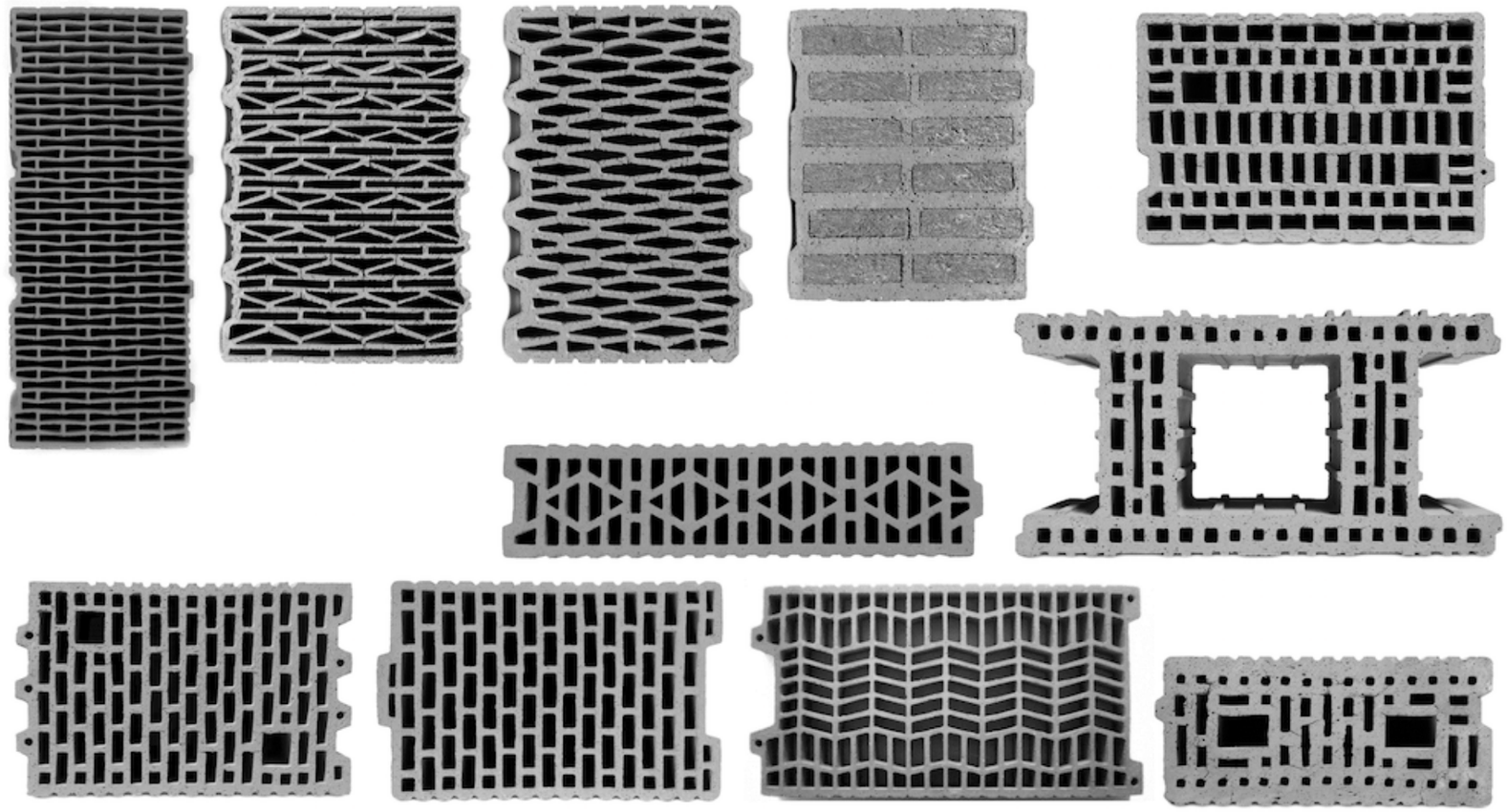
Zum Trocknen ausgelegte Ziegel
Bricks set out to dry


© Petr Brož


JAMES BOOTH (BOLTON) Ltd.

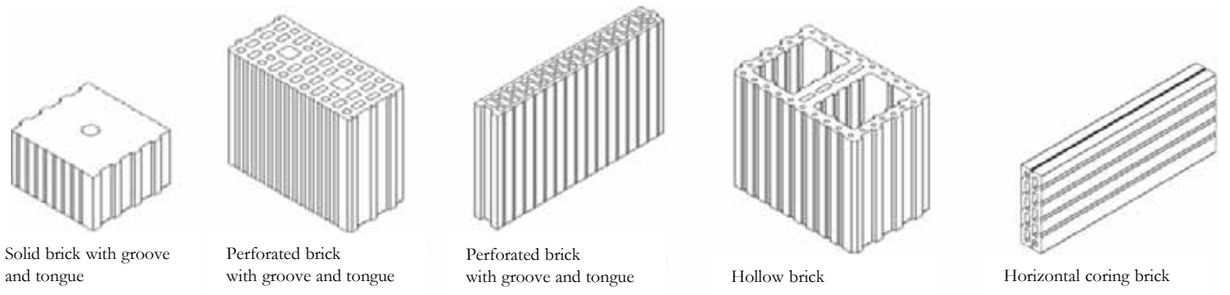
Stein								
Format L X B x H [mm]	290/60/190	290/75/190	290/100/240 290/100/190	290/125/240 290/125/190	290/150/240 290/150/190	290/175/240 290/175/190	290/200/190	290/250/190

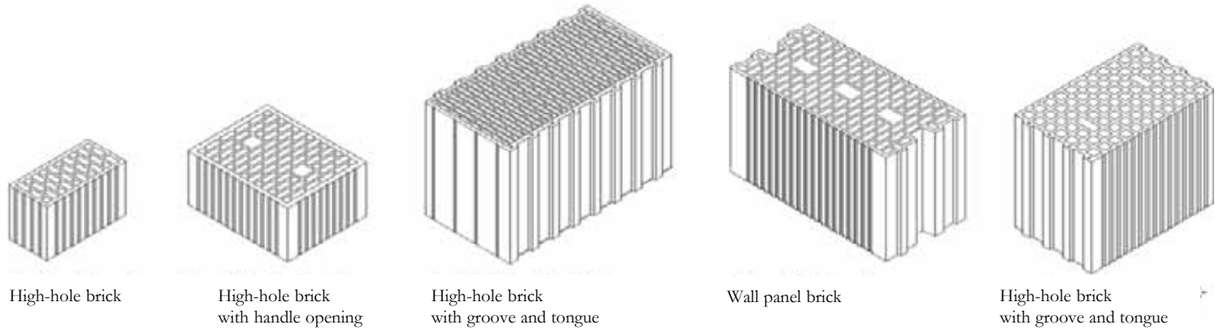
Swissmodul Mauersteine
Swissmodul type bricks



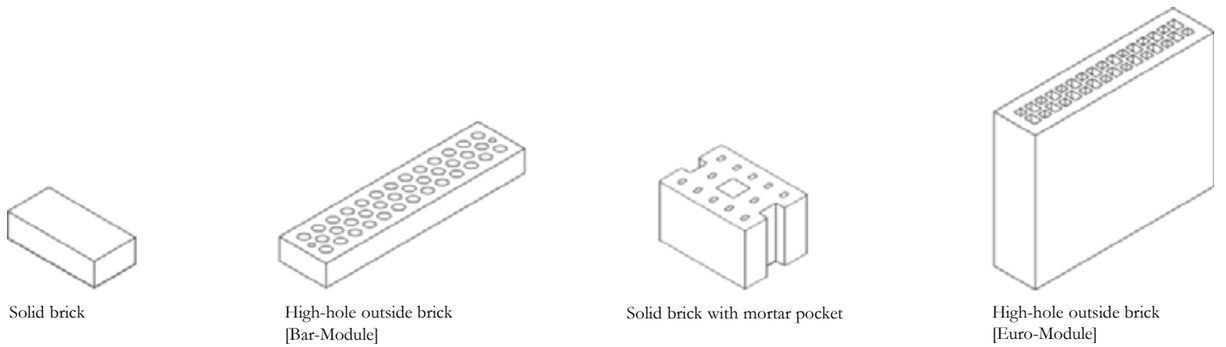
Verschiedene Lochmuster von Backsteinen
Various hole patterns of perforated bricks

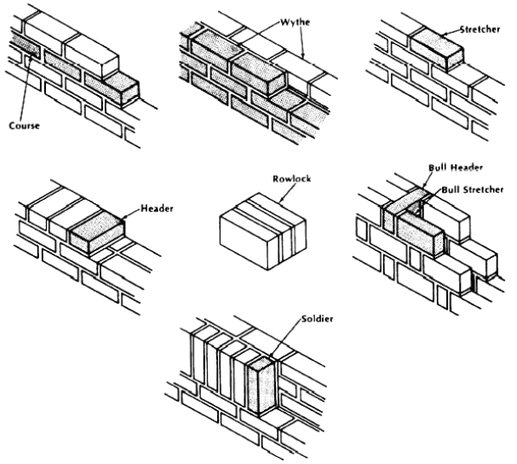
Mauerwerk mit selbständiger Schutzschicht
Masonry with indipendent protective layer

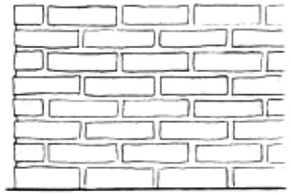


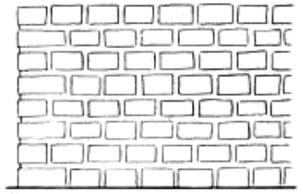


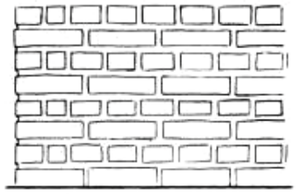
Freigelegtes Mauerwerk
Exposed masonry

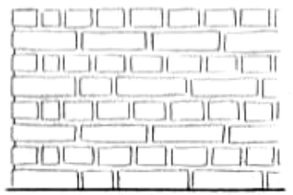


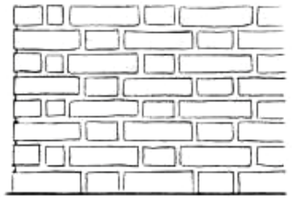


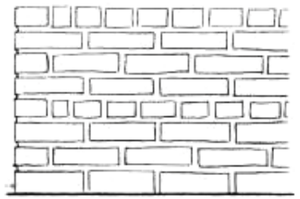

STRETCHING BOND.

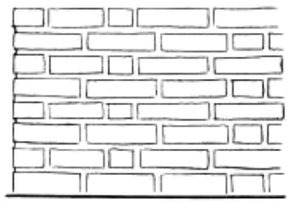

HEADING BOND.

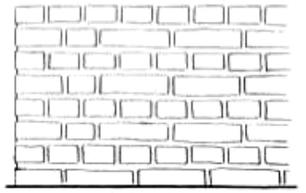

ENGLISH BOND.


ENGLISH CROSS BOND.

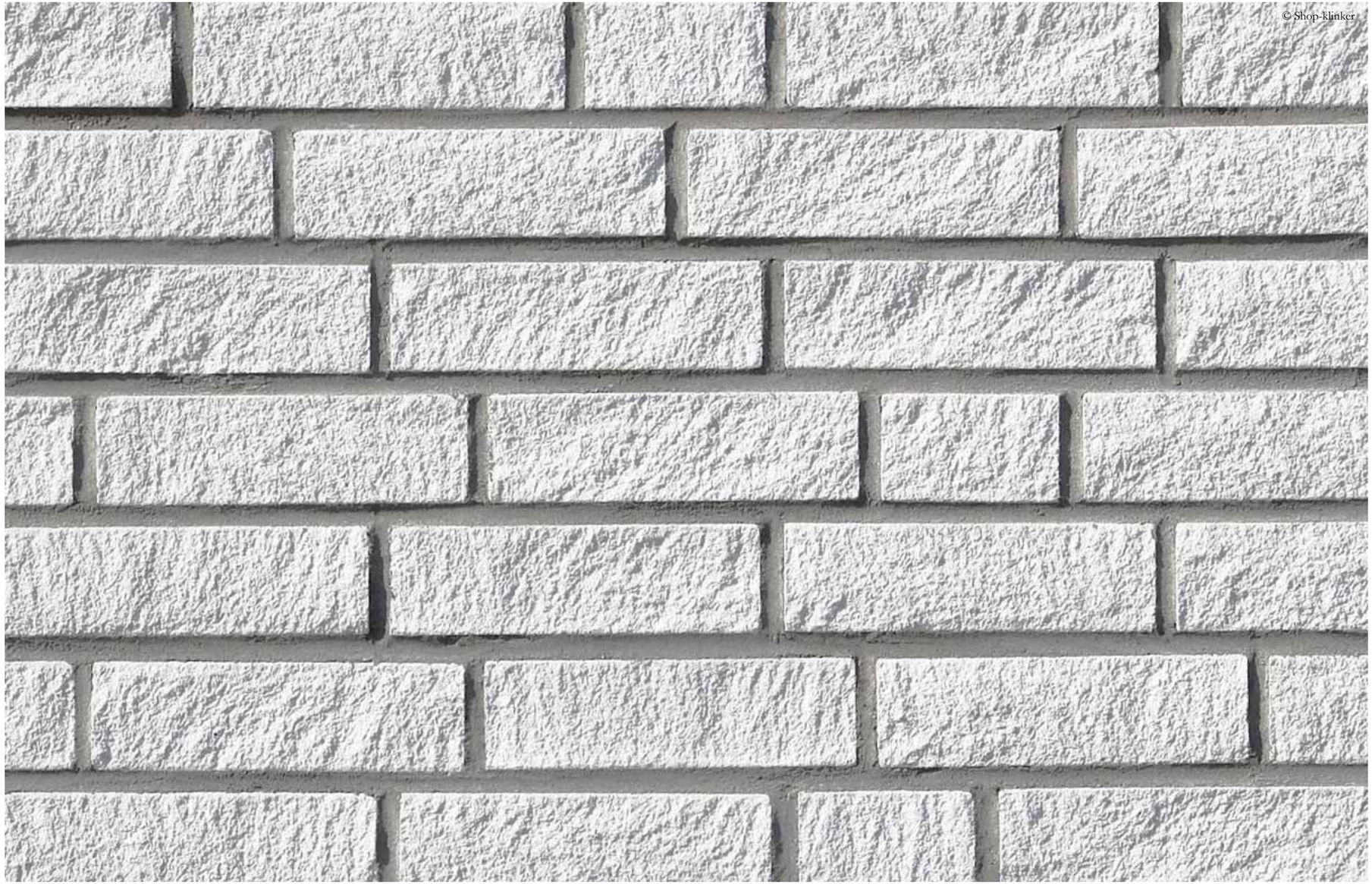

FLEMISH BOND.


ENGLISH GARDEN
WALL BOND.


FLEMISH GARDEN
WALL BOND.


DUTCH BOND.

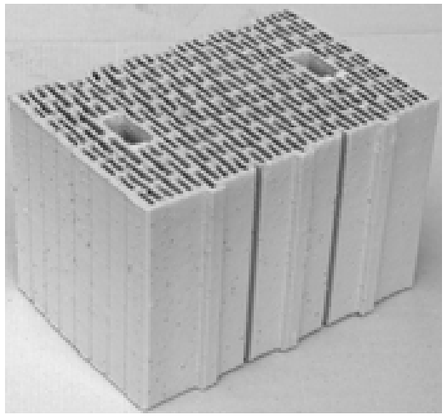
Verbandarten
Masonry patterns



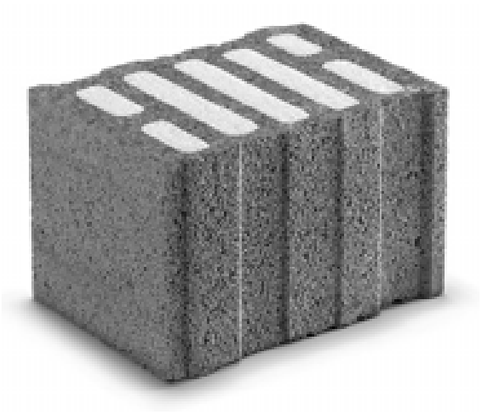
Grober Kalksandstein
Rough Sand-lime brick

Stein					
Format L X B x H [mm]	250/100/190 250/100/140	250/120/190 250/120/140	250/150/190 250/150/140	250/180/190 250/180/140	250/200/140

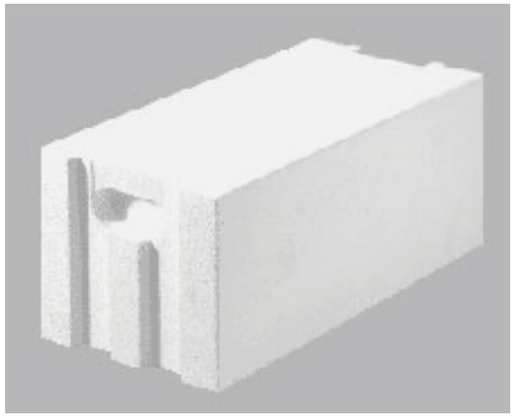
Betonsteine
Concrete blocks



Leichter Backstein
Lightweight brick



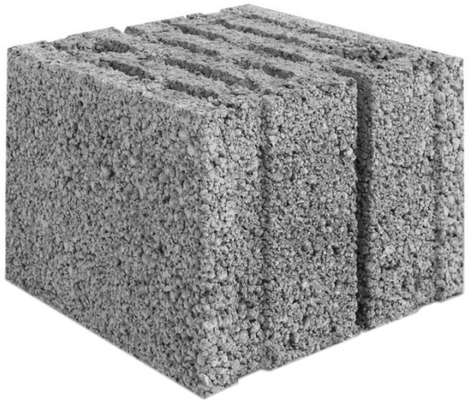
Leichtzementblock
Lightweight cement block



Autoklavierter Porenbetonblock
Autoclaved aerated concrete block

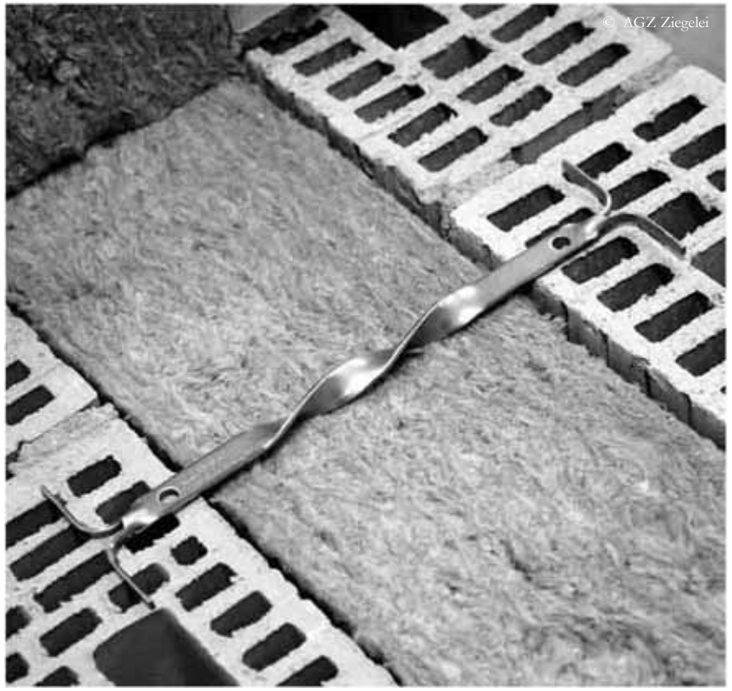
Schallabsorbierender Backstein
Soundabsorbing brick

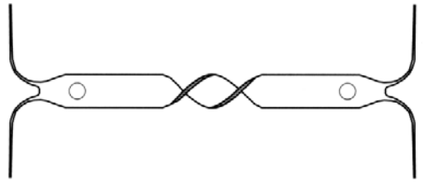
Schalldämmender Zementblock
Soundabsorbing cement block

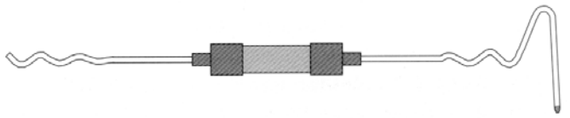


Schalldämmender Betonblock
Soundabsorbing concrete block


NIKE







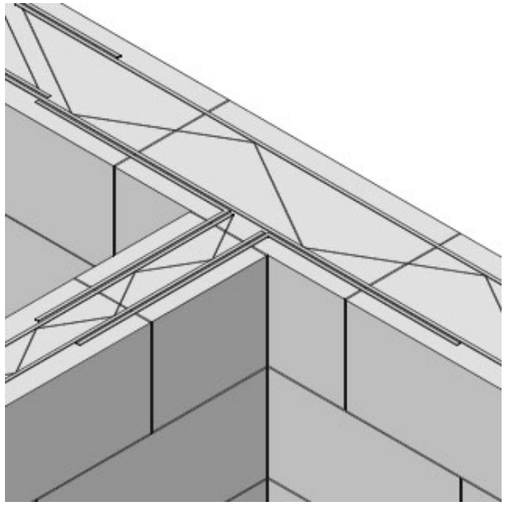
Zweischaliges Mauerwerk
Double-shell ties

BEFESTIGUNG AN DER INNENWAND
FIX TO INTERIOR WALL

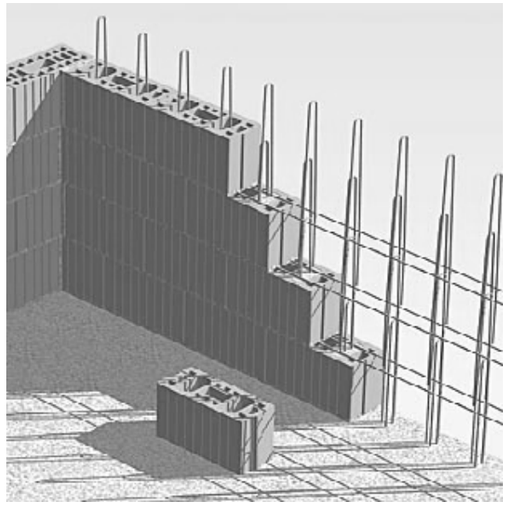
MIT BALKEN VERBUNDEN
CONNECT WITH BEAM

STAHLBEWEHRUNG
STEEL REINFORCEMENT

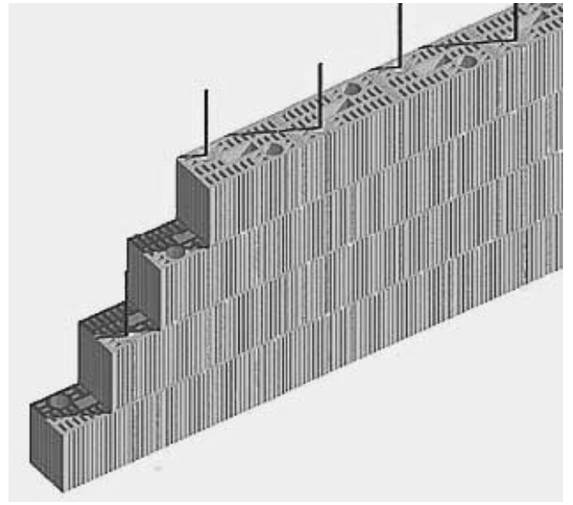
Verschiedene Arten von Stahlverbindungen
Different types of steel connections



HORIZONTALE BEWEHRUNG
HORIZONTAL REINFORCEMENT



VERTIKALE BEWEHRUNG
VERTICAL REINFORCEMENT



VERTIKALE BEWEHRUNG
VERTICAL REINFORCEMENT

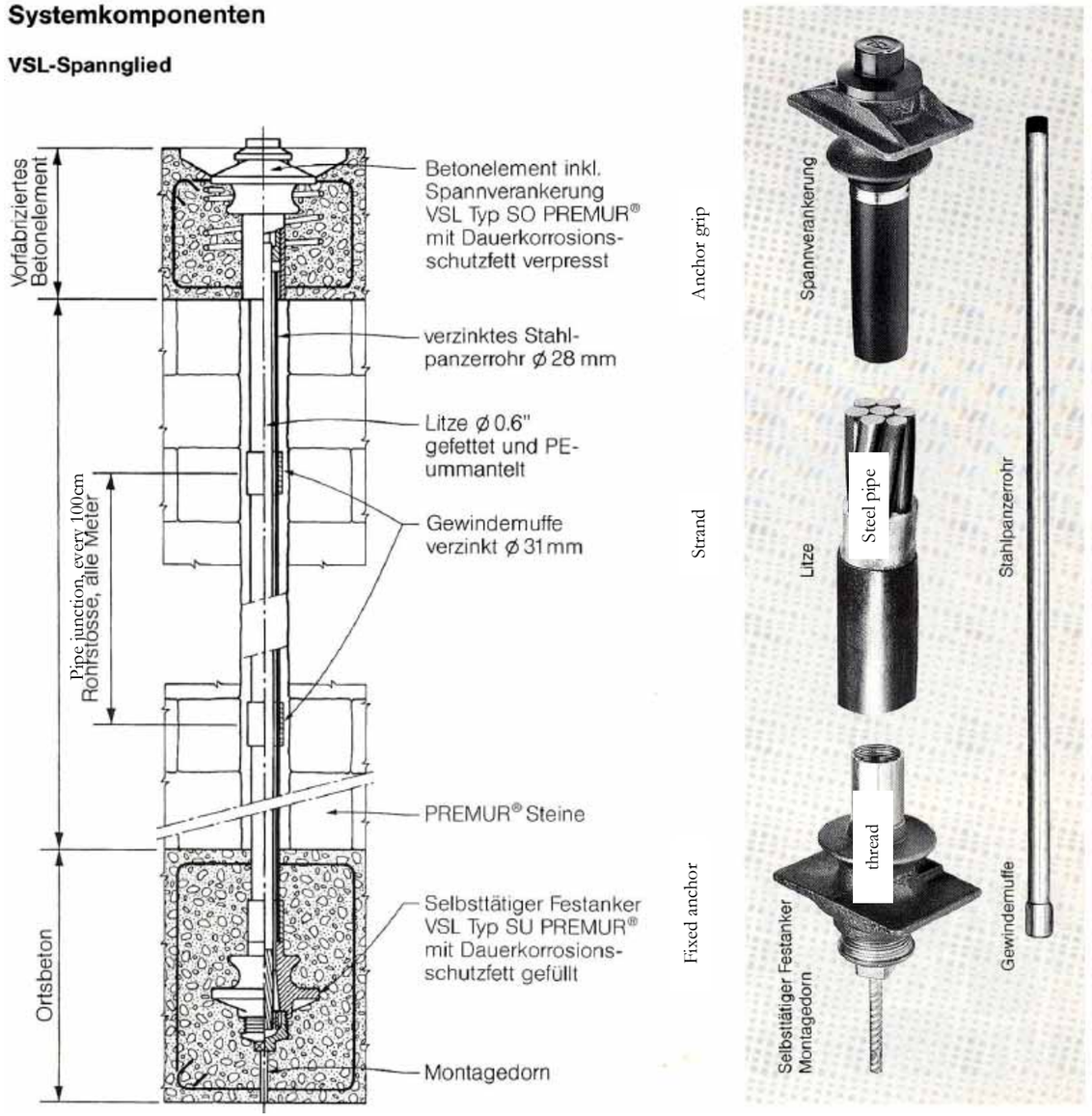
Verschiedene Arten von Mauerwerksbewehrungen
Different types of reinforcement for masonry walls

HORIZONTALE BEWEHRUNG
HORIZONTAL REINFORCEMENT

VERTIKALE BEWEHRUNG
VERTICAL REINFORCEMENT

VERTIKALE BEWEHRUNG
VERTICAL REINFORCEMENT

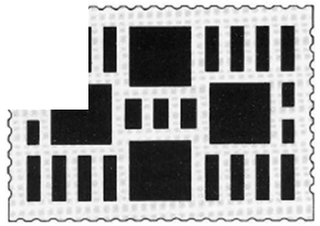
Verschiedene Arten von Mauerwerksbewehrungen
Different types of reinforcement for masonry walls



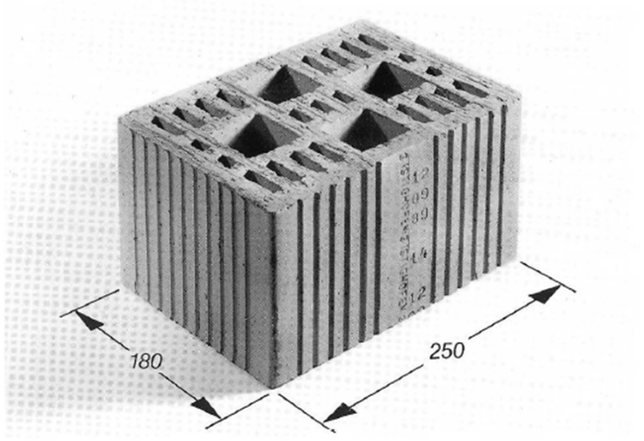
Vertikales Vorspannsystem für Mauerwerk
Vertical prestressing system for masonry

System components
zz-PREMUR© Bricks

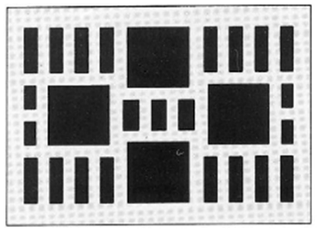
Reinforcement against horizontal loads and buckling.



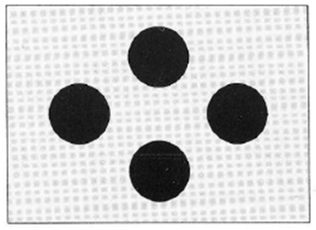
Standard brick BH18 PREMUR©



Exposed brick BH18 S PREMUR©

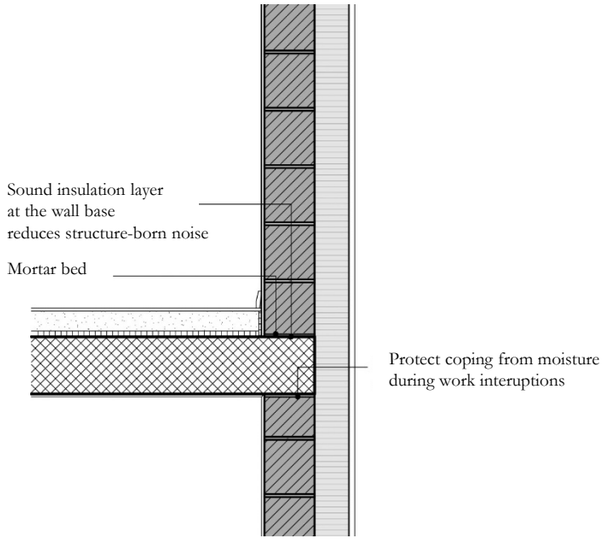


Sandstone KH18 PREMUR©



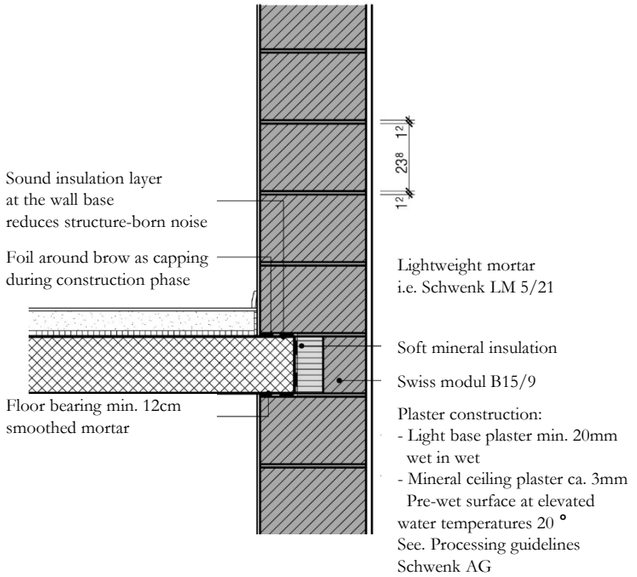
Vertikales Vorspannsystem für Mauerwerk - Steinarten und Konstruktion auf der Baustelle

Vertical prestressing system for masonry – stone types and construction on a building site



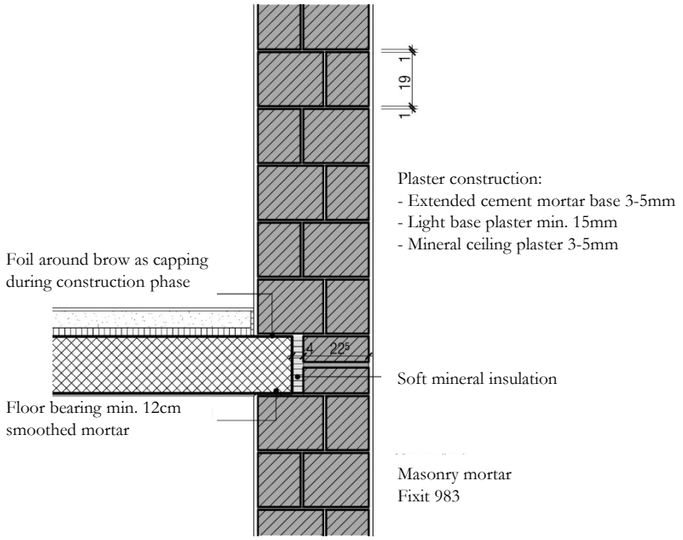
Mauerwerkswand mit Aussendämmung, Wohnsiedlung Kilchberg, Arch. Gigon/Guyer, 1996

Masorny wall with external insulation , Housing development Kilchberg, Arch. Gigon/Guyer, 1996



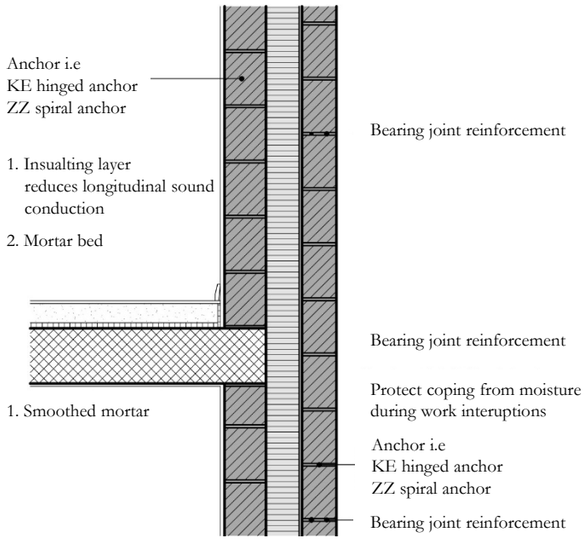
Wärmedämmendes Mauerwerk, Schulhaus Dreirosen Basel, 1996, Arch. Morger Degelo

Insulated masonry, School building Dreirosen Basel, 1996, Arch. Morger Degelo



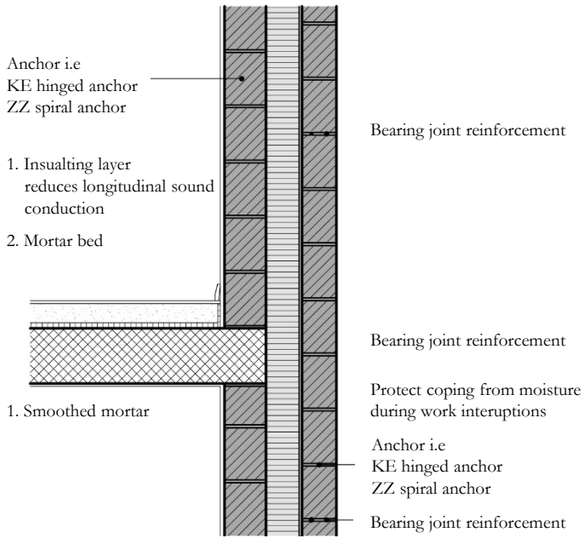
Wärmedämmendes Mauerwerk, Haus in Zürich, 1994, Arch. Gigon/Guyer

Insulated masonry, House in Zürich, 1994, Arch. Gigon/Guyer



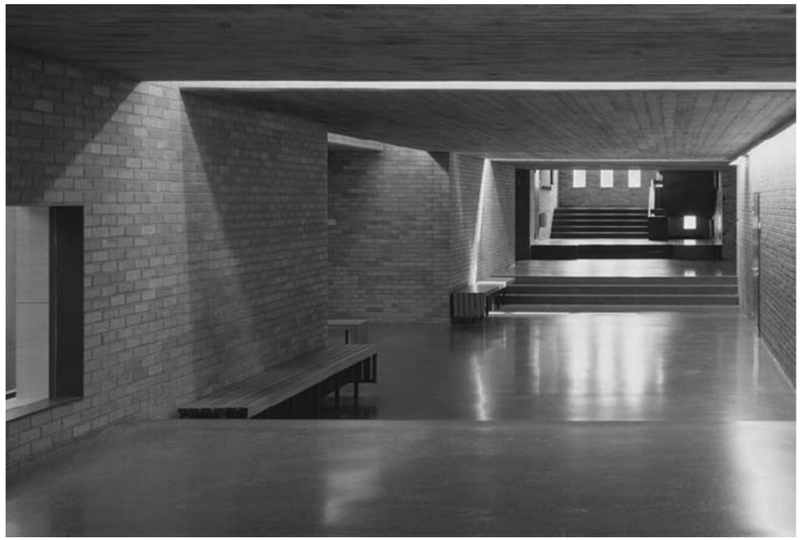
Zweischaliges Mauerwerk mit Aussenputz, Schule Ackermätteli, Basel, 1996, Arch. Ackermann & Friedli

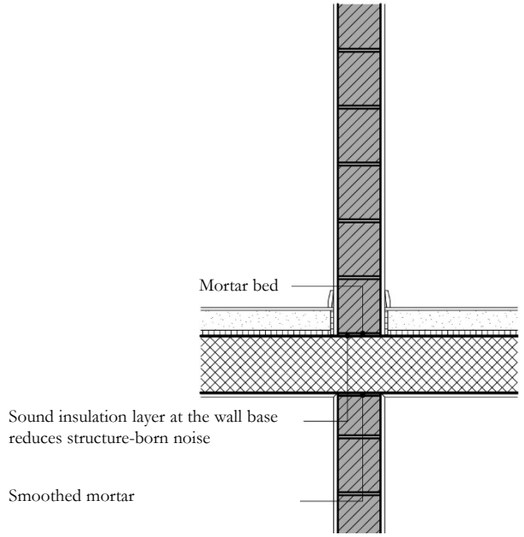
Double-shell masonry with plaster outside, School Ackermätteli, Basel, 1996, Arch. Ackermann & Friedli



Zweischaliges Mauerwerk mit Sicht-Betonsteinen, Einfamilienhaus in Ligornetto, 1976, Arch. M. Botta

Double-shell masonry with external concrete blocks, Single-family house in Ligornetto, 1976, Arch. M. Botta





Tragende Innenwand aus Mauerwerk, Schule Schönau, 2003, Arch. Romero & Schaefle

Structural interior masonry wall, School Schönau, 2003, Arch. Romero & Schaefle

Home Insurance Building, Chicago, 1885, Le Baron Jenney
Home Insurance Building, Chicago, 1885, Le Baron Jenney

Bauteil	Standard-mauerwerk	Feuerwiderstandsklasse					
		R 30	R 60	R 90	R 120	R 180	R 240
Tragend, nicht raumabschliessend	*MB, MBL*	115 115	125 115	175 125	250 150	300 200	350 250
	MC, MCL	150 125	175 150	200 175	225 200	250 225	300 275
	MK	115 115	125 115	150 125	175 150	225 200	275 250
	MP, MPL	115 115	125 115	150 125	175 150	200 175	250 200
Tragend, raumabschliessend	*MB, MBL*	115 115	115 115	150 115	175 125	225 175	275 225
	MC, MCL	125 115	150 115	150 125	175 150	200 175	250 225
	MK	115 115	115 115	125 115	150 125	200 175	250 225
	MP, MPL	115 115	115 115	125 115	150 125	175 150	225 200
Nicht tragend, raumabschliessend	*MB, MBL*	60 50	100 60	115 75	125 100	175 150	200 175
	MC, MCL	75 50	75 50	100 75	115 100	150 115	175 150
	MK	75 50	100 75	125 100	150 125	175 150	200 175
	MP, MPL	75 50	75 50	100 75	115 100	125 115	150 125

