UNIVERSITÀ DEGLI STUDI FIRENZE
Scuola di Architettura

MULTIMEDIA | ARCHITECTURE | INTERACTION

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

Understanding the interrelation between structural diagrams and architectural forms

prof. arch. Giuseppe Ridolfi PhD

structural diagrams & architectural forms

STRUCTURE. PRELIMINARY DEFINITION

- a metaphor for forces

  A load-bearing system to ‘transport’ loads from the point of their origin and down to the ground.

- a diagrammatic organization

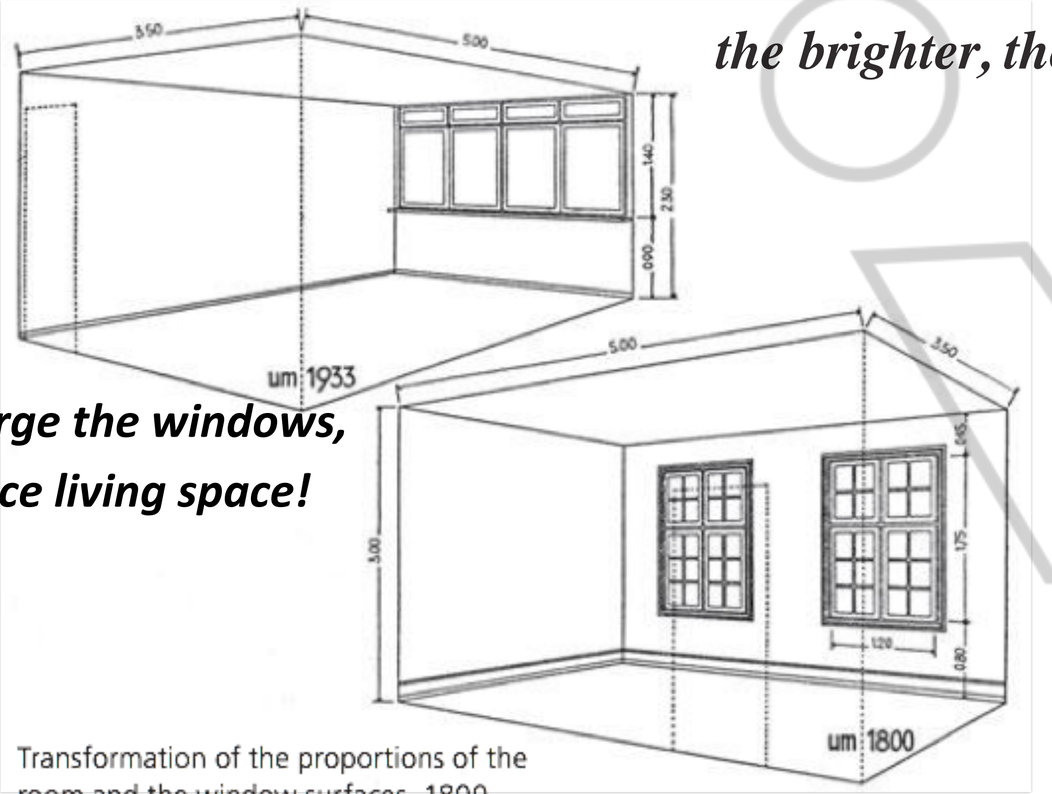
  Schematic organization of material (according to its properties) and of the most efficient geometrical configuration in the space in order to ensure stability and rigidity

STRUCTURE. PRELIMINARY DEFINITION

From Maison Domino: A mere technological problem

the brighter, the better

Enlarge the windows, reduce living space!



Transformation of the proportions of the room and the window surfaces, 1800 versus 1933: Ceiling heights lower, new window forms, increased percentage of window surfaces.

Ludwig Mies van der Rohe, Tugendhat House, Brno, 1928–30. View from the garden, living area with large window facing the garden.

Hans Scharoun, Schminke House, Löbau, 1930–33. Winter garden.

STRUCTURE. PRELIMINARY DEFINITION

To some recent architectures*: An adaptation to the ‘from the skin in’ design

**Tschumi, Coop Himmelb(l)au, Gehry*

STRUCTURE. PRELIMINARY DEFINITION

- structures as **space-definer** & means for **expression**.

'structural design is concerned with much more than science and techniques: it is also very much concerned with art, common sense, sentiment, aptitude, and the enjoyment of the task of creating opportune outlines to which scientific calculations will add finishing touches, substantiating that the structure is sound and strong in accordance with the requirements'.

Torroja, Edouardo, *Philosophy of Structures*, Berkeley and Los Angeles: University of California Press, 1958.

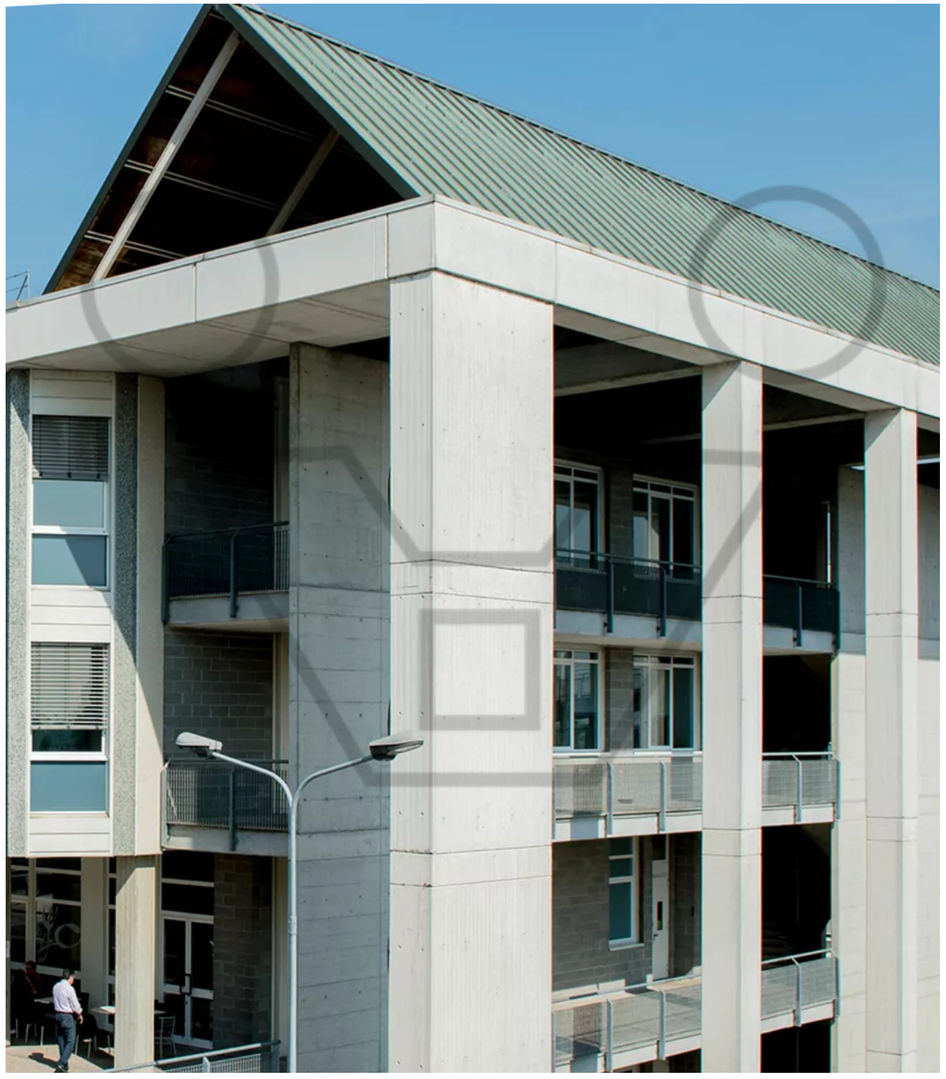
THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

Richard Rogers, Lloyd's Building, London Year : 1986

Norman Foster / Ove Arup & Partners, Hong Kong-Shangai Bank, 1985

the beauty of structures

1.10 Column in the central nave. Architect Jules Astric: Église Notre-Dame du Travail (1902), Paris.



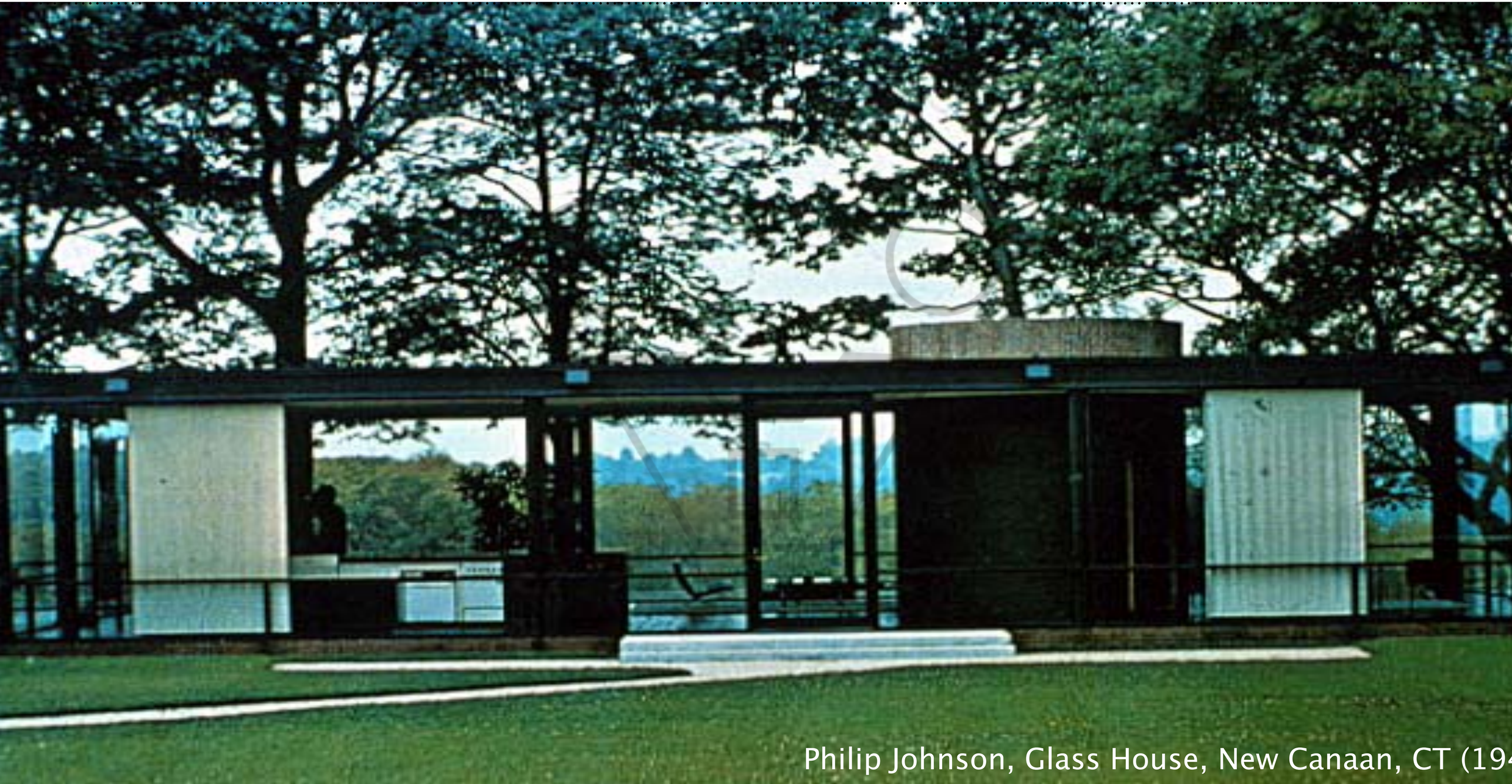
CSPE, Ospedale Baggiovara, Modena, 1991-96

Tadao Ando, Casa Azuma, Osaka , 1976

Farnsworth House, Mies van der Rohe, Illinois 1945-51

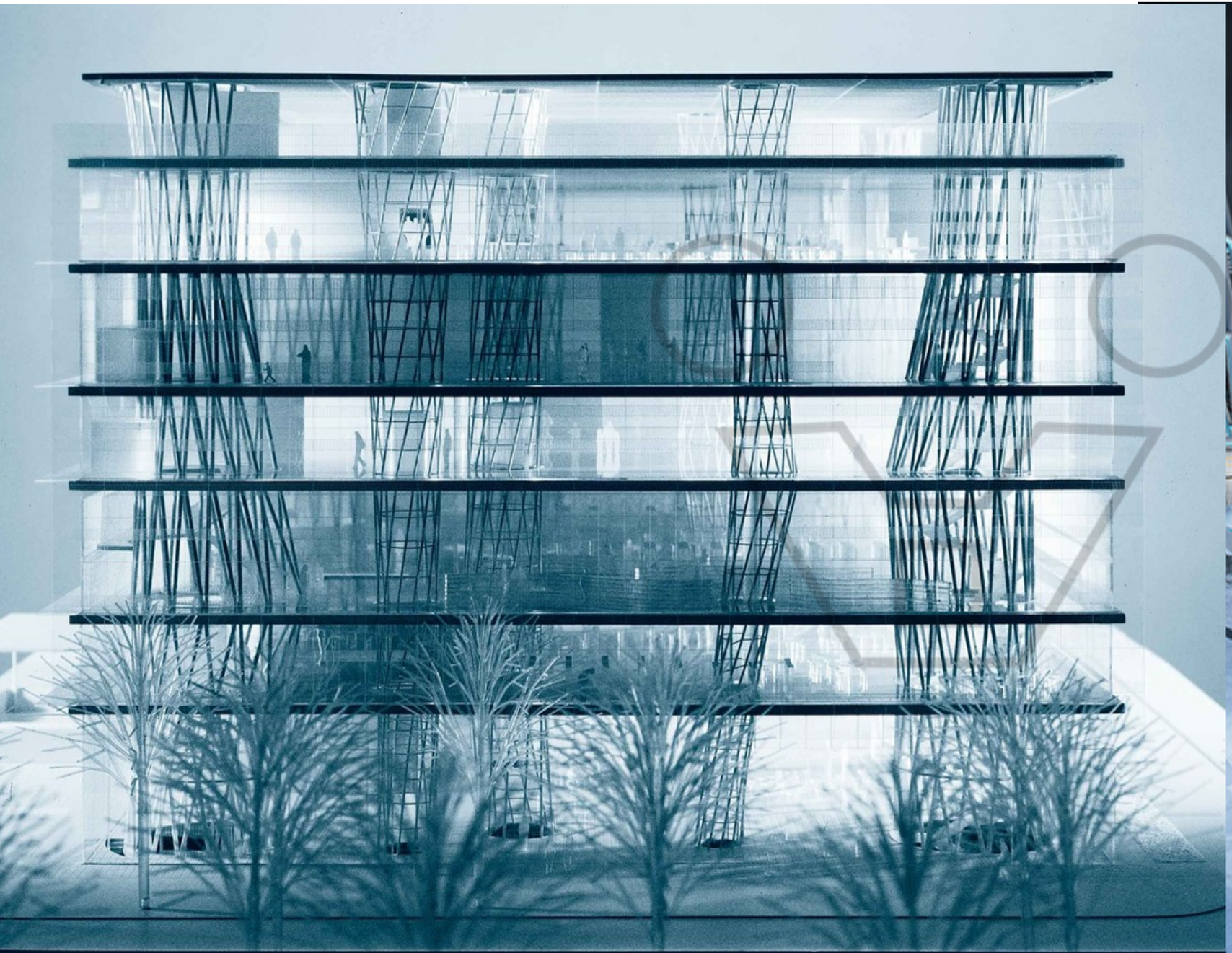
Farnsworth House, Mies van der Rohe, Illinois 1950