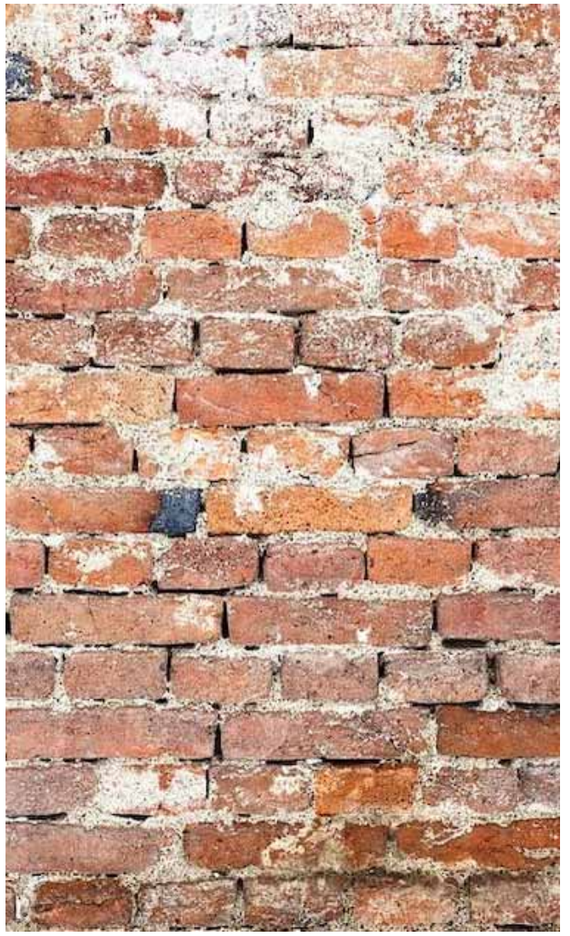
Minimale Wandstärke t_F in mm. obere Werte ohne Putz, untere Werte mit Putz

Minimal wall thickness t_F in mm. Values above without plaster, values below with plaster

Verwitterung des Mauerwerks
Masonry deterioration

ALVEOLISIERUNG
ALVEOLIZATION

PULVERISIERUNG
PULVERIZATION

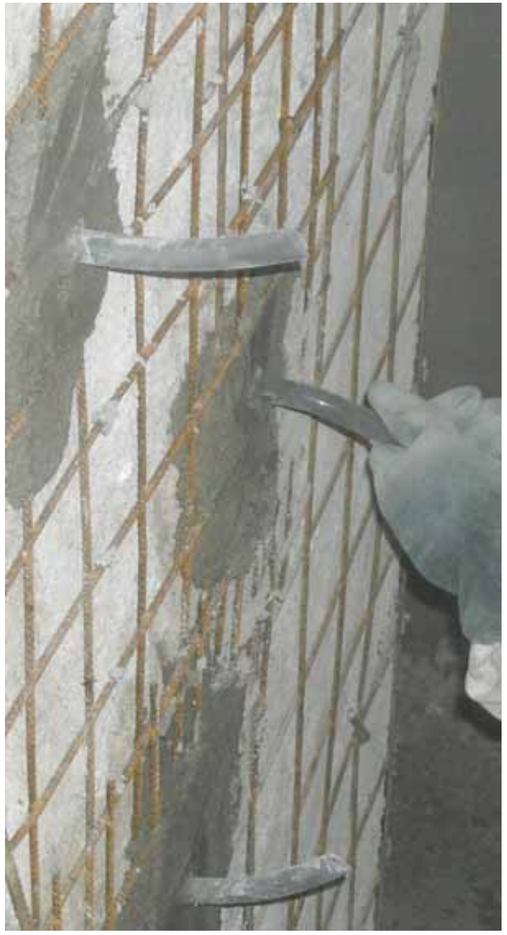


EFFLORESZENZ
EFFLORESCENCE

Verwitterung des Mauerwerks
Masonry deterioration

BESTEHENDER GEMAUERTER BOGEN
EXISTING MASONRY ARCH

STAHLBINDER
STEEL TIE



HARZINJEKTIONEN
RESIN INJECTIONS

STAHLBETONSCHICHT
REINFORCED CONCRETE LAYER

KOHLENSTOFFFASERVERSTÄRKTES POLYMER
CARBON FIBER REINFORCED POLYMER

Verschiedene Verstärkungsstrategien für bestehendes Mauerwerk
Different structural retrofitting strategies for existing masonry walls

Mauerwerk
Masonry

Ayub Hospital

Bangladesh, 1963

Architect: Louis I. Kahn

Engineer: M. G. Siddiqui

Louis I. Kahn bei der Arbeit an einem Stadtmodell von Dhaka
Louis I. Kahn working on the urban physical model of Dhaka

Parlamentsgebäude, Sher-e-Banglanagar, Dhaka, Bangladesch, 1962-1974, arch. Louis I. Kahn
Parlament Building, Sher-e-Banglanagar, Dhaka, Bangladesh,1962-1974, arch. Louis I. Kahn

Parlamentsgebäude, Sher-e-Banglanagar, Dhaka, Bangladesch, 1962-1974, arch. Louis I. Kahn
Parlamentsgebäude, Sher-e-Banglanagar, Dhaka, Bangladesch, 1962-1974, arch. Louis I. Kahn

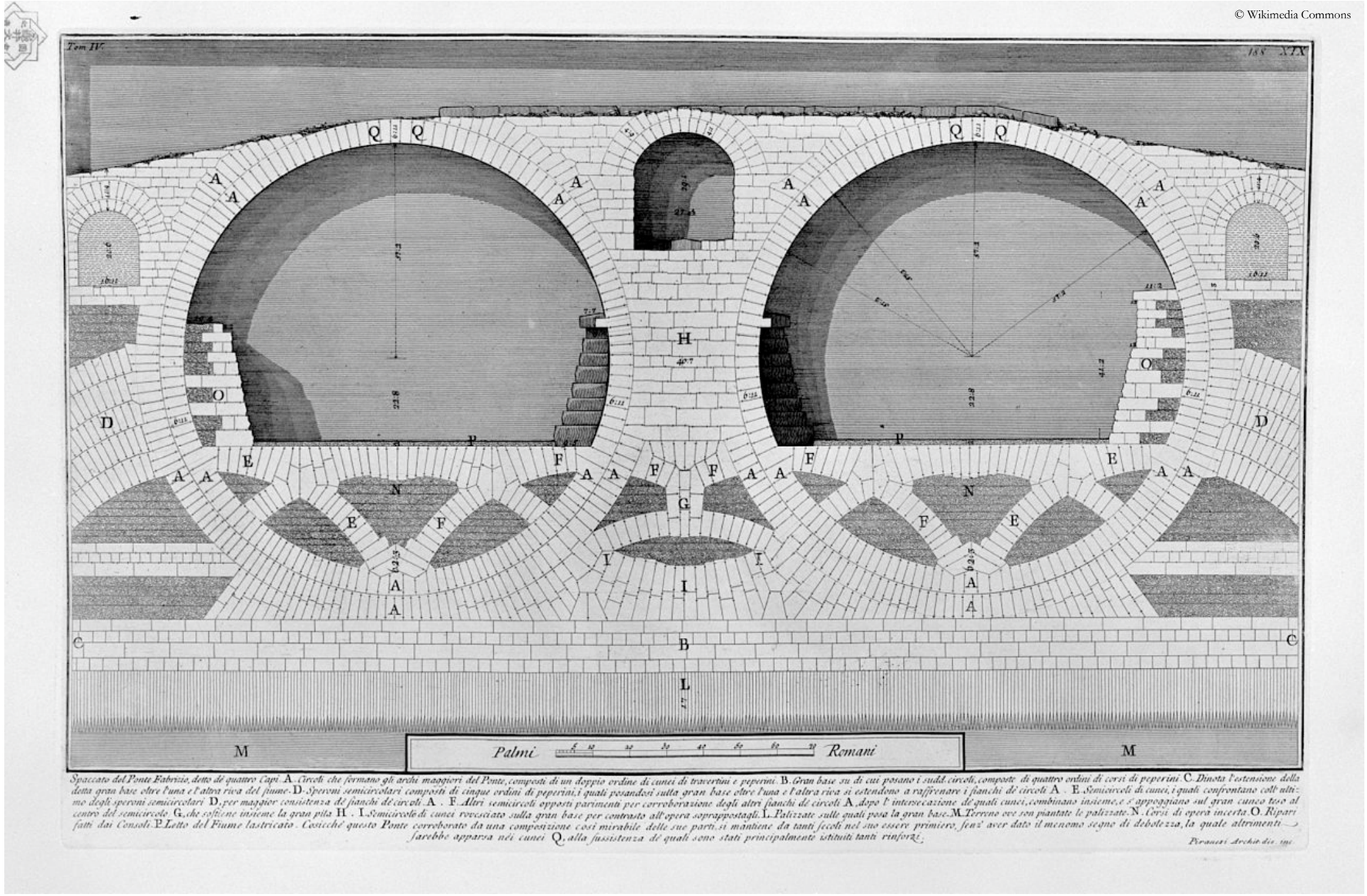
Zitadelle, Sher-e-Banglanagar, Dhaka, Bangladesch, 1962-1974, arch. Louis I. Kahn
Citadel, Sher-e-Banglanagar, Dhaka, Bangladesh,1962-1974, arch. Louis I. Kahn

Zitadelle, Sher-e-Banglanagar, Dhaka, Bangladesch, 1962-1974, arch. Louis I. Kahn
Citadel, Sher-e-Banglanagar, Dhaka, Bangladesh,1962-1974, arch. Louis I. Kahn

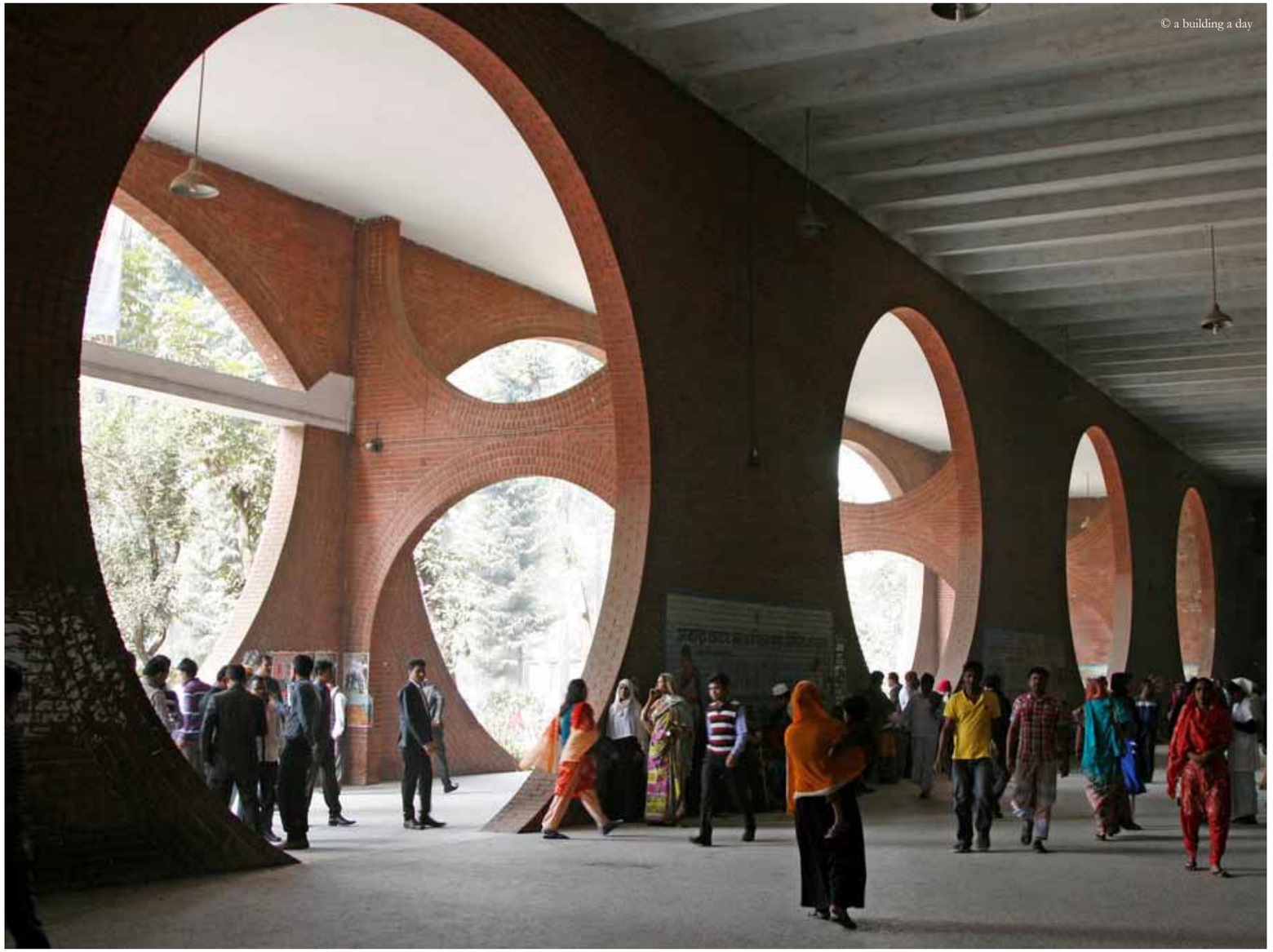
Zitadelle, Sher-e-Banglanagar, Dhaka, Bangladesch, 1962-1974, arch. Louis I. Kahn
Citadel, Sher-e-Banglanagar, Dhaka, Bangladesh,1962-1974, arch. Louis I. Kahn

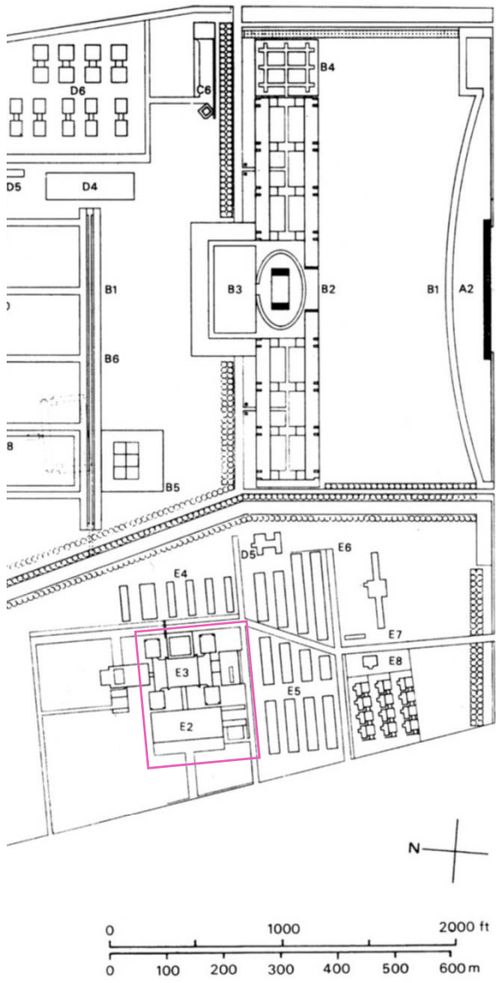
Variationen des Mauerwerks für die Gebäude in Dhaka, Bangladesch, 1962-1974, Arch. Louis I. Kahn
Variations on masonry for the buildings in Dhaka, Bangladesh,1962-1974, arch. Louis I. Kahn

Louis I. Kahn, Vorläufige Skizze
Louis I. Kahn, Preliminary sketch



G.B. Piranesi, Ponte Fabricio, 1756


© a building a day


D6
C6
B4
D5
D4
B1
B3
B2
B1
A2
B6
B5
D5
E6
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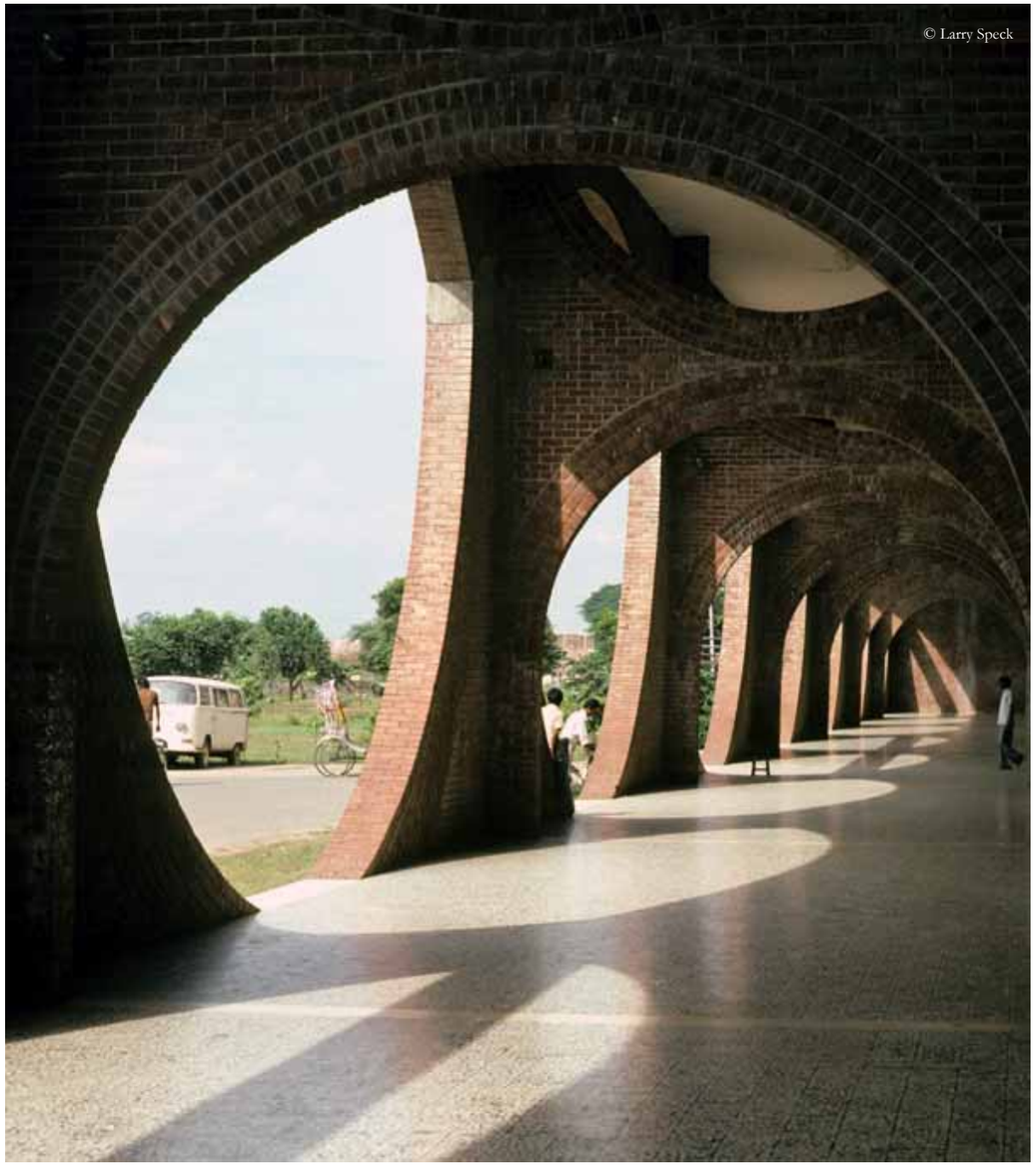
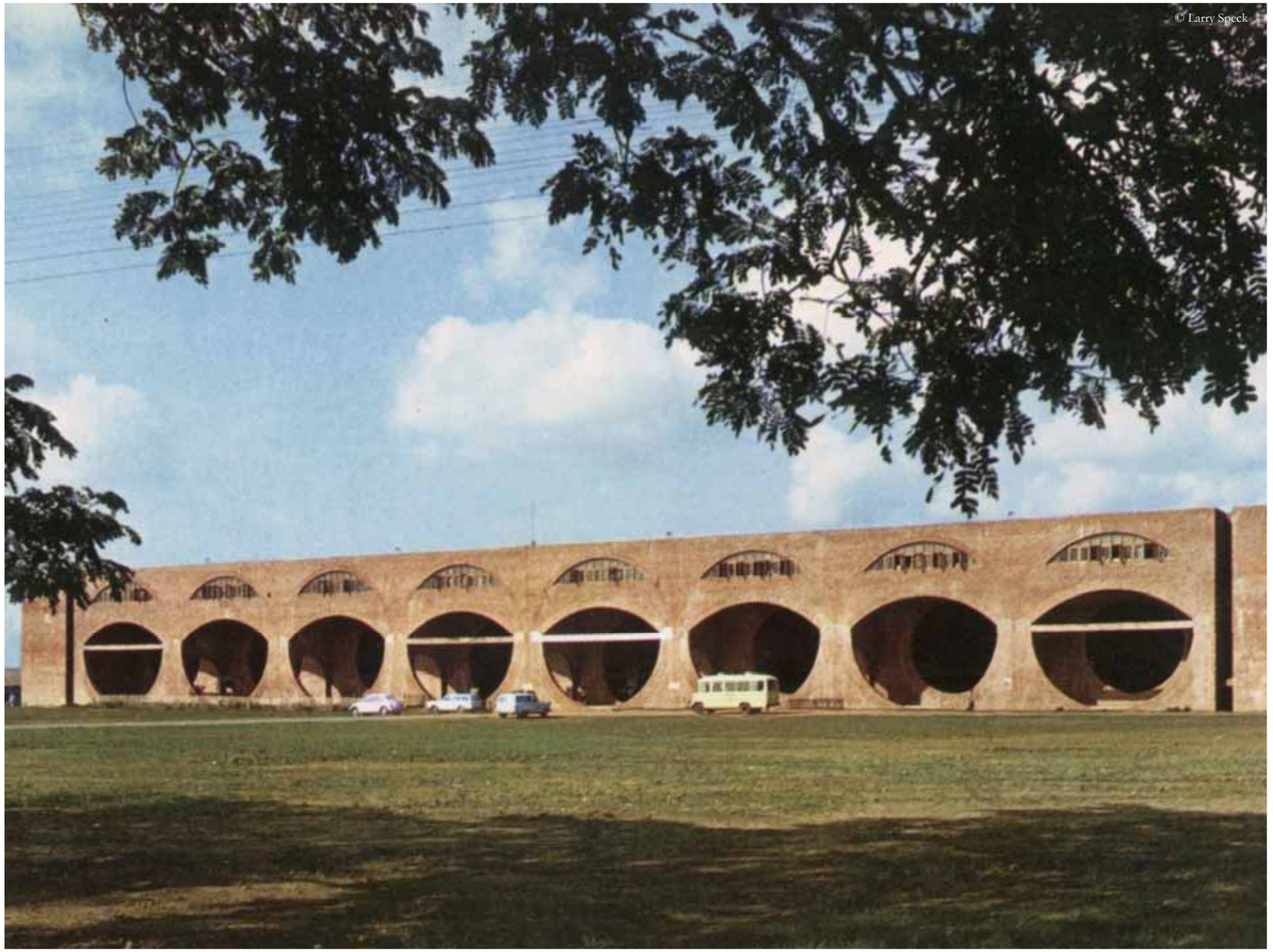
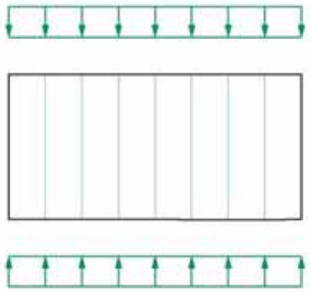
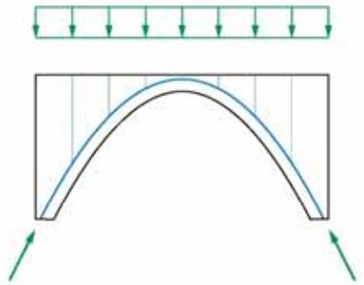
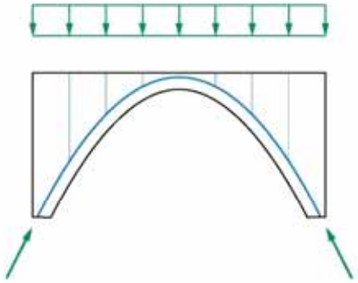
E8
E3
E5
E2
N
0
1000
2000 ft
0
100
200
300
400
500
600 m

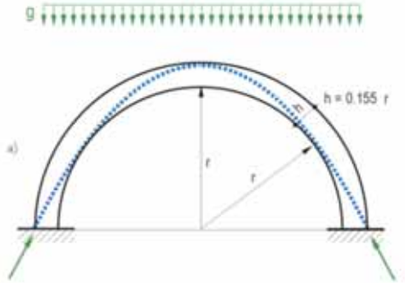

© Larry Speck


© Larry Speck





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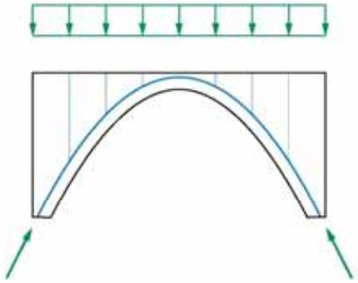
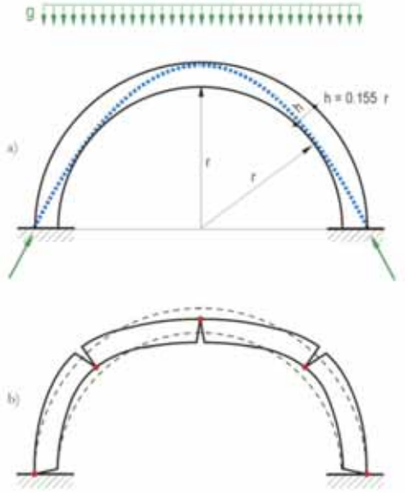
r
r

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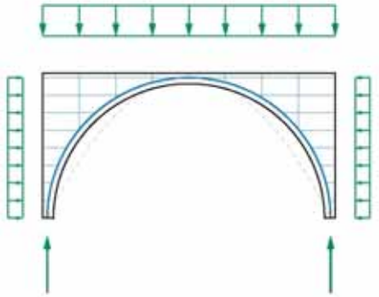
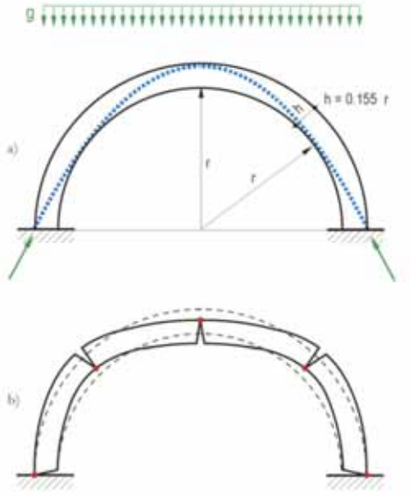
b)

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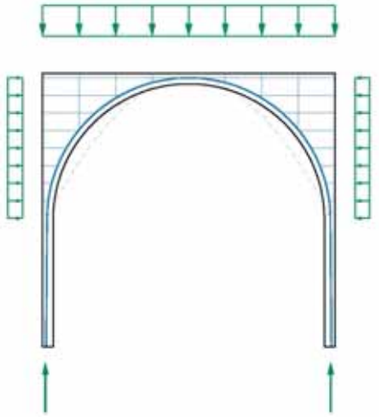
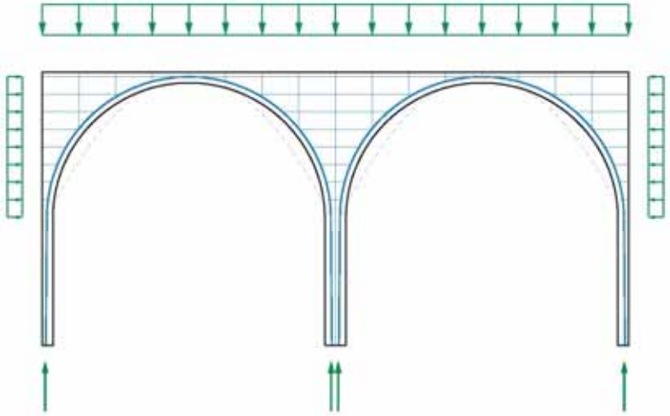
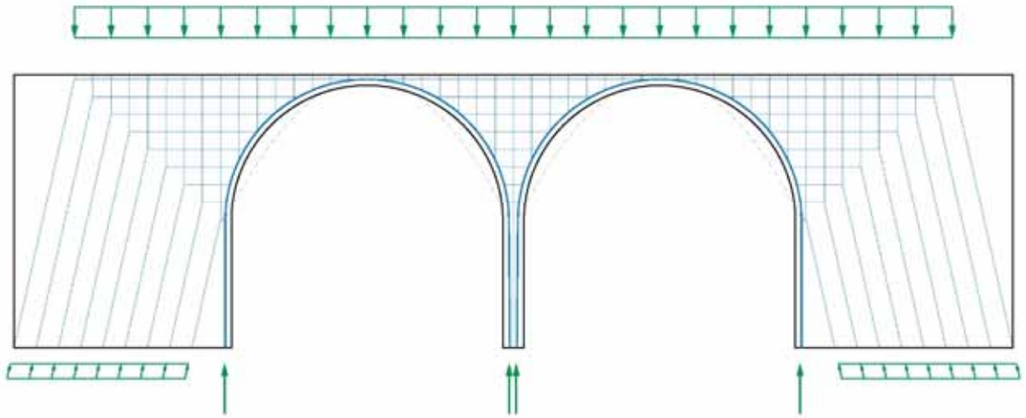
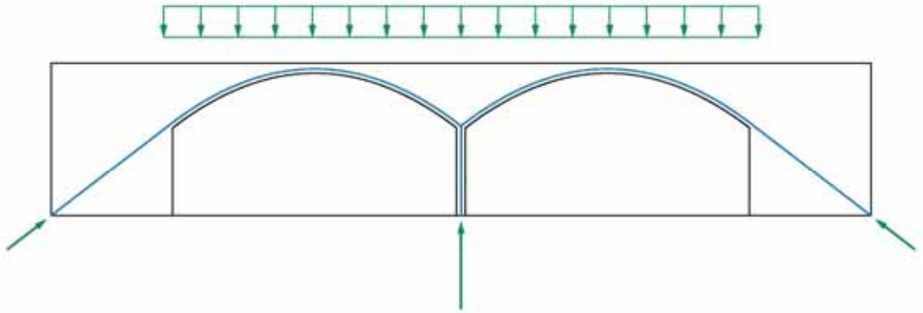
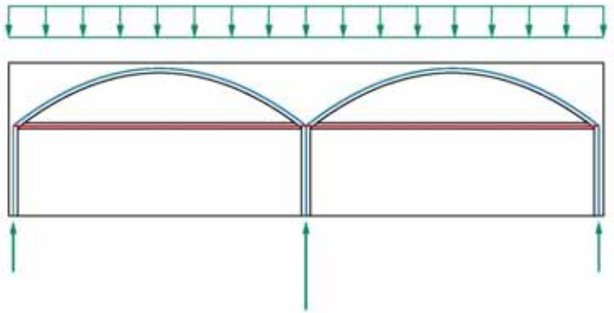
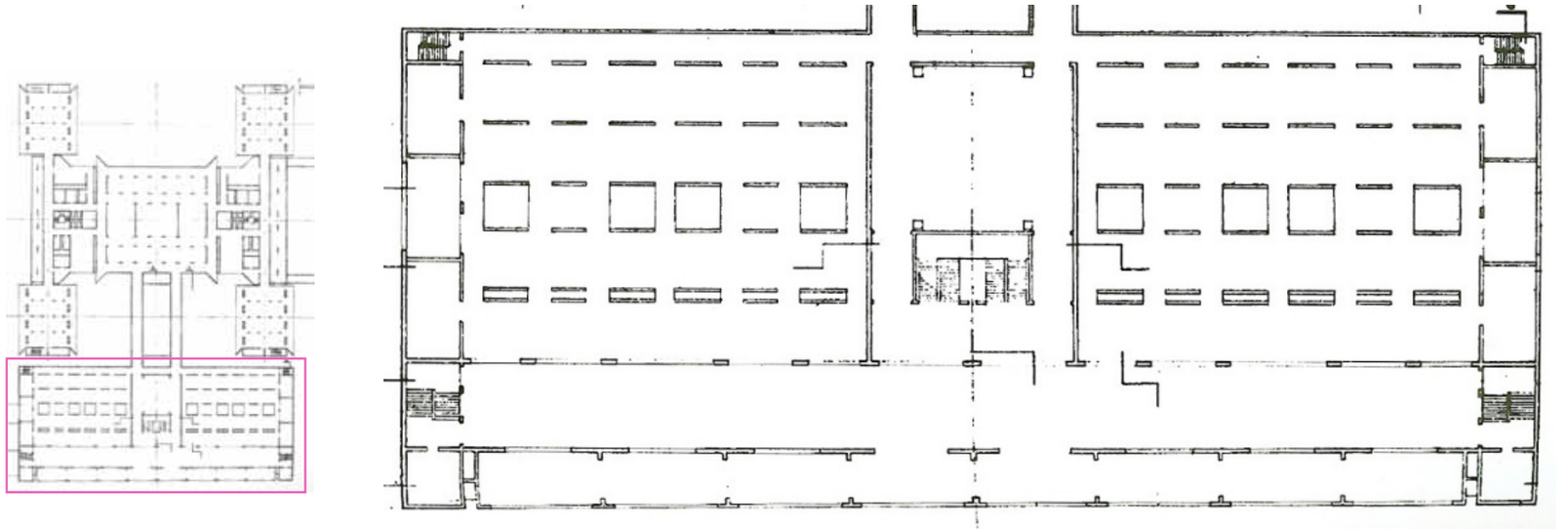




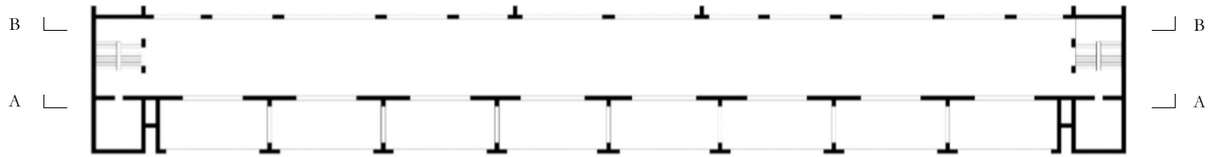




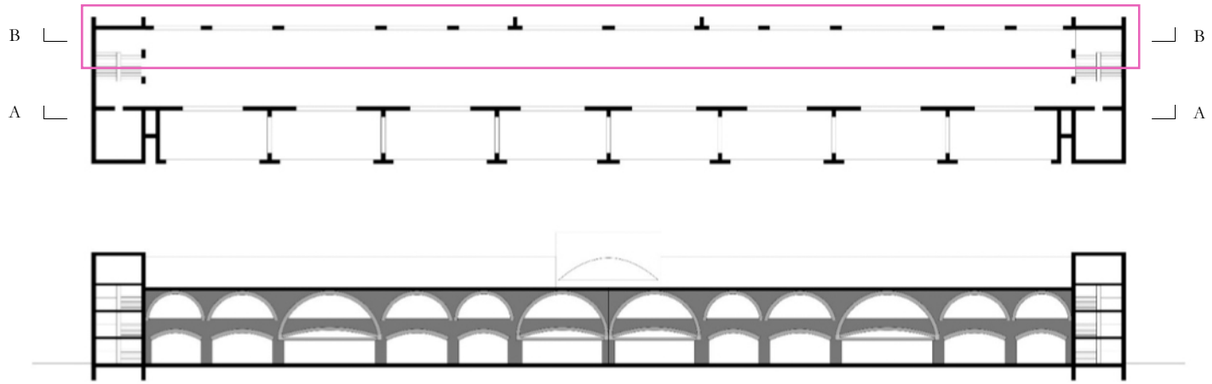




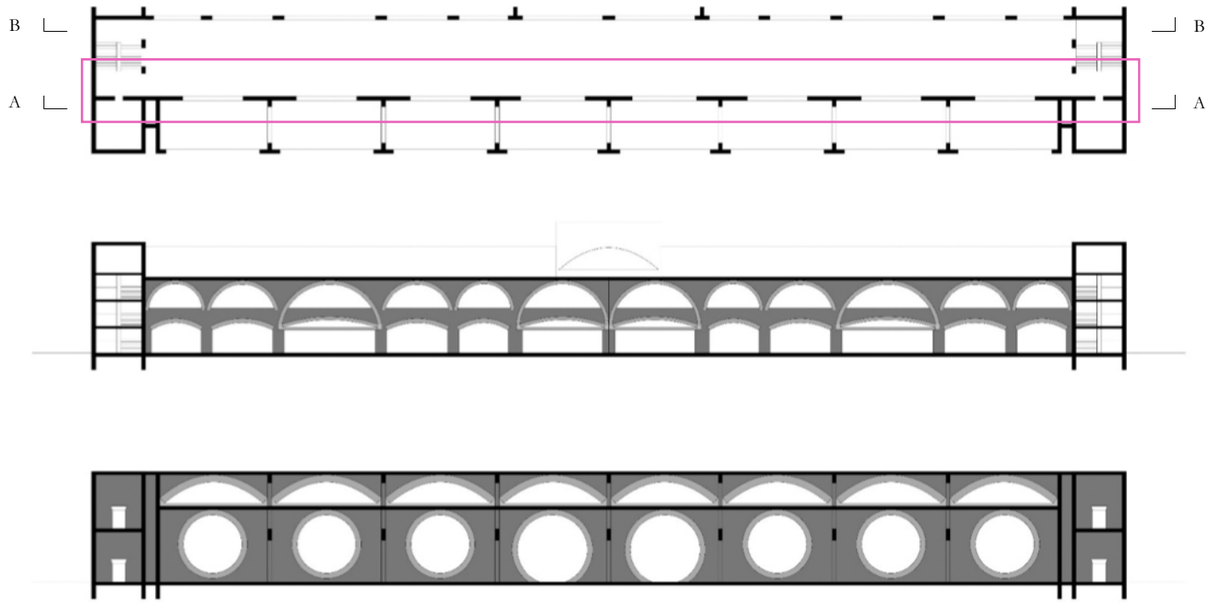
Grundriss
Floor plan



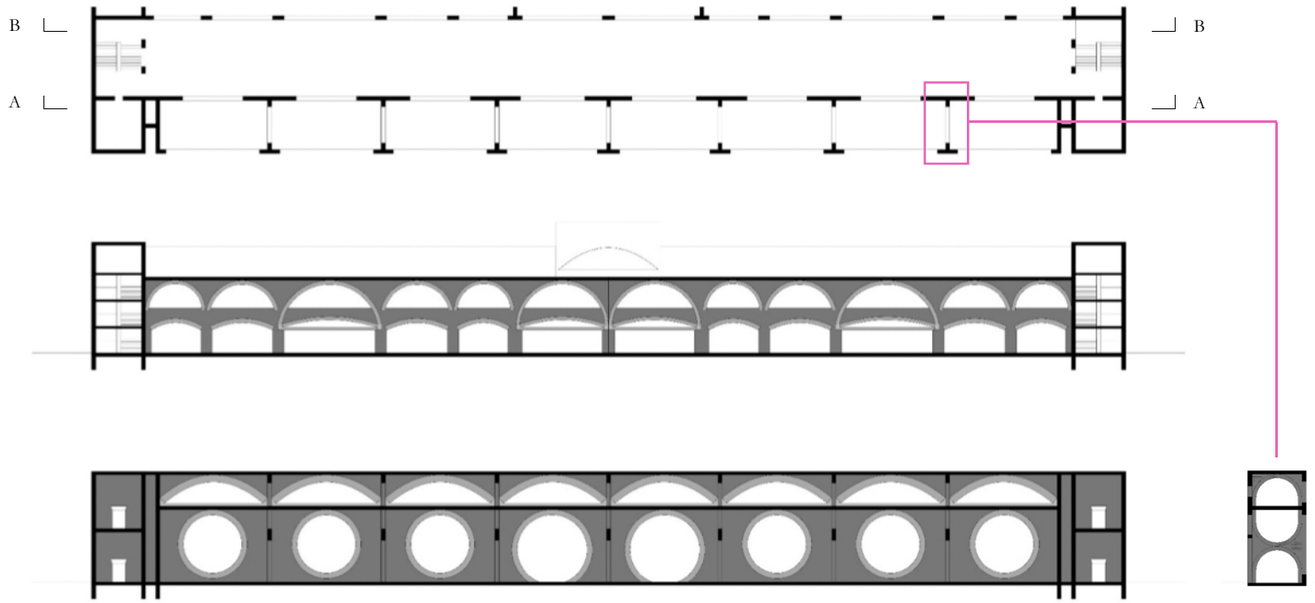
Wandabschnitte der beiden Eingangshallen
Wall sections of the two entrance halls



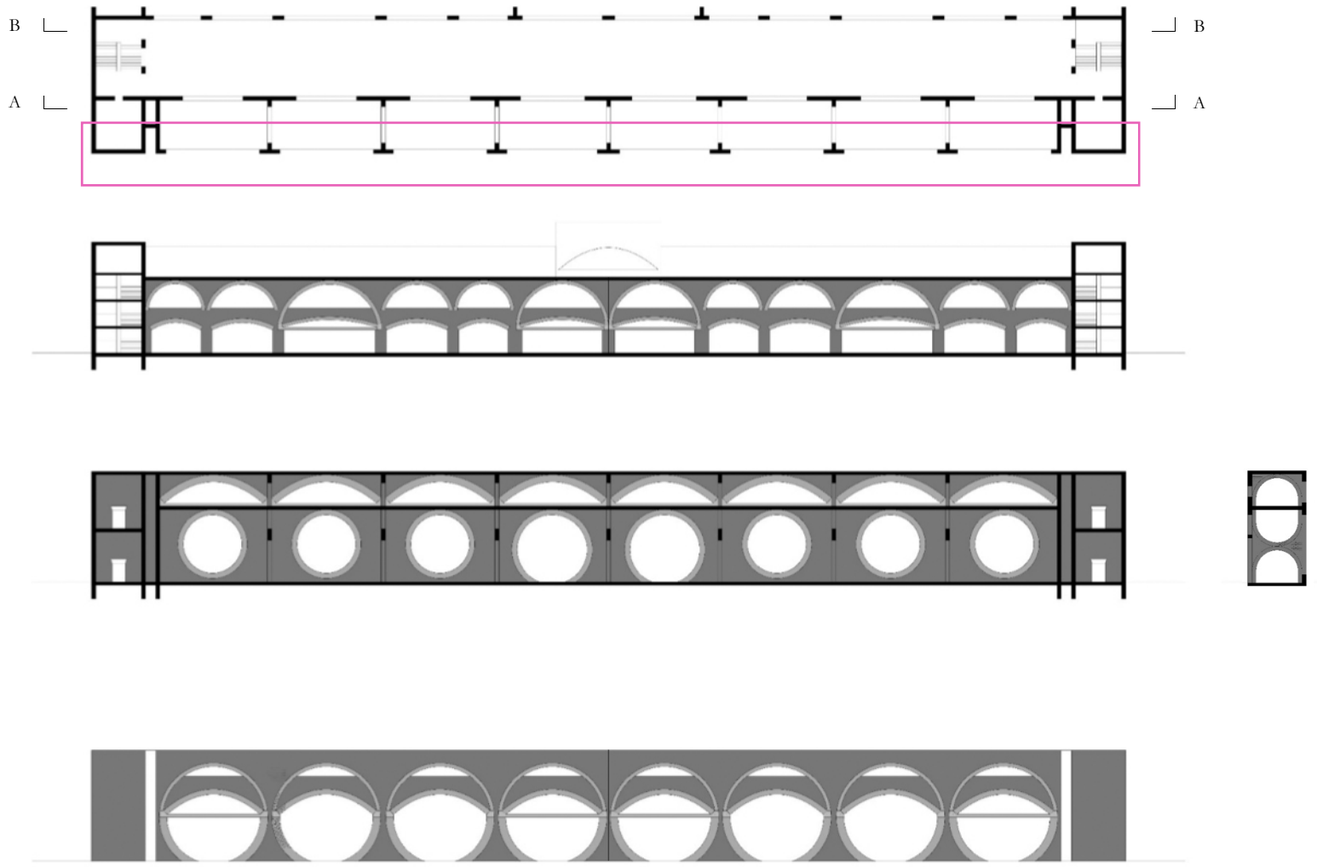
Wandabschnitte der beiden Eingangshallen
Wall sections of the two entrance halls



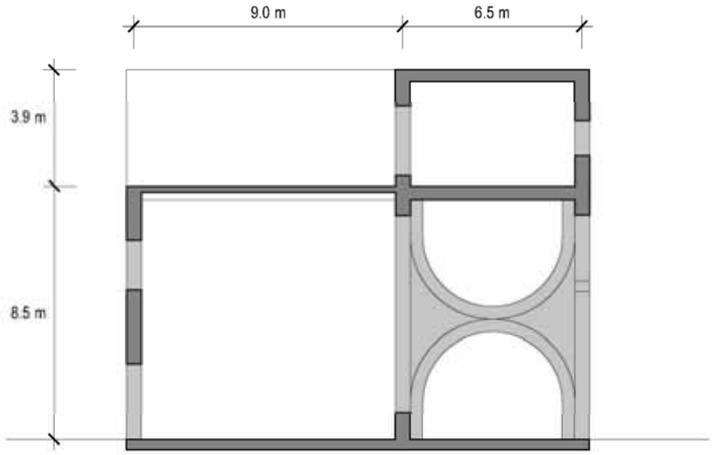
Wandabschnitte der beiden Eingangshallen
Wall sections of the two entrance halls



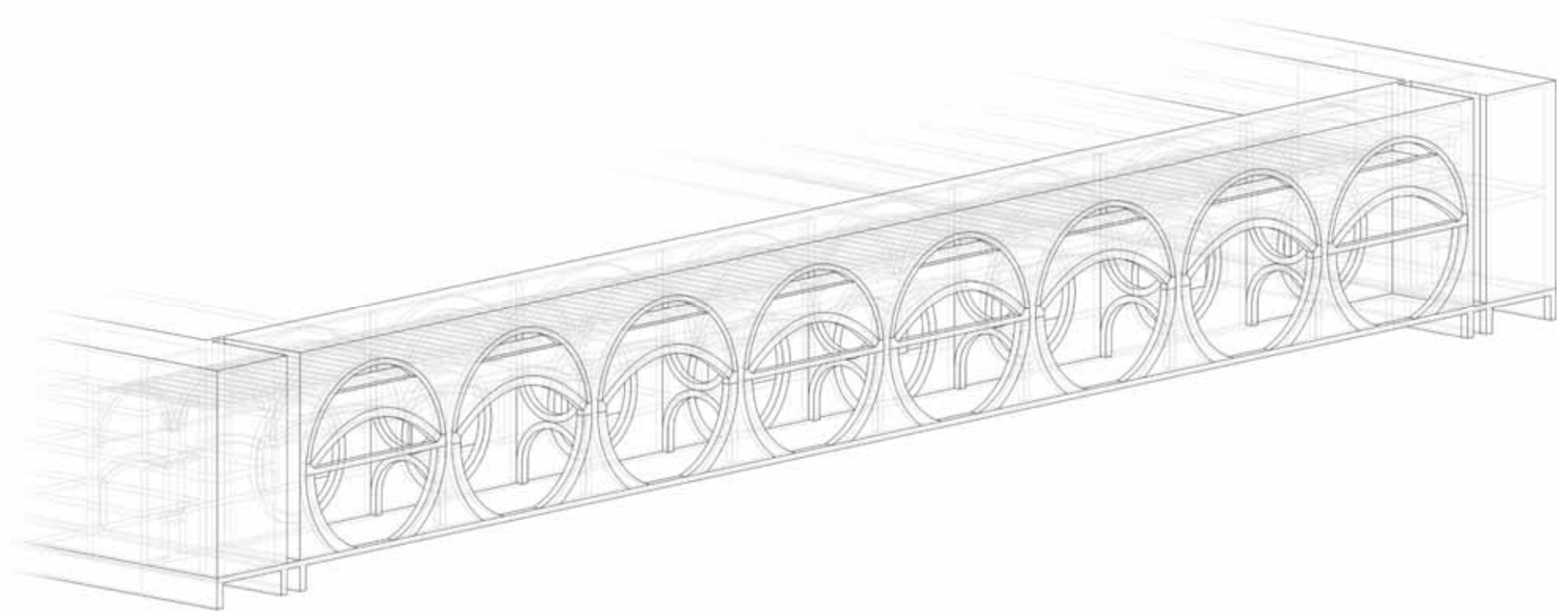
Wandabschnitte der beiden Eingangshallen
Wall sections of the two entrance halls



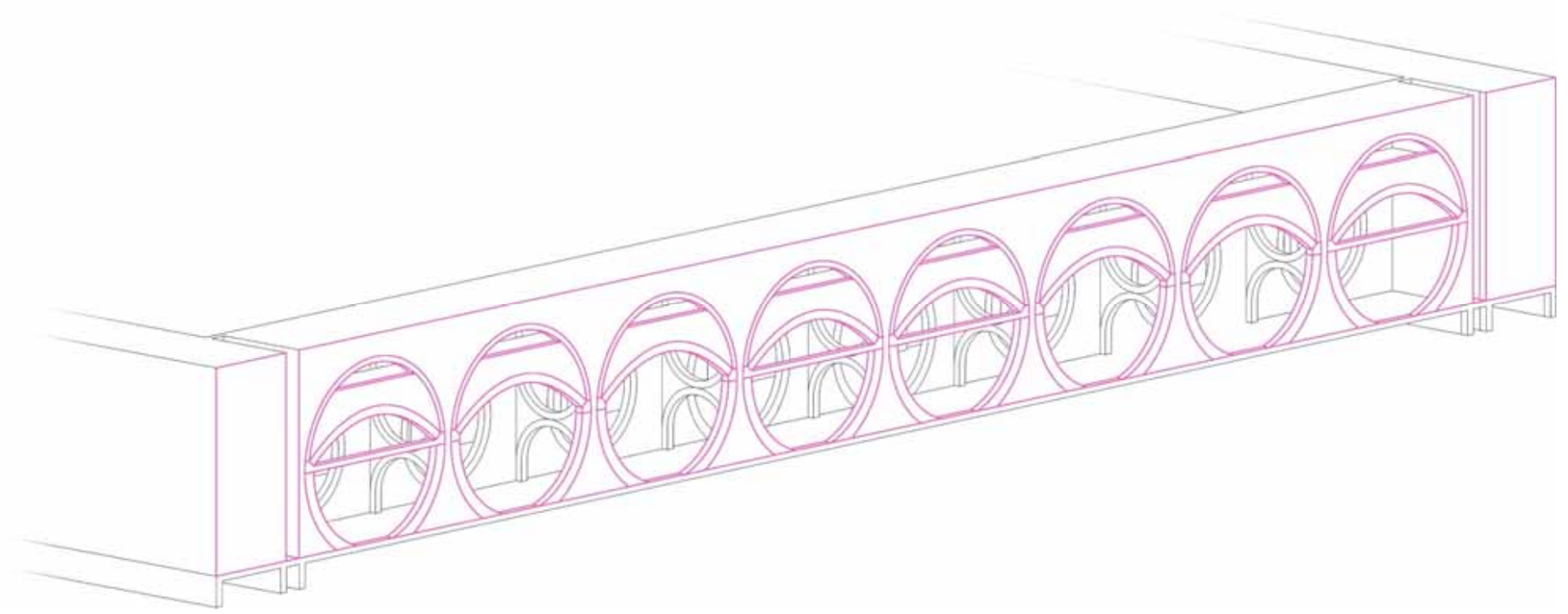
Wandabschnitte der beiden Eingangshallen
Wall sections of the two entrance halls



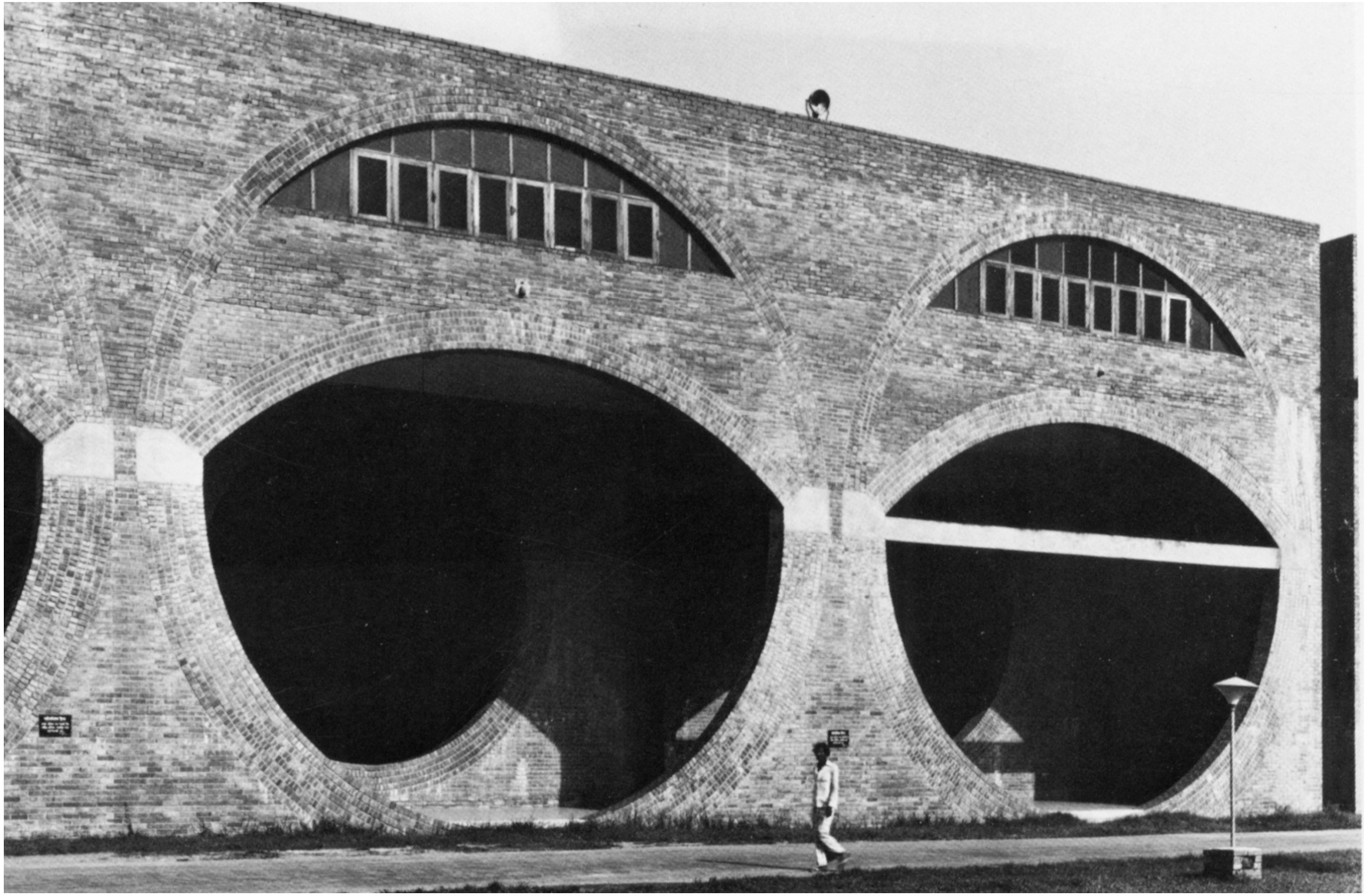
Transversaler Schnitt
Transversal section

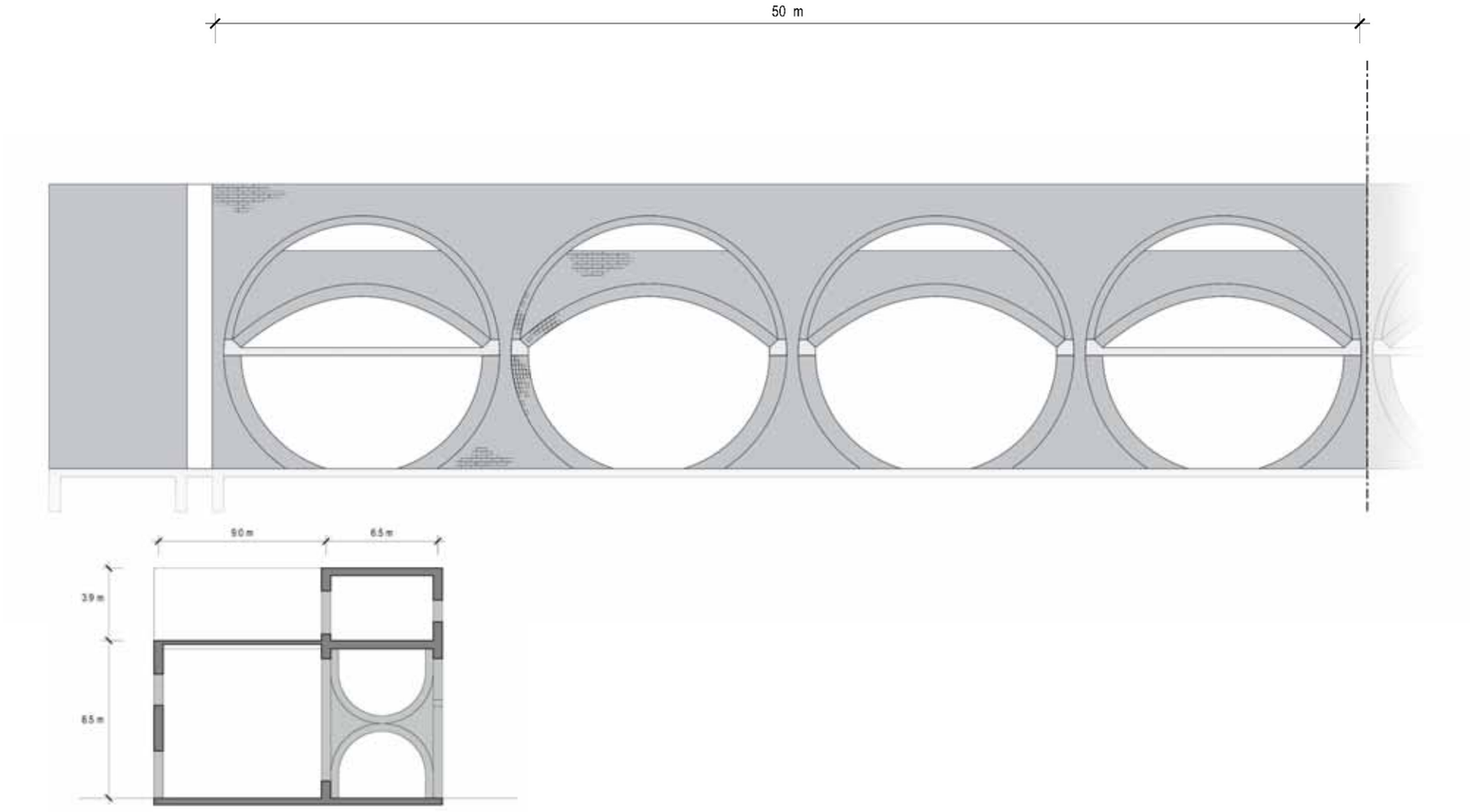


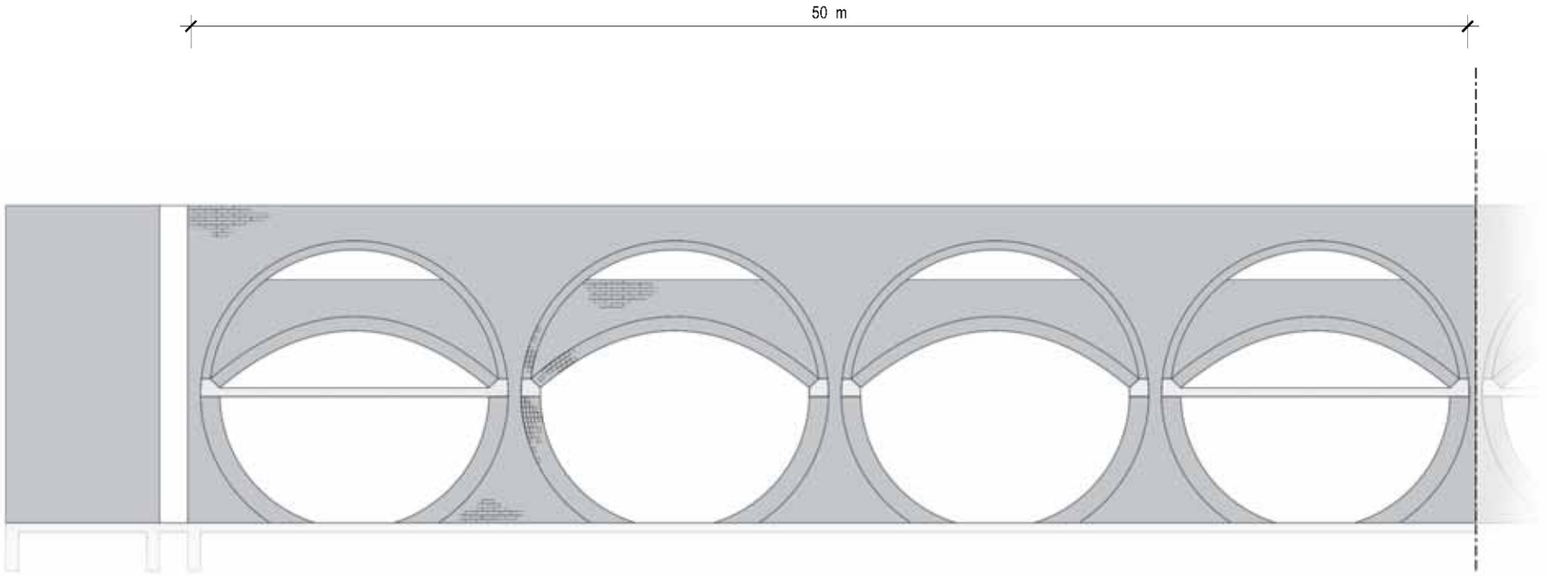
Axonometrische Ansicht
Axonometric view

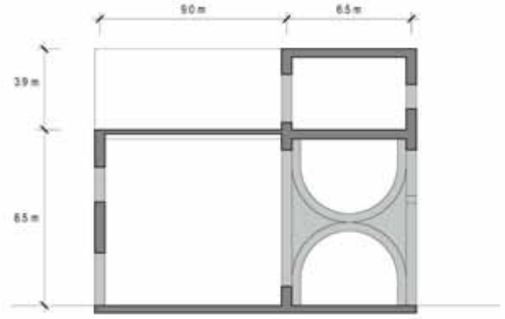


West-Fassade
West façade

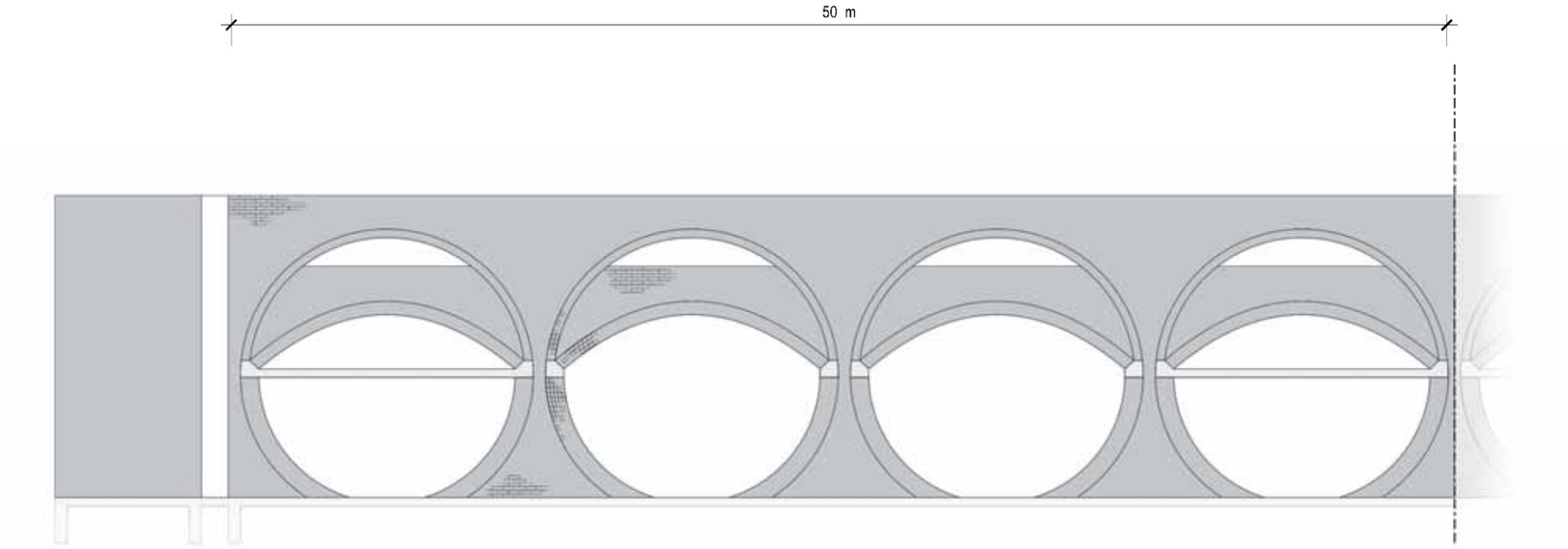


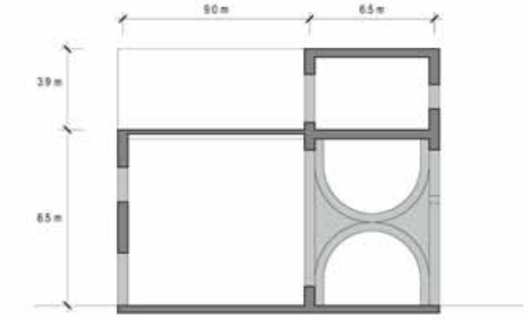

50 m
9.0 m
6.5 m
3.9 m
6.5 m





RC slabs
$\varrho = 25\ kN/m^3$



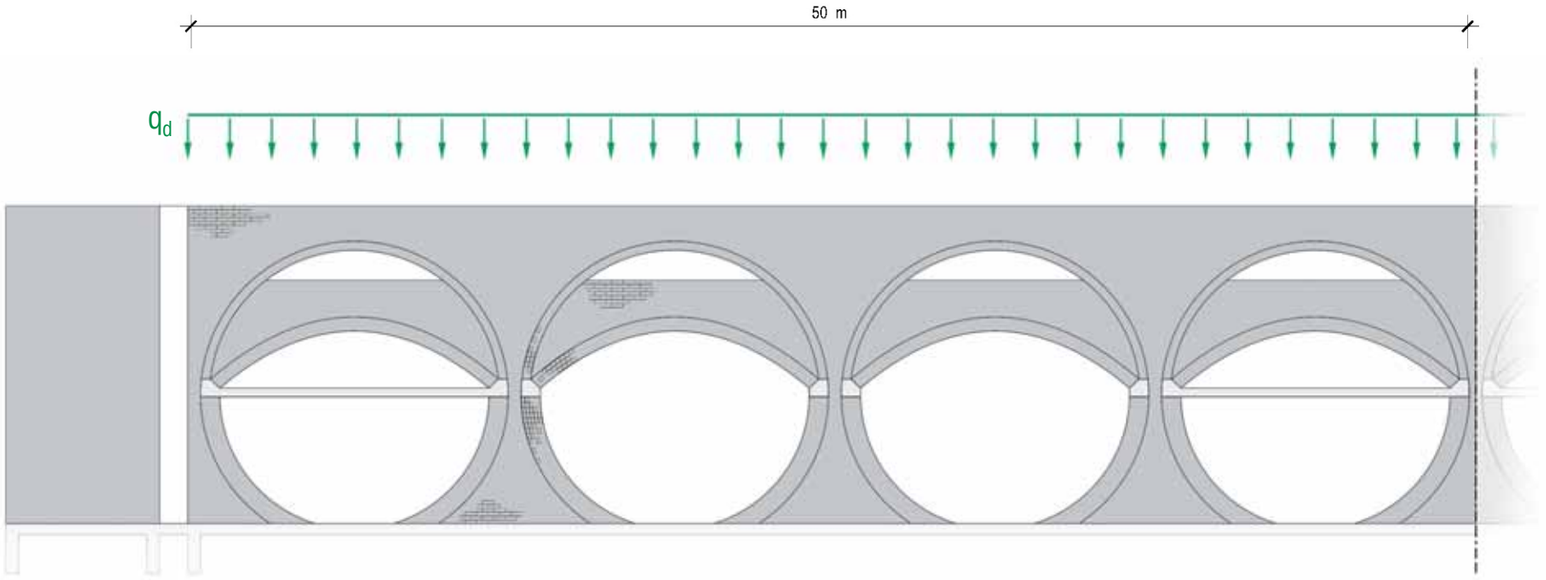


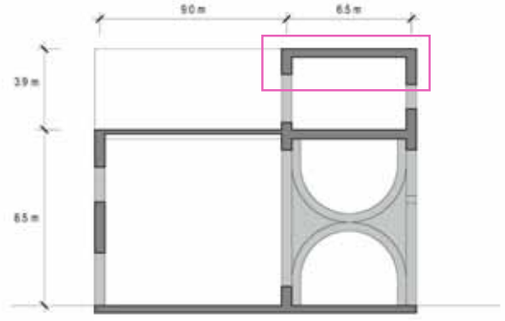
RC slabs
$\varrho = 25\ kN/m^3$

External Loads

Dead loads
$g_{slab} = 25\ kN/m^3 \cdot 0.45\ m = 11.25\ kN/m^2$

Live loads (people)
$q_p = 5\ kN/m^2$





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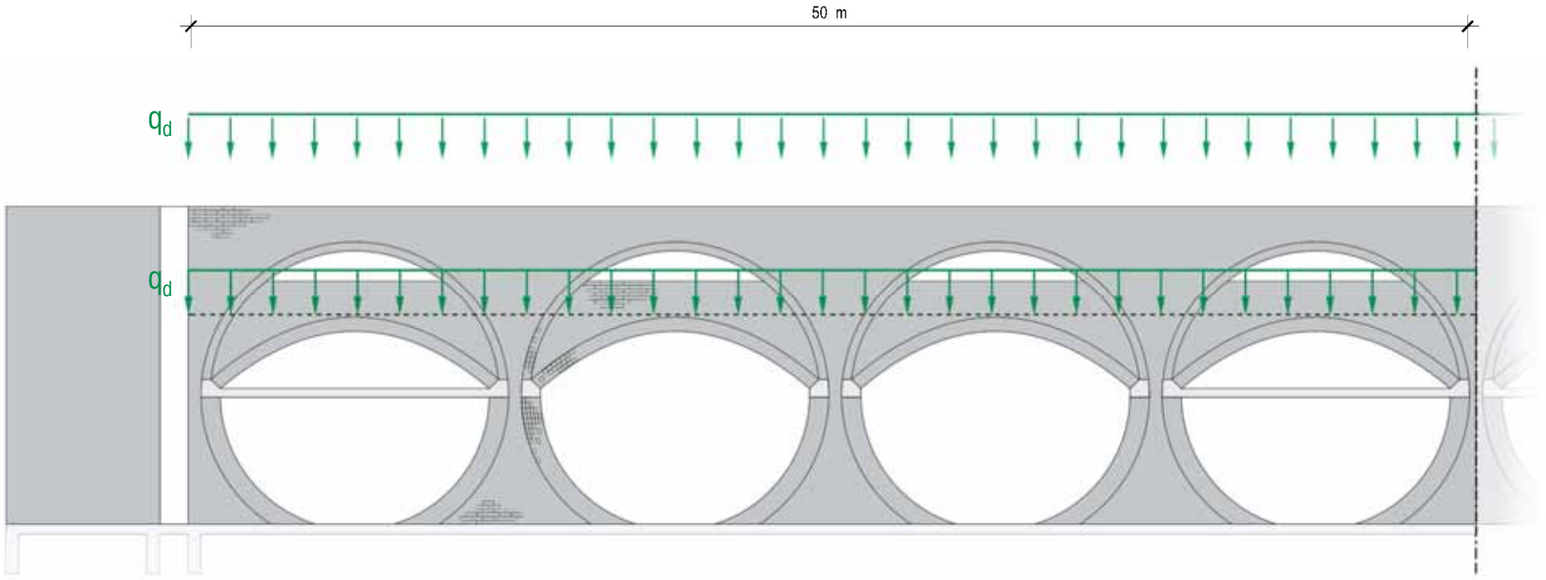
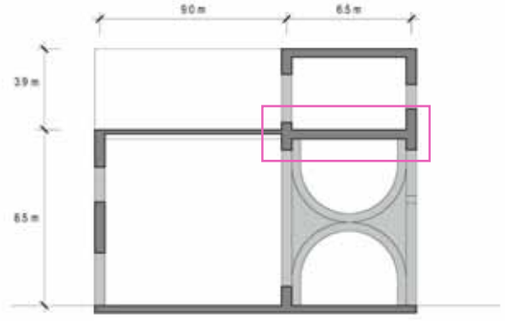
External Loads

Dead loads
$g_{slab} = 25\ kN/m^3 \cdot 0.45\ m = 11.25\ kN/m^2$

Live loads (people)
$q_p = 5\ kN/m^2$

$q_d = ((1.35 \cdot g_{slab} + 1.5 \cdot q_p) \cdot 6.5\ m)/2 =$
$= 73.7\ kN/m$





RC slabs
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$q_d = ((1.35 \cdot g_{slab} + 1.5 \cdot q_p) \cdot 6.5\ m)/2 =$
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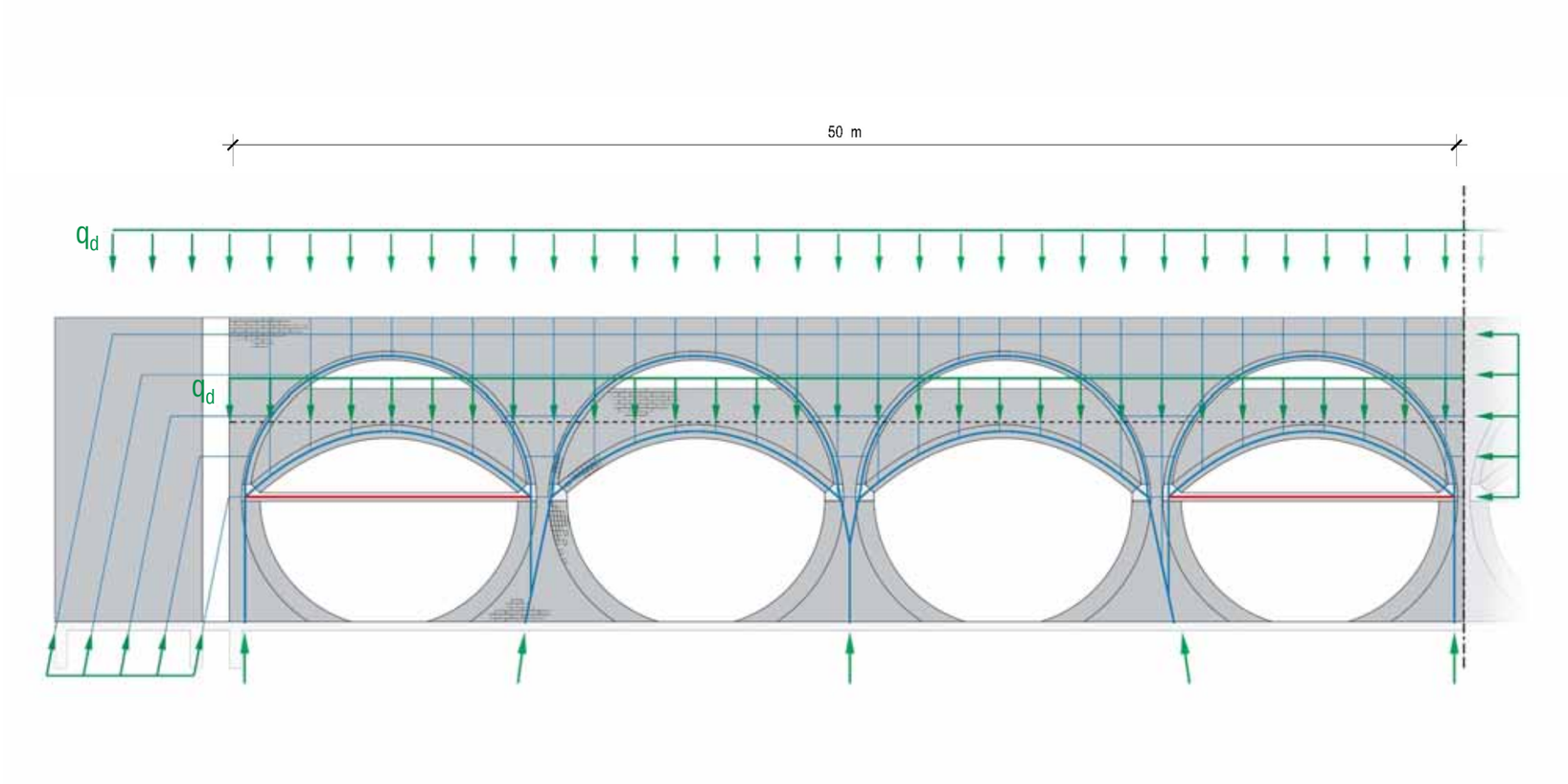
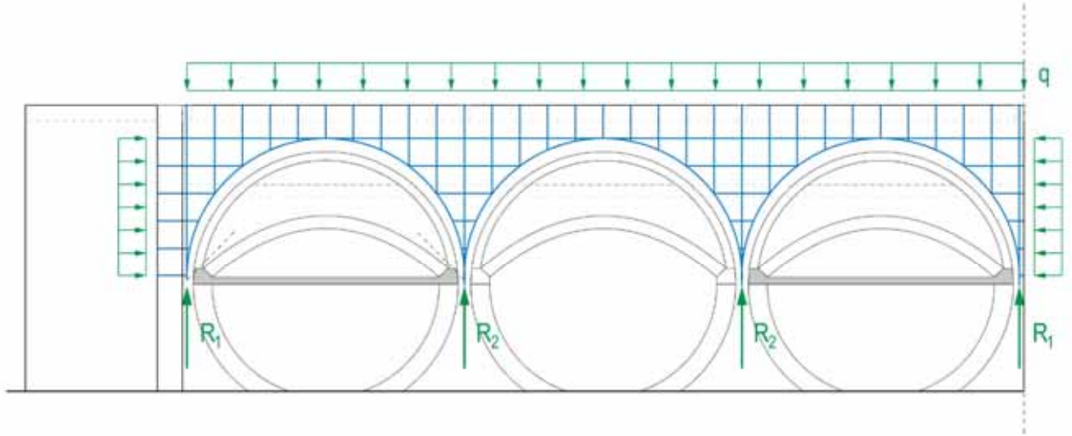
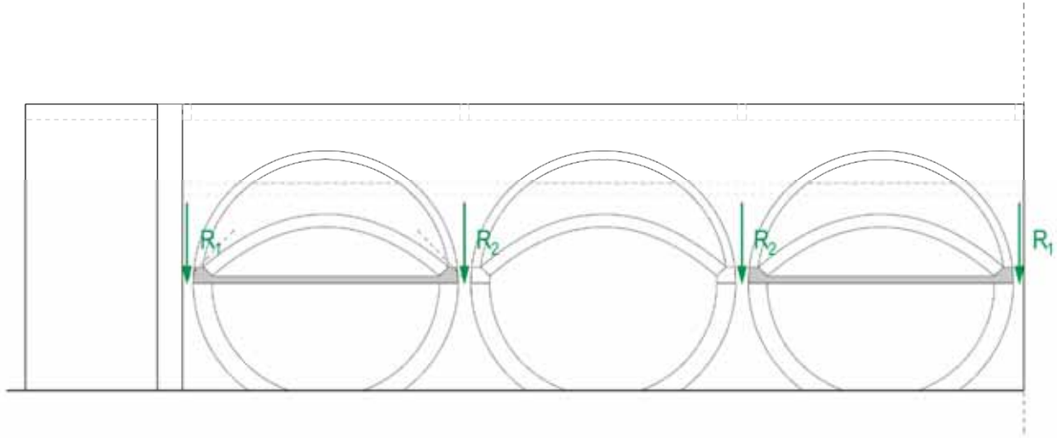
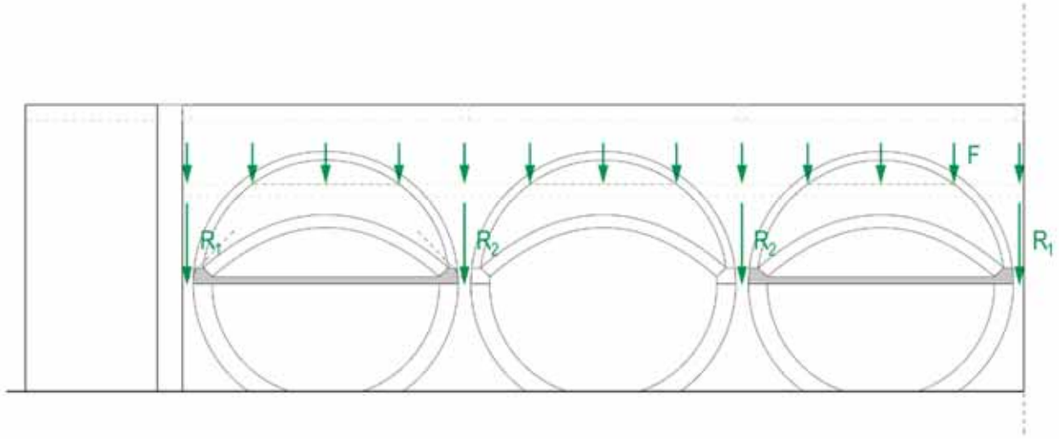