1950 illinois farnsworth mies van der rohe



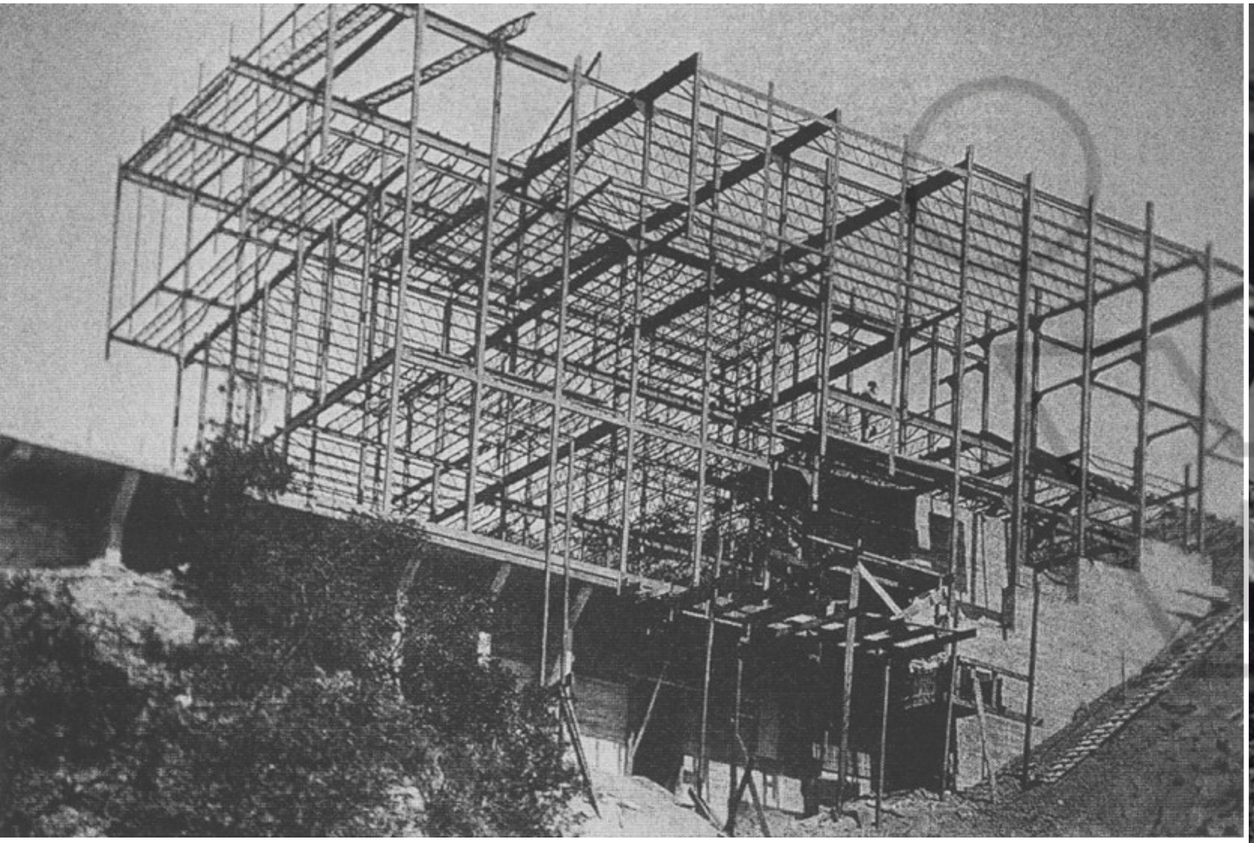
Philip Johnson, Glass House, New Canaan, CT (19

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



Sendai Mediatheque by Toyo Ito, 2003

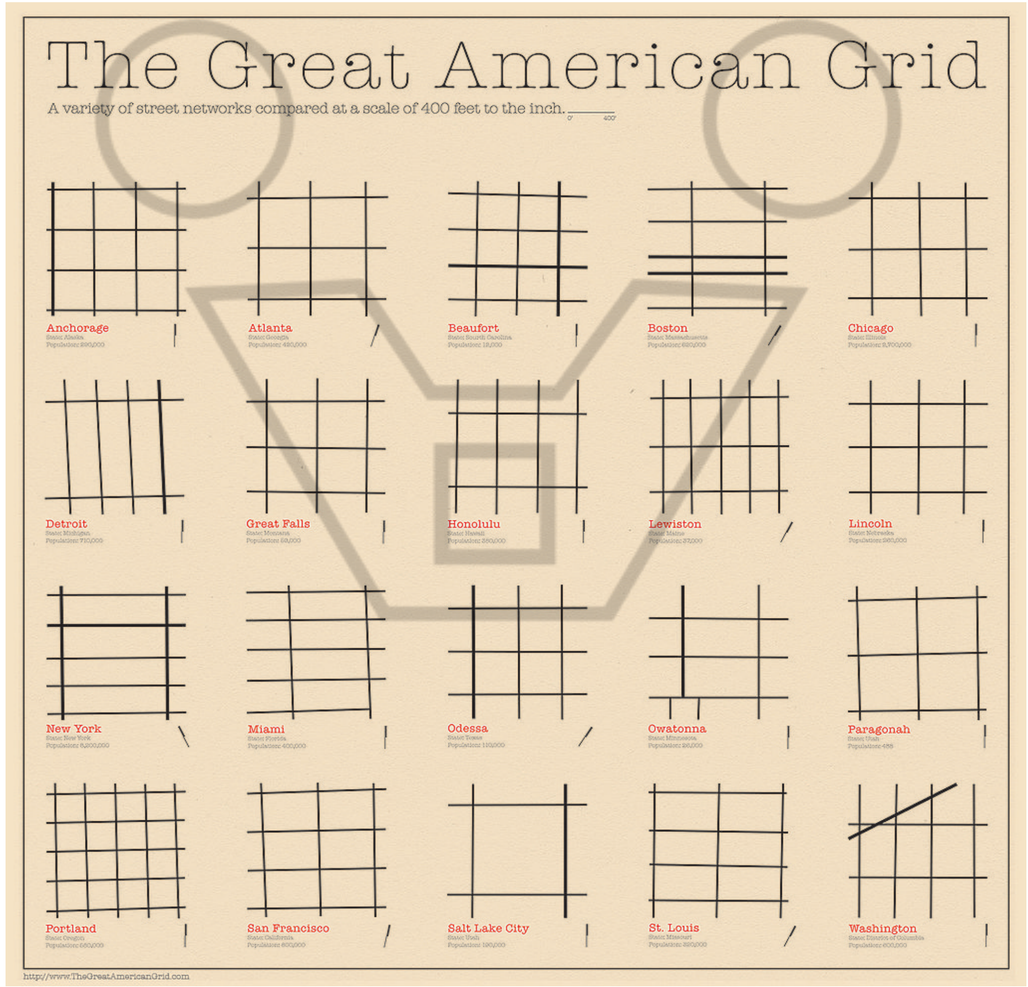
THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



R. Neutra,Lovell Health House, 1927-29

From Hippodamus of Miletus to president Jefferson

GRID AS A SPACE ORGANIZER & CONSTRUCTION COORDINATION

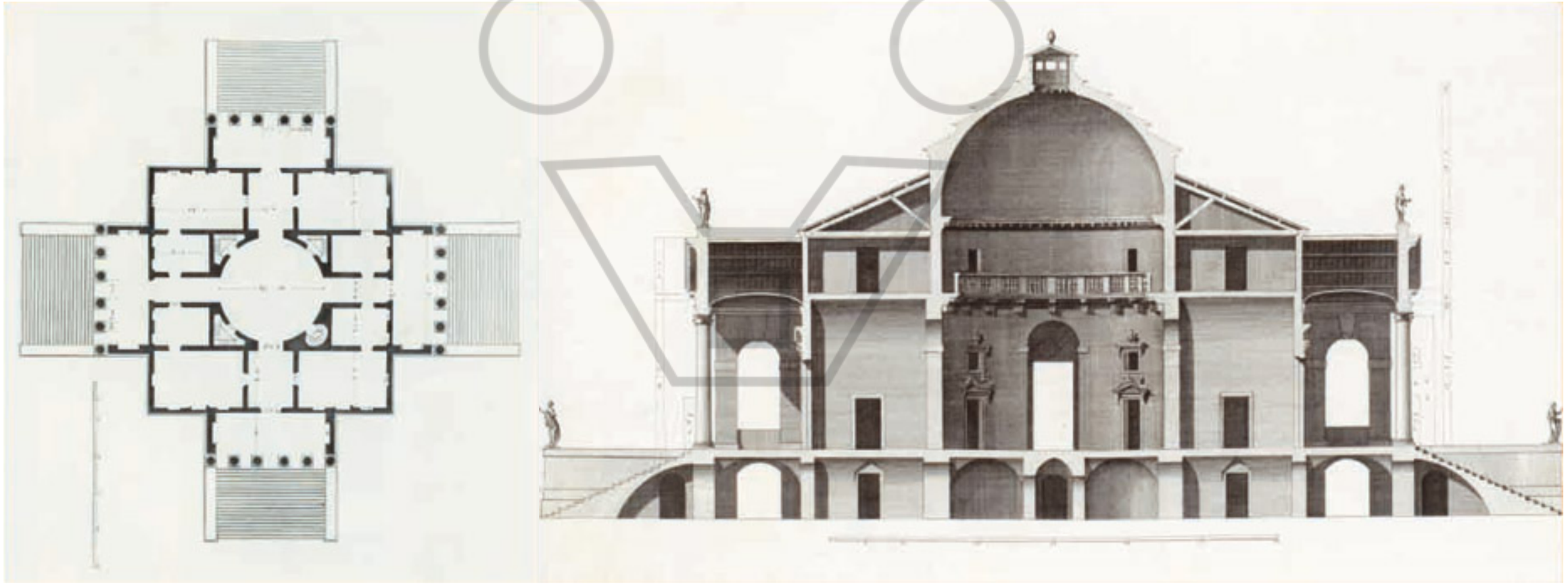


GRID AS A FORM MANIFESTATION

Park Hill is a council housing estate in Sheffield, England. Designed by Jack Lynn and Ivor Smith and built between 1957 and 1961

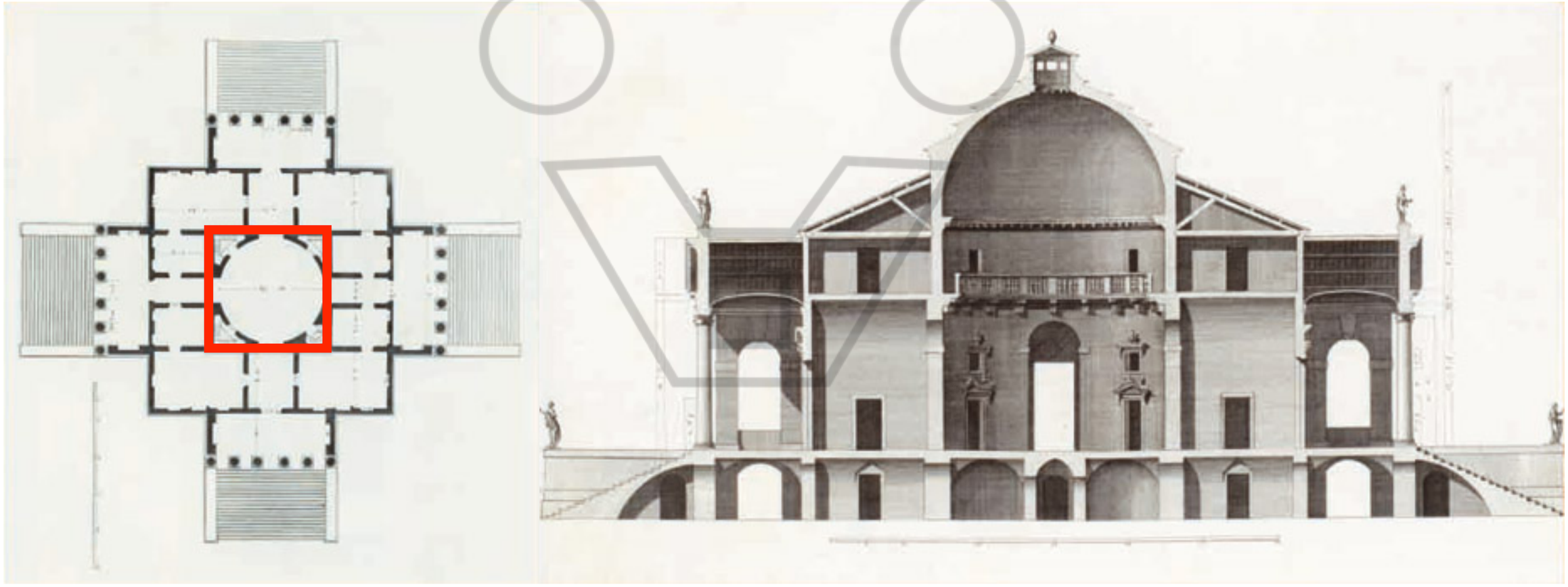
HARMONY AS A PRINCIPLE OF COMPOSITION

GRIDS | MODULES | RITHMS



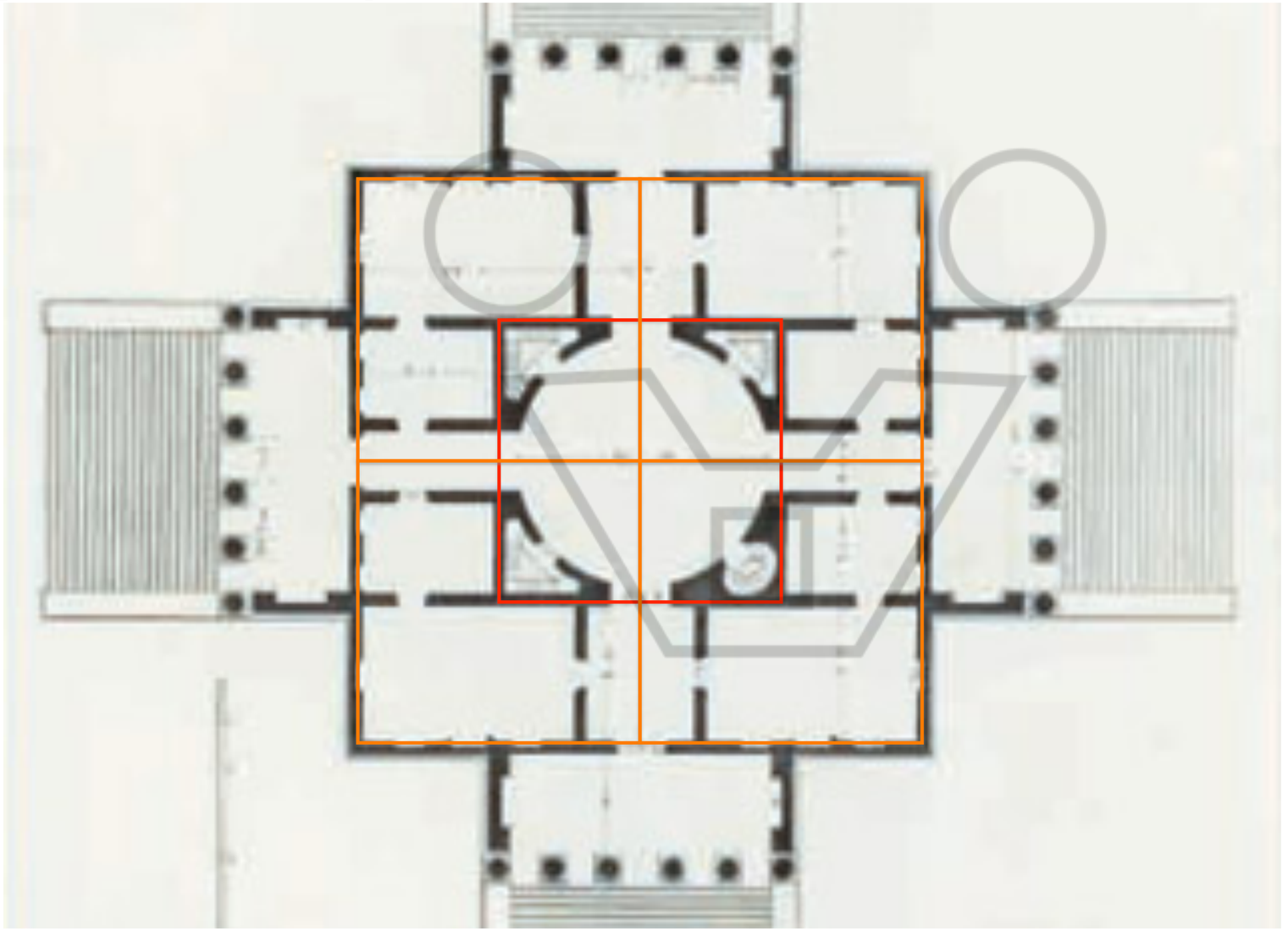
Andrea Palladio, Villa La Rotonda, 1566

GRIDS | MODULES | RITHMS



Andrea Palladio, Villa La Rotonda, 1566

GRIDS | MODULES | RITHMS

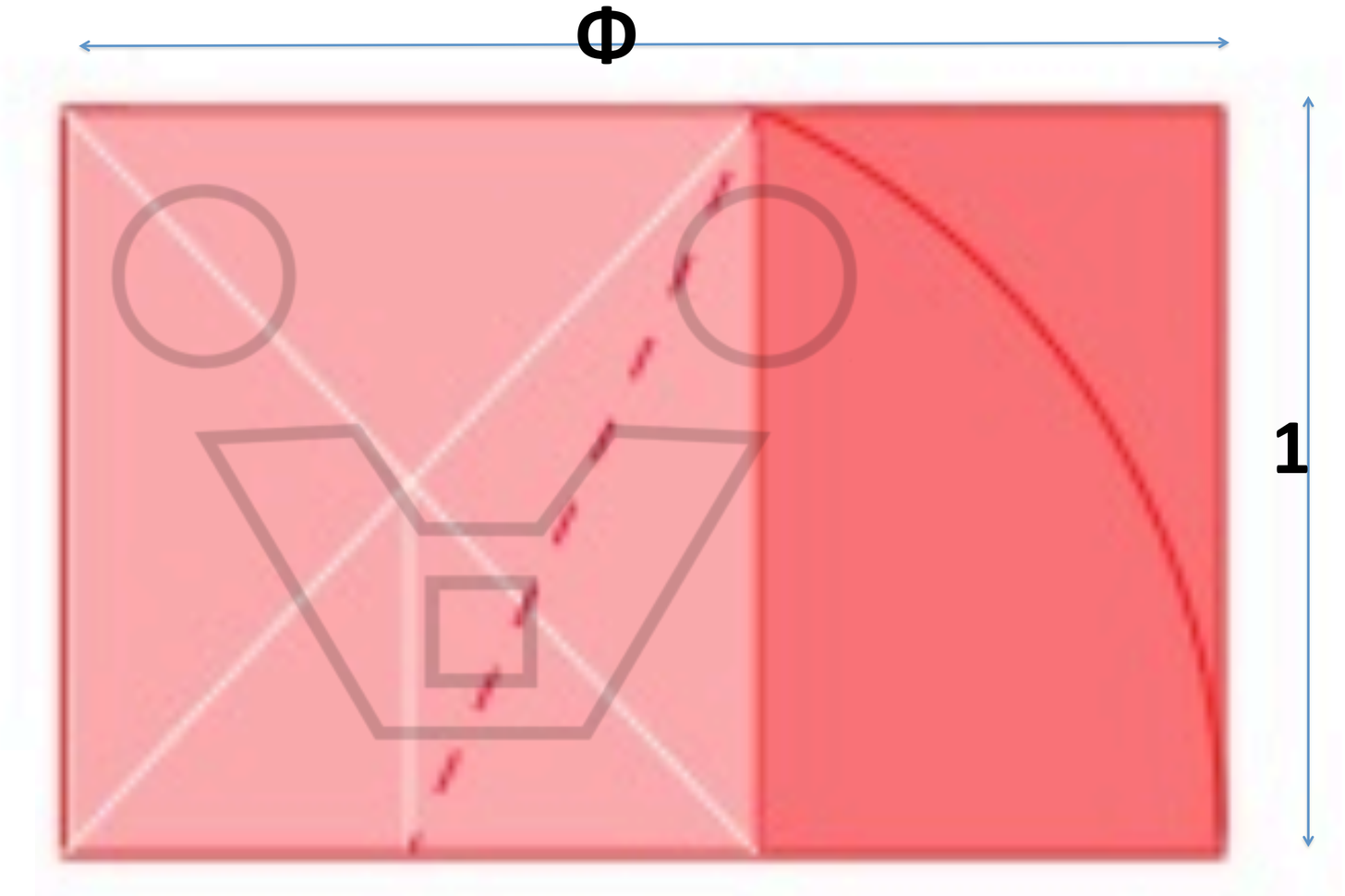


Andrea Palladio, Villa La Rotonda, 1566

The DIVINA PROPORTIONE

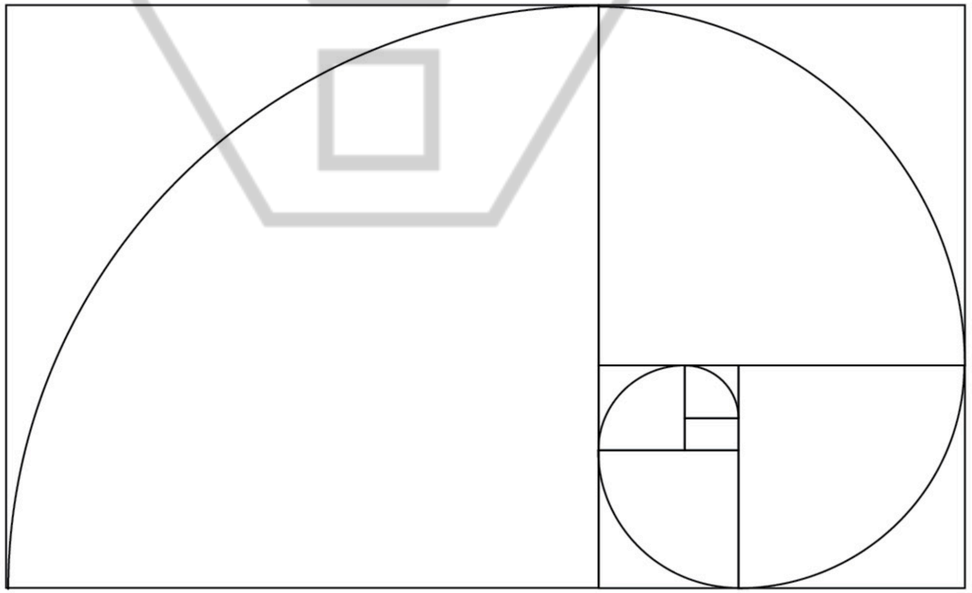
Andrea Palladio, Villa Emo, 1556-59

THE GOLDEN RATIO



$$\Phi = \frac{1+\sqrt{5}}{2} = 1{,}6180339887\ldots$$

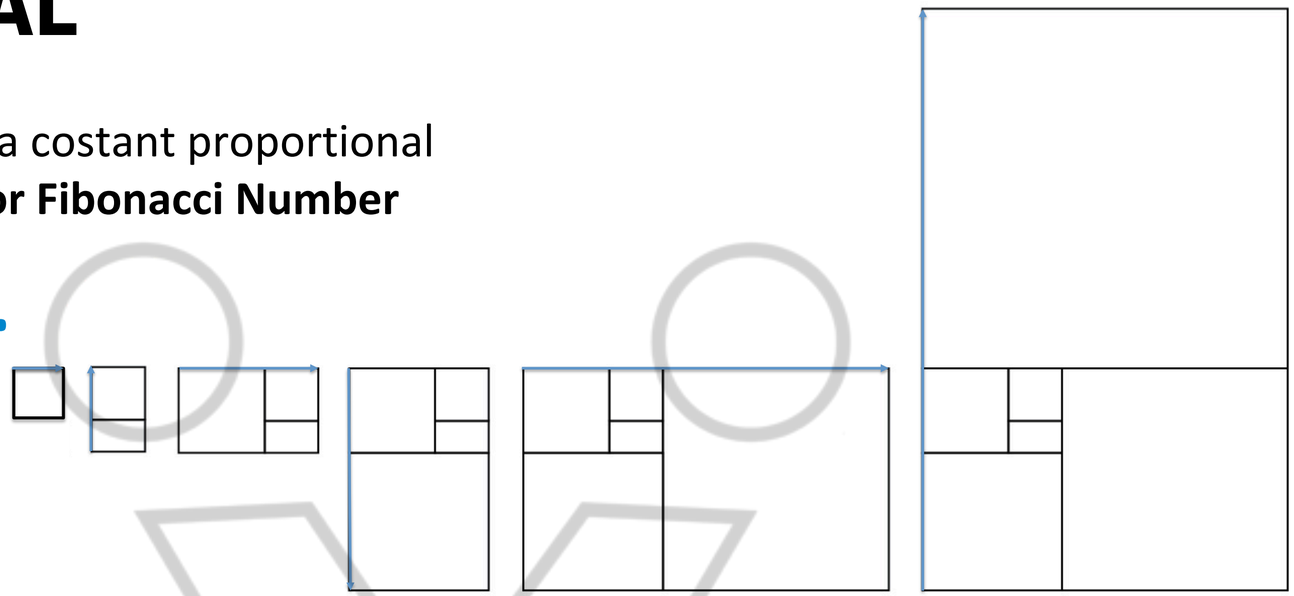
THE GOLDEN SPIRAL



THE GOLDEN SPIRAL

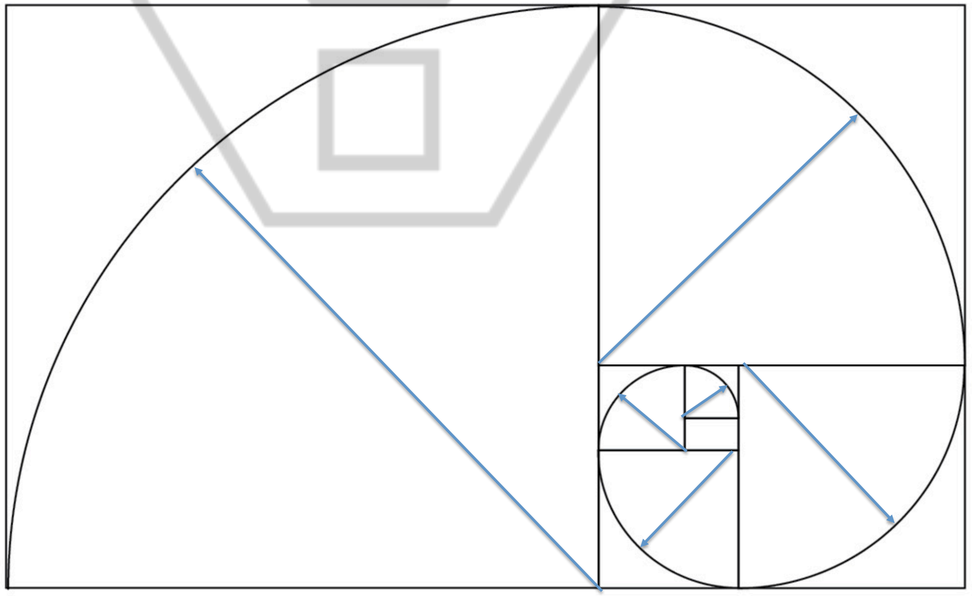
Where circle radius increases with a costant proportional value equal to the **Fidia's Number or Fibonacci Number**