50 m
q_d
q_d



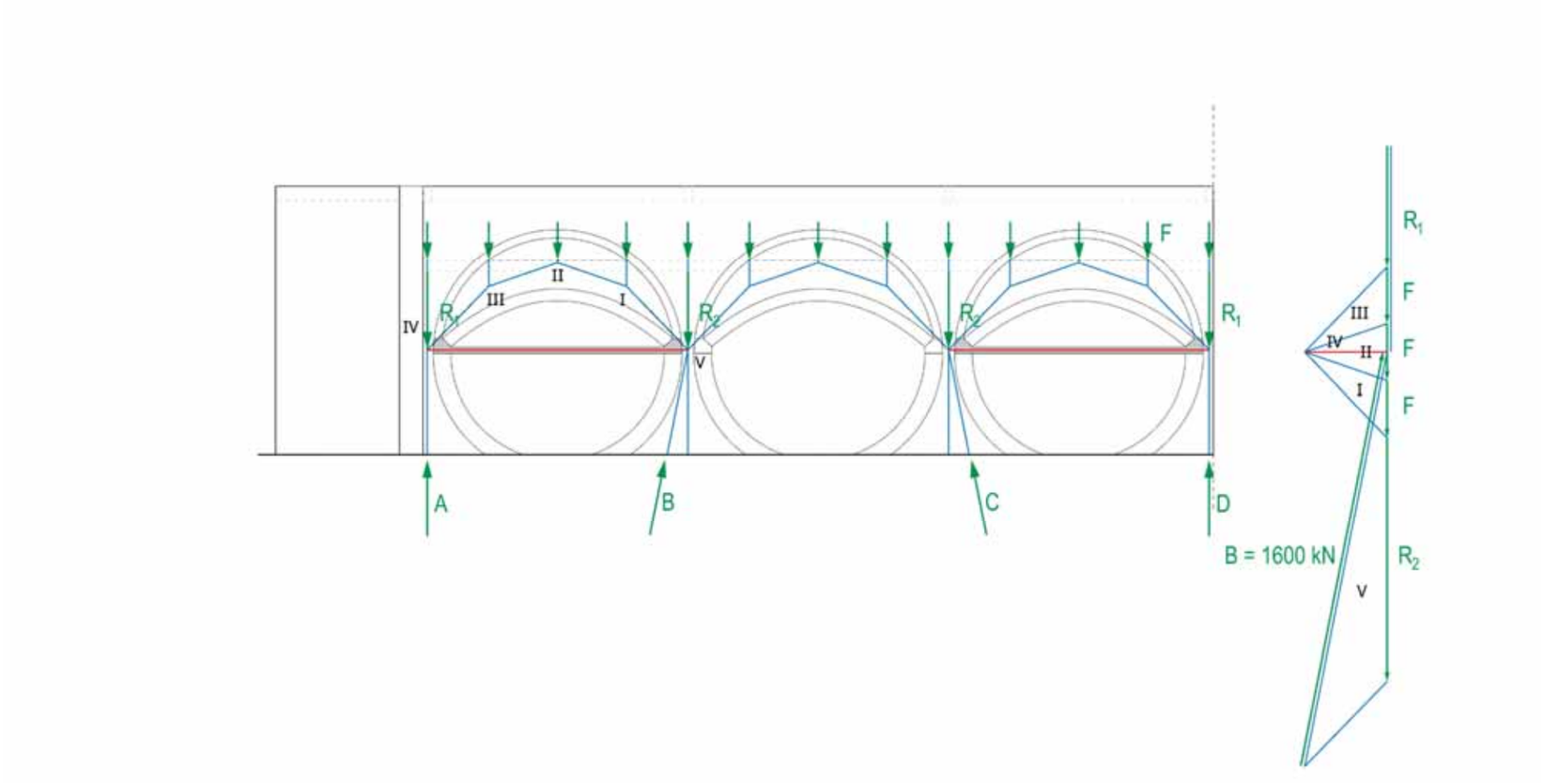
West-Fassade
West façade



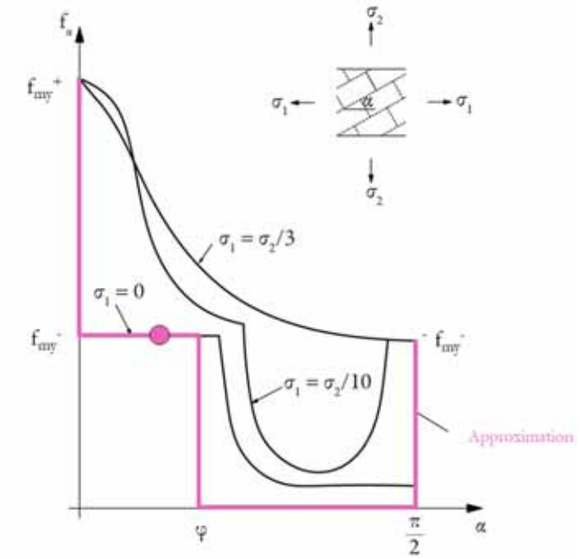
West-Fassade
West façade

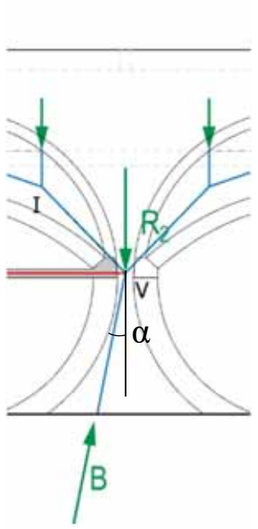


West-Fassade
West façade

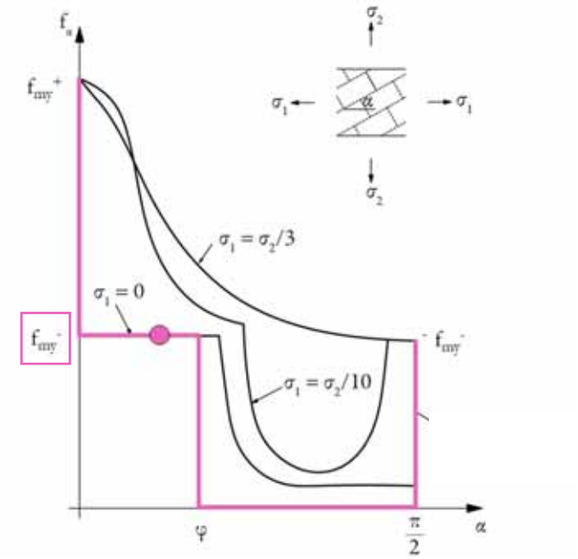


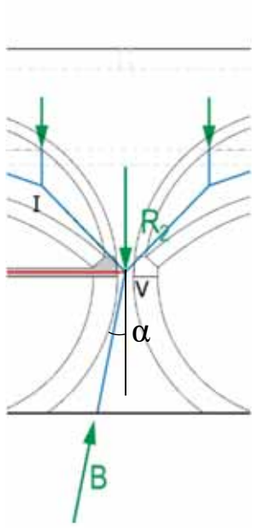
West-Fassade
West façade





Masonry	Standard Masonry Type	$f_{mx,d}$ [N/mm²]	$f_{my,d}$ [N/mm²]	$E_{my,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
Brick (B)	MB	3.5	1.5	3.5	0.6
Lightweight Brick (LB)	MBL	1.6	0.75	1.6	
Sand-lime Brick (K)	MK	3.5	1.5	3.5	
Concrete Block (C)	MC	3.5	2.55	3.5	
Lightweight Concrete Block (CL)	MCL	0.9	0.6	0.9	
Aerated Concrete Block (P)	MP	1.6	1.2	1.6	
Aerated L. Concrete B. (PL)	MPL	0.9	0.6	0.9	





$0 < \alpha < \varphi$

Masonry	Standard Masonry Type	$f_{ma,d}^-$ [N/mm²]	$f_{my,d}^-$ [N/mm²]	$E_{my,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
Brick (B)	MB	3.5	1.5	3.5	0.6
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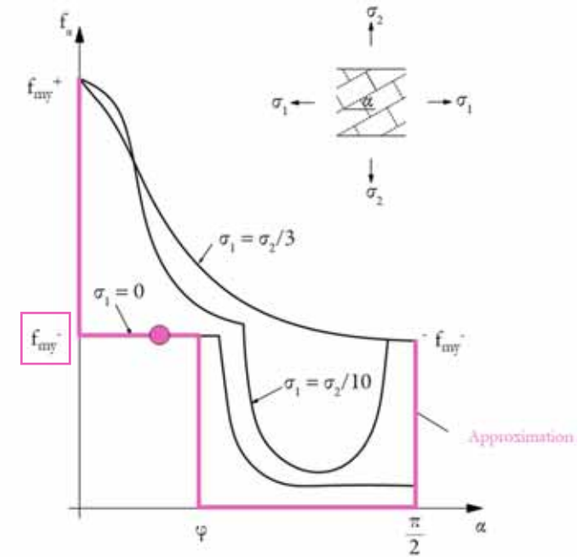

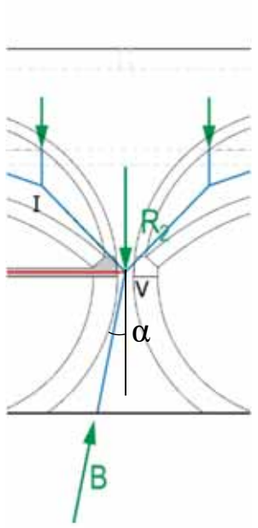

$0 < \alpha < \varphi$

Bricks
$f_{my} = 1.5\ N/mm^2$

Masonry	Standard Masonry Type	$f_{ma,d}^-$ [N/mm²]	$f_{my,d}^-$ [N/mm²]	$E_{my,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
Brick (B)	MB	3.5	1.5	3.5	0.6
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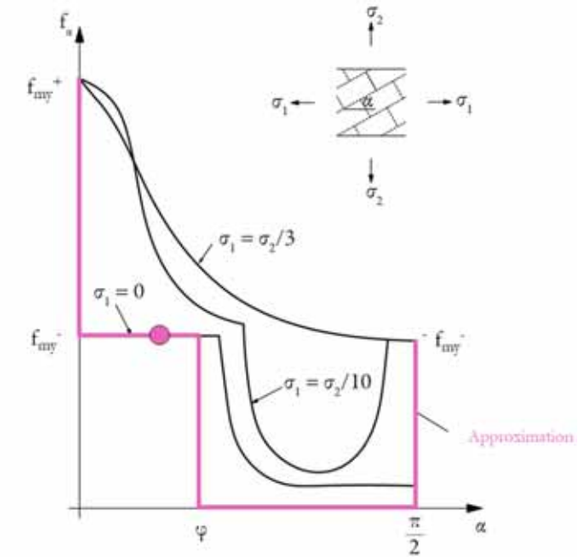

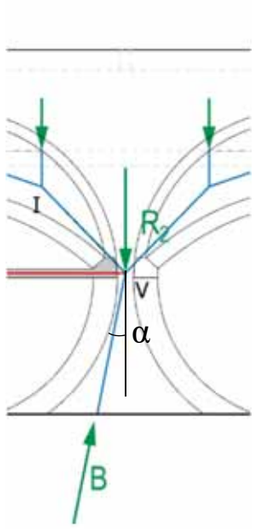

$0 < \alpha < \varphi$

Bricks
$f_{my} = 1.5\ N/mm^2$

$f_{my,d} = 1.5\ N/mm^2 \cdot 0.85 \cdot 1.5 =$
$= 1.9\ N/mm^2$

Masonry	Standard Masonry Type	$f_{ma,d}$ [N/mm²]	$f_{my,d}$ [N/mm²]	$E_{my,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
Brick (B)	MB	3.5	1.5	3.5	0.6
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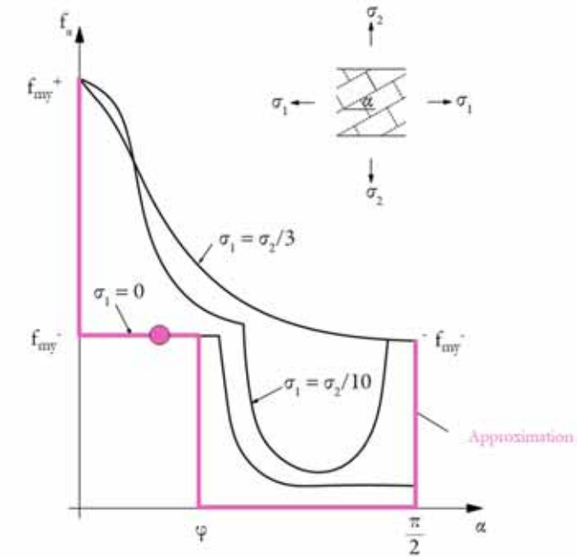

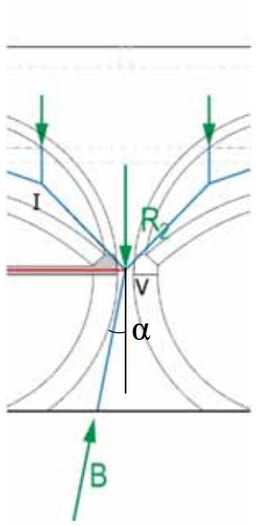

$0 < \alpha < \varphi$

Bricks
$f_{my} = 1.5\ N/mm^2$

$f_{my,d} = 1.5\ N/mm^2 \cdot 0.85 \cdot 1.5 =$
$= 1.9\ N/mm^2$

B = 1600 kN
Wall thickness t = 1.0 m
Wall width w = ?

Masonry	Standard Masonry Type	$f_{ma,d}$ [N/mm²]	$f_{my,d}$ [N/mm²]	$E_{my,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
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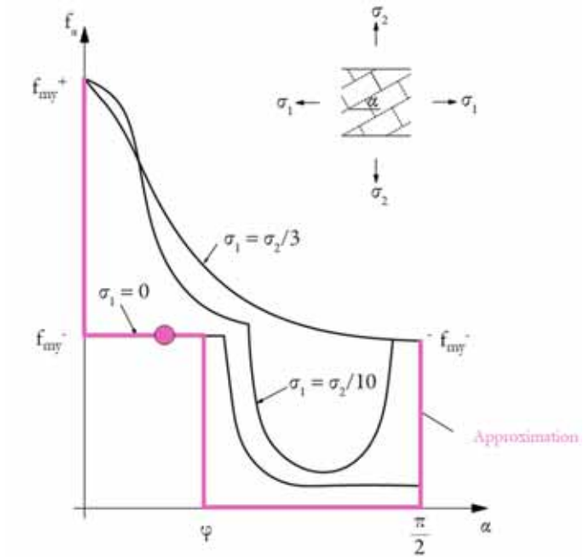

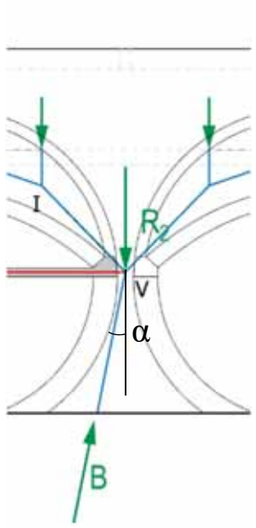

$0 < \alpha < \varphi$

Bricks
$f_{my} = 1.5$ N/mm²

$f_{my,d} = 1.5$ N/mm² · 0.85 · 1.5 =
$= 1.9$ N/mm²

B = 1600 kN
Wall thickness t = 1.0 m
Wall width w = ?

B / Area ≤ f_{yd}

Masonry	Standard Masonry Type	$f_{ma,d}$ [N/mm²]	$f_{my,d}$ [N/mm²]	$E_{my,d}$ [kN/mm²]	$(\tan\varphi)_d$ [-]
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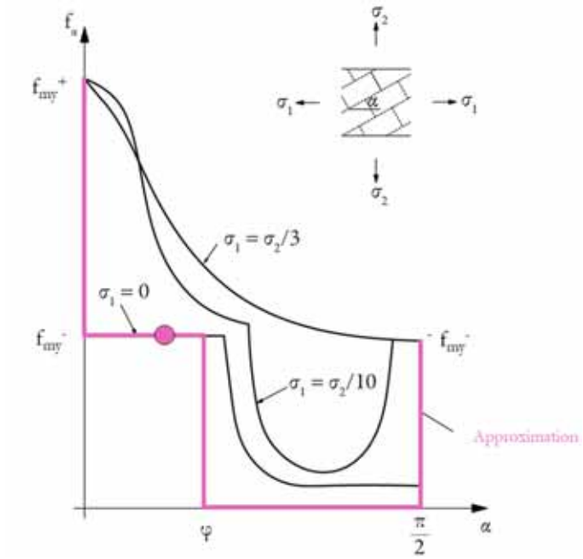

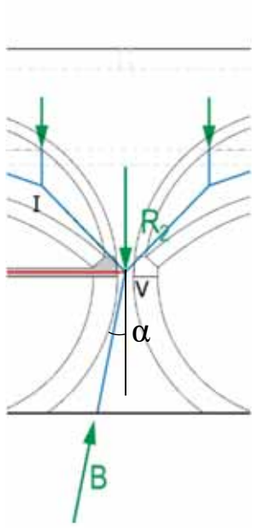

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$0 < \alpha < \varphi$

Bricks
$f_{my} = 1.5$ N/mm²

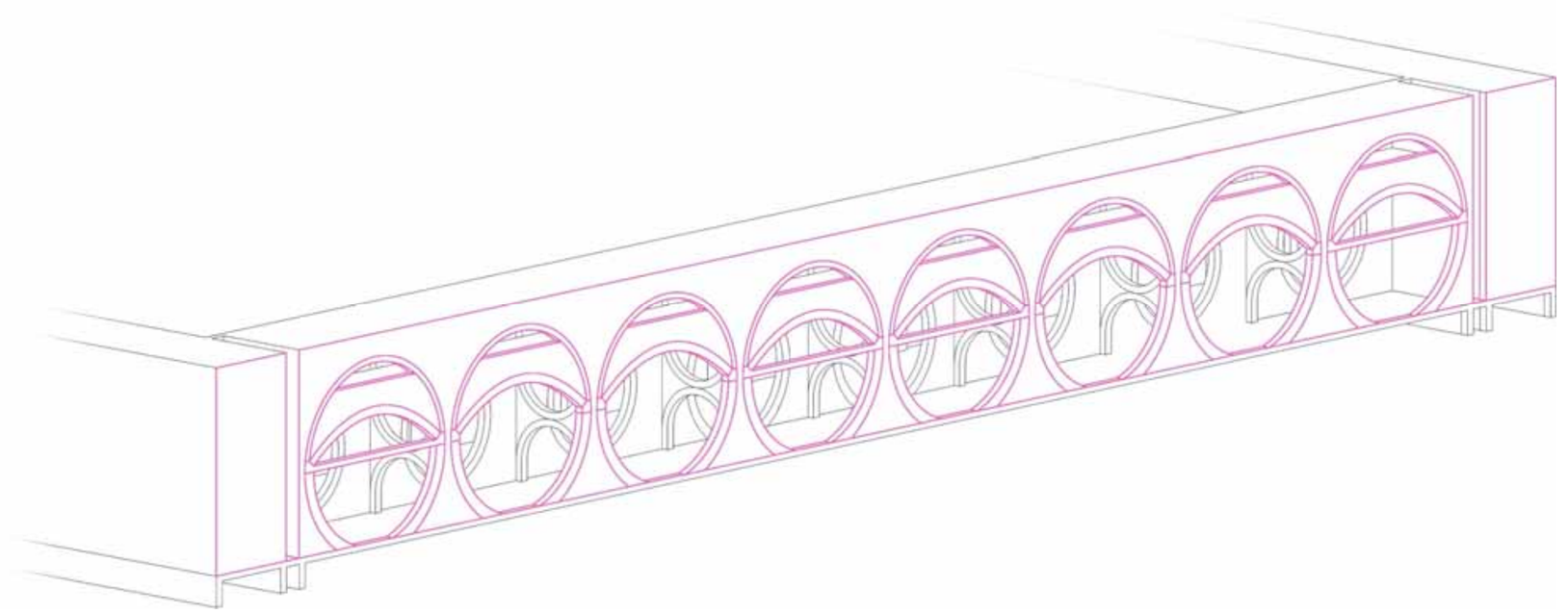
$f_{my,d} = 1.5$ N/mm² · 0.85 · 1.5 =
$= 1.9$ N/mm²

B = 1600 kN
Wall thickness t = 1.0 m
Wall width w = ?