Φ=1,6180339887…



$$\frac{1}{\Phi} = 0{,}6180339887\ldots$$

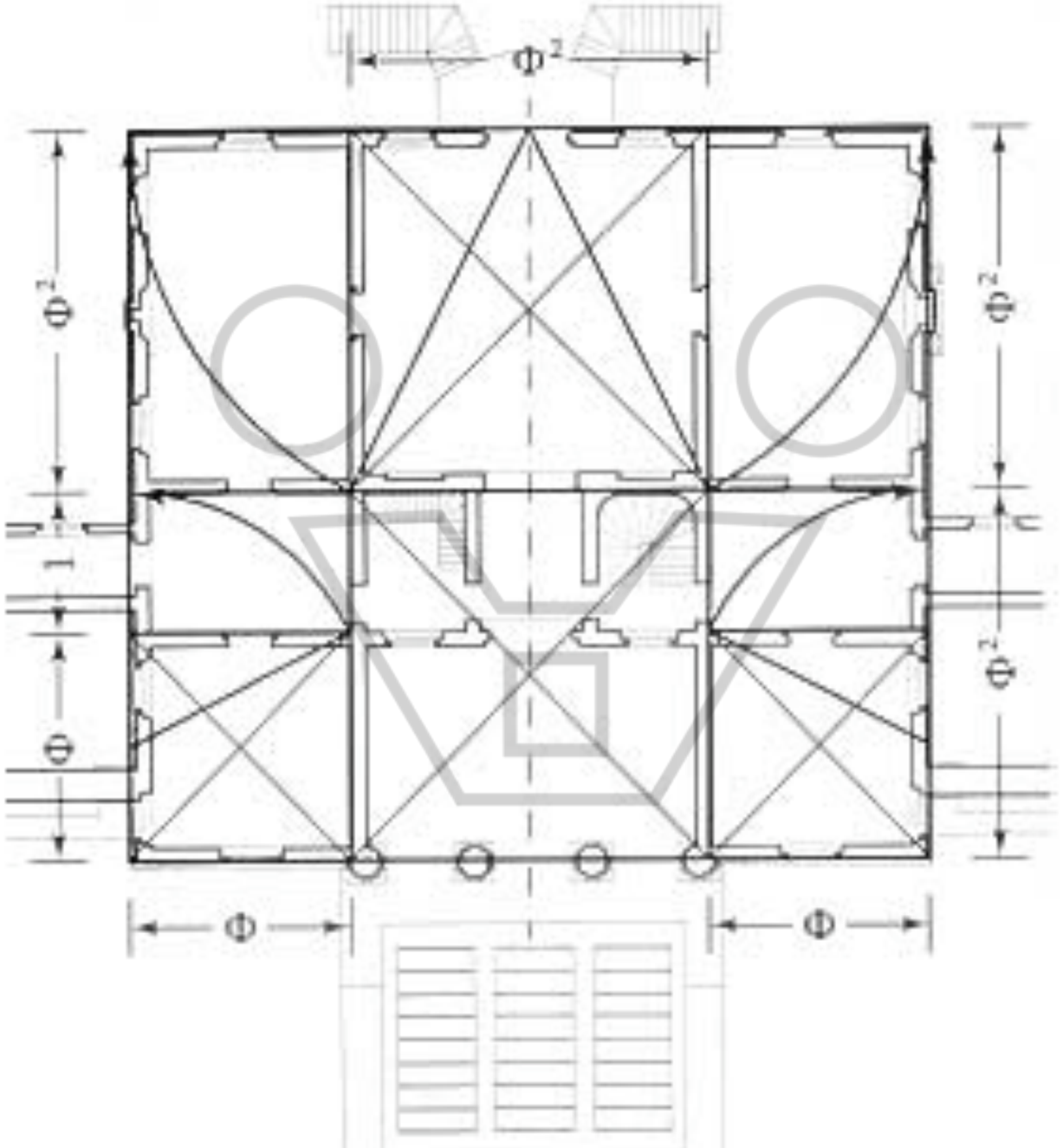
$$\Phi - 1 = 0{,}6180339887\ldots$$



1
1*Φ
(1*Φ)*Φ
((1*Φ)*Φ)*Φ

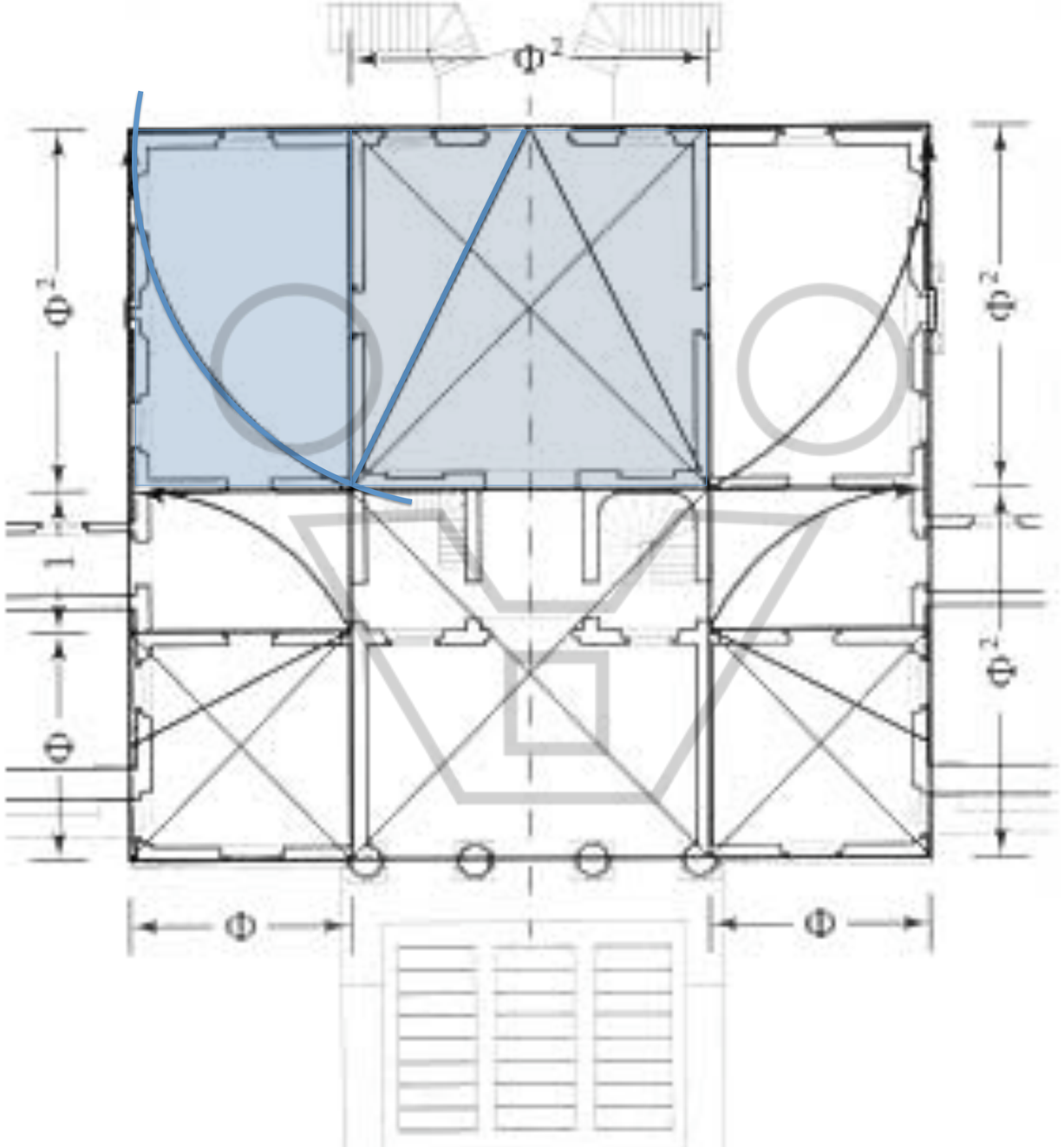
……

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



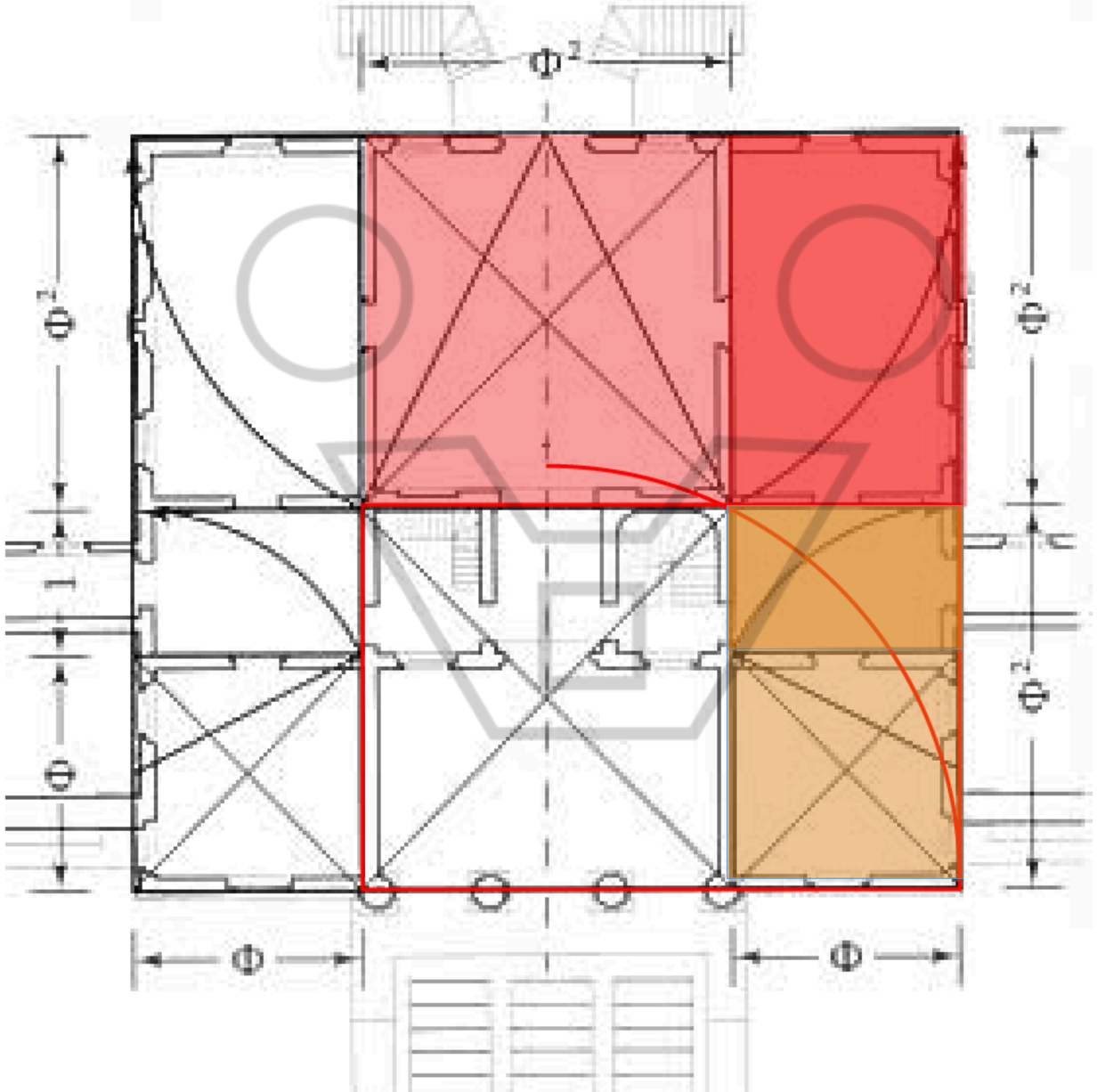
Andrea Palladio, Villa Emo, 1556-59

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



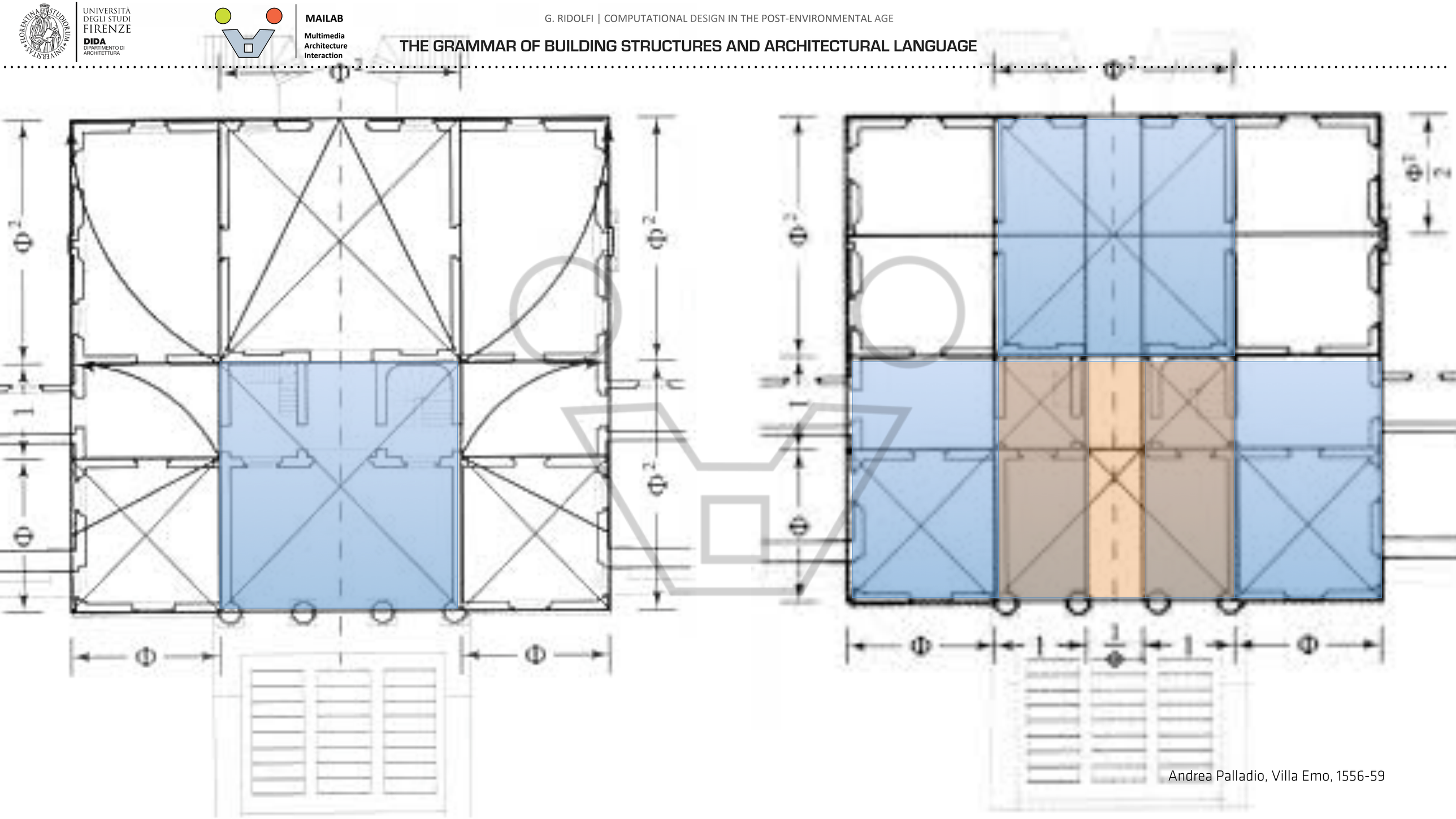
Andrea Palladio, Villa Emo, 1556-59

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



Andrea Palladio, Villa Emo, 1556-59

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



Andrea Palladio, Villa Emo, 1556-59

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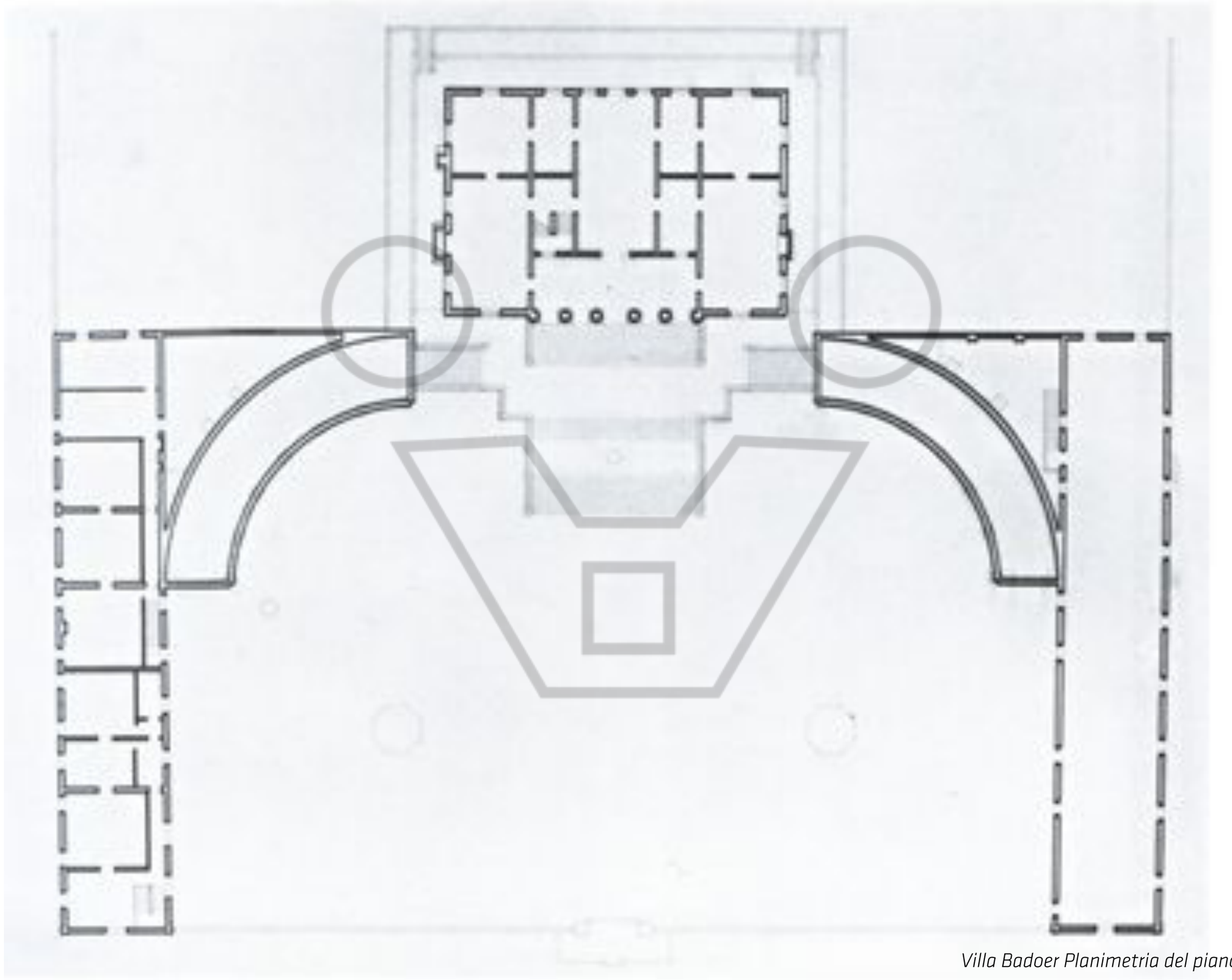
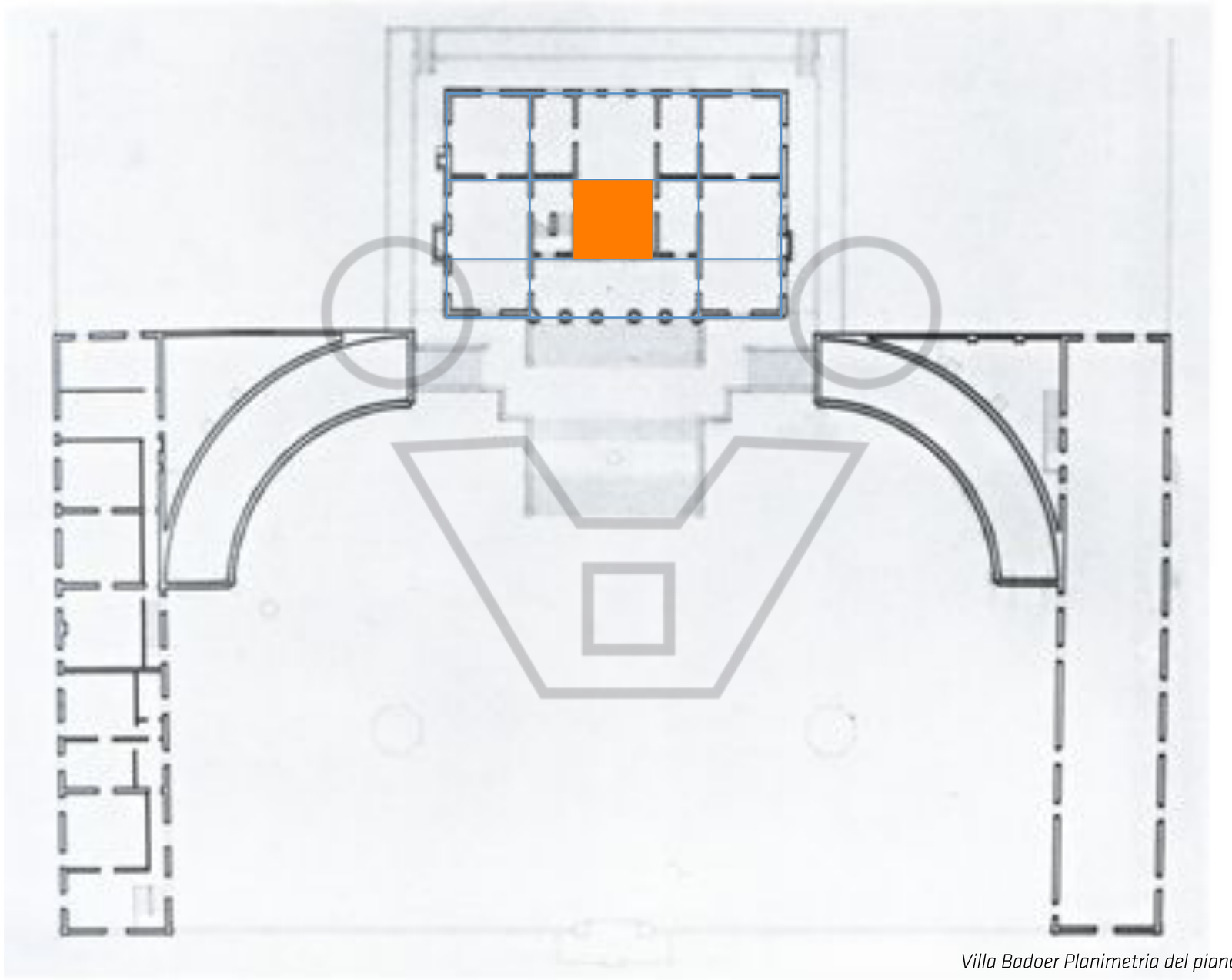
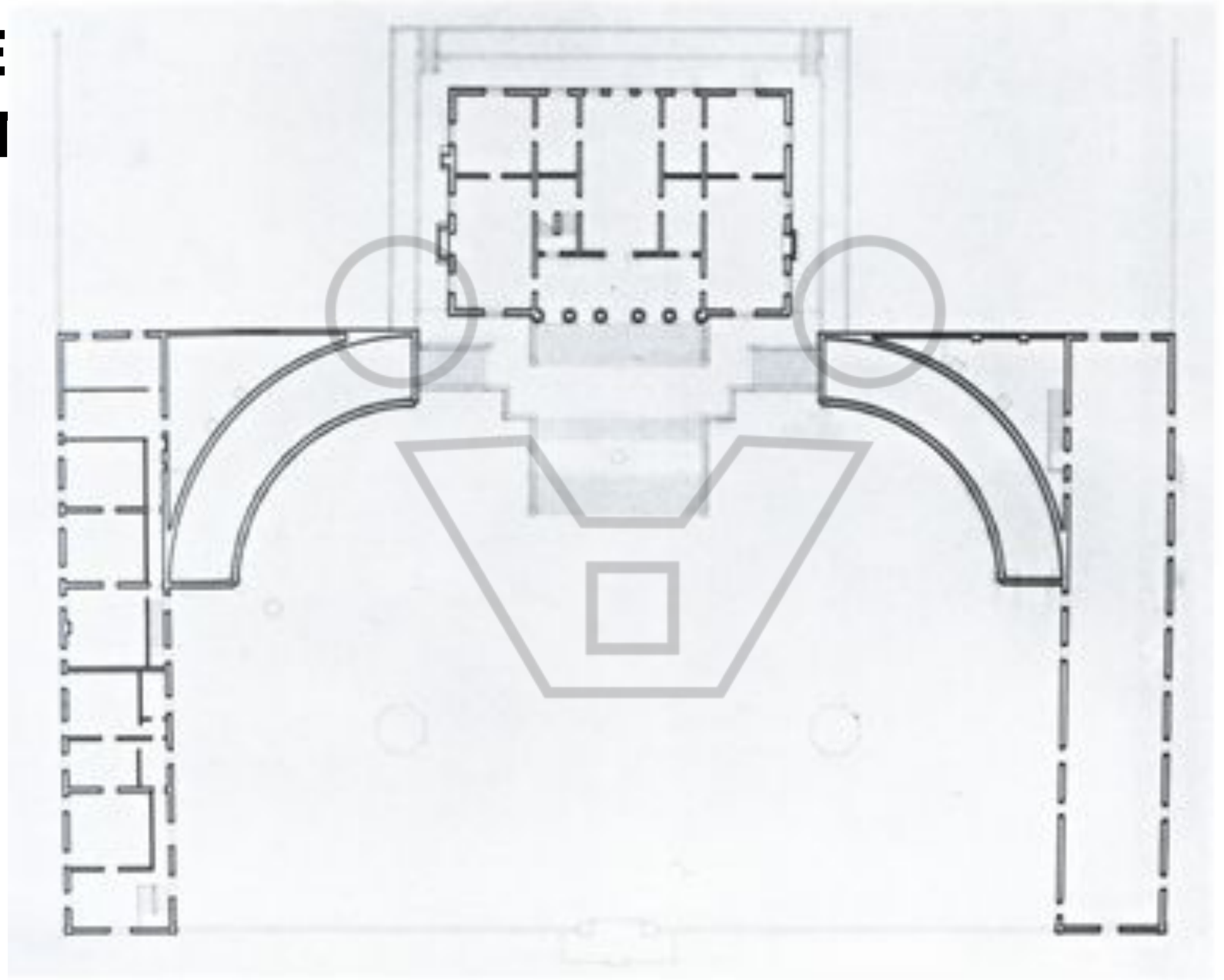


Villa Badoer Planimetria del piano nobile (A. e E. Pereswet Soltan, 1967).

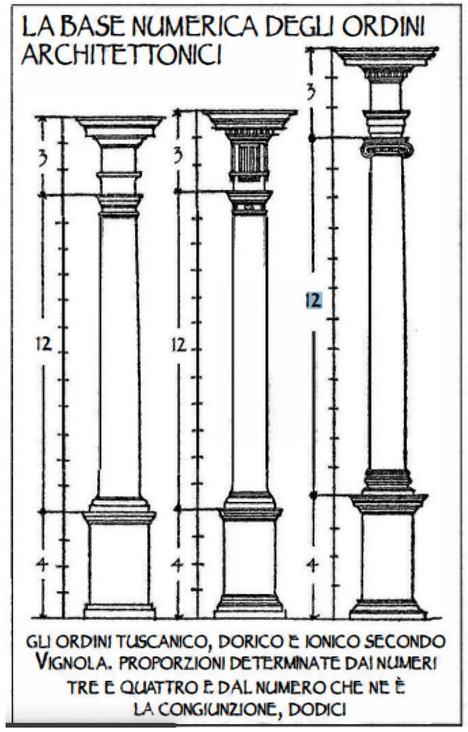


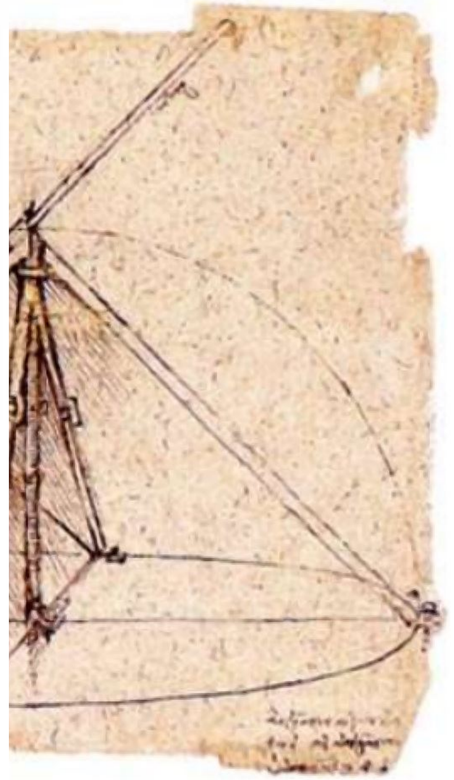
Villa Badoer Planimetria del piano nobile (A. e E. Pereswet Soltan, 1967).