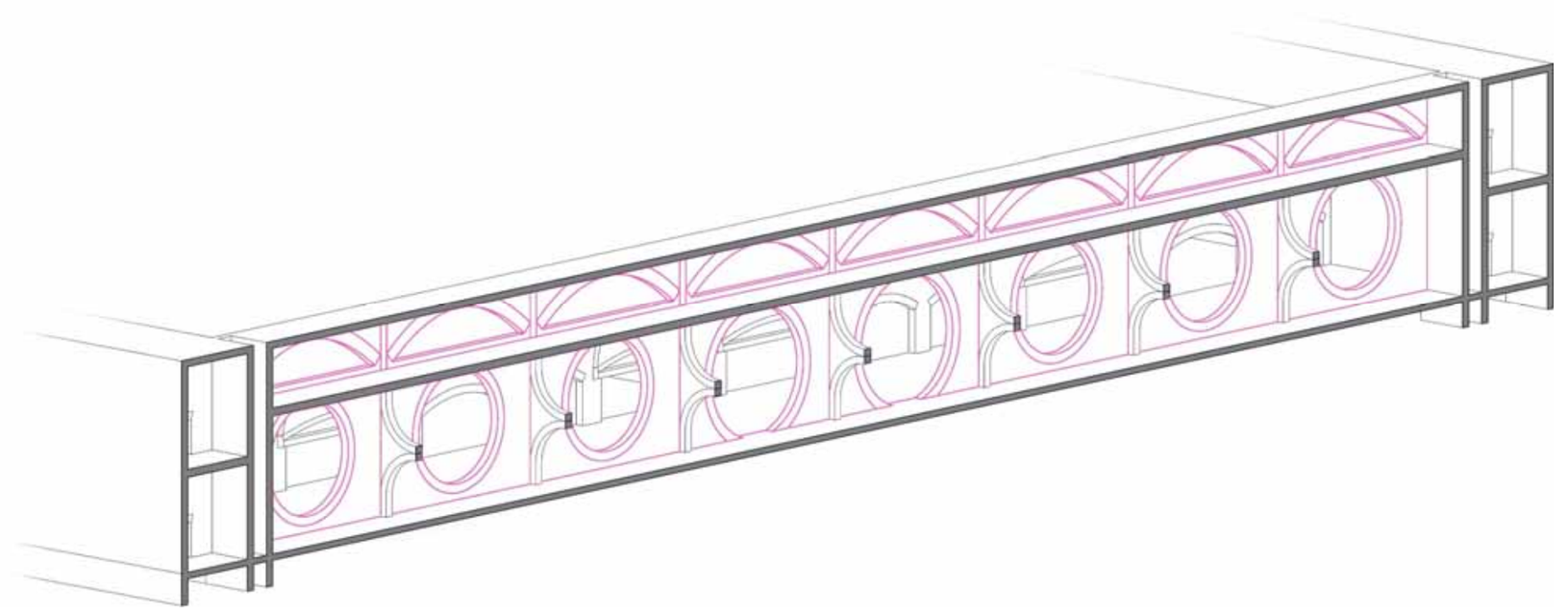
B / Area ≤ f_{yd}

Area ≥ B / f_{yd} = 1600 kN / 1.9 N/mm² =
= 0.84 m²

Area = t · w
w ≥ A / t = 0.84 m² / 1.0 m = 0.84 m

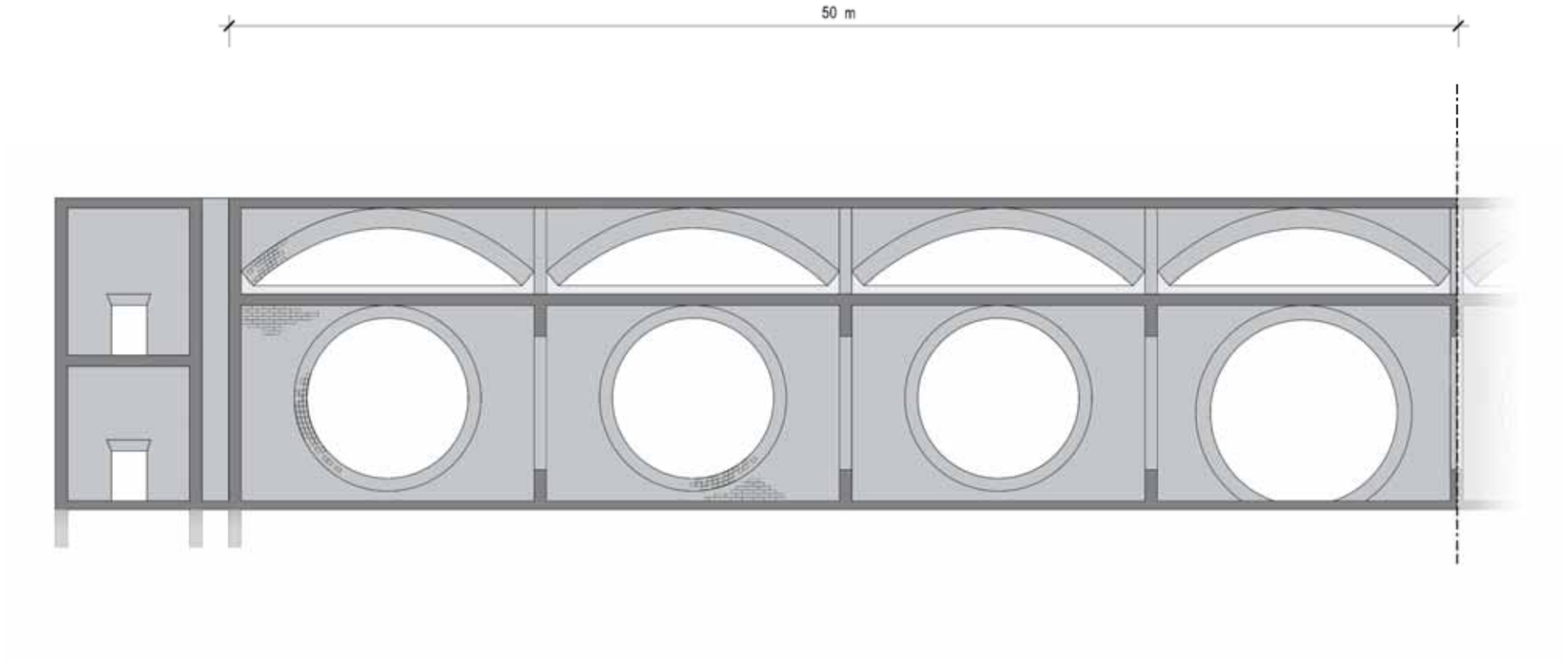


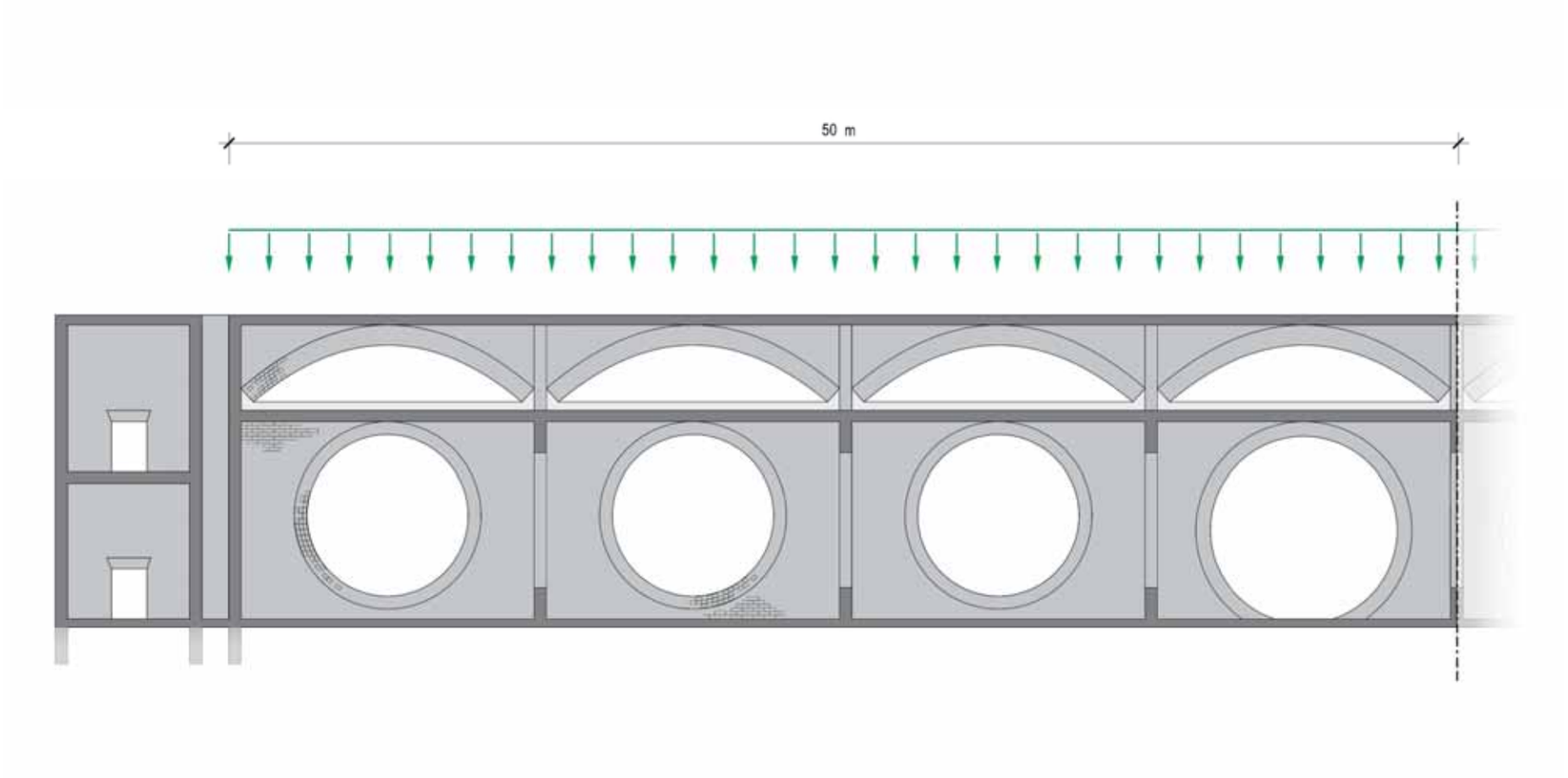
West-Fassade
West façade

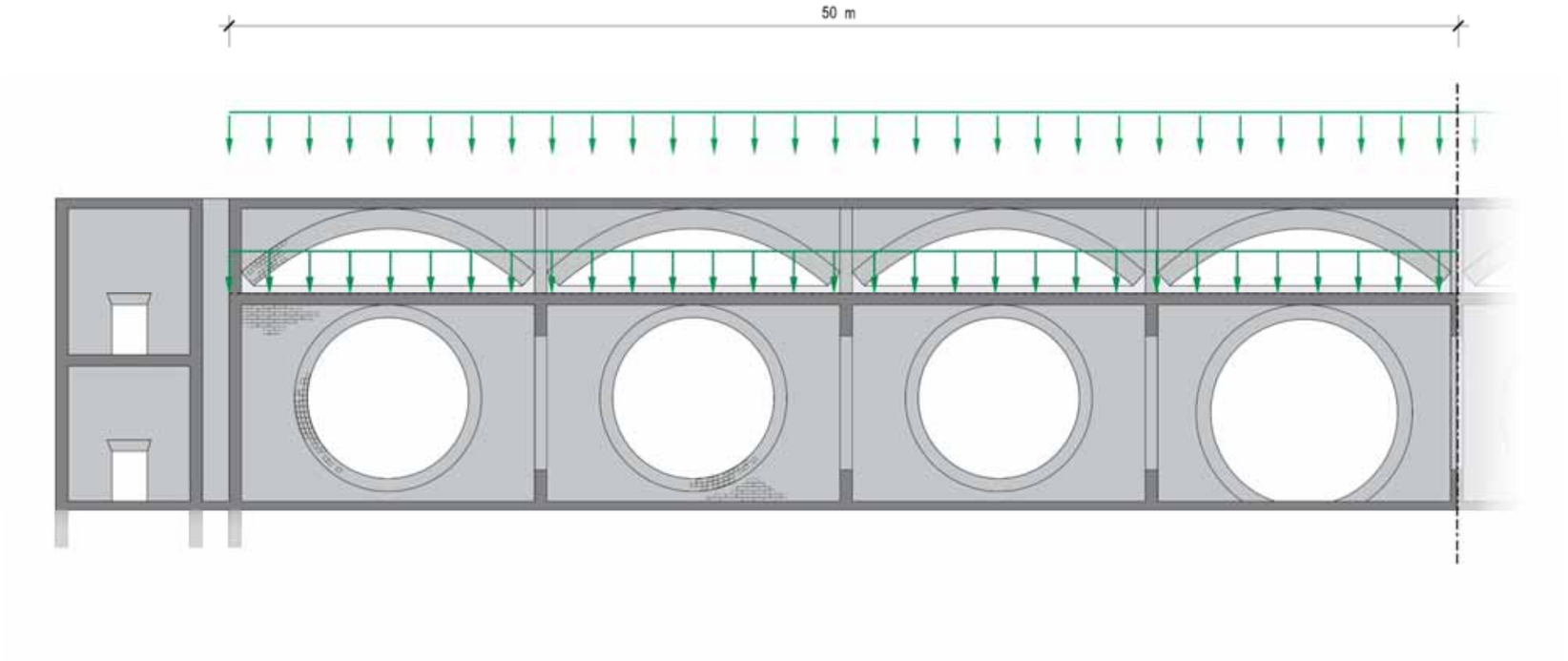


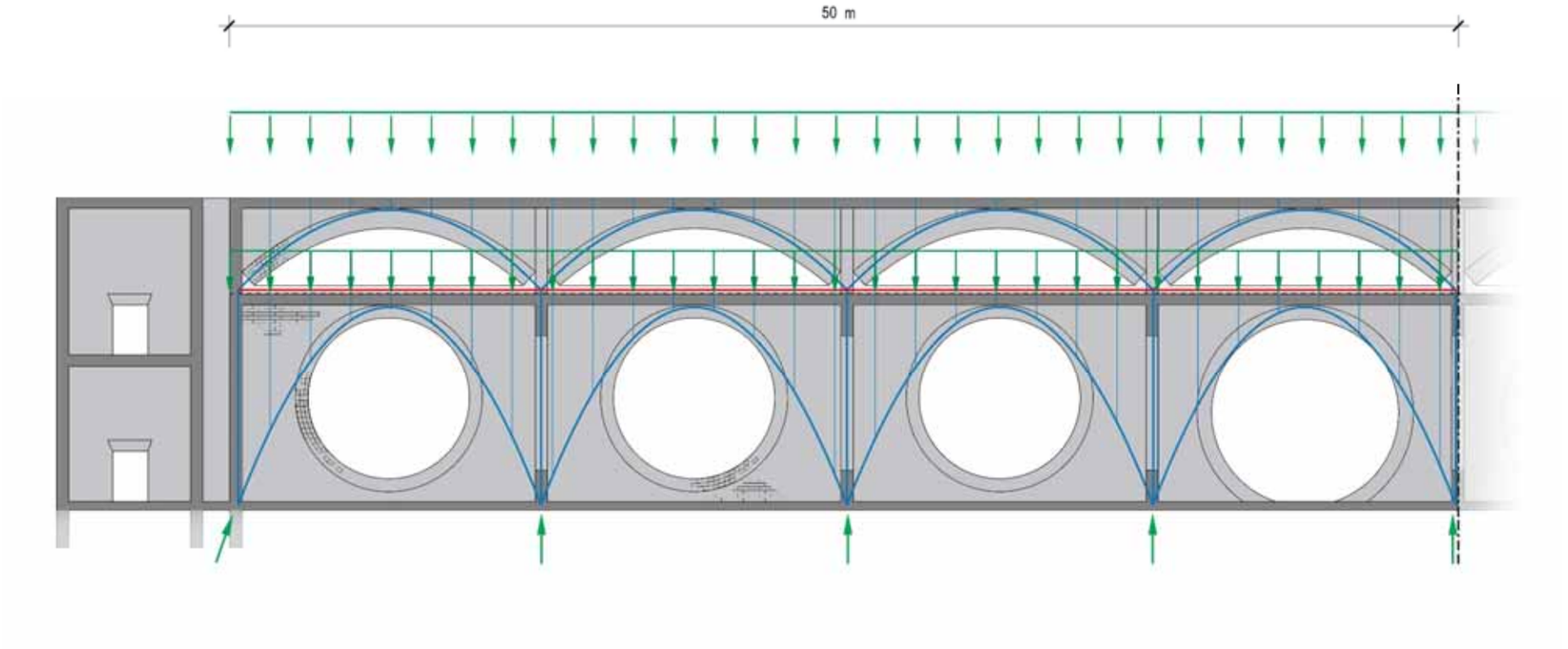
Wand A
Wall A

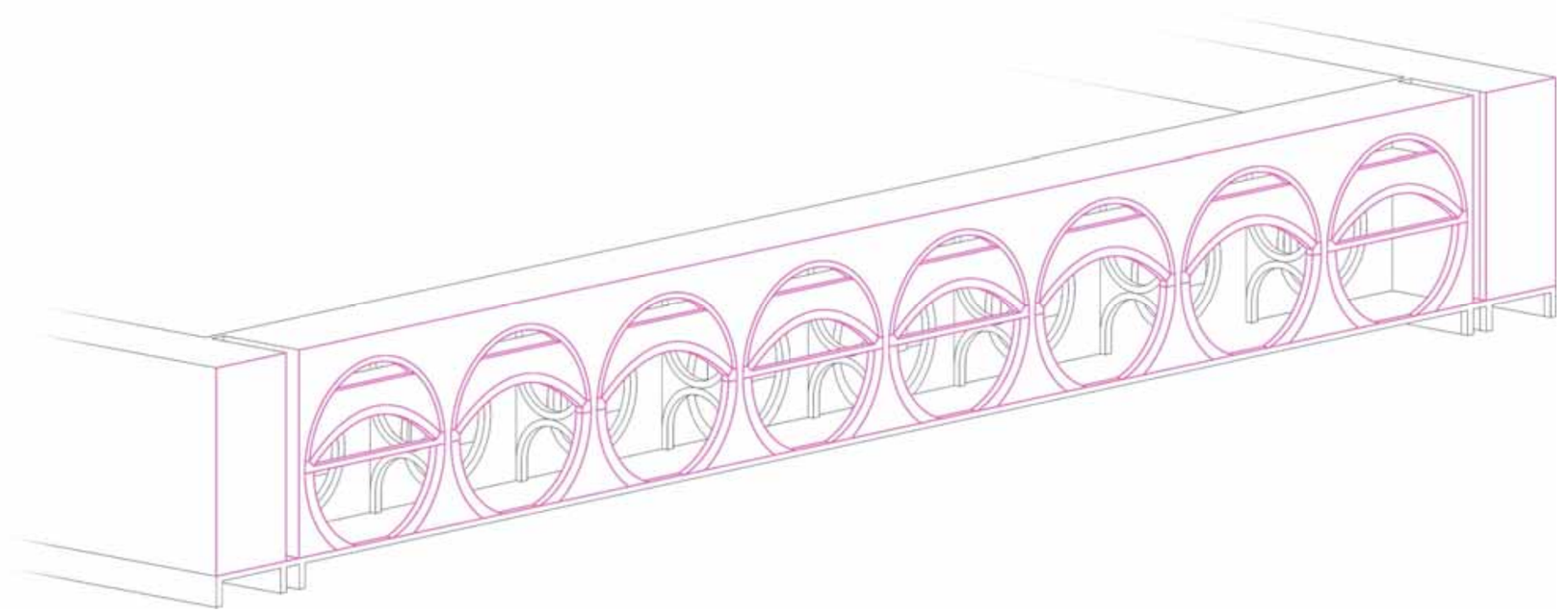

© Larry Speck


50 m

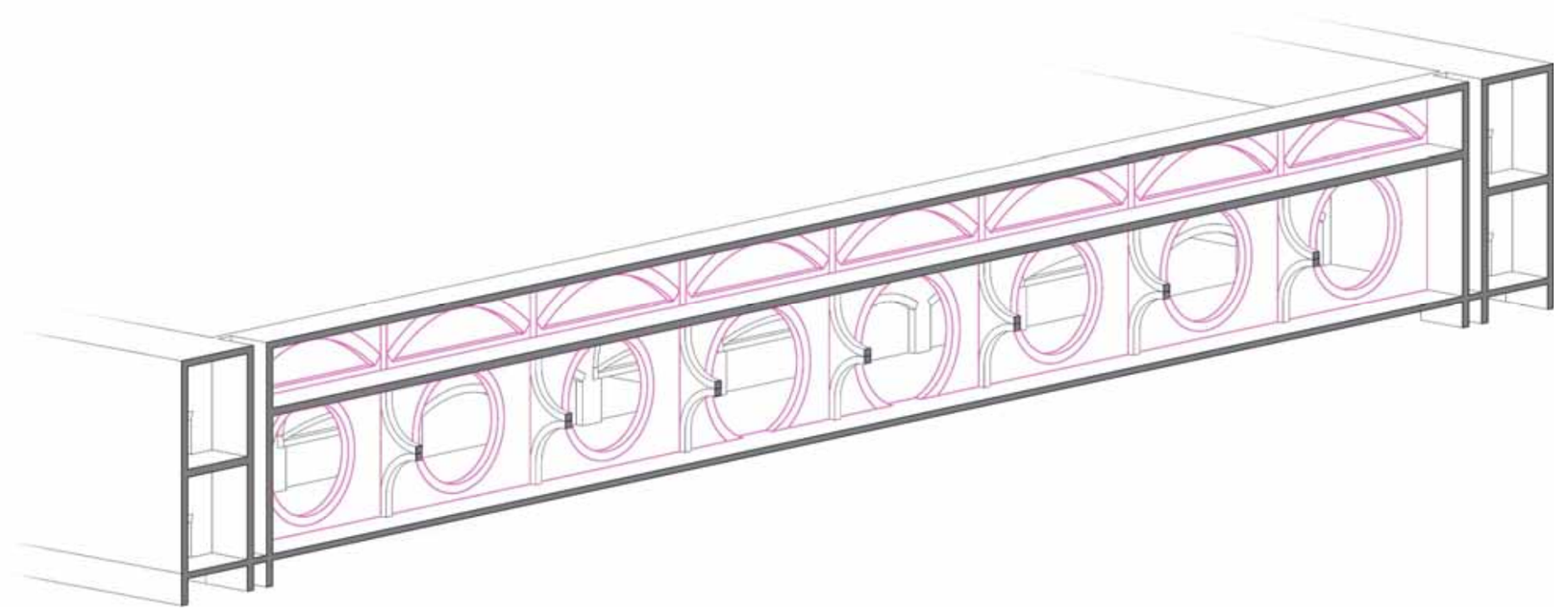

50 m


50 m

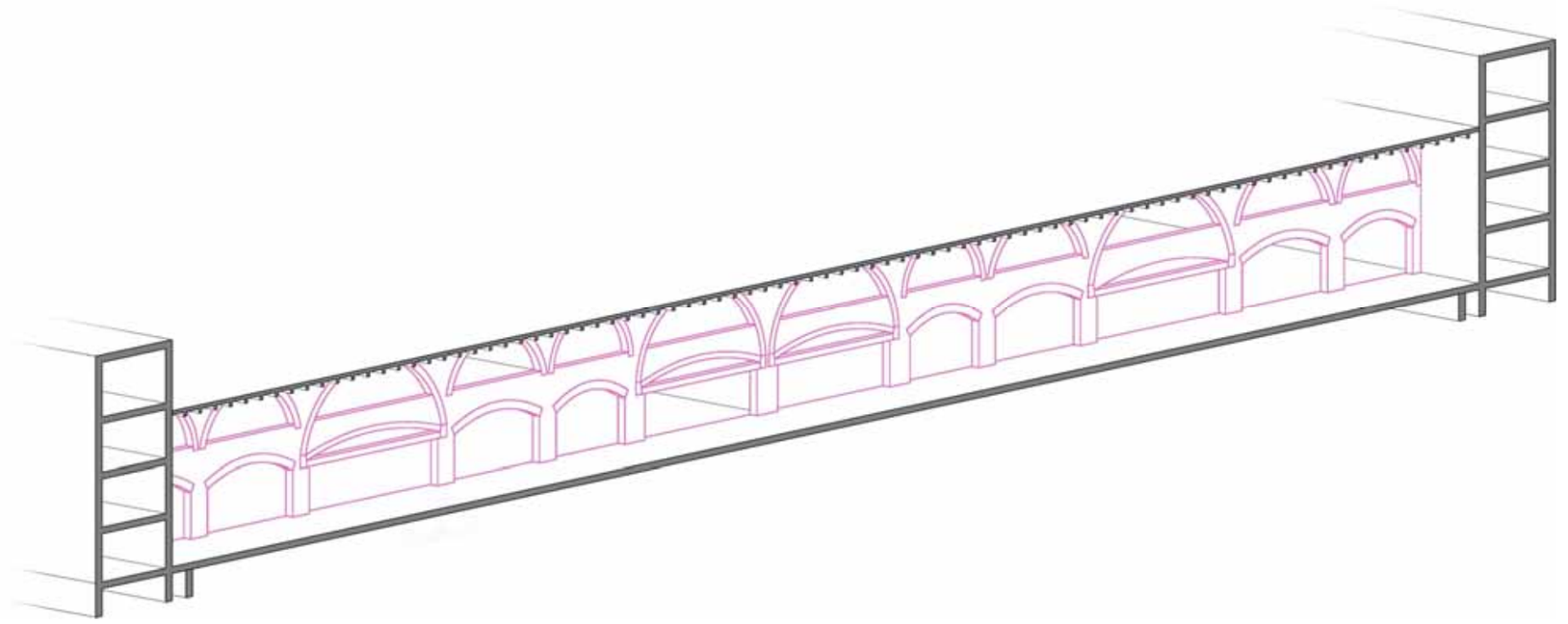

50 m



West-Fassade
West façade

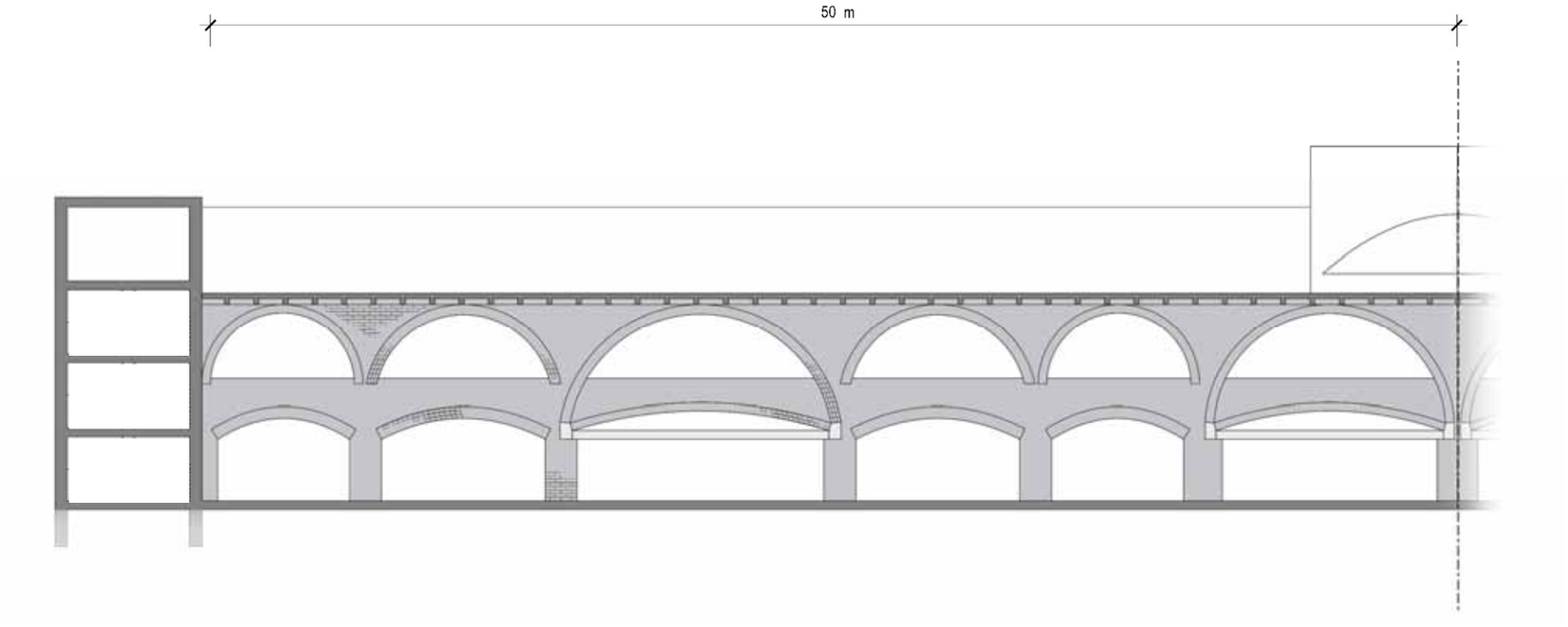


Wand A
Wall A

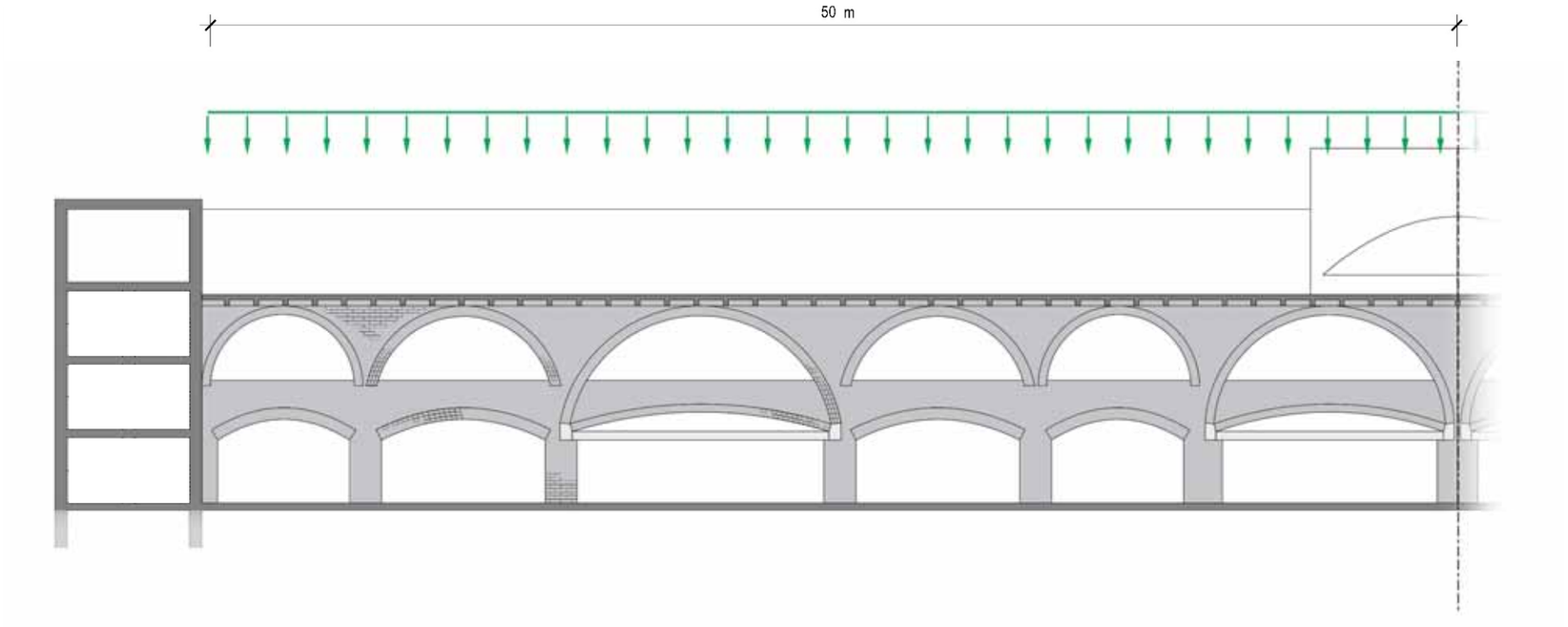


Wand B
Wall B


© Panoramio: A.D.A



Wand B
Wall B



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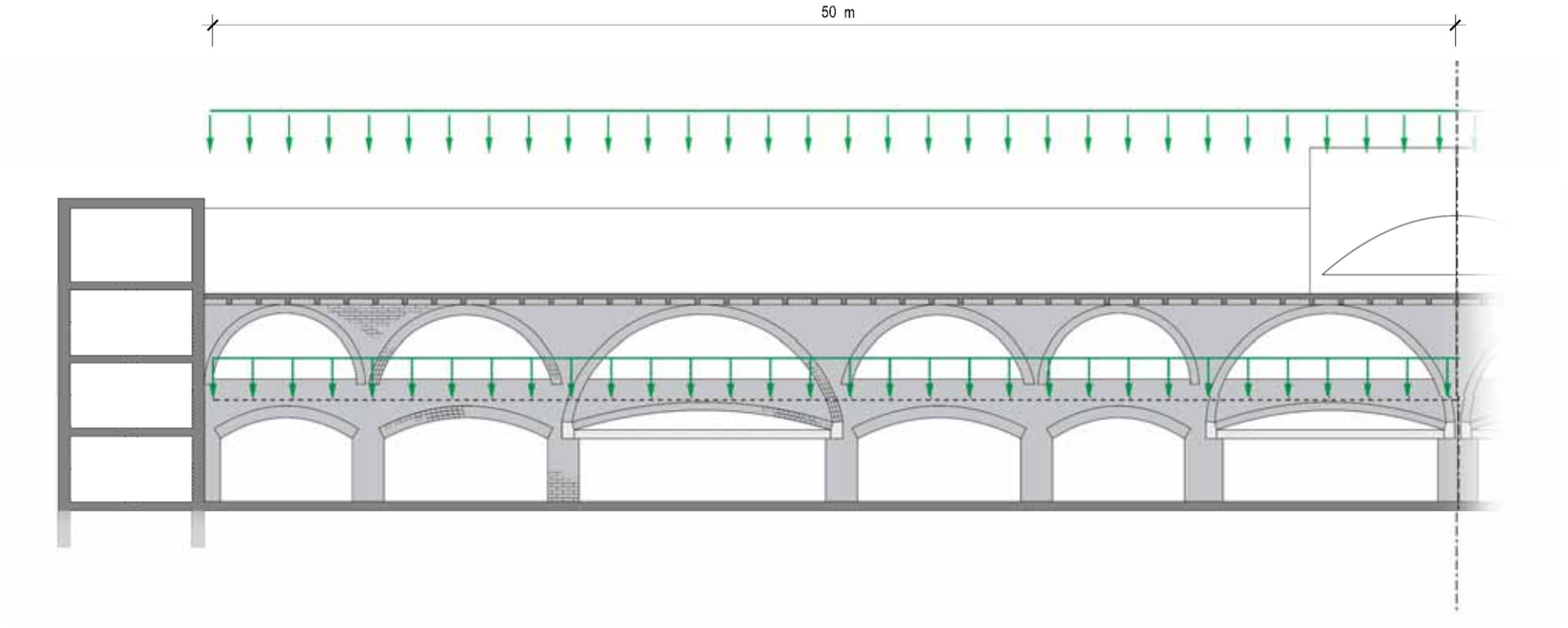
Wall B



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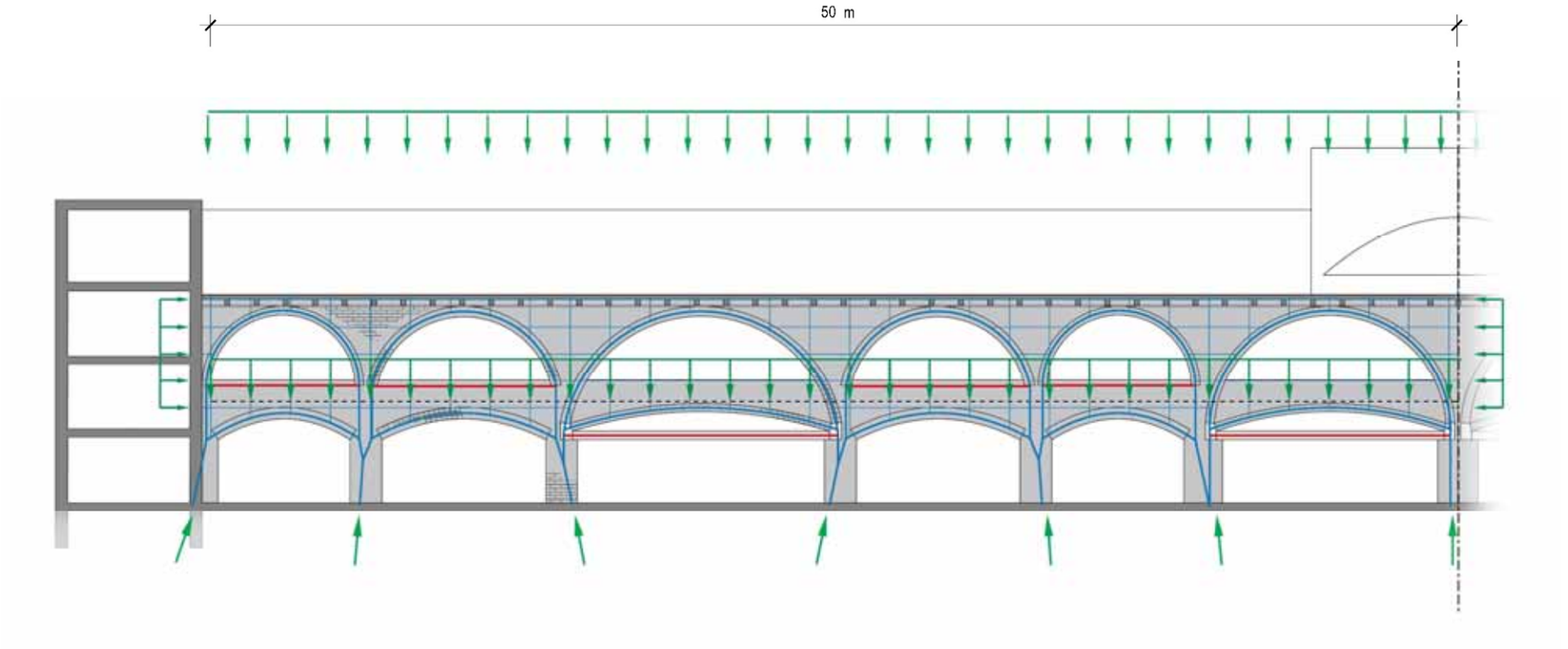
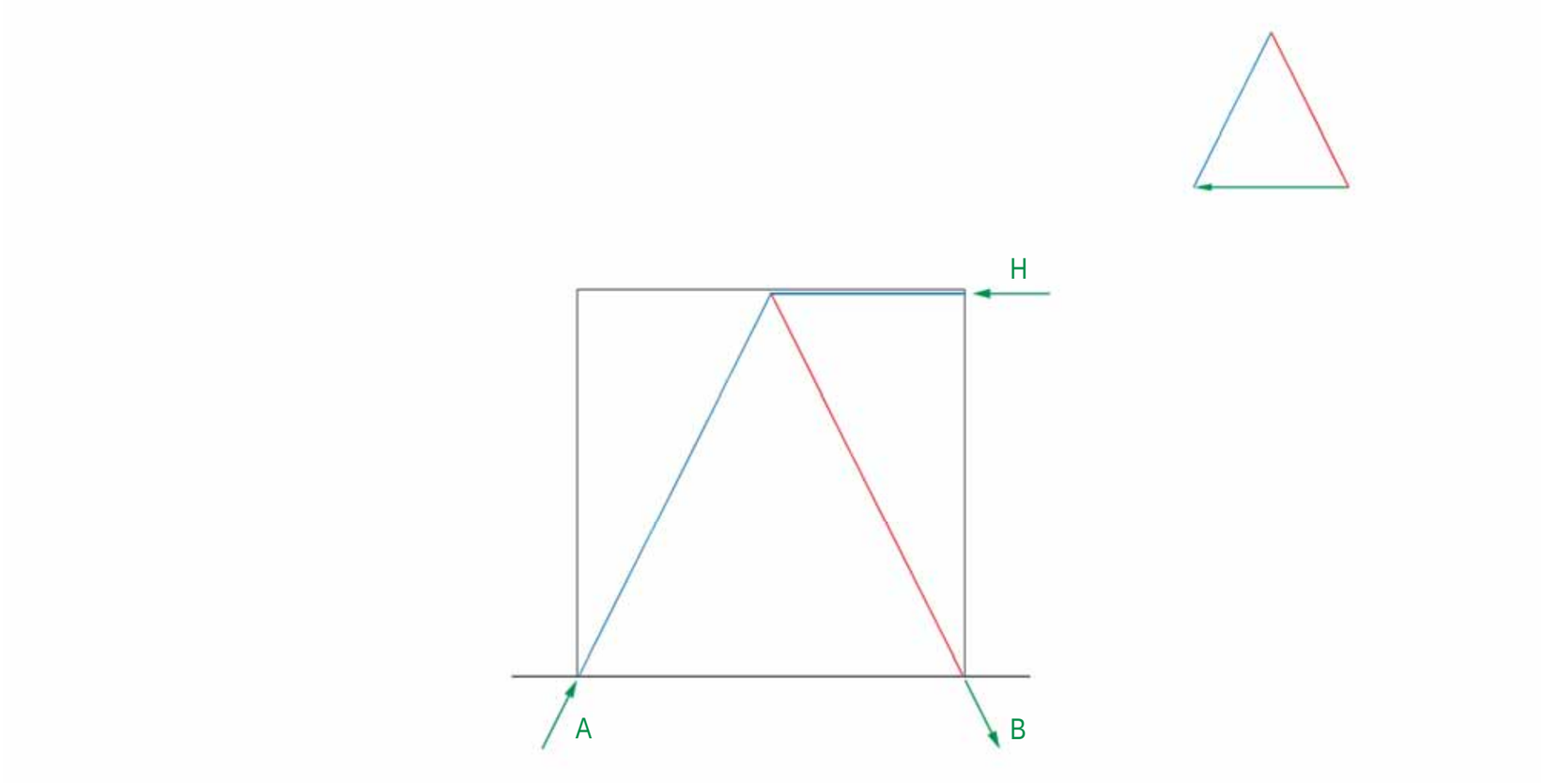
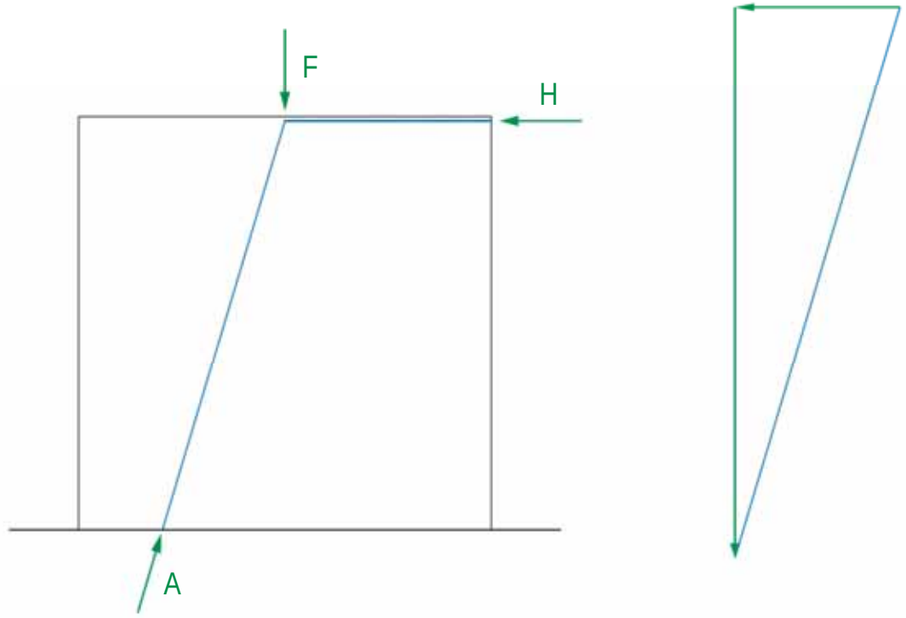


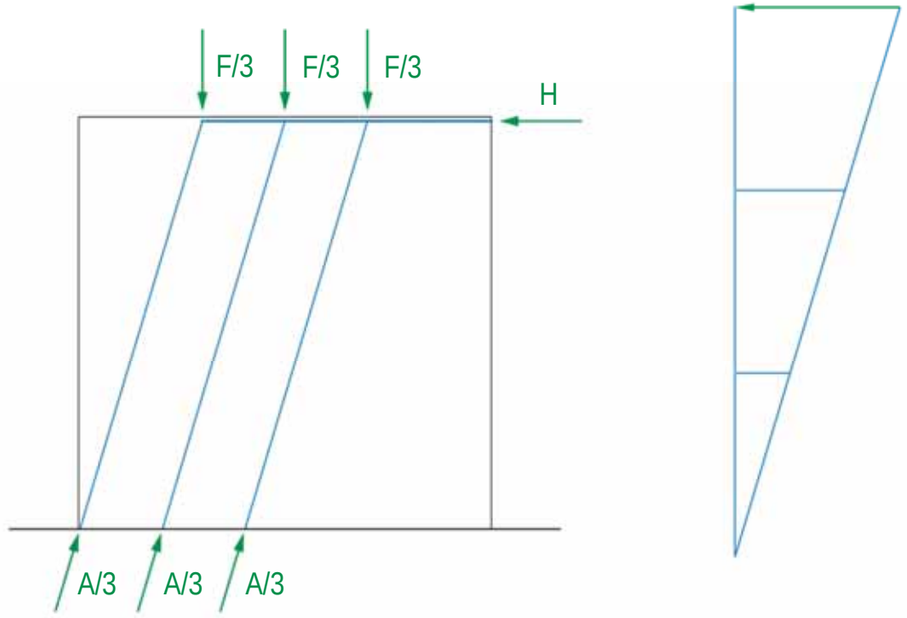
Wand B
Wall B



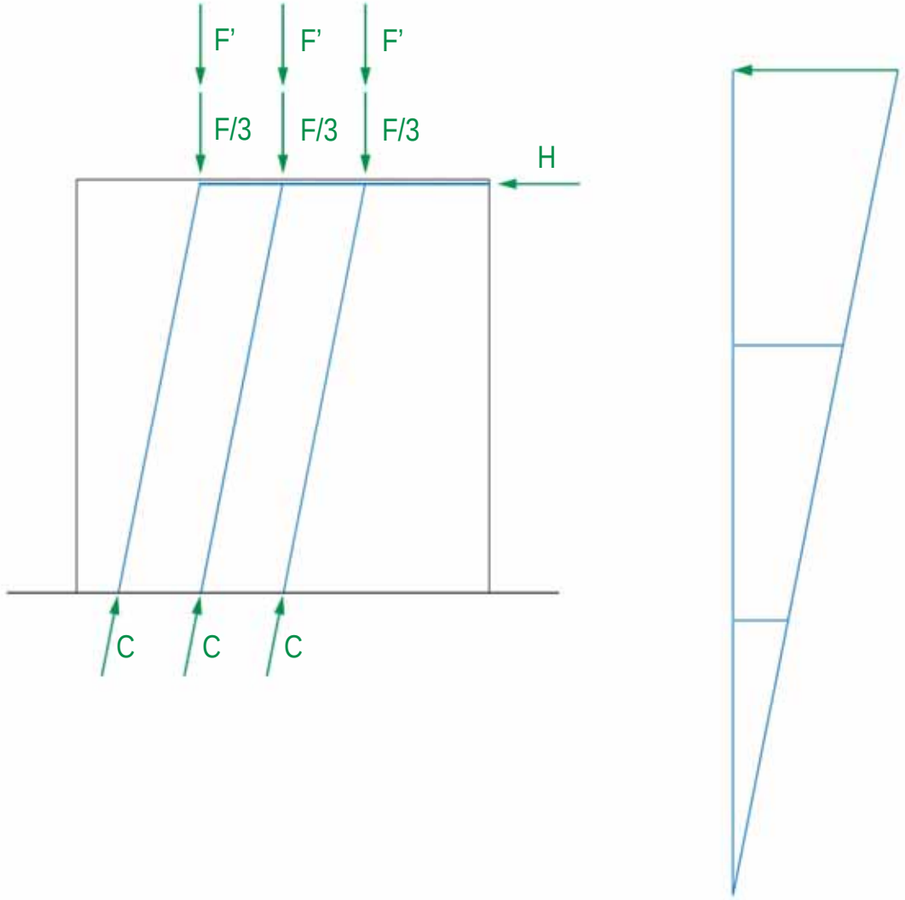
Stabilisierende Wirkung von vertikalen Lasten
Stabilizing effect of vertical loads



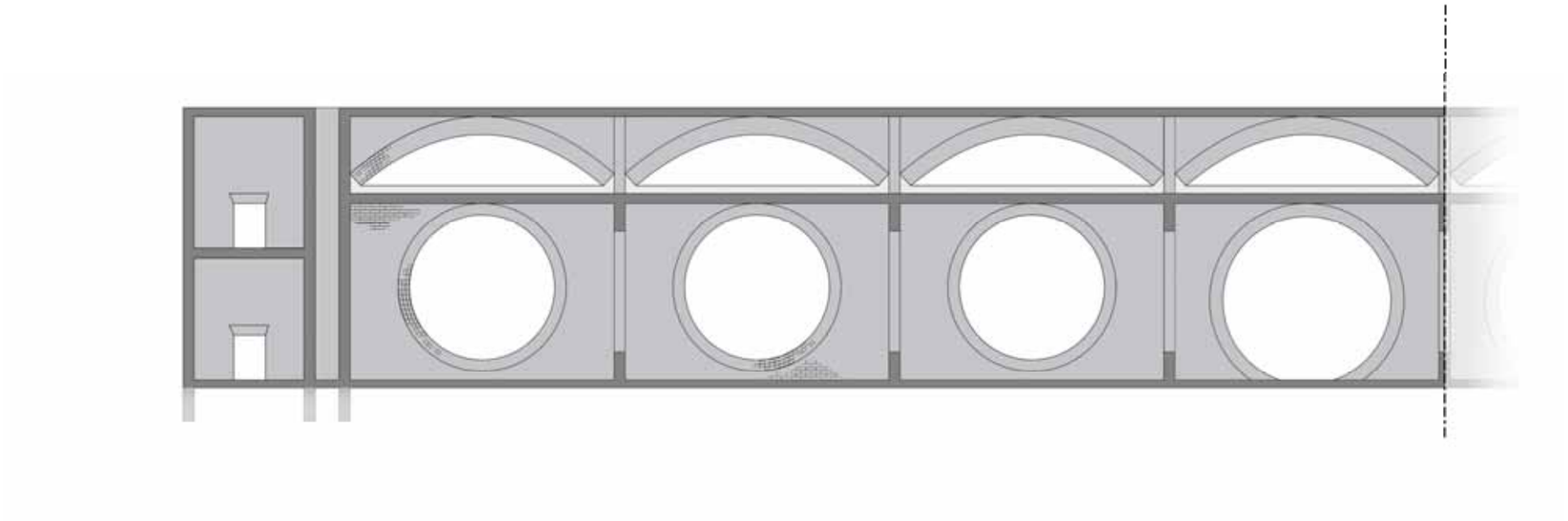
Stabilisierende Wirkung von vertikalen Lasten
Stabilizing effect of vertical loads



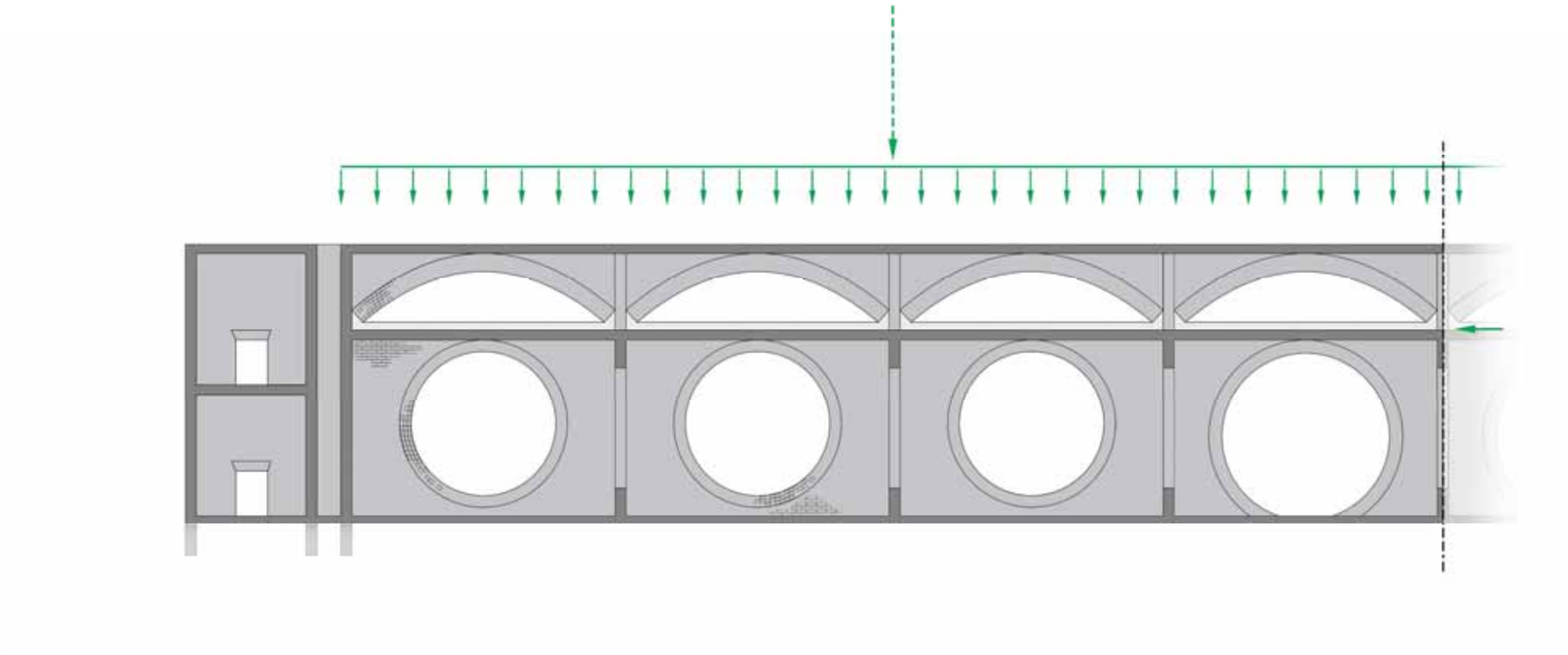
Stabilisierende Wirkung von vertikalen Lasten
Stabilizing effect of vertical loads



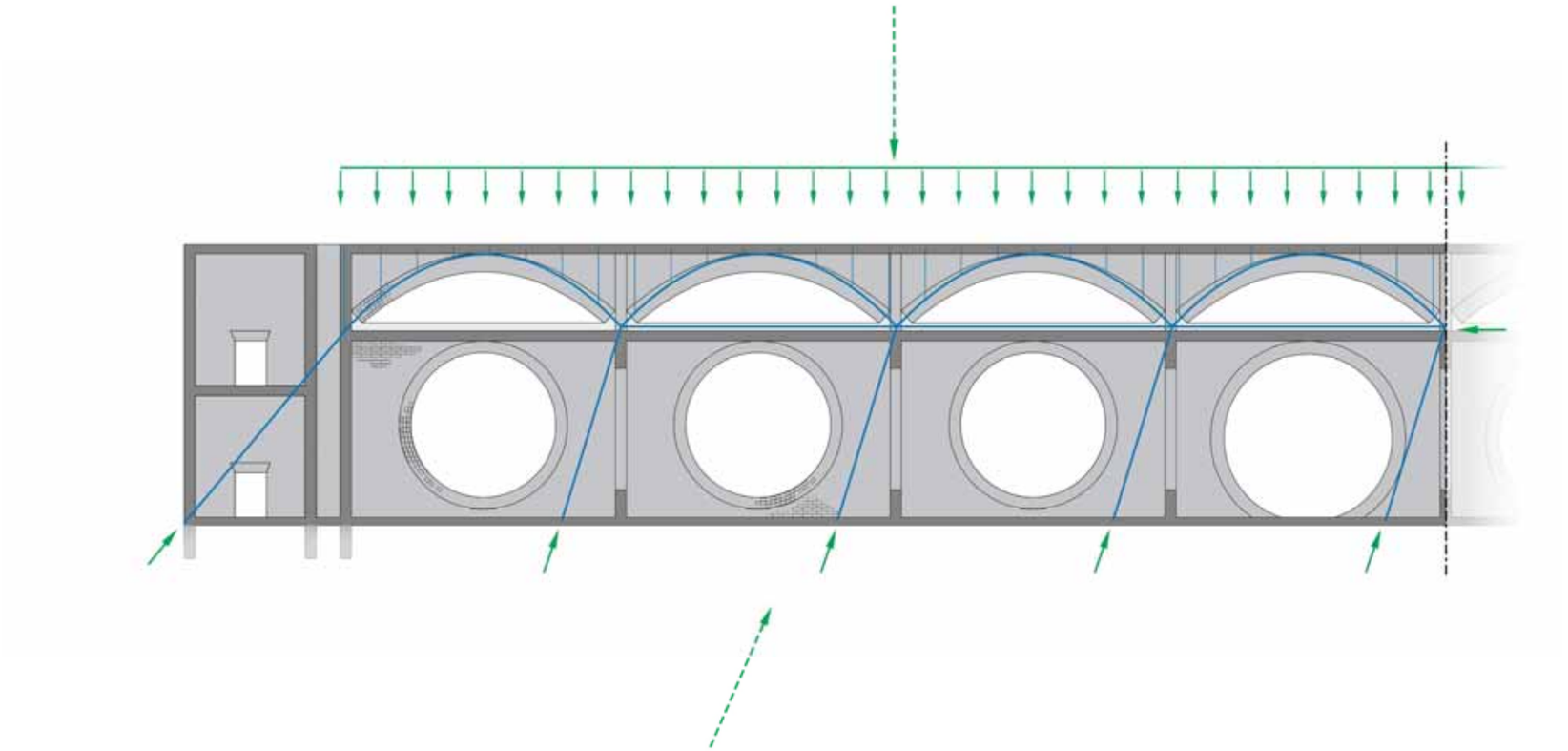
Stabilisierende Wirkung von vertikalen Lasten
Stabilizing effect of vertical loads



Wand A
Wall A



Wand A
Wall A



Wand A
Wall A

Mauerwerk
Masonry

2D ELEMENTS IN SPACE

Teletón Centre
Gabinete de Arquitectura

3D ELEMENTS IN SPACE

Stadttor Isny
Peter Zumthor

3D STRUCTURES

Armadillo Vault
Block Research Group

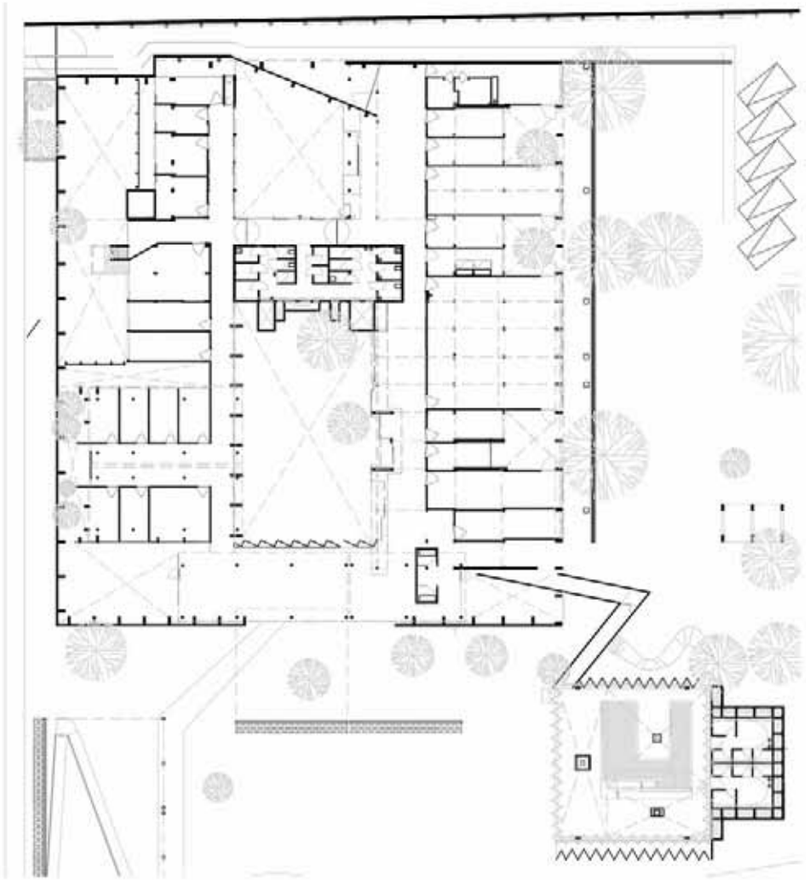
Teletón Children's Rehabilitation Center