ARCHITE
DESIGN T



on is different from scale

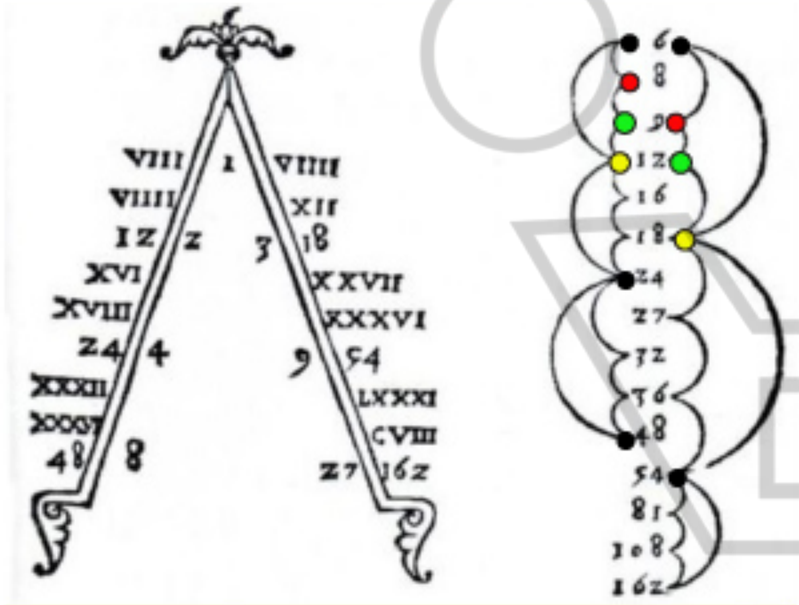




un suo disegno (1514).

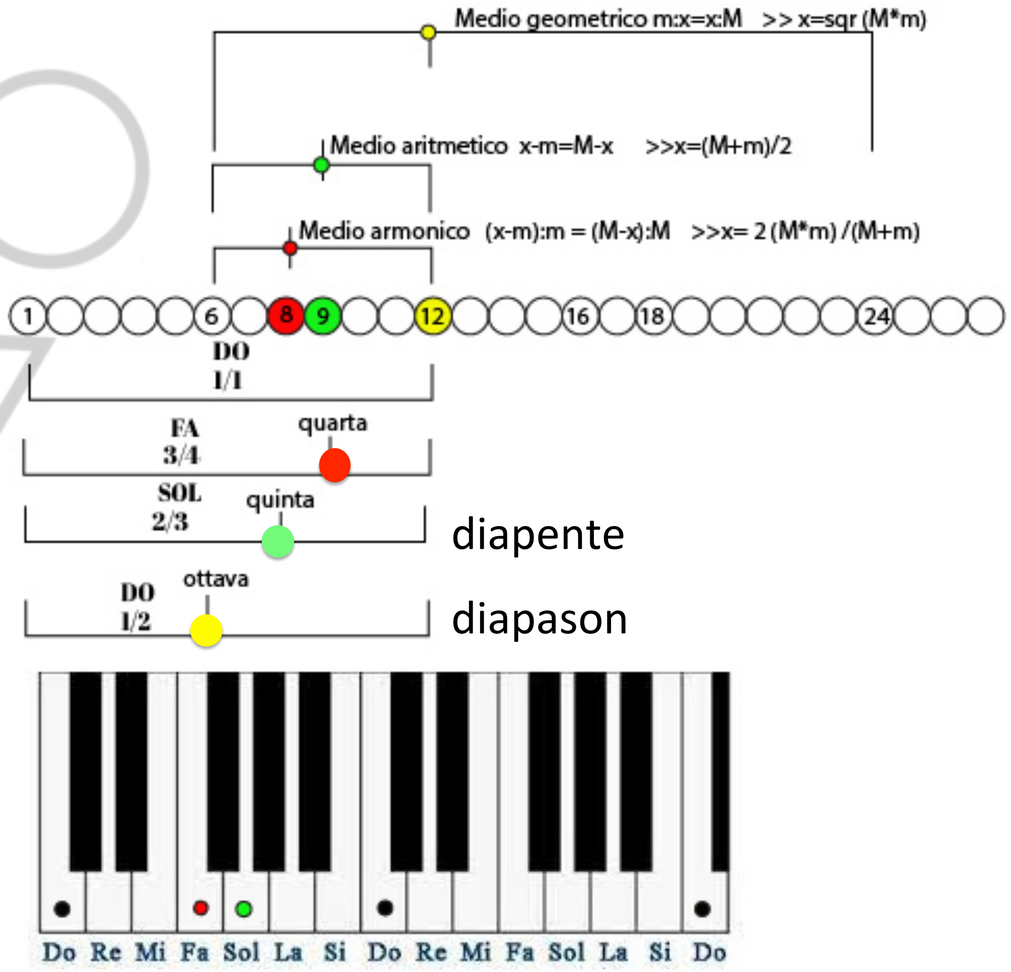
ARCHITECTURE OF PROPORTIONS AND DESIGN THROUGH DRAWING COMPASS

Tabulcain, Pitagora e Filolao

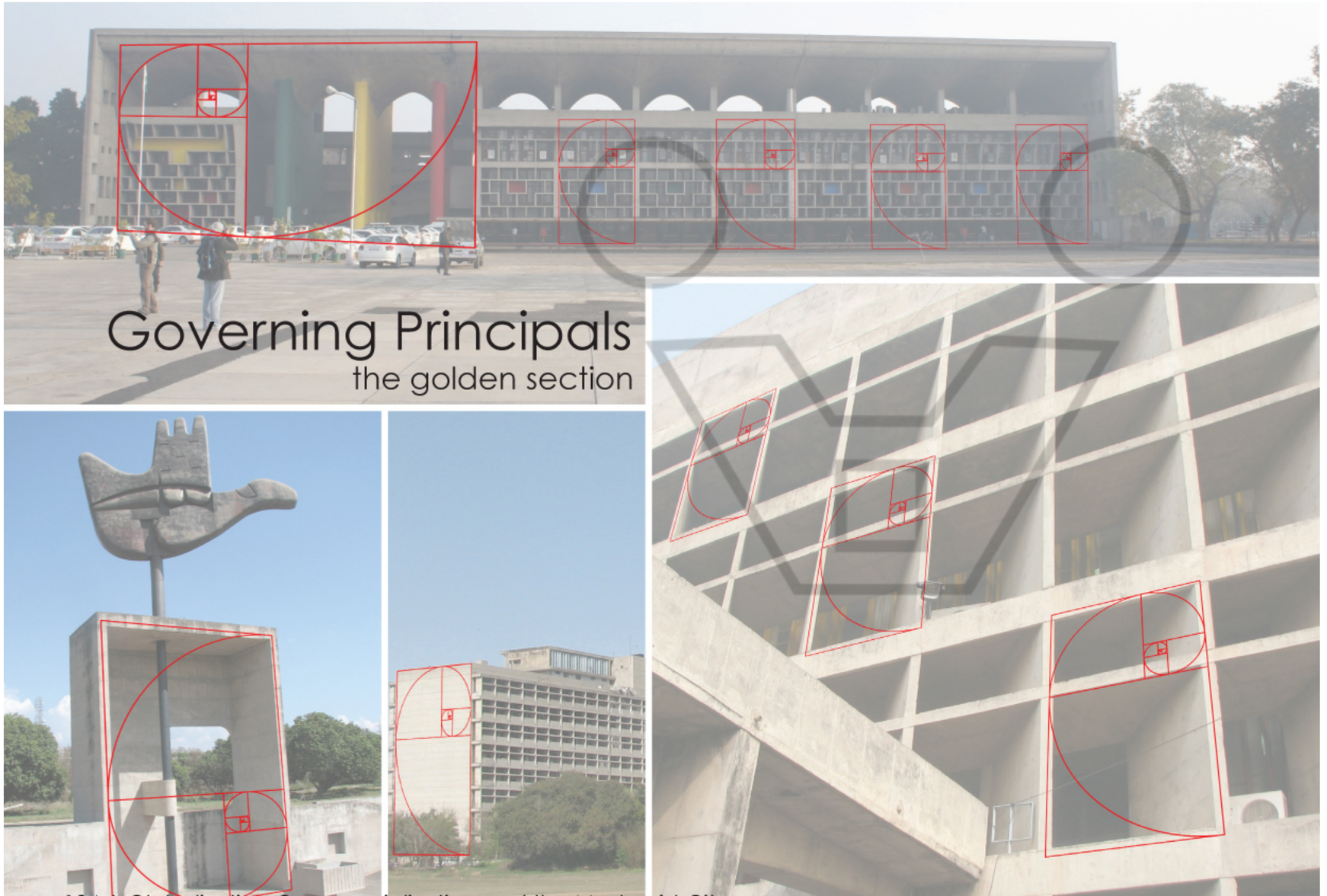


LAMBDA ARMONIA DEL MONDO O EPTACORDO PITAGORICO-PLATONICO

Fig. Diagramma delle consonanze armoniche di Francesco Giorgi.

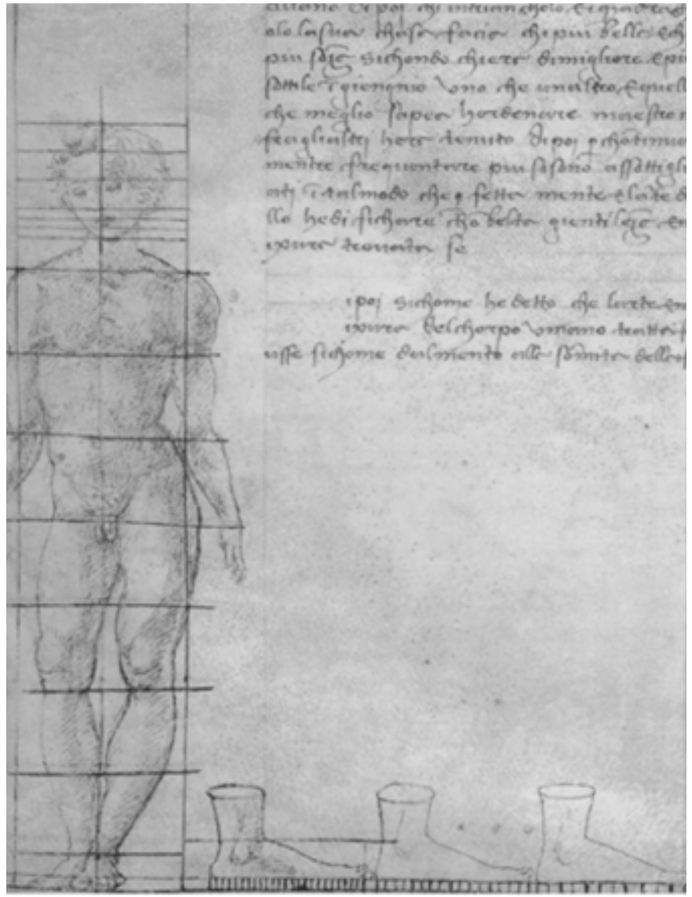


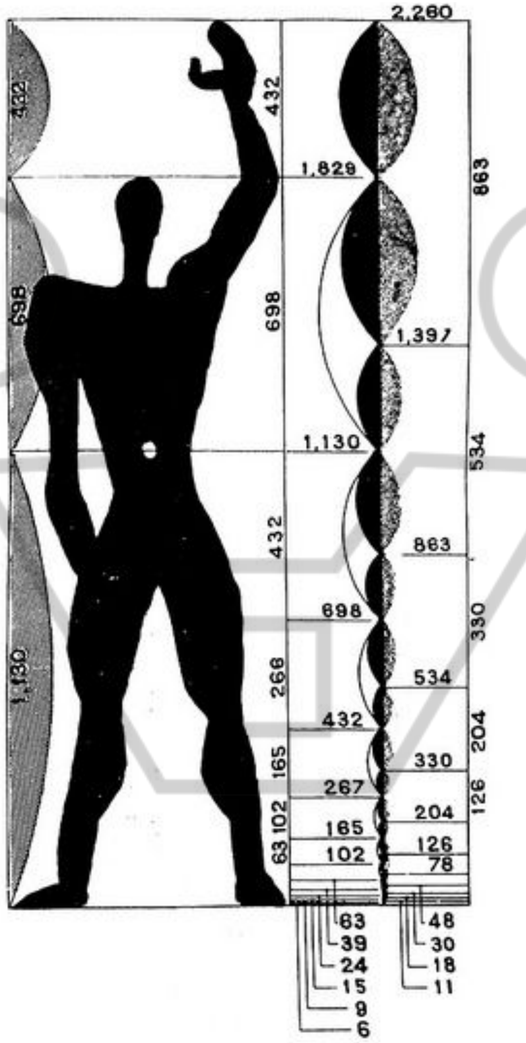
ARCHITECTURE OF MEASURES AS PROPORTIONS: the *CANONE**



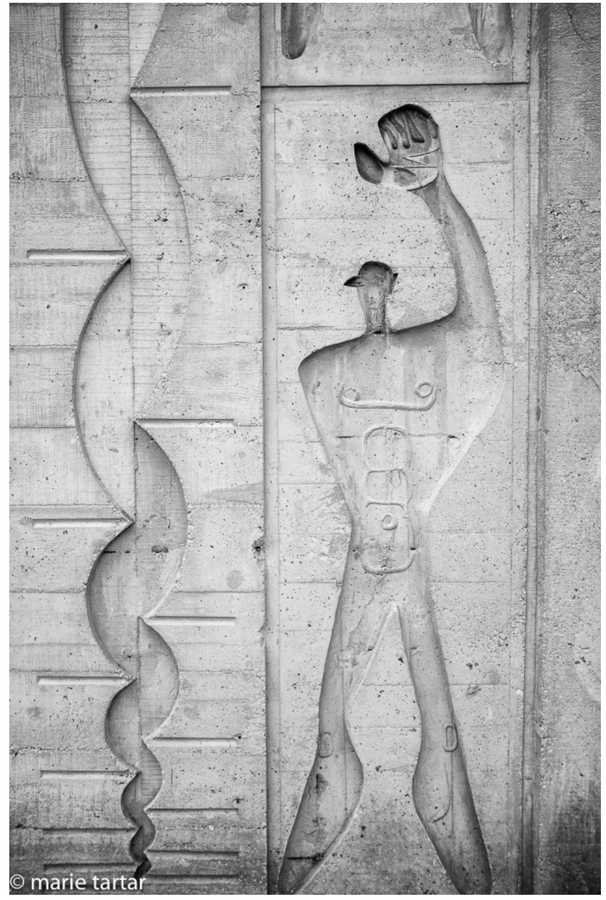
**) a metaphysical concept of beauty, and originates from the theory and sculptures of Polykleitos (Greek sculptor, 5c. B.C.).*

ARCHITECTURE OF MEASURES AS PROPORTIONS: the *CANONE*





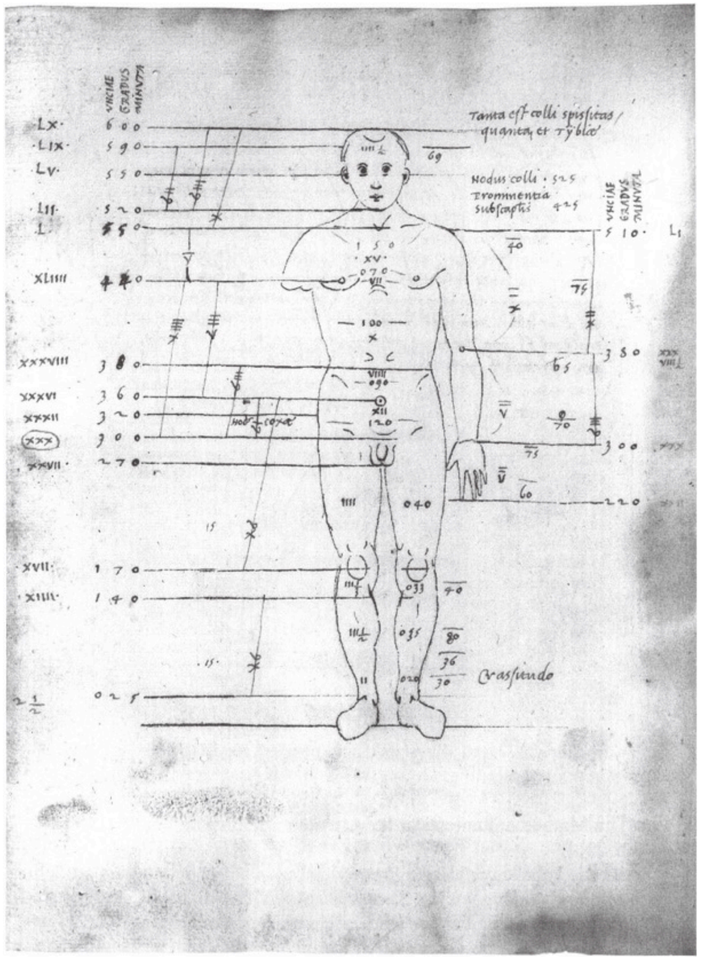
"... este novo instrumento (o modulor) tem como objetivo primordial unir, reunir e harmonizar o trabalho dos homens que, neste momento, estão precisamente desunidos... prova disto é a presença de dois sistemas que dificilmente se conciliam: o pé-polegada dos anglo-saxónicos de um lado, e o sistema métrico, de outro..." (citação de Le Corbusier, in "Caminhos da Arquitetura", Vilanova Artigas, FVA/Pini)



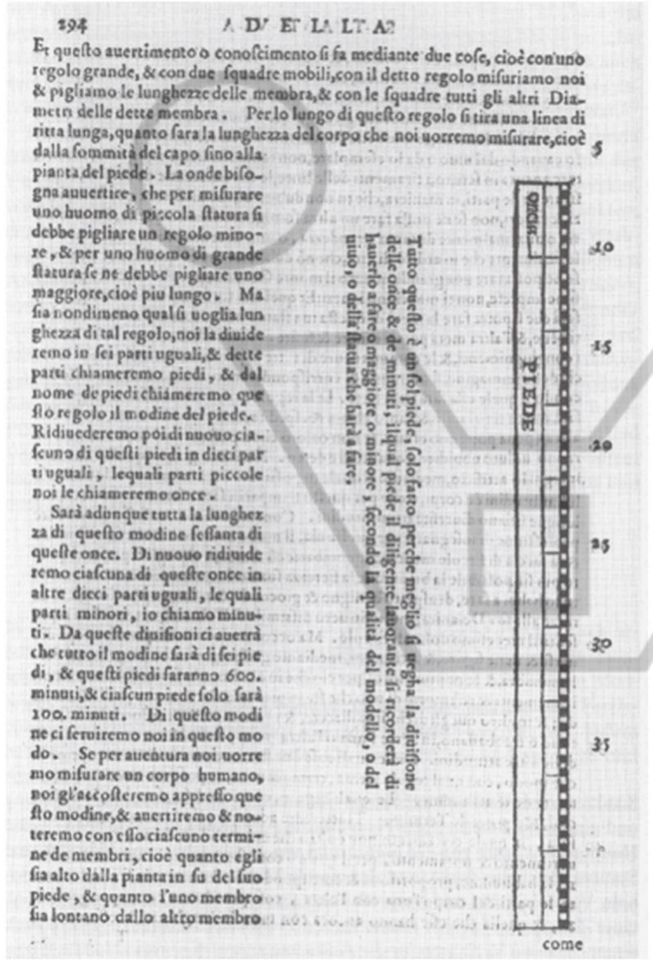
FROM the *CANONE TO COUNTABLE QUANTITY : the NUMBER LINE*

The EXEMPEDA RULER: A QUASI-DECIMAL SYSTEM (1 Exempeda = 6 Pedes = 60 Unceolae = 600 Minuta)

1 1/ 6 1/60 1/600



Alberti's Proportion figure, an ink drawing from the manuscript of **De Statua**, 15c later, Oxford, Bodleian Library, University of Oxford, Ms. Canon. Misc 172, fol. 232v.

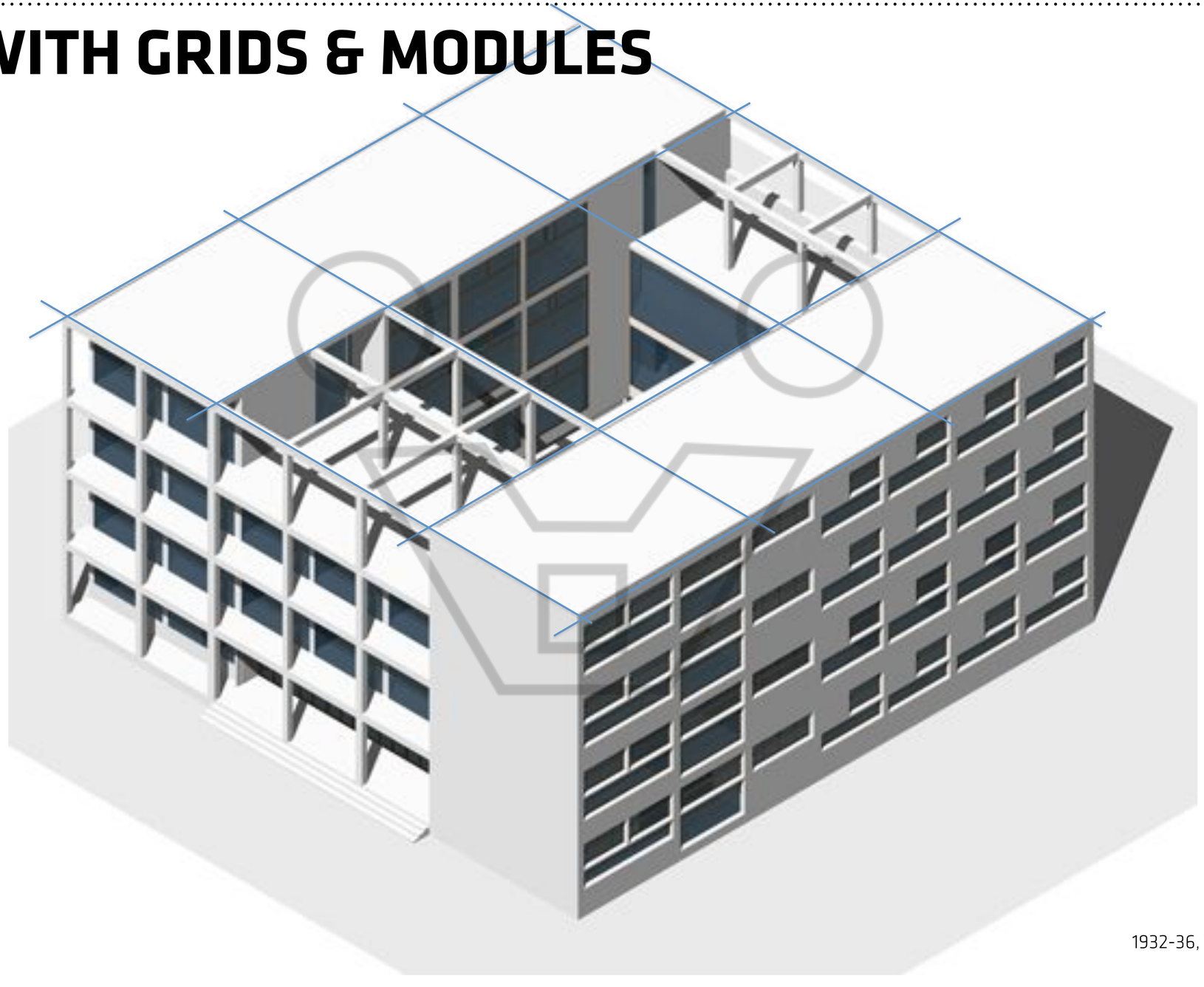


The "Exempeda" from L.B.Alberti, **Opuscoli morali**, 1568 p.294, Vatican, Biblioteca Apostolica Vaticana.

	The Height from the sole of the foot	Pedes	Gradus	Minuta	Decimal Fraction
1	to the greatest height of the instep	0	3	0	0.05
2	to the outside of the malleolus	0	2	2	0.036···
3	to the inside of the malleolus	0	3	1	0.051···
4	to the ankle	0	8	5	0.141···
5	to the popliteal	1	4	3	0.238···
6	to the joint of knees	1	7	0	0.283 ···
7	to the testicles and the nates	2	6	9	0.448···
8	to the pubis	3	0	0	0.5
9	**to the tuber of sciatic joint**	3	1	5	0.525
10	to the navel	3	6	0	0.6
11	to the waist measurement	3	7	5	0.625
12	to the mammilla and the solar plexus	4	3	5	0.725
13	to the joint of the throat	5	0	0	0.833···
14	to the tuber of the neck	5	1	0	0.85
15	to the chin	5	2	0	0.866···
16	to the bottom of the thoracic vertabrae	4	2	5	0.708···
17	to the ear hole	5	5	0	0.916···
18	to the hairline above the forehead	5	9	0	0.983···
19	from the chin to the vertex	0	8	0	0.133···
20	from the chin to the ear hole	0	3	0	0.05

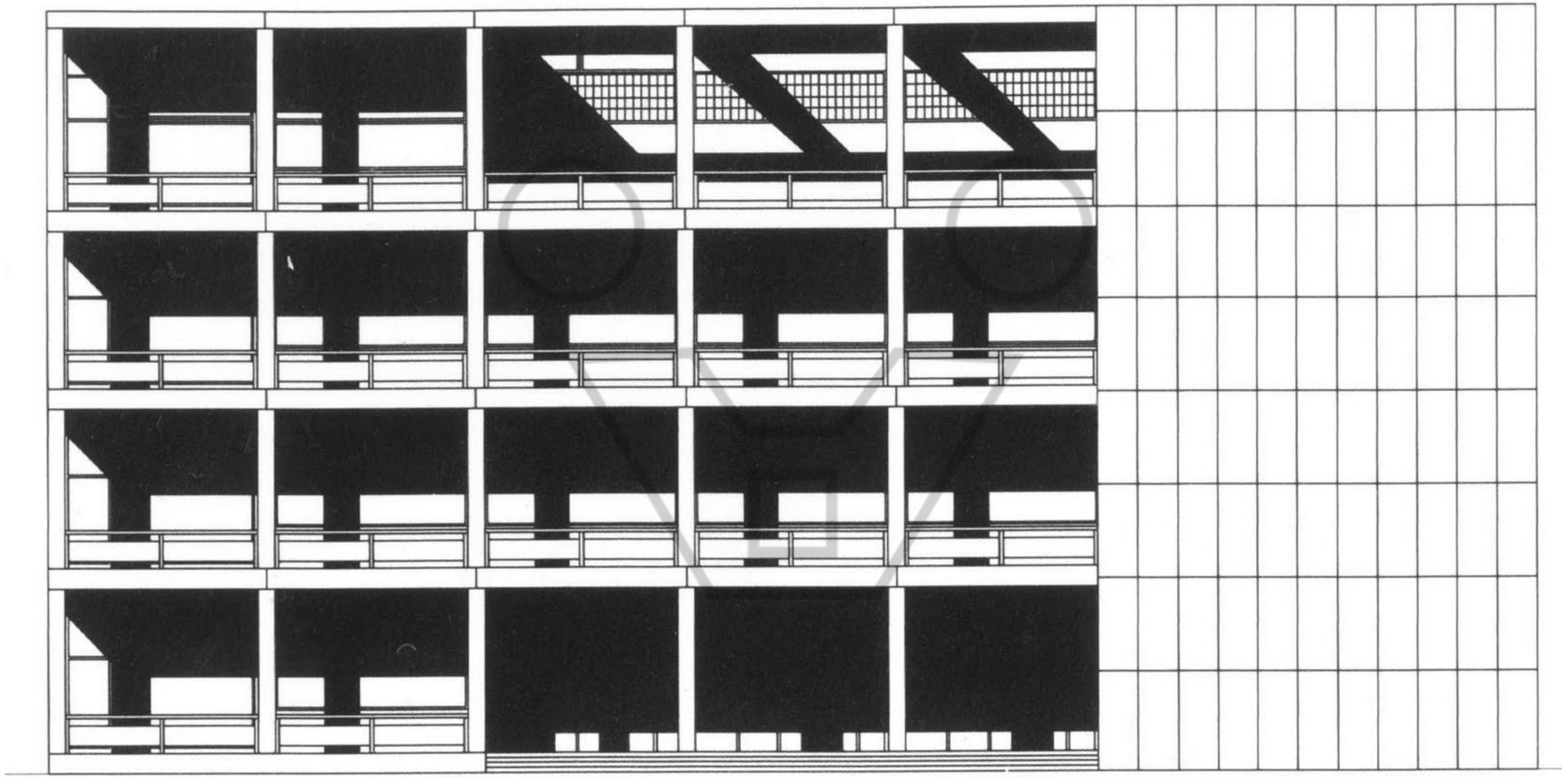
[Table.1]
The Table of the measurement of the human body (part)