Lambare (Paraguay), 2010

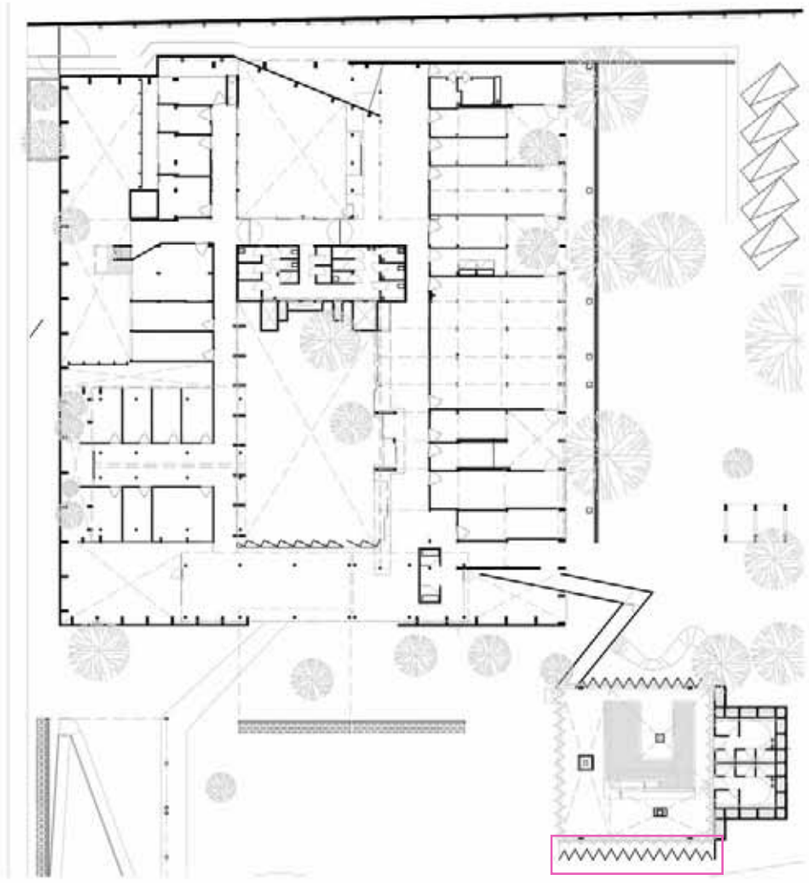
Architect: Gabinete de Arquitectura

Engineer: Enrique Granada, Carlos Escobar

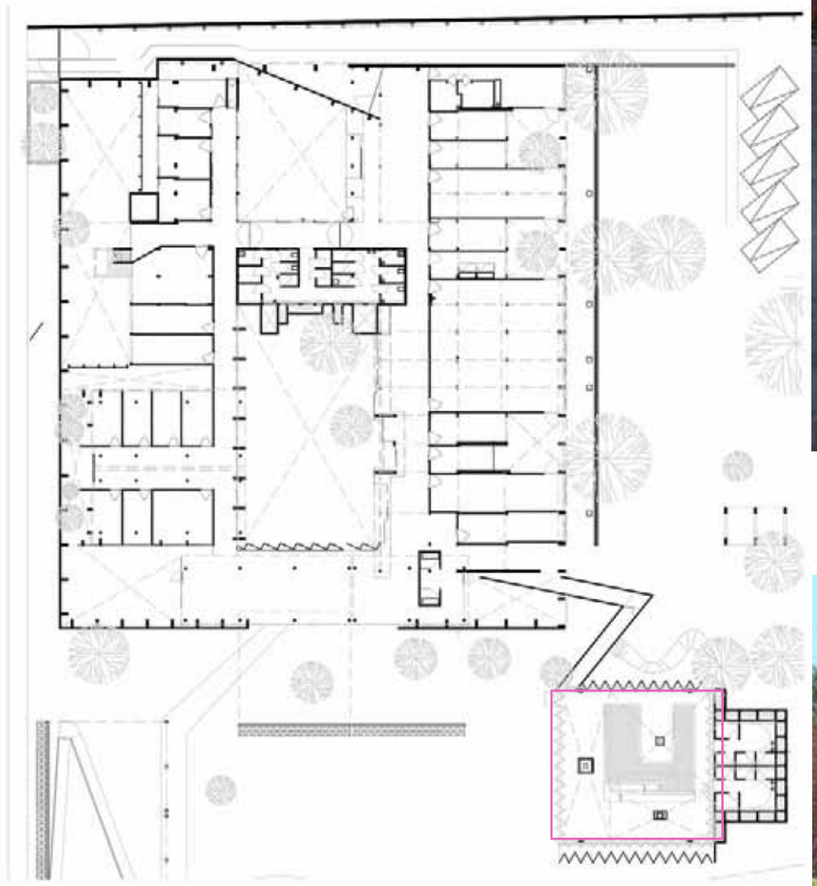

© Federico Cairoli



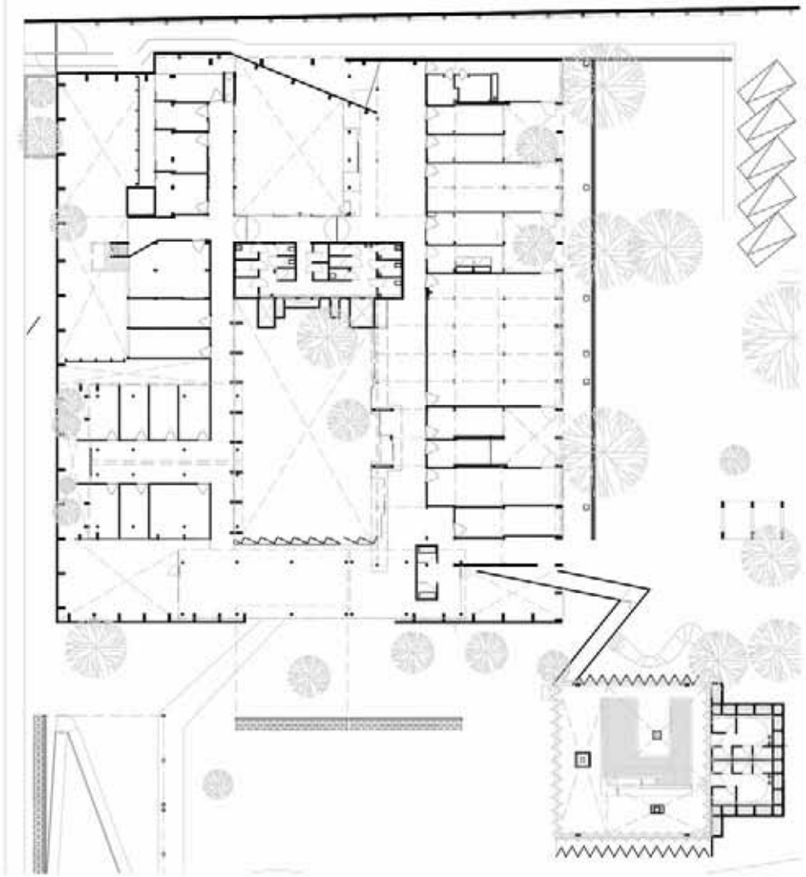
Grundriss
Plan view



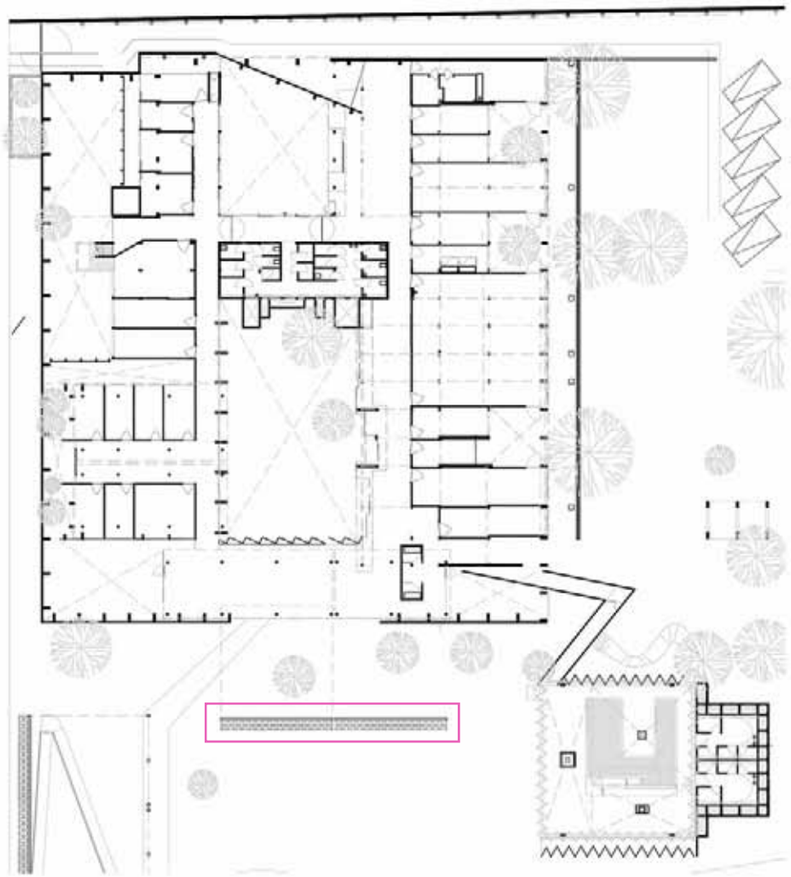
Grundriss
Plan view



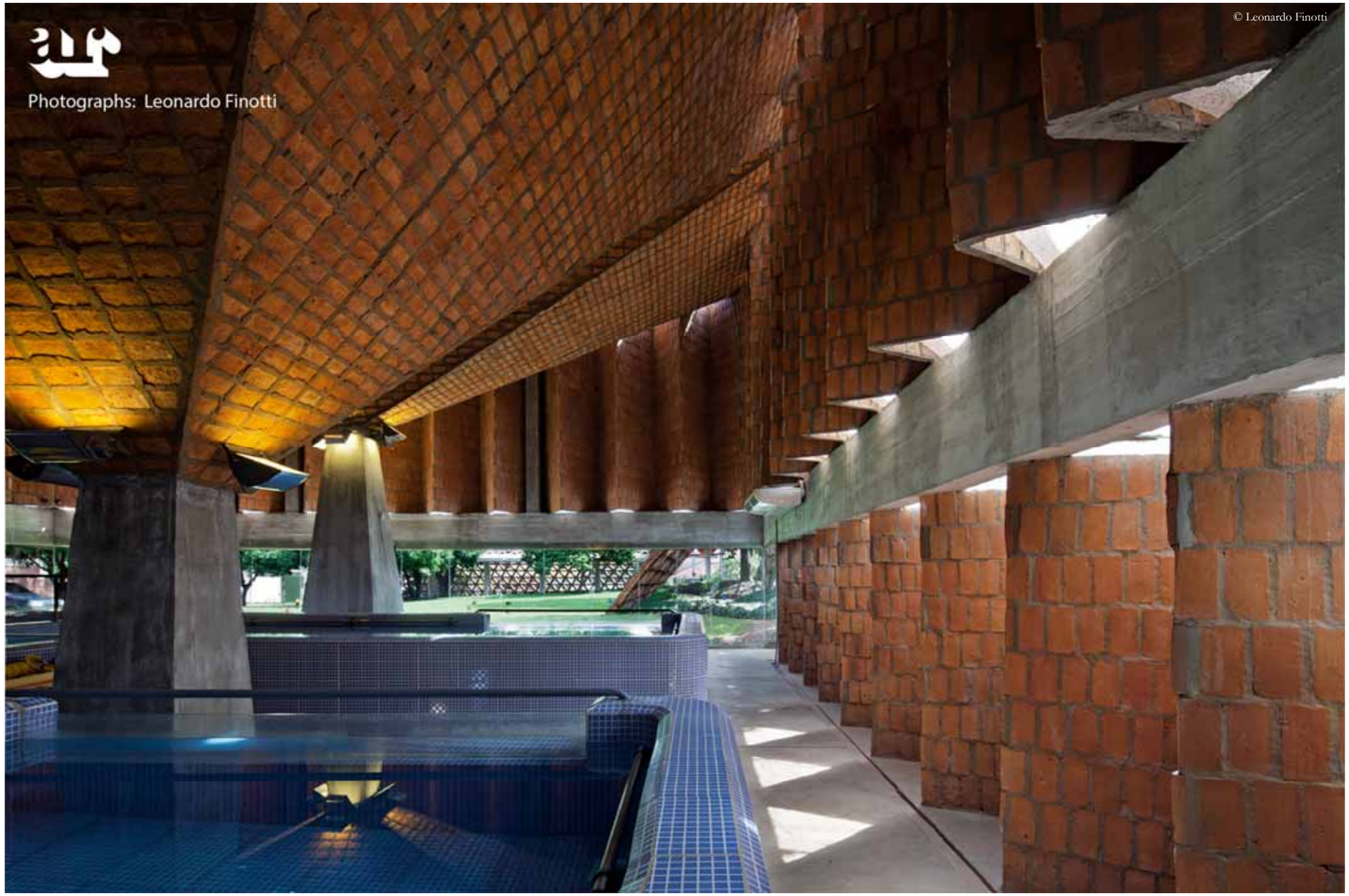
Grundriss
Plan view



Grundriss
Plan view

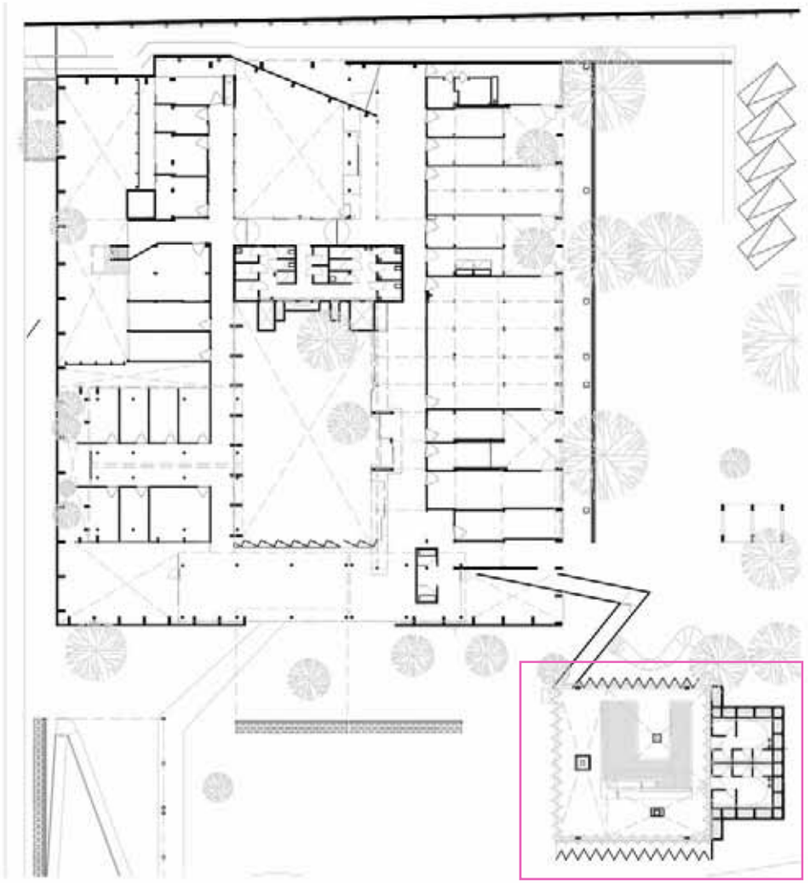


Grundriss
Plan view

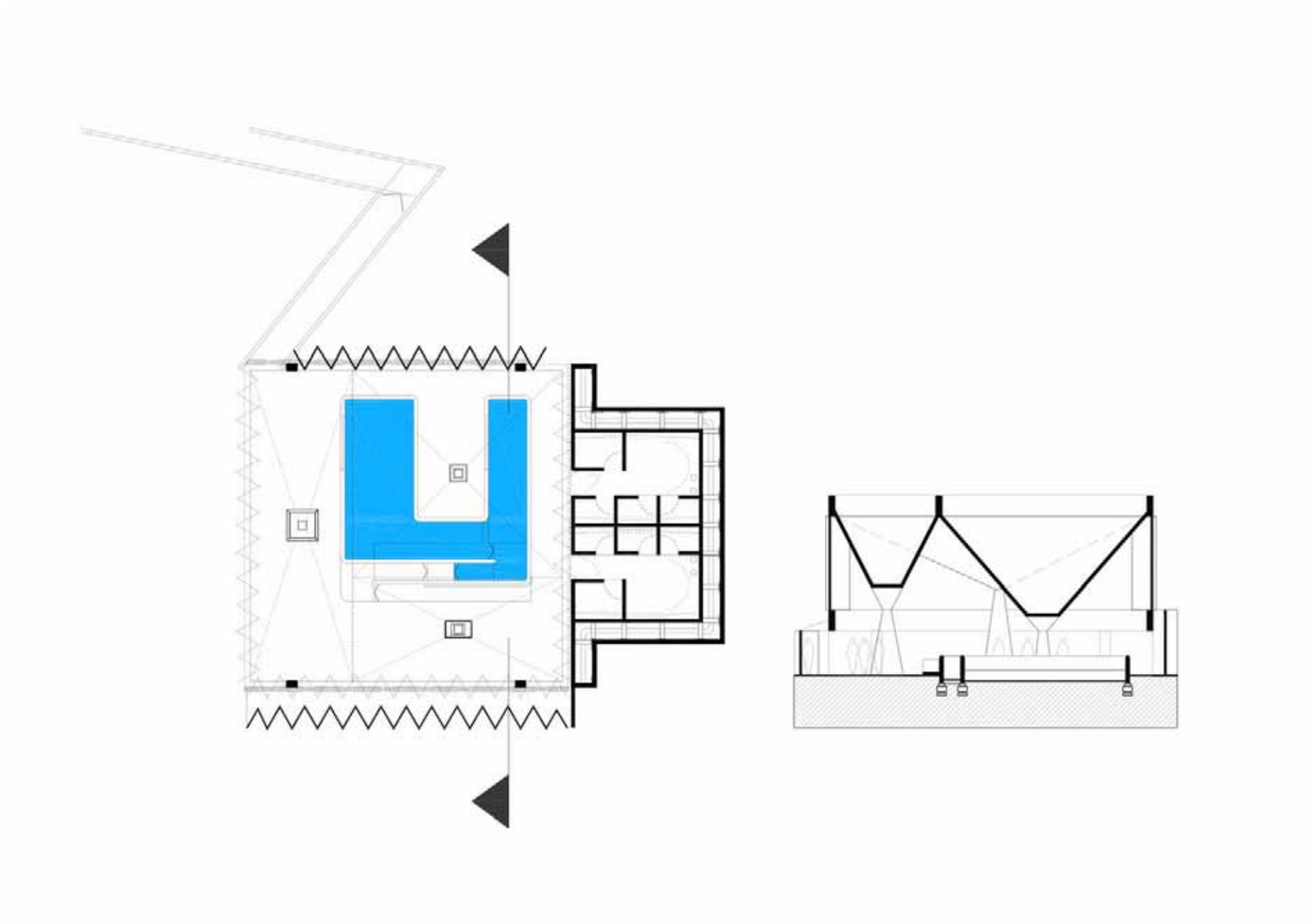

Photographs: Leonardo Finotti
© Leonardo Finotti

Gefaltete Fassade
Folded facade

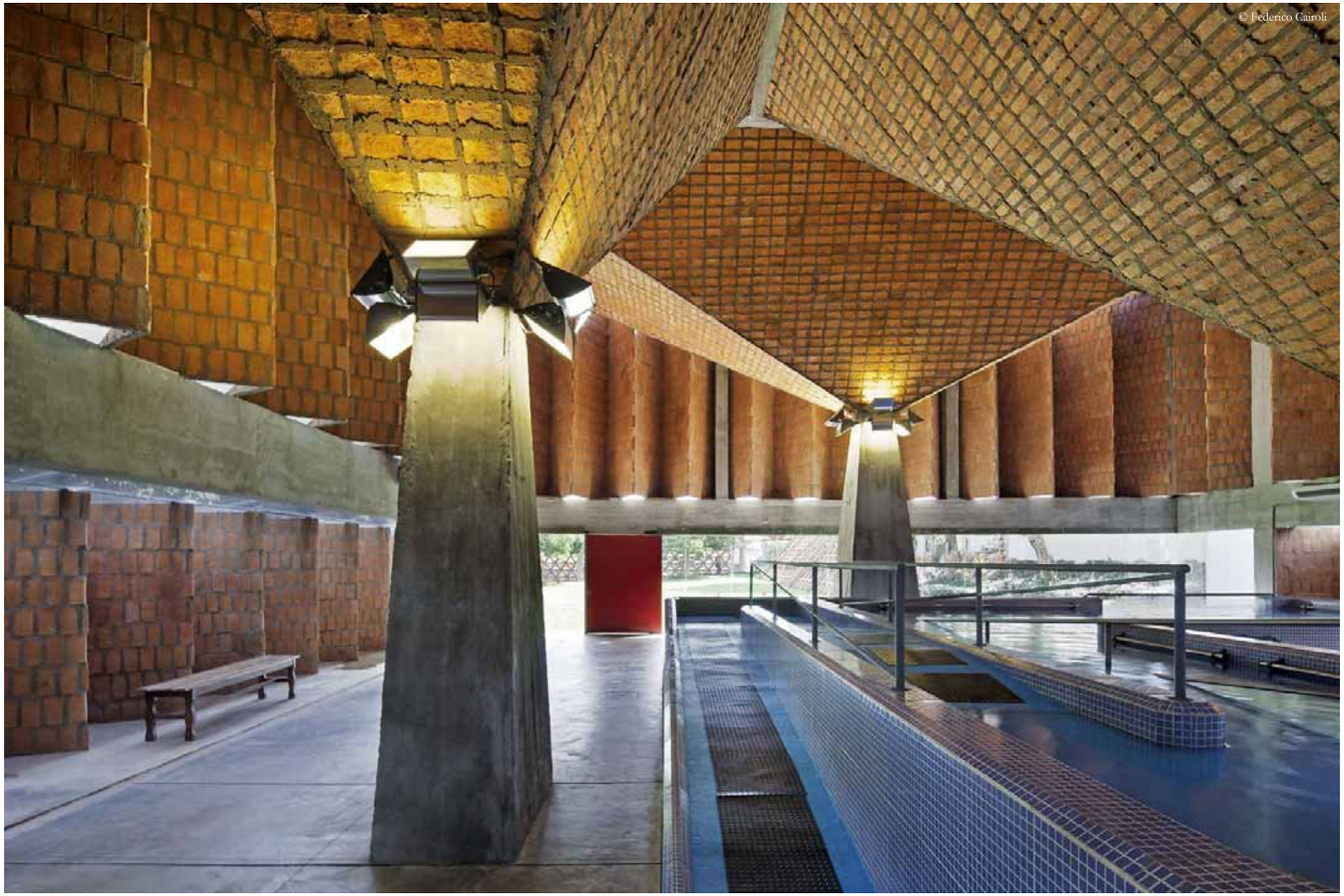
Gefaltete Fassade
Folded facade

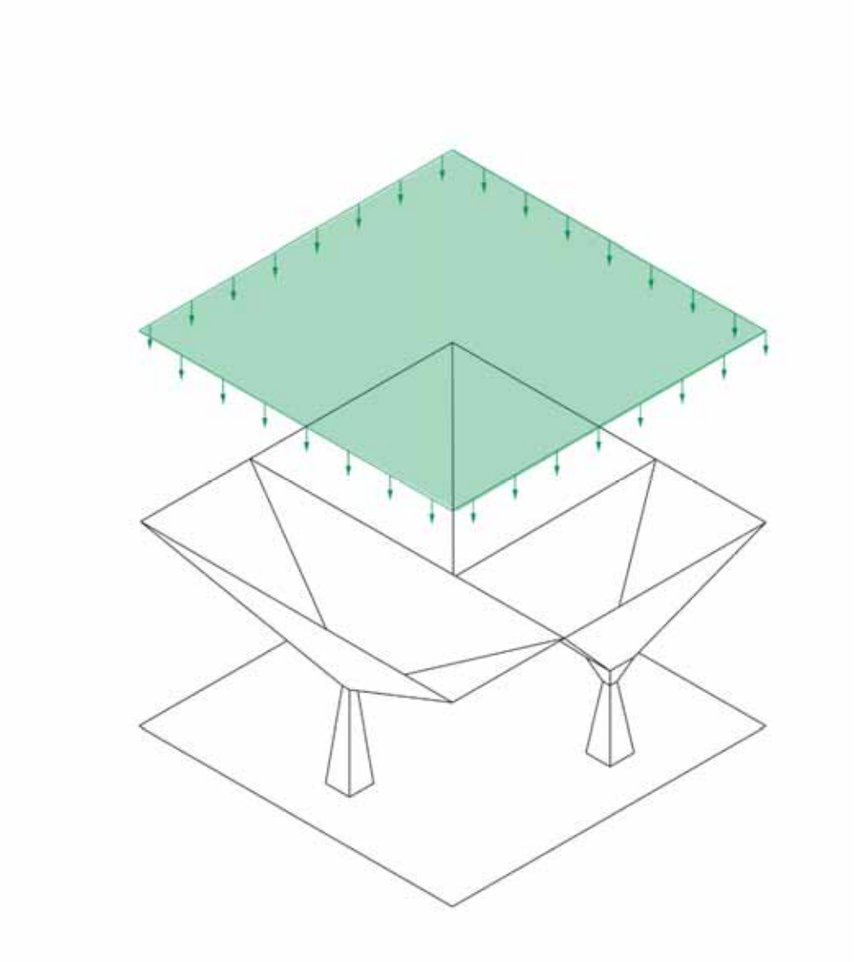


Grundriss
Plan view

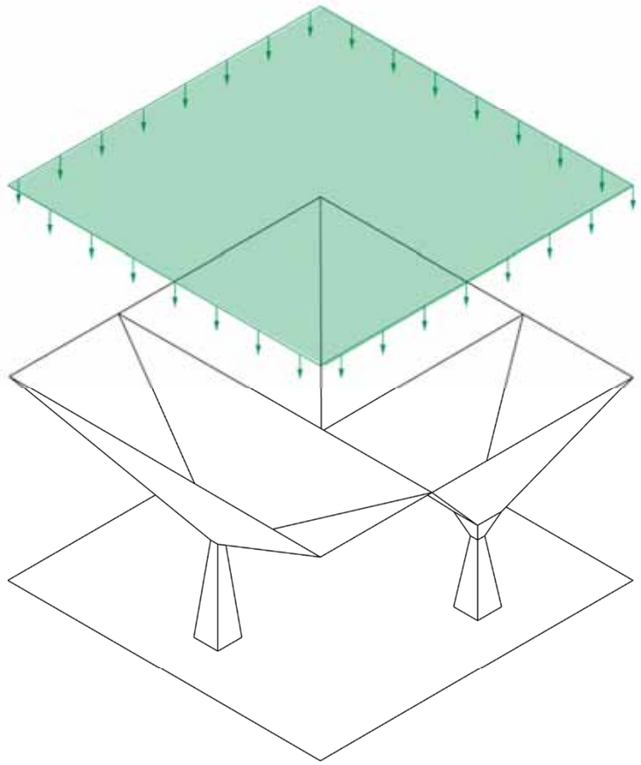


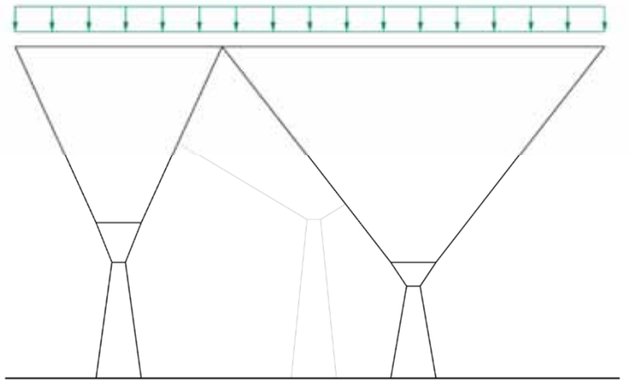
Schwimmbadgebäude, Grundriss und Schnitt
Swimming pools building, plan view

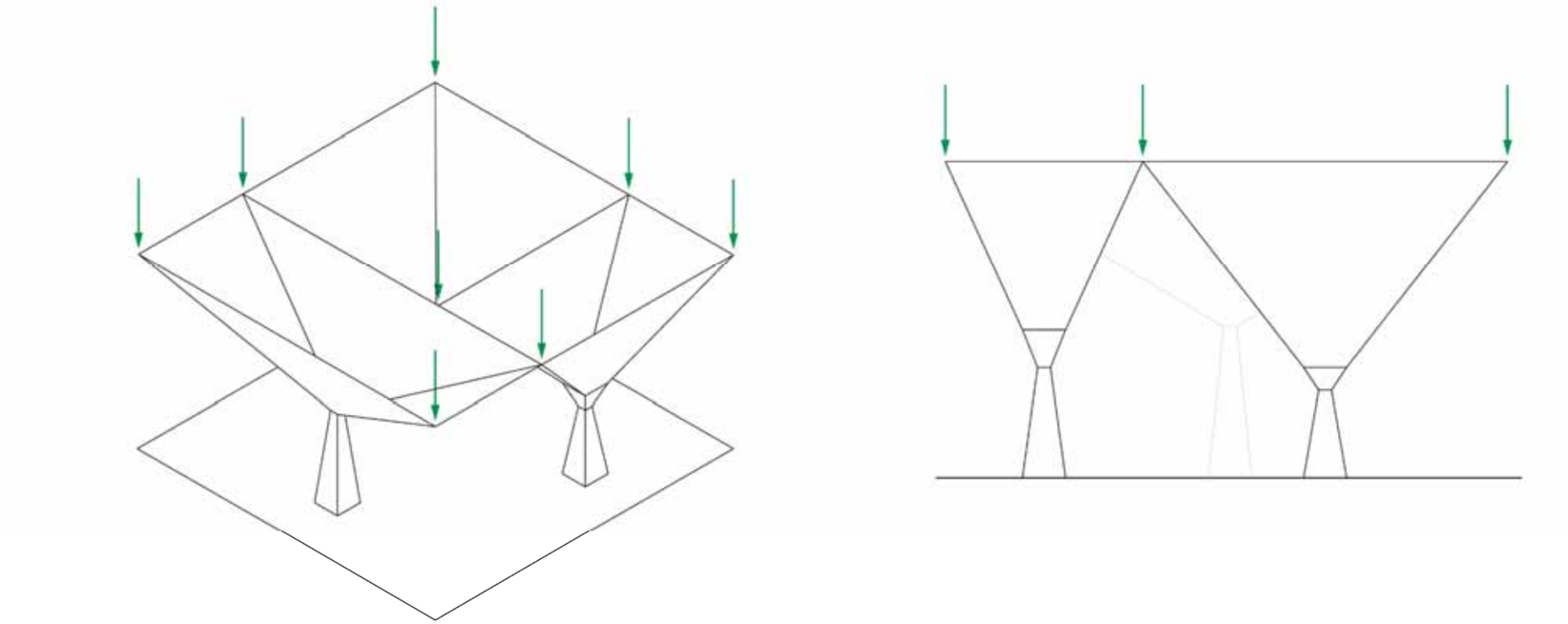

© Federico Cairoli

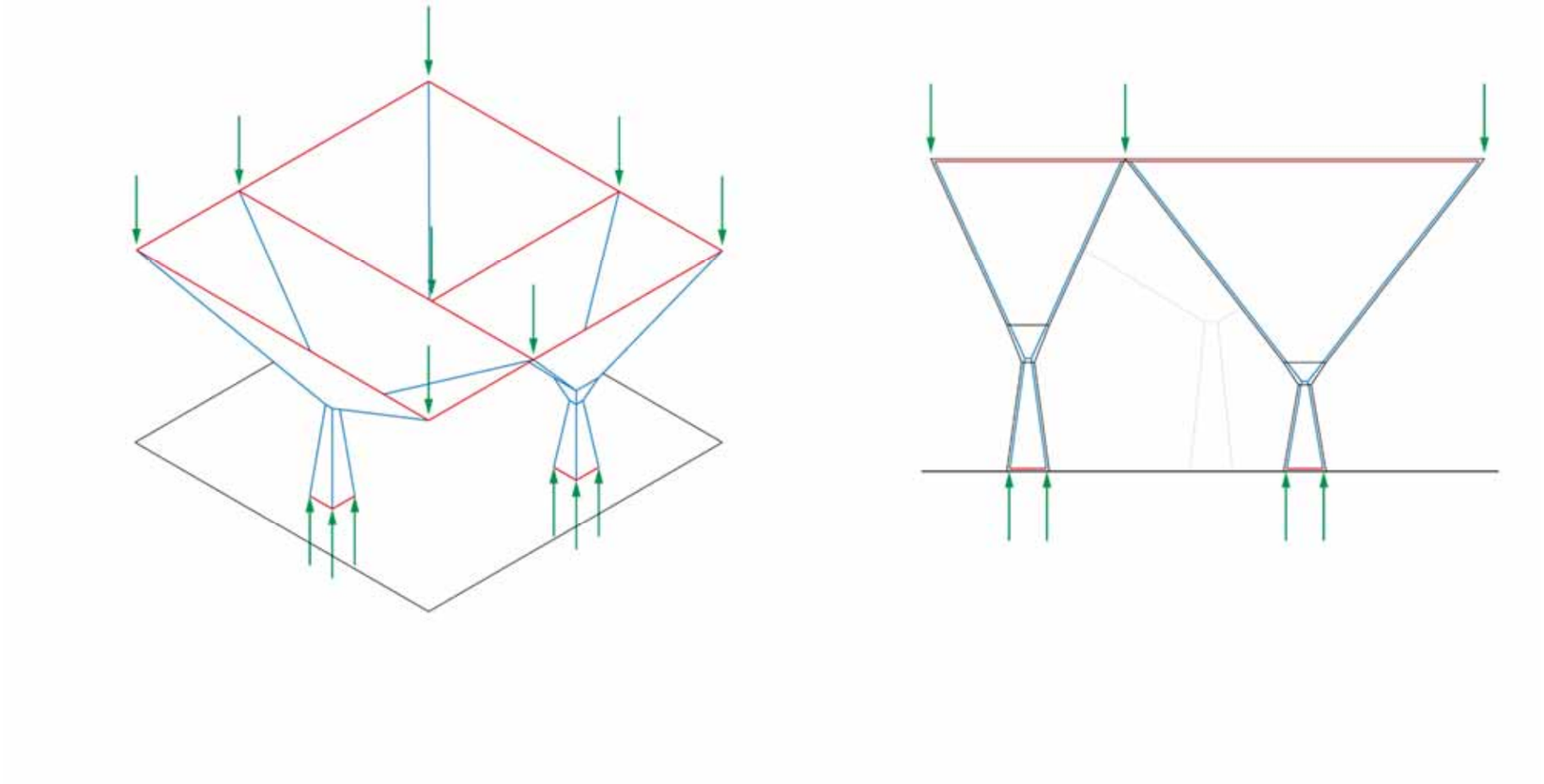


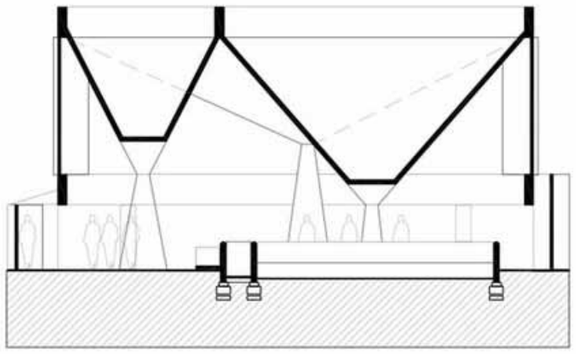
Schwimmbadbau
Swimming pools building









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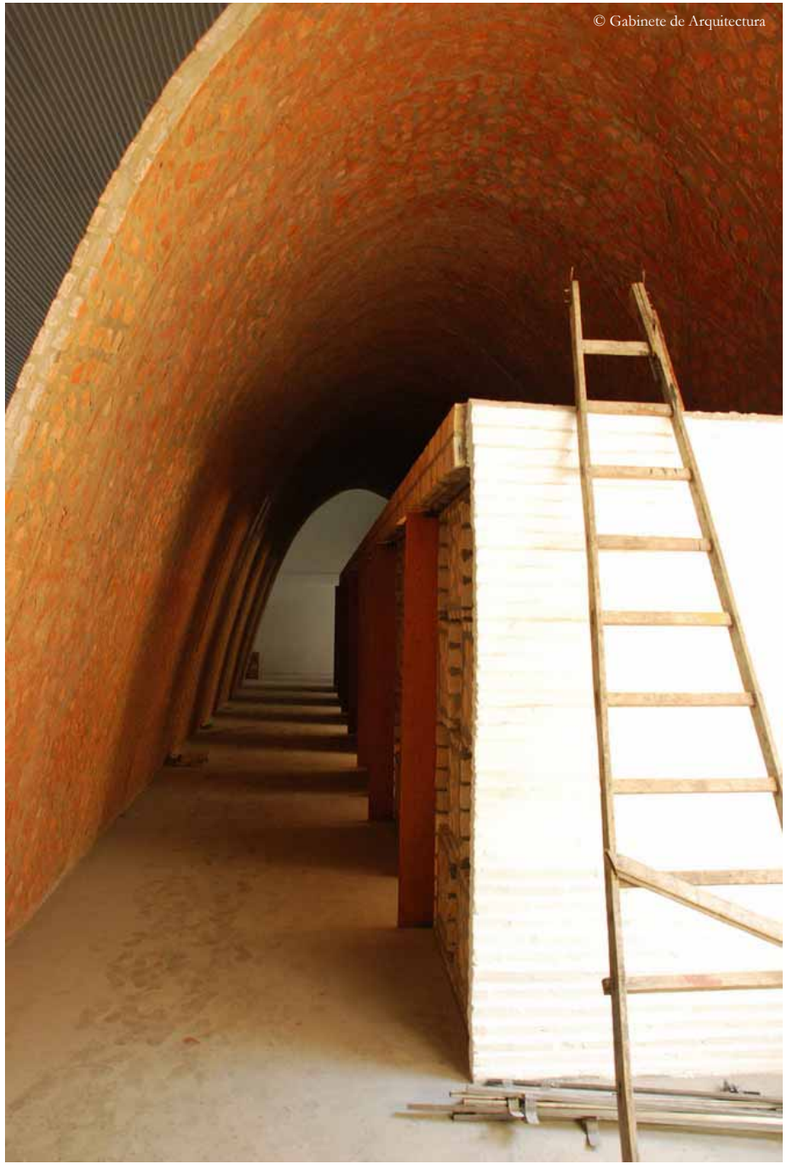
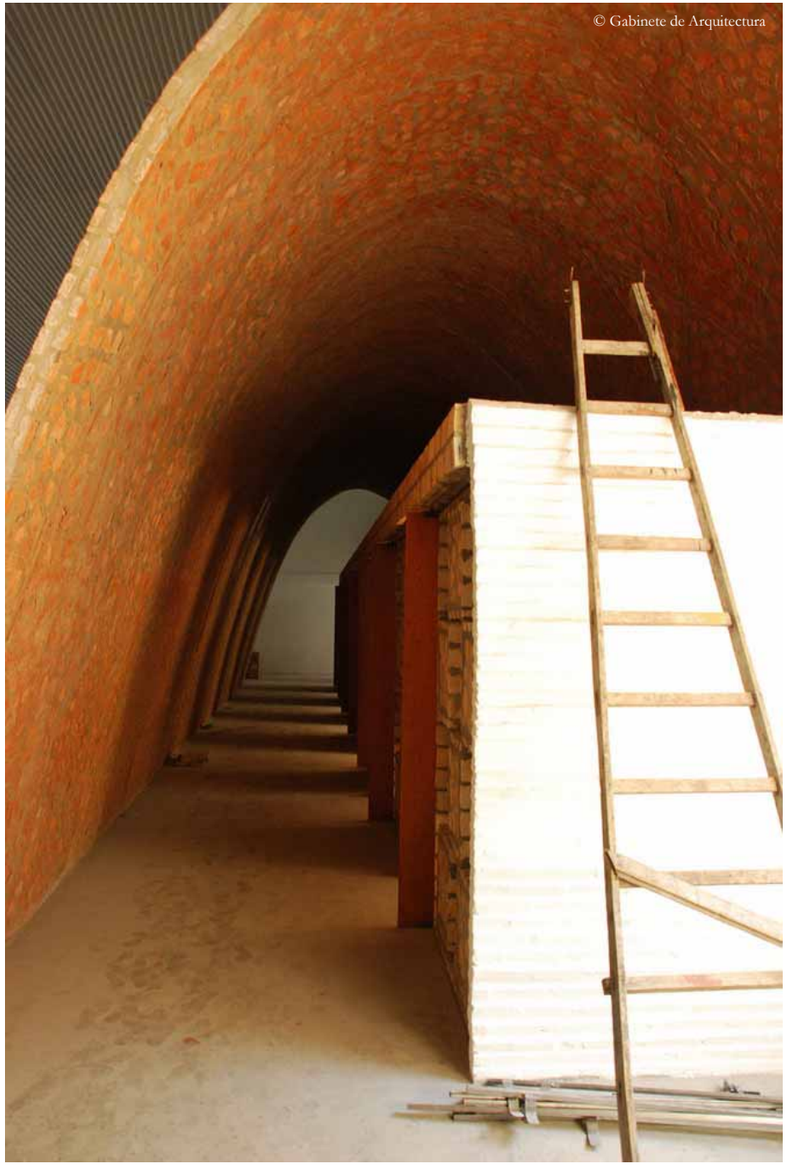


Gemauerter Bogen I
Masonry arch I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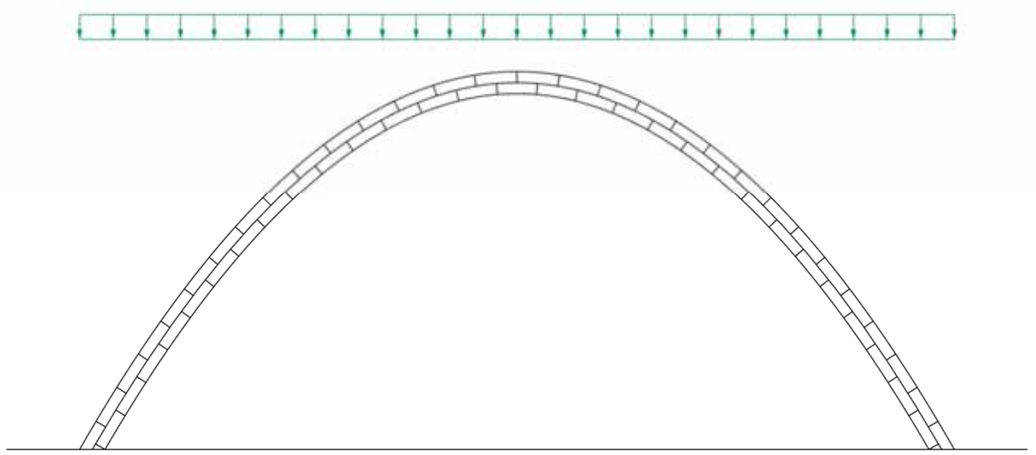
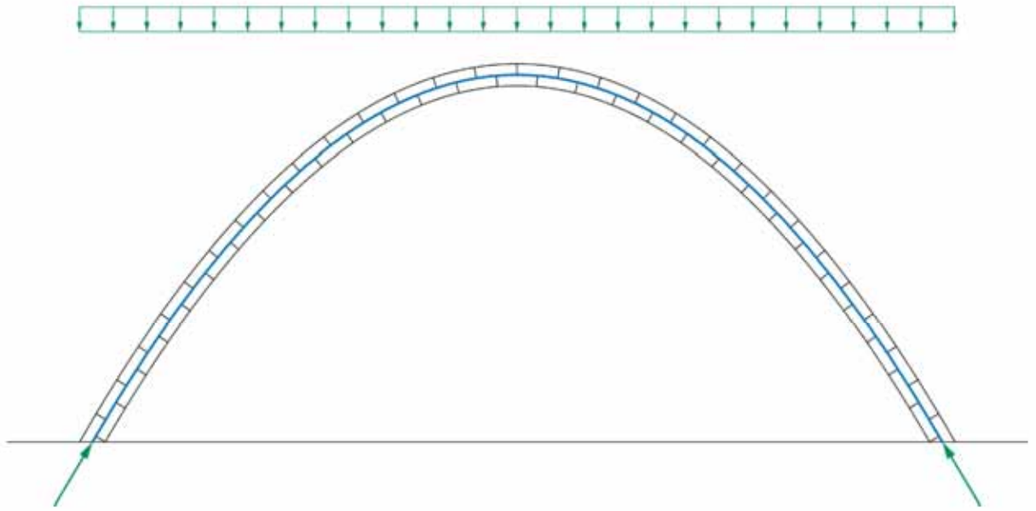
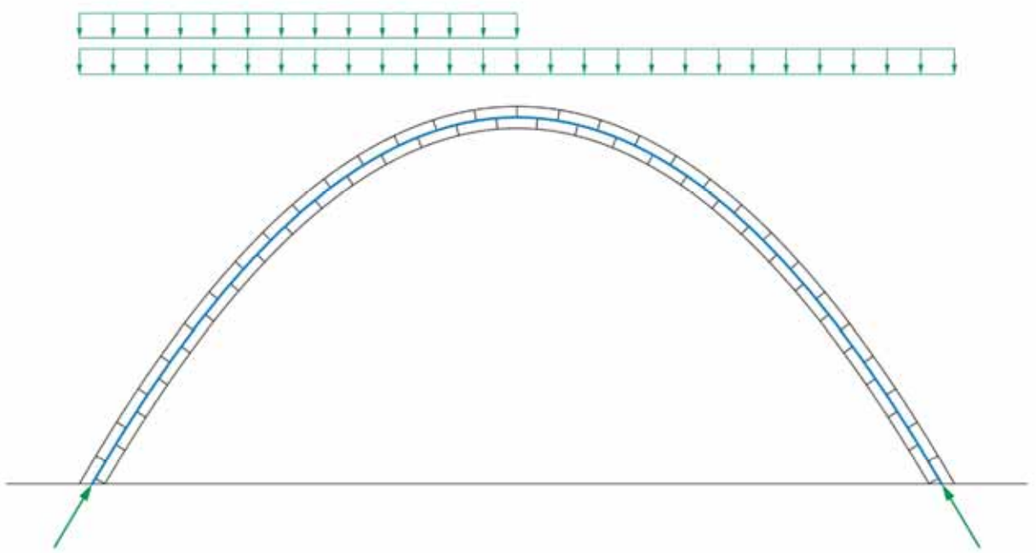


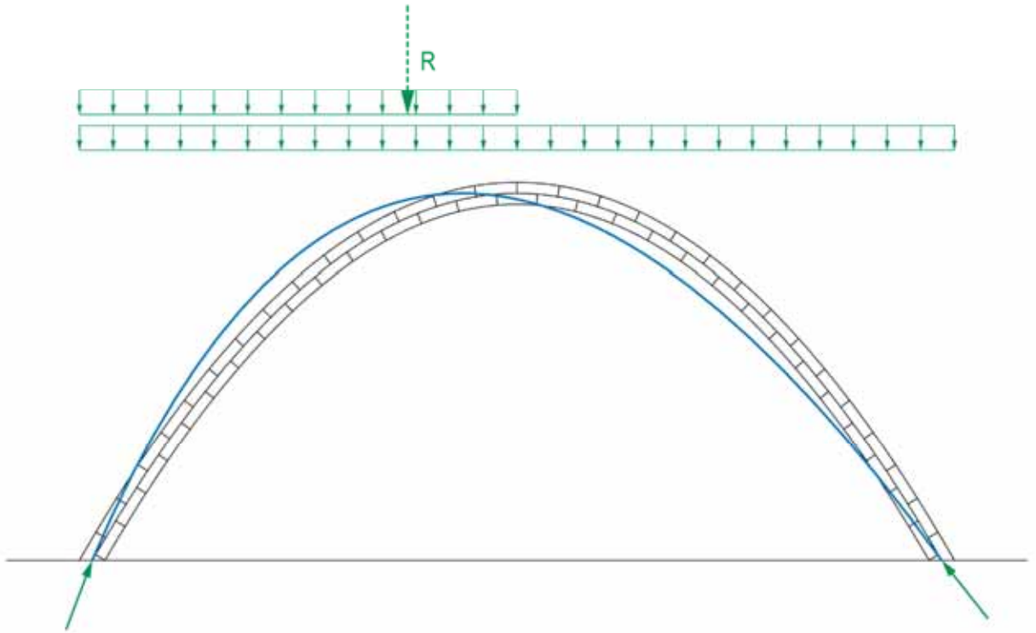
Parabelbogen unter gleichmäßig verteilten Lasten
Parabolic arch under uniformly distributed loads



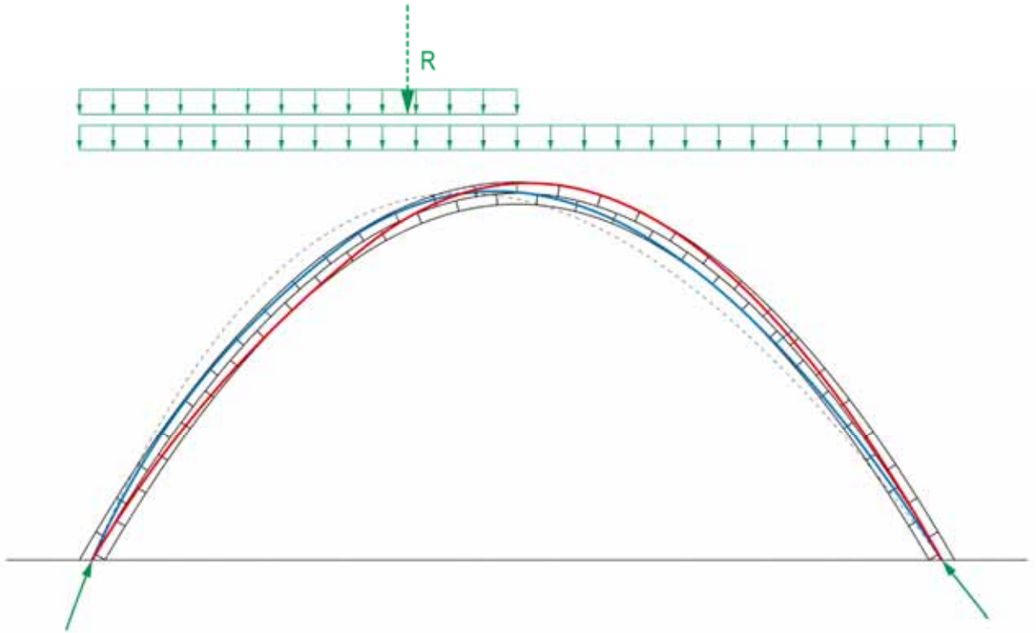
Parabelbogen unter gleichmäßig verteilten Lasten
Parabolic arch under uniformly distributed loads



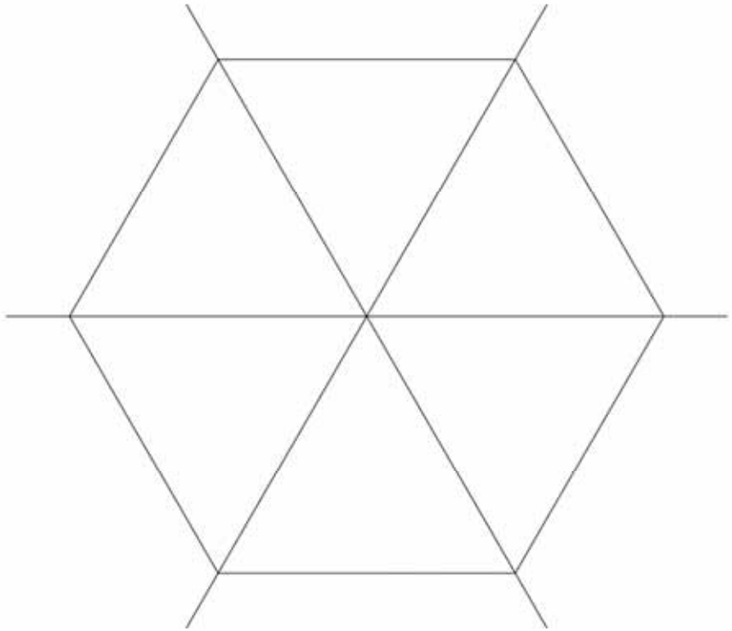
Parabelbogen unter gleichmäßig verteilten Lasten
Parabolic arch under uniformly distributed loads



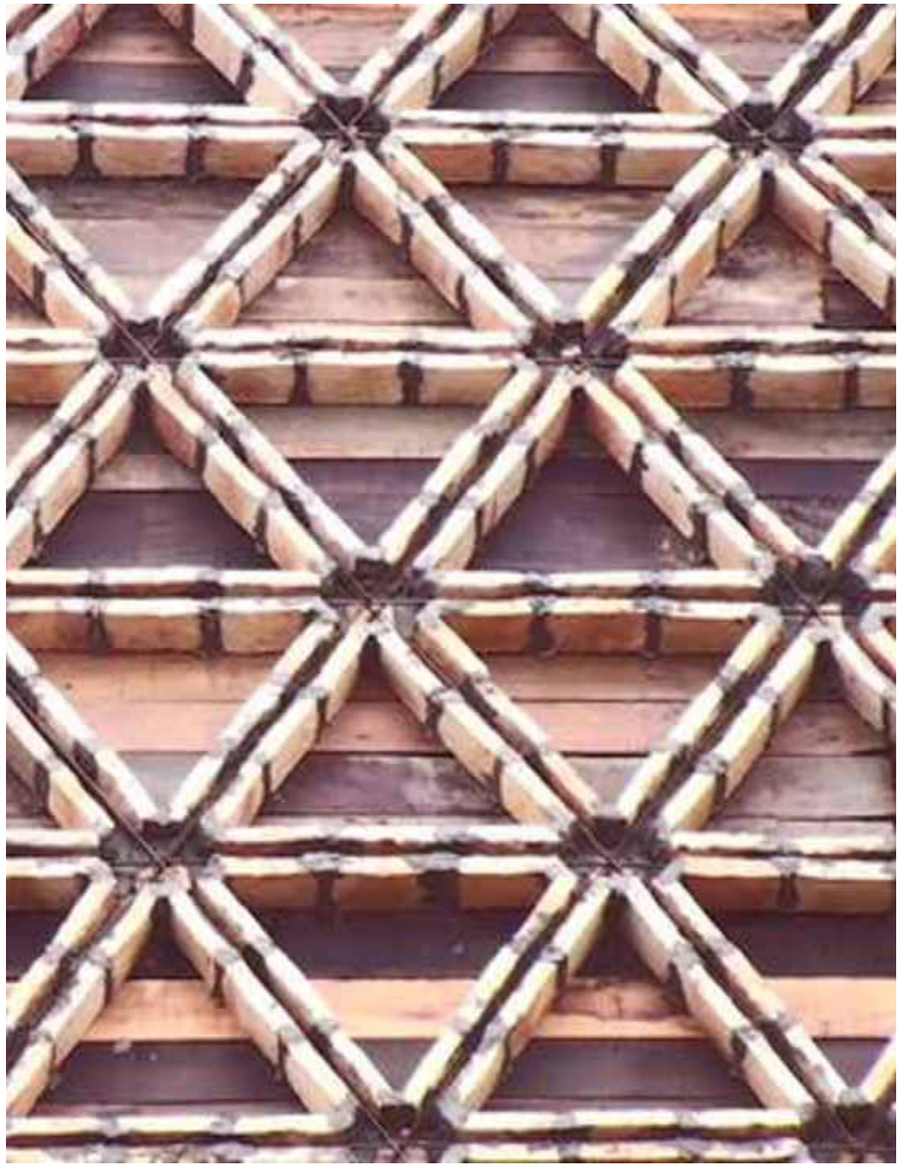
Parabelbogen unter gleichmäßig verteilten Lasten
Parabolic arch under uniformly distributed loads

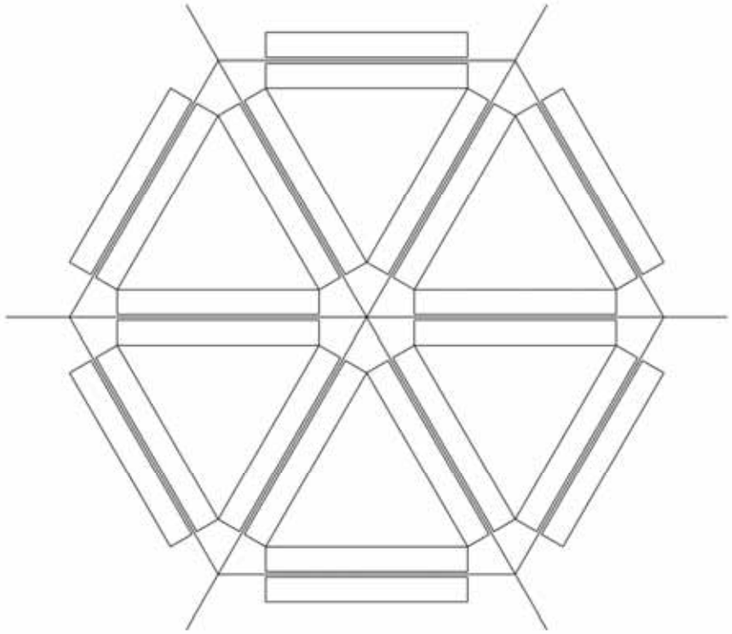


Parabelbogen unter gleichmäßig verteilten Lasten
Parabolic arch under uniformly distributed loads

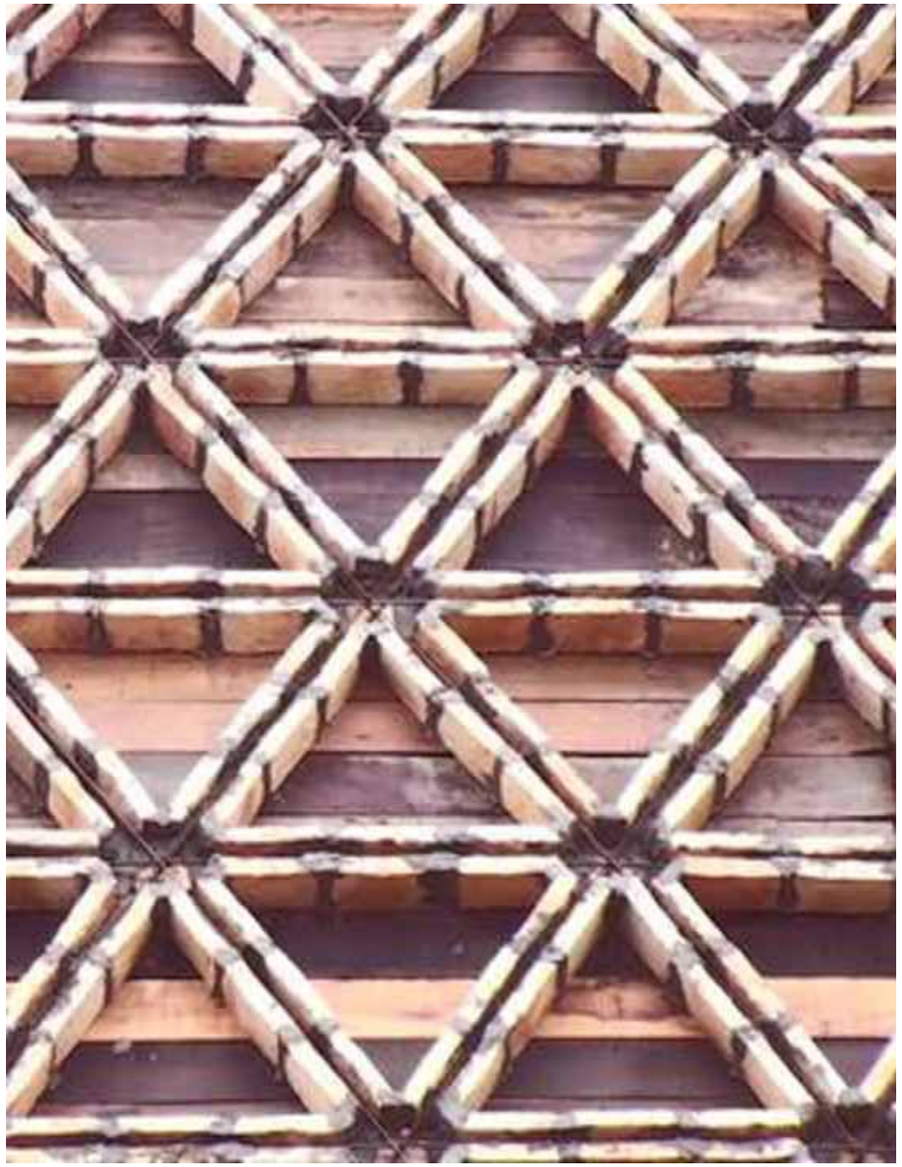


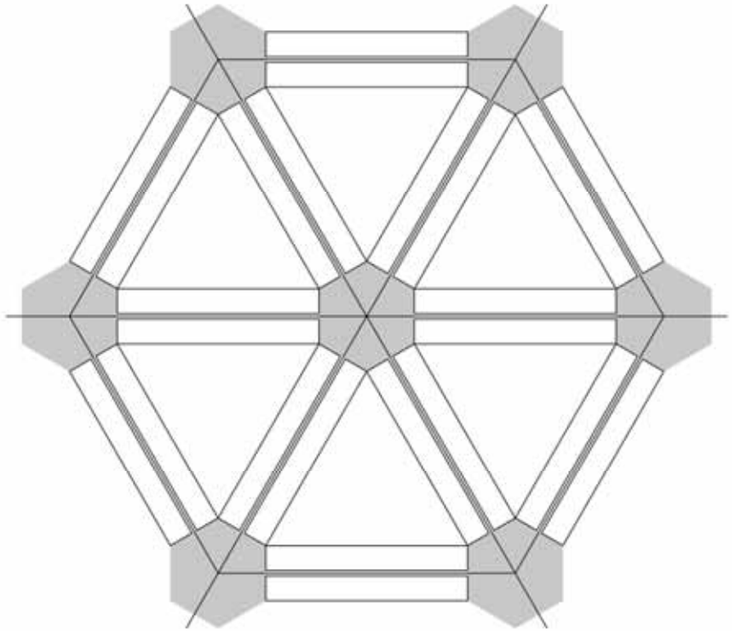
Stahlstäbe
Steel bars



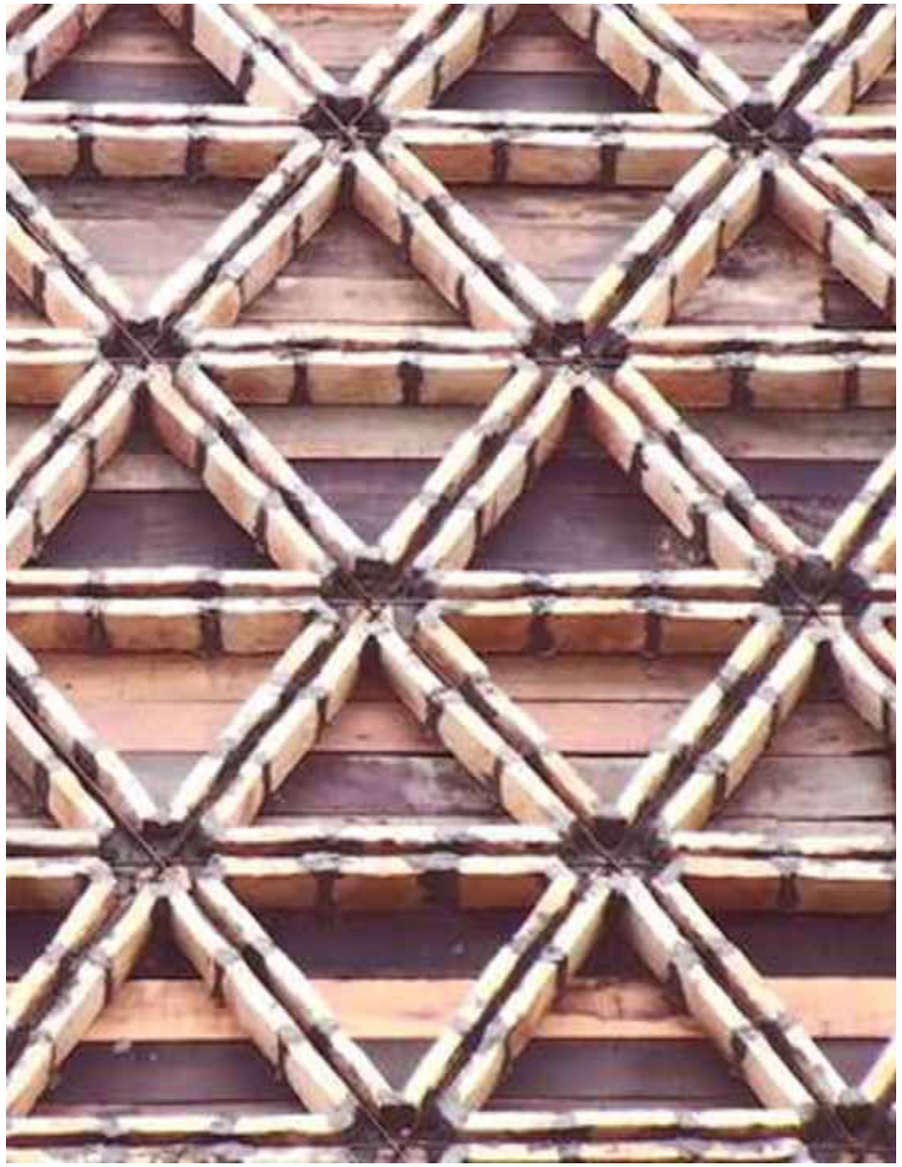


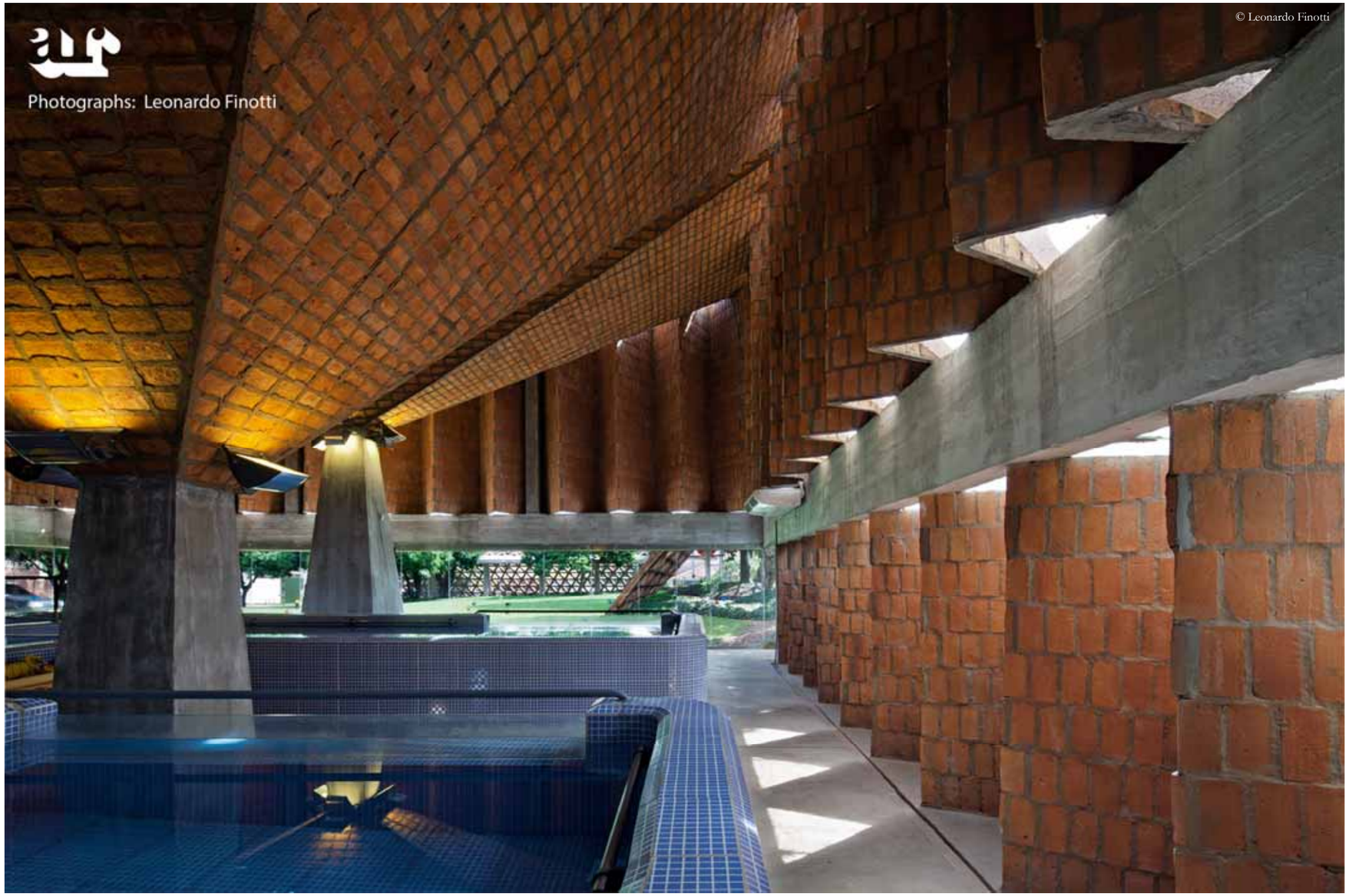
Stahlstäbe
Steel bars





Stahlstäbe
Steel bars
+
Backsteine
Bricks
+
Mörtel
Mortar infills




Photographs: Leonardo Finotti
© Leonardo Finotti

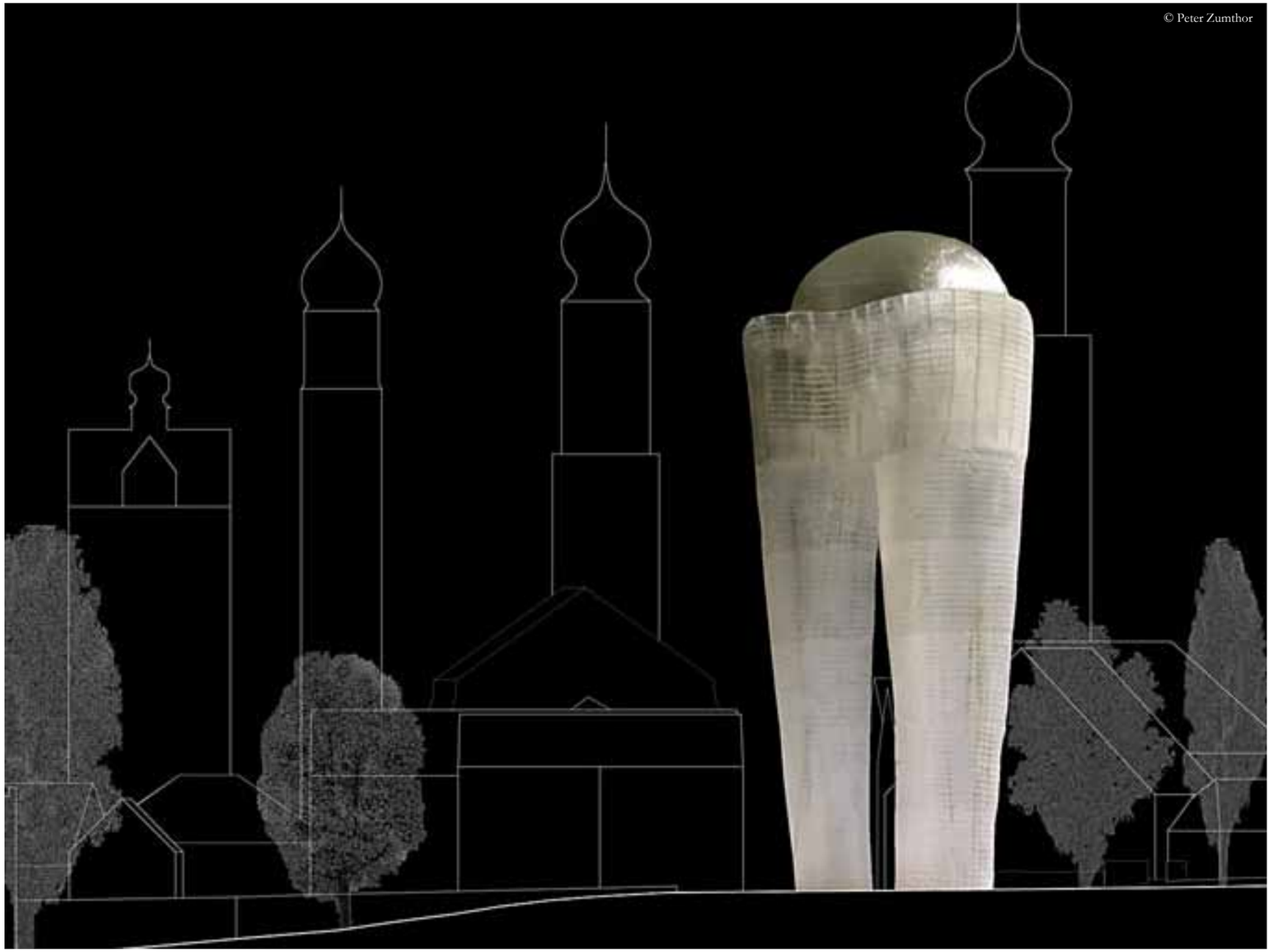
Stadttor

Isny, 2012

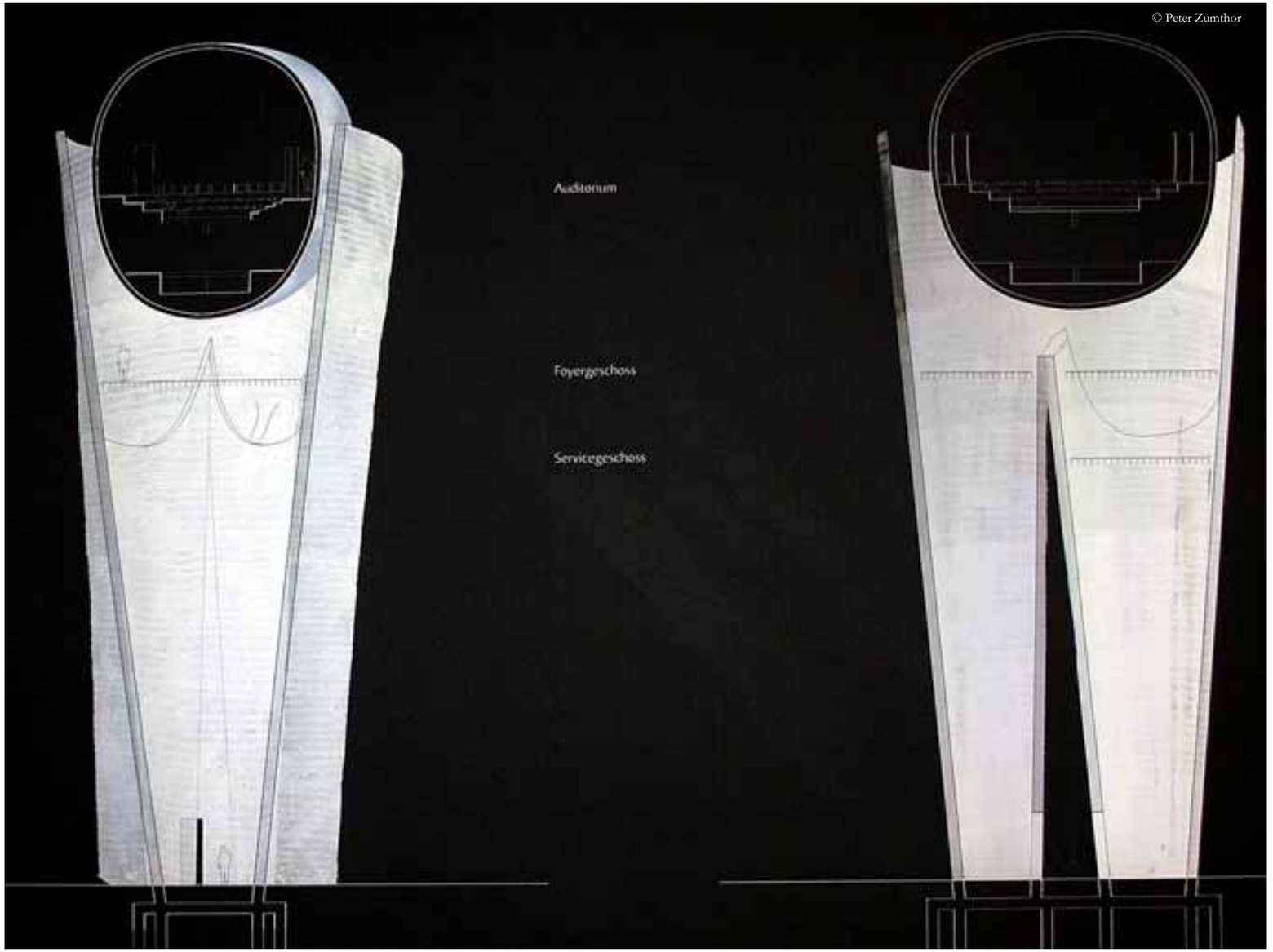
Architect: Peter Zumthor

Engineer: Joseph Schwartz


© Peter Zumthor



Glasturm
Glasturm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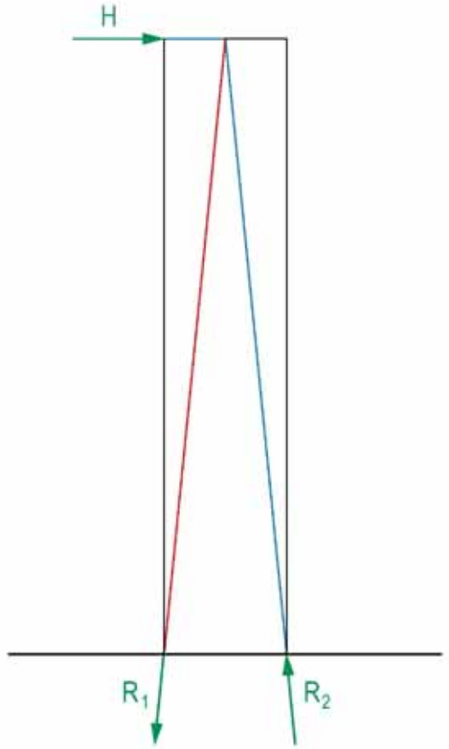
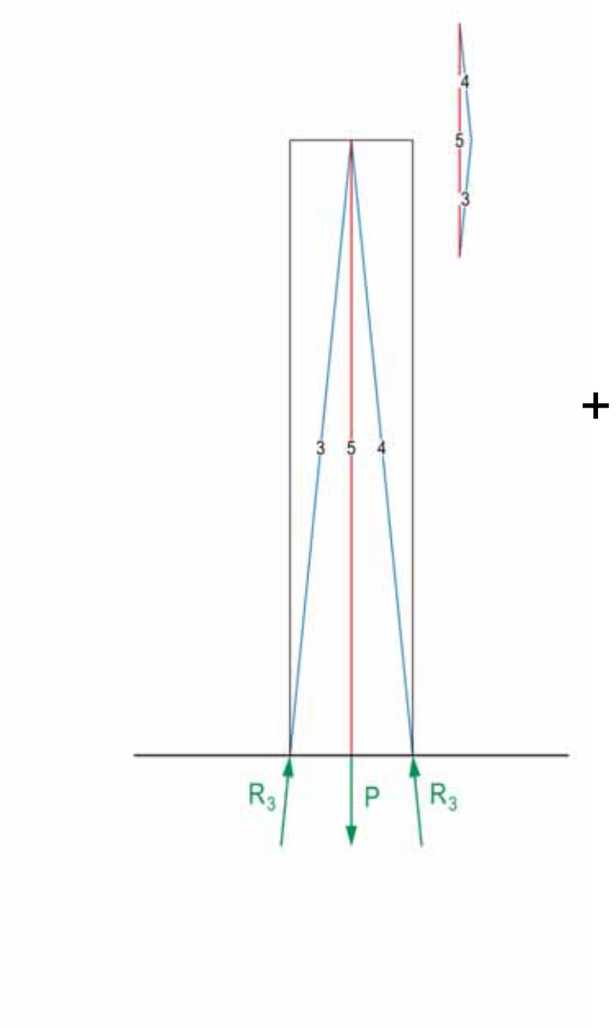
Auditorium
Foyergeschoss
Servicegeschoss

Glasblock
Glasblock

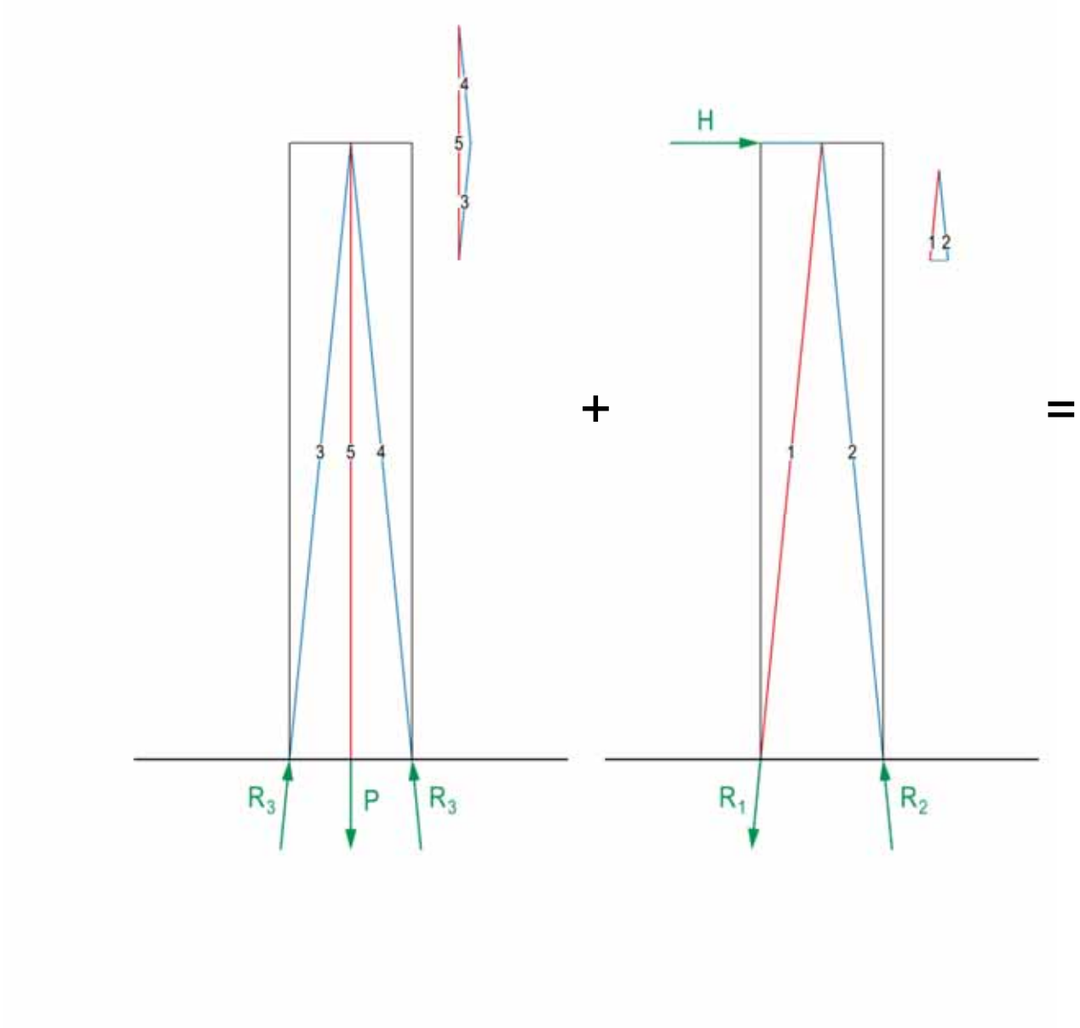
Mauerwerk mit Glassteinen
Masonry with glass blocks

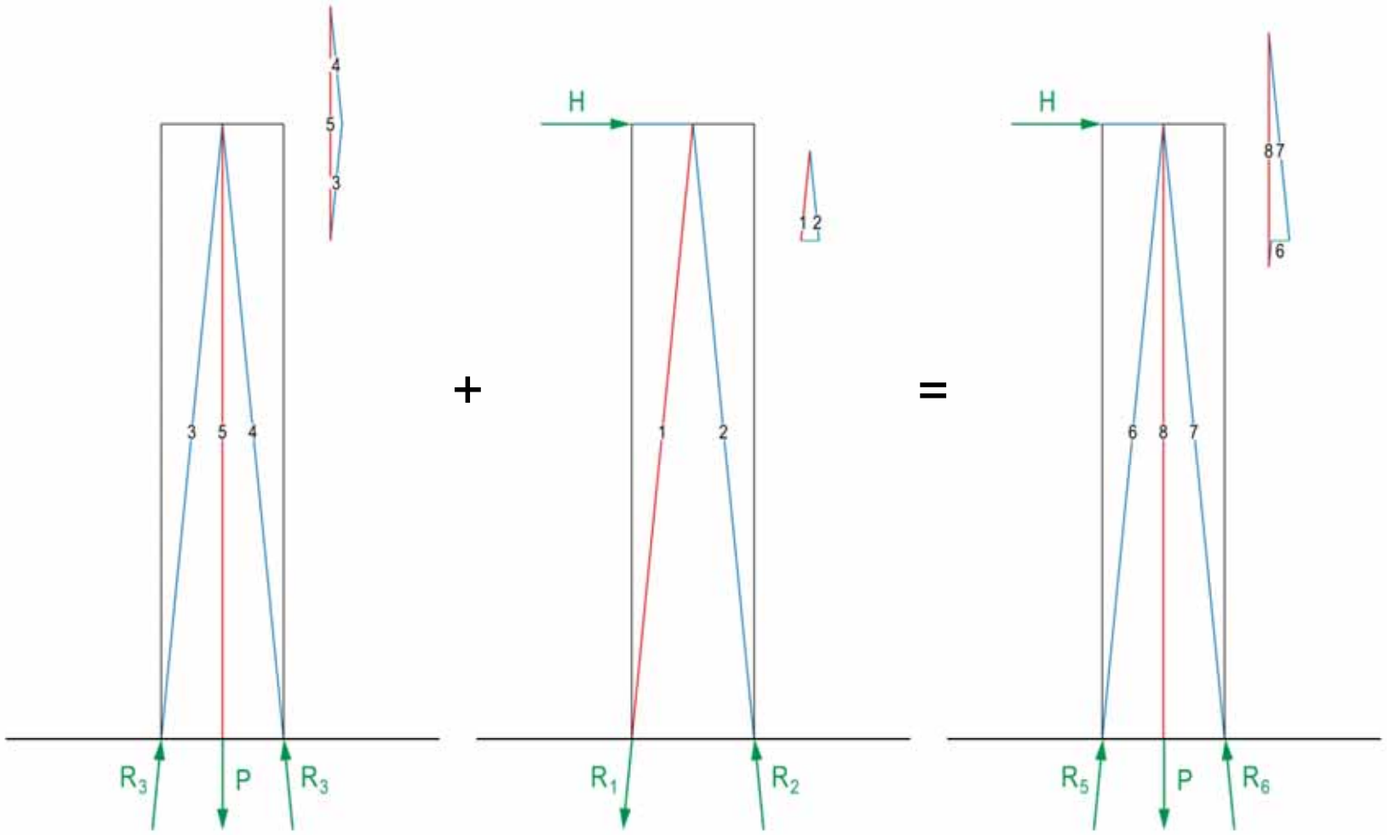
Druckfestigkeit des Mauerwerks mit Glassteinen
Lack of resistance in compression for the masonry with glass blocks

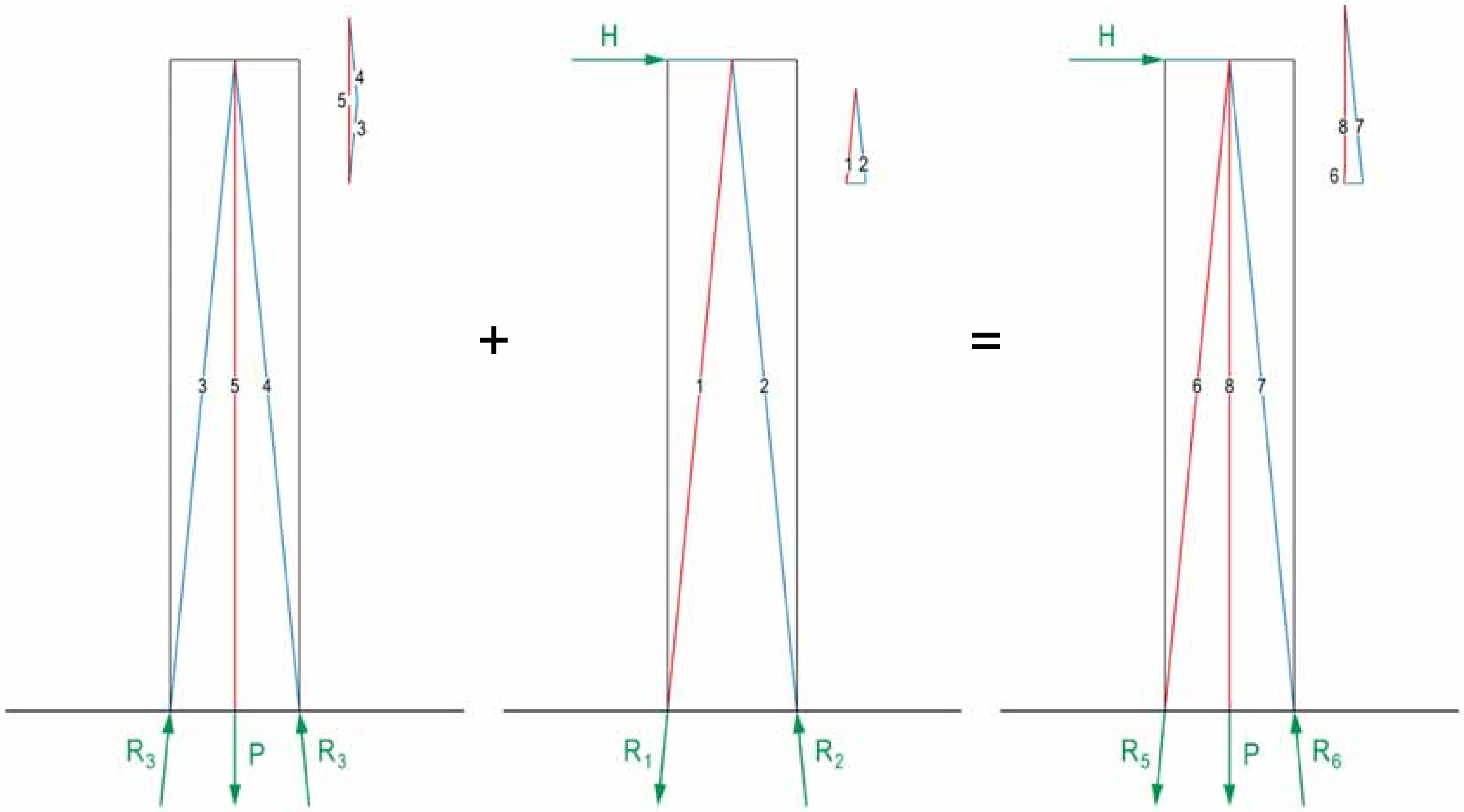

H
R1
R2


4
5
3
3
5
4
R3
P
R3

+

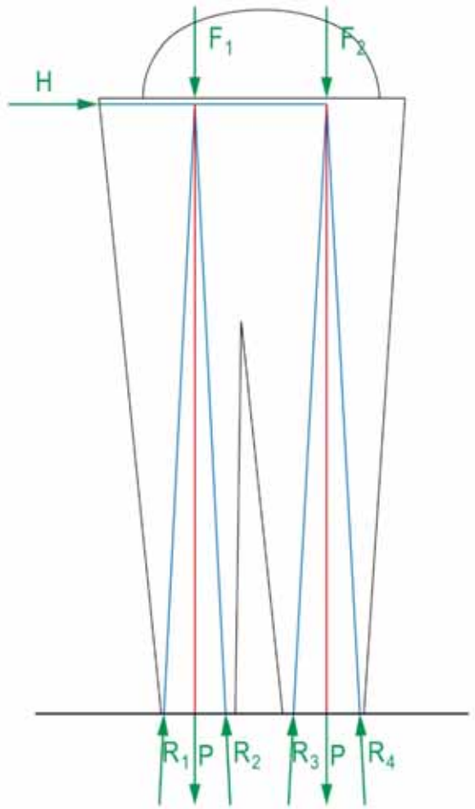

4
5
3
3 5 4
R3 P R3
+
H
1 2
1 2
R1 R2
=


4
5
3
3 5 4
R3 P R3
+
H
1 2
1 2
R1 R2
=
H
8 7
6
6 8 7
R5 P R6



Vorspannung

Prestressing


F1
F2
H
R1
P
R2
R3
P
R4

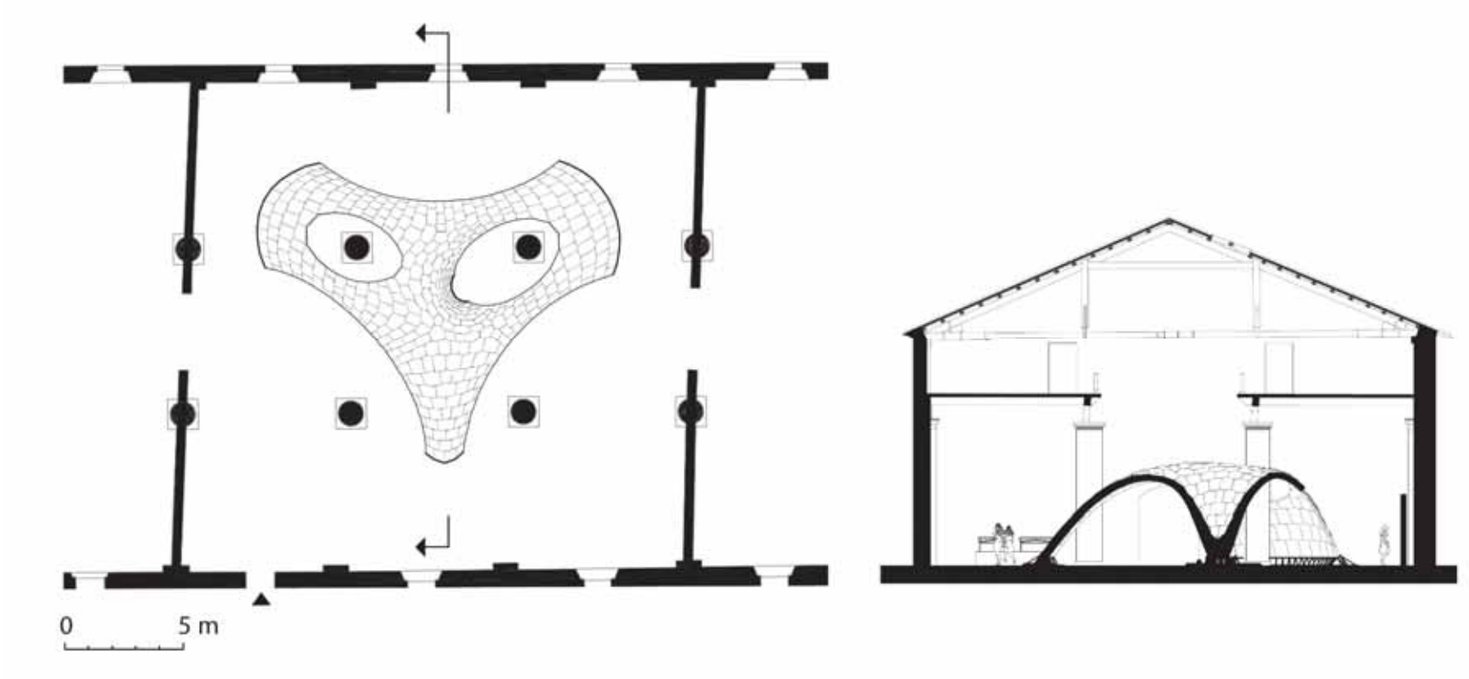
Armadillo Vault

Venice, 2012

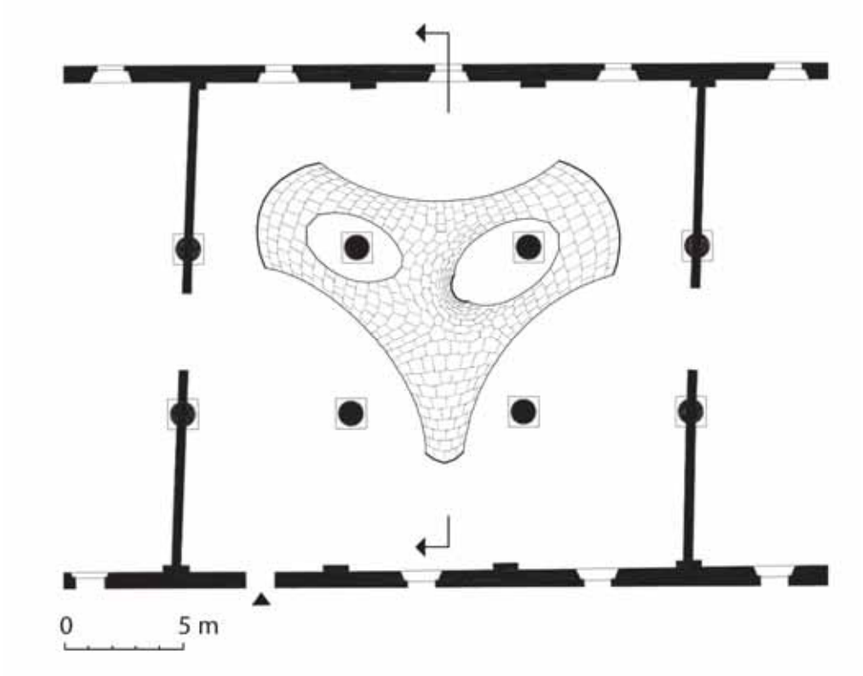
Architect: Block Research Group

Engineer: Ochsendorf, DeJong & Block, Escobedo Group


© BRG

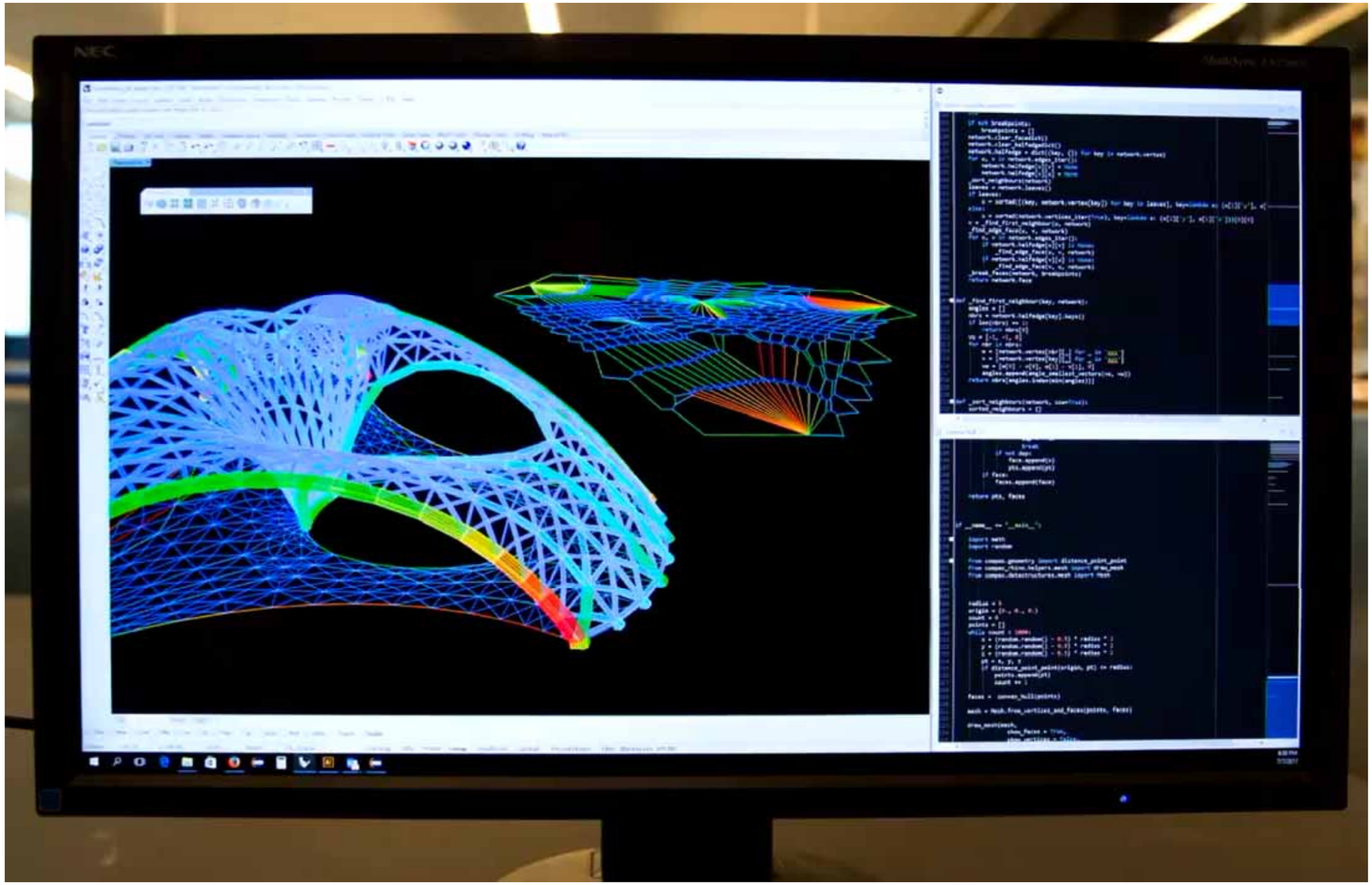


Grundriss
Floor plan

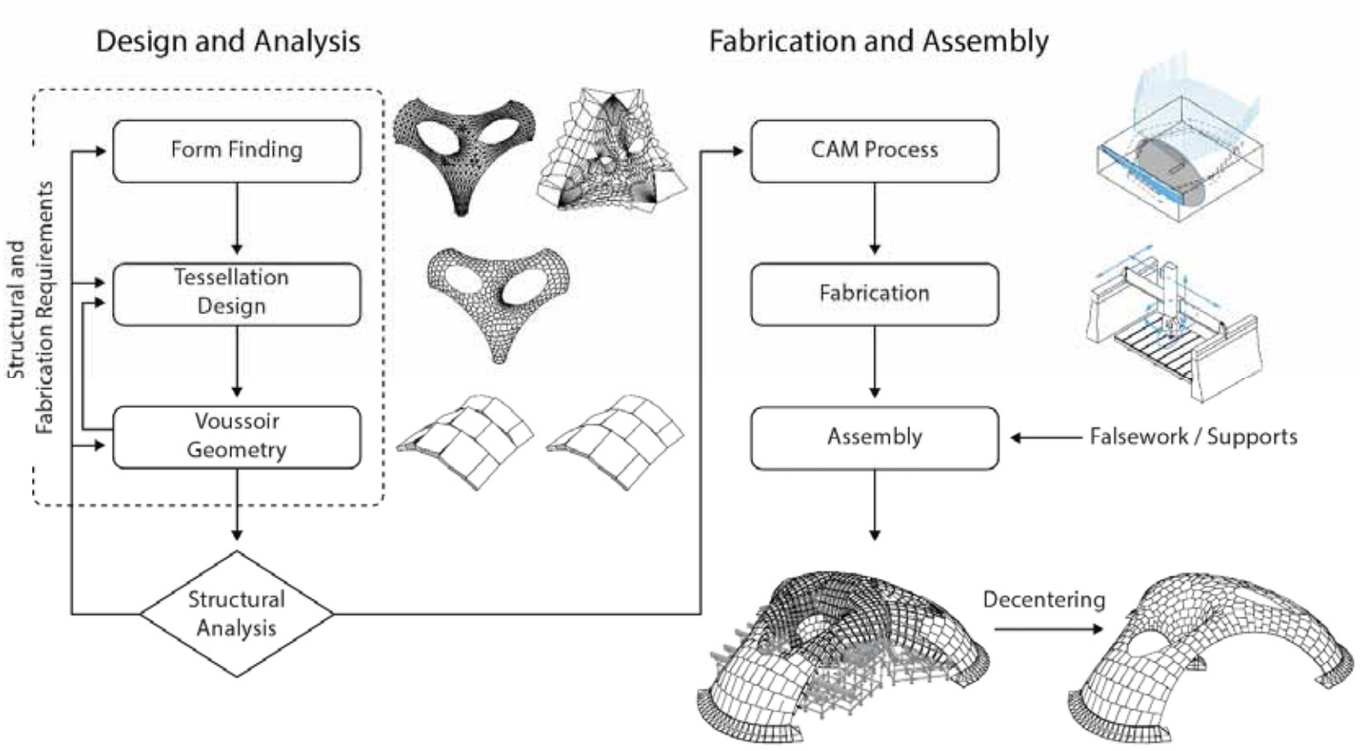


- **399 individual limestone blocks**
- **No mortar or mechanical connections**
- 75 m^2 covered area
- 4.3 m maximum height
- **15 m maximum span**
- **5 cm minimum thickness**
- 23.7 tons total weight (excl. supports)
- 48 kg average size of stone
- **185 span-to-thickness ration**

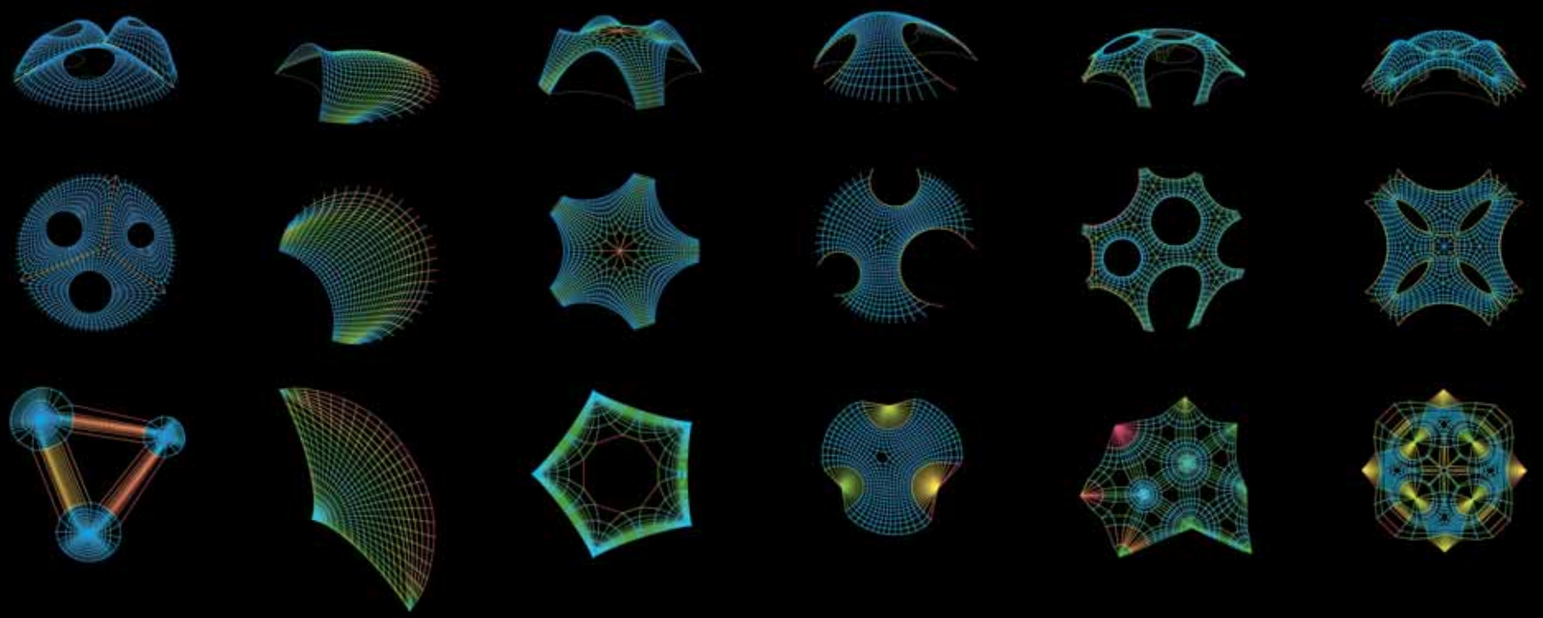
Grundriss
Floor plan

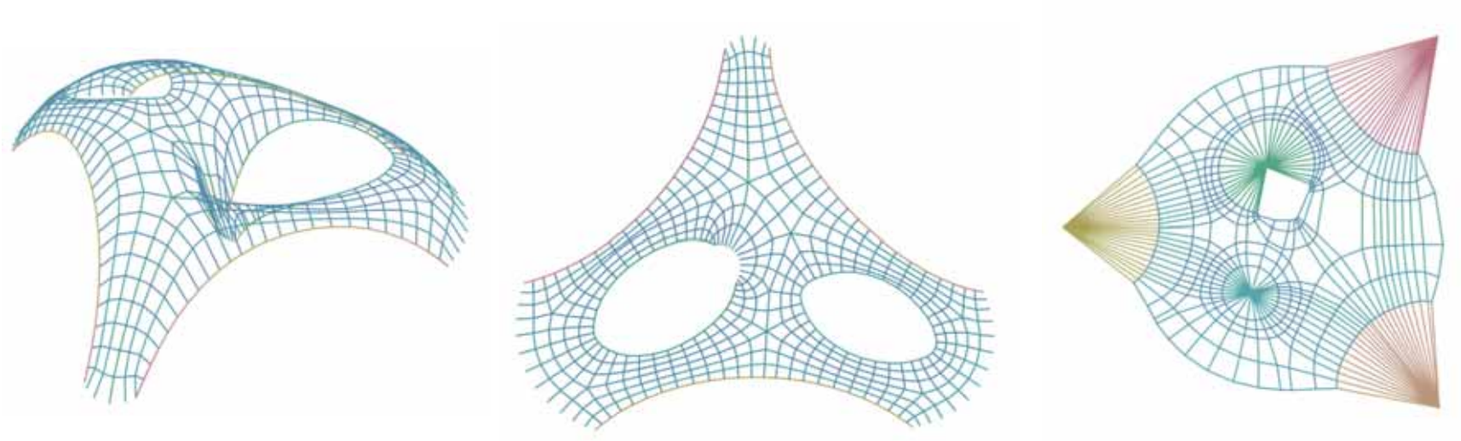

NEC

Selected Projects

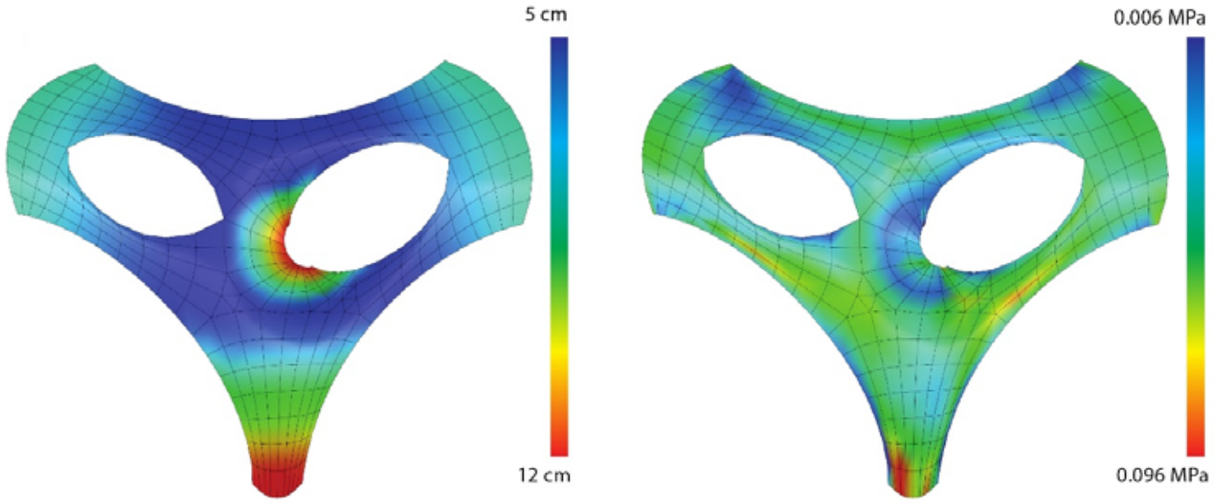


compAS-Framework (computational framework for architecture structures and digital fabrication)
compAS framework (computational framework for architecture structures and digital fabrication)

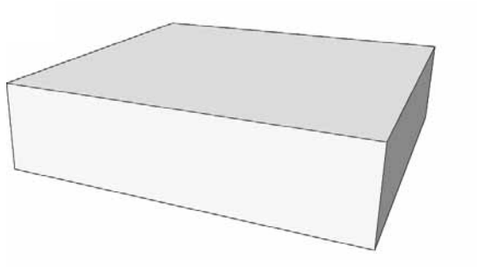


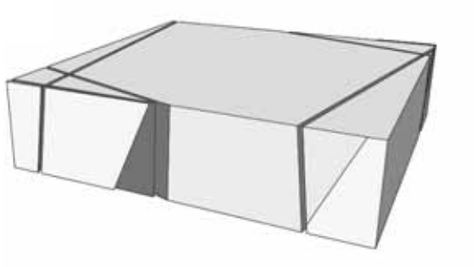


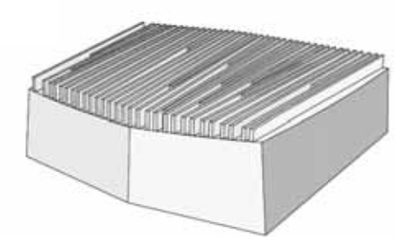
Abstrahierte 3D-Kraftflüsse
Abstracted 3D force flows

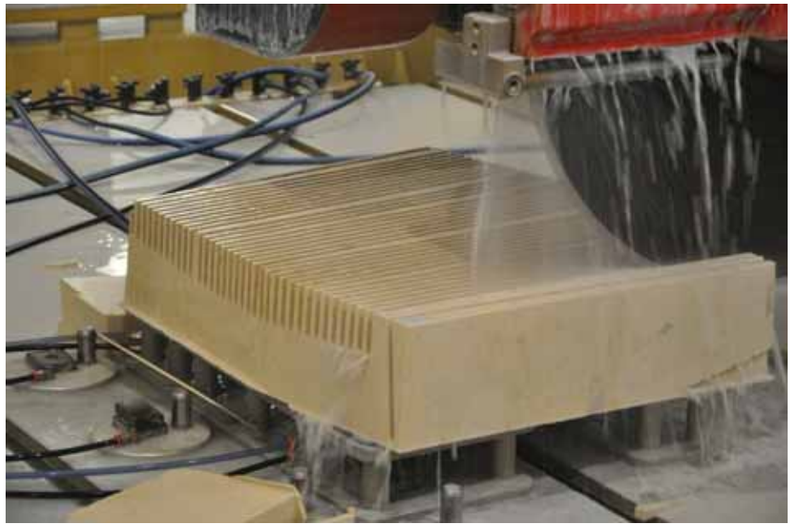


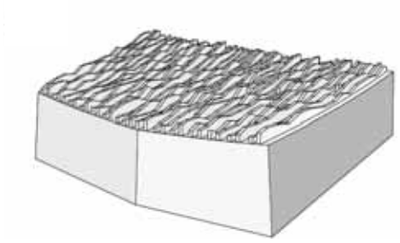
Analyse der Dicken- und Spannungsverteilung
Analysis of thickness and stress distributions

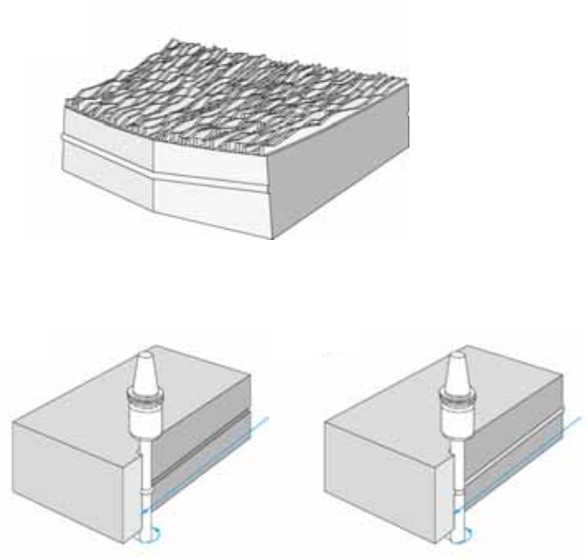










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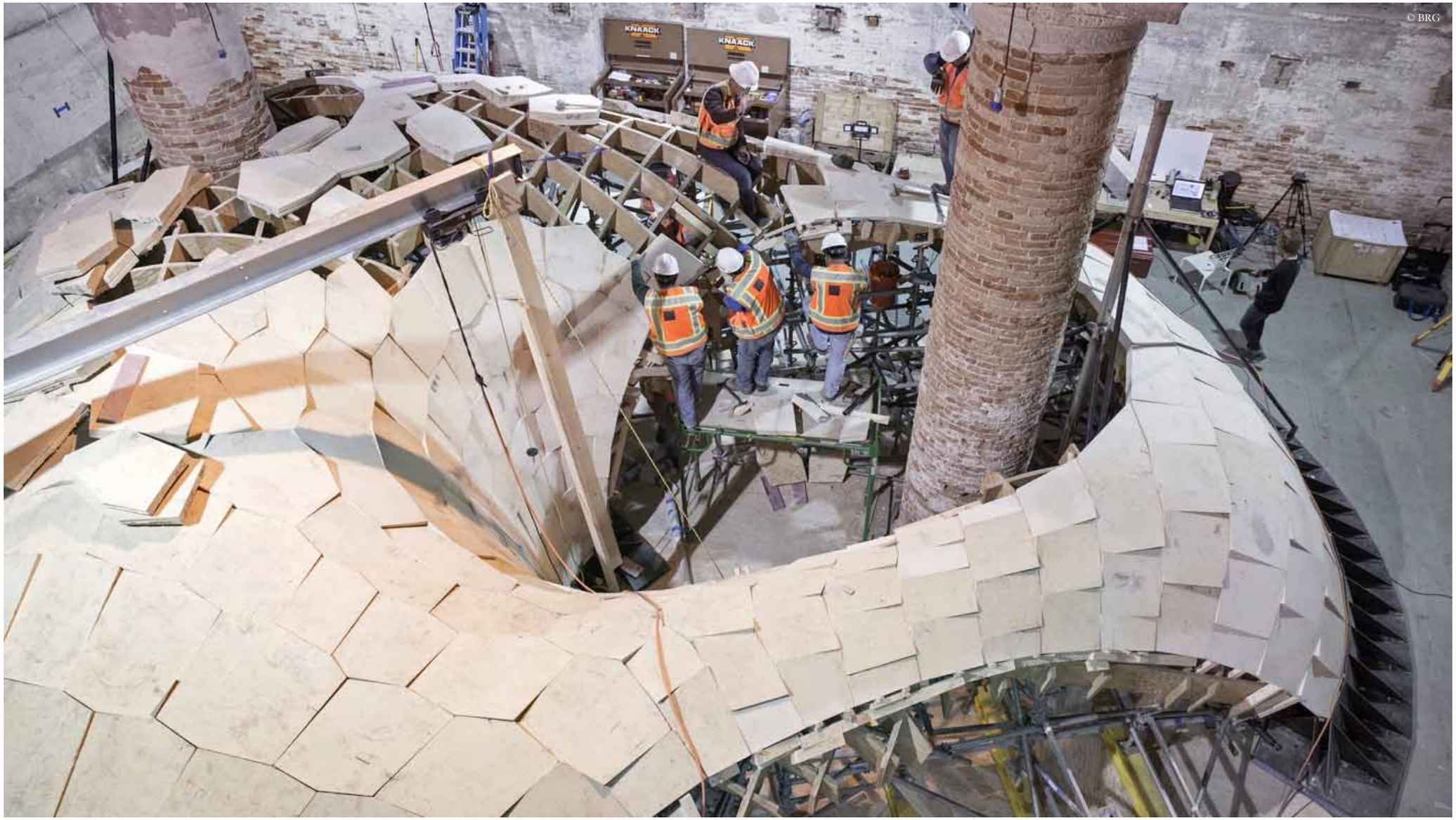
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