PLAYING WITH GRIDS & MODULES

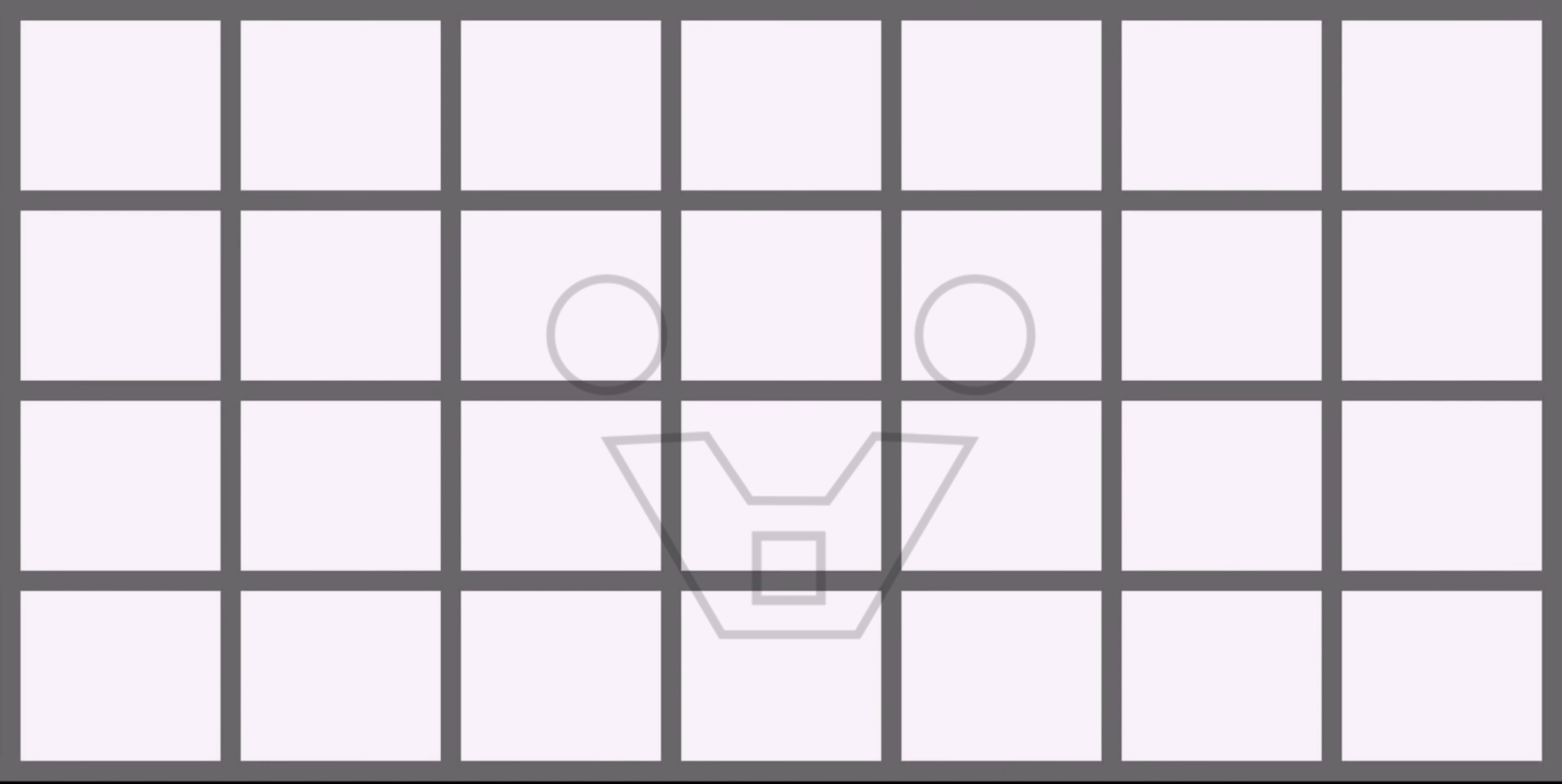


1932-36, Terragni, Como, Casa del Fascio

PLAYING WITH GRIDS & MODULES

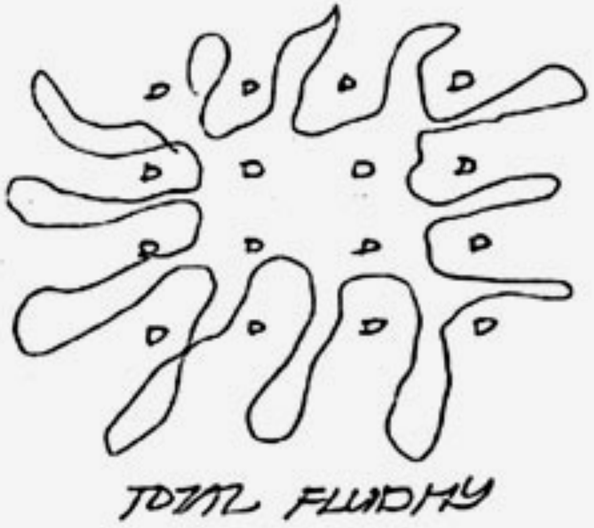


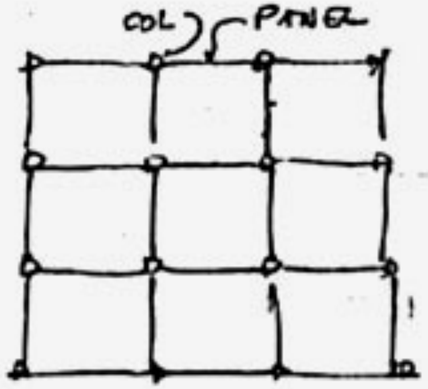
1932-36, Terragni, Como, Casa del Fascio

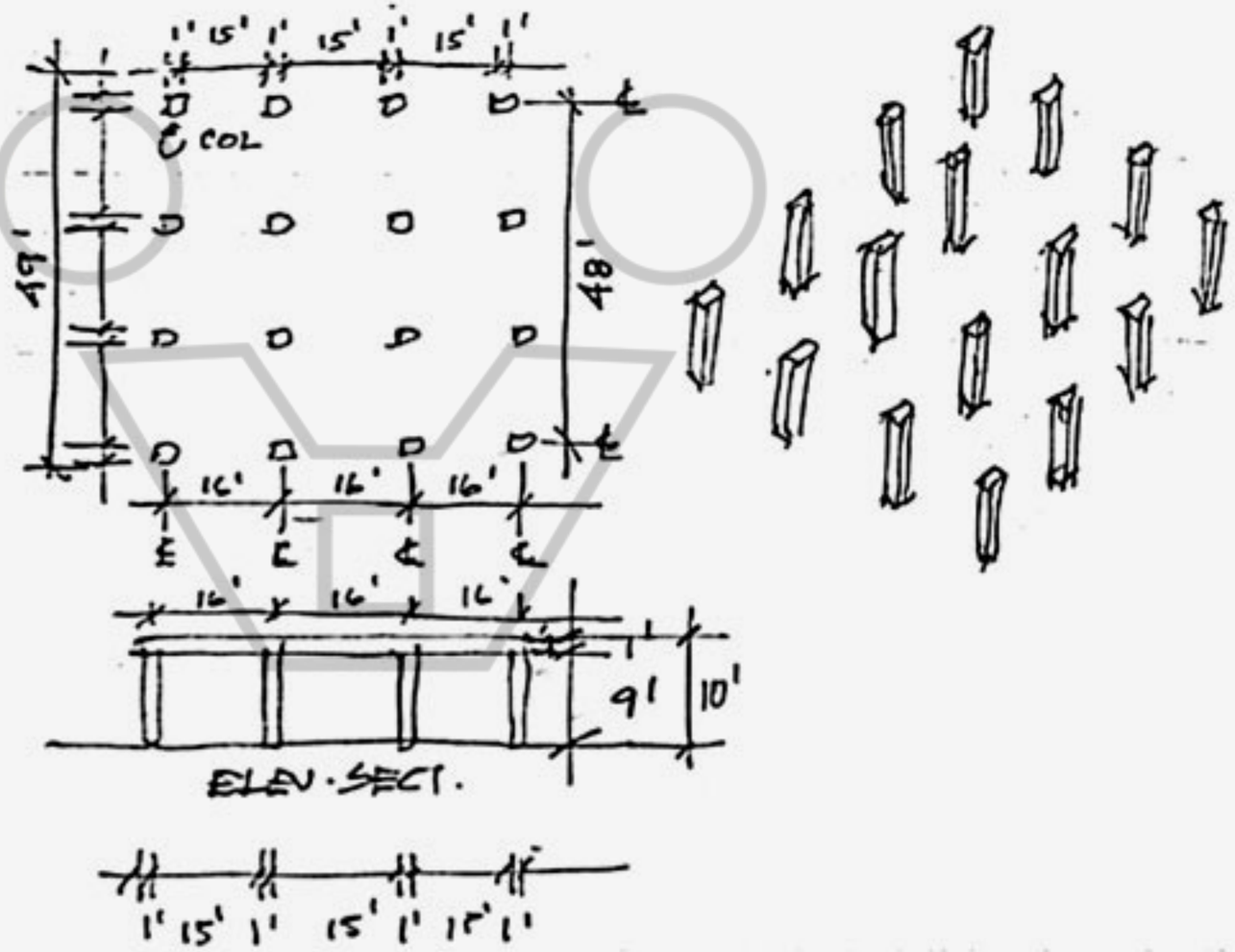


PLAYING WITH GRIDS & MODULES

Initial instructions for the 9-Square-Grid exercise.



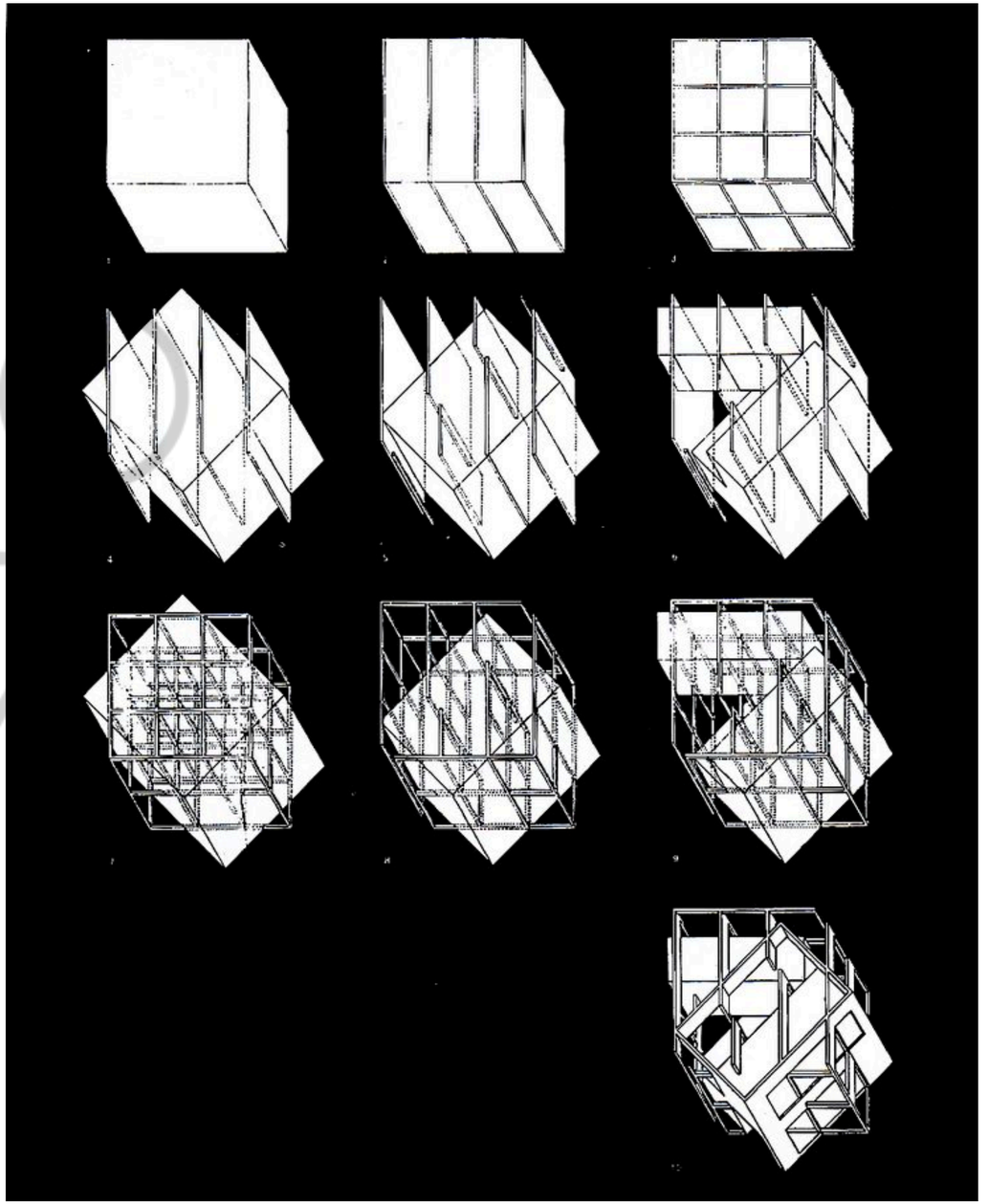




Robert Slutzky, John Hejduk, Colin Rowe and Lee Hirsche, NINE-SQUARE GRID, 1954-58

PLAYING WITH GRIDS & MODULES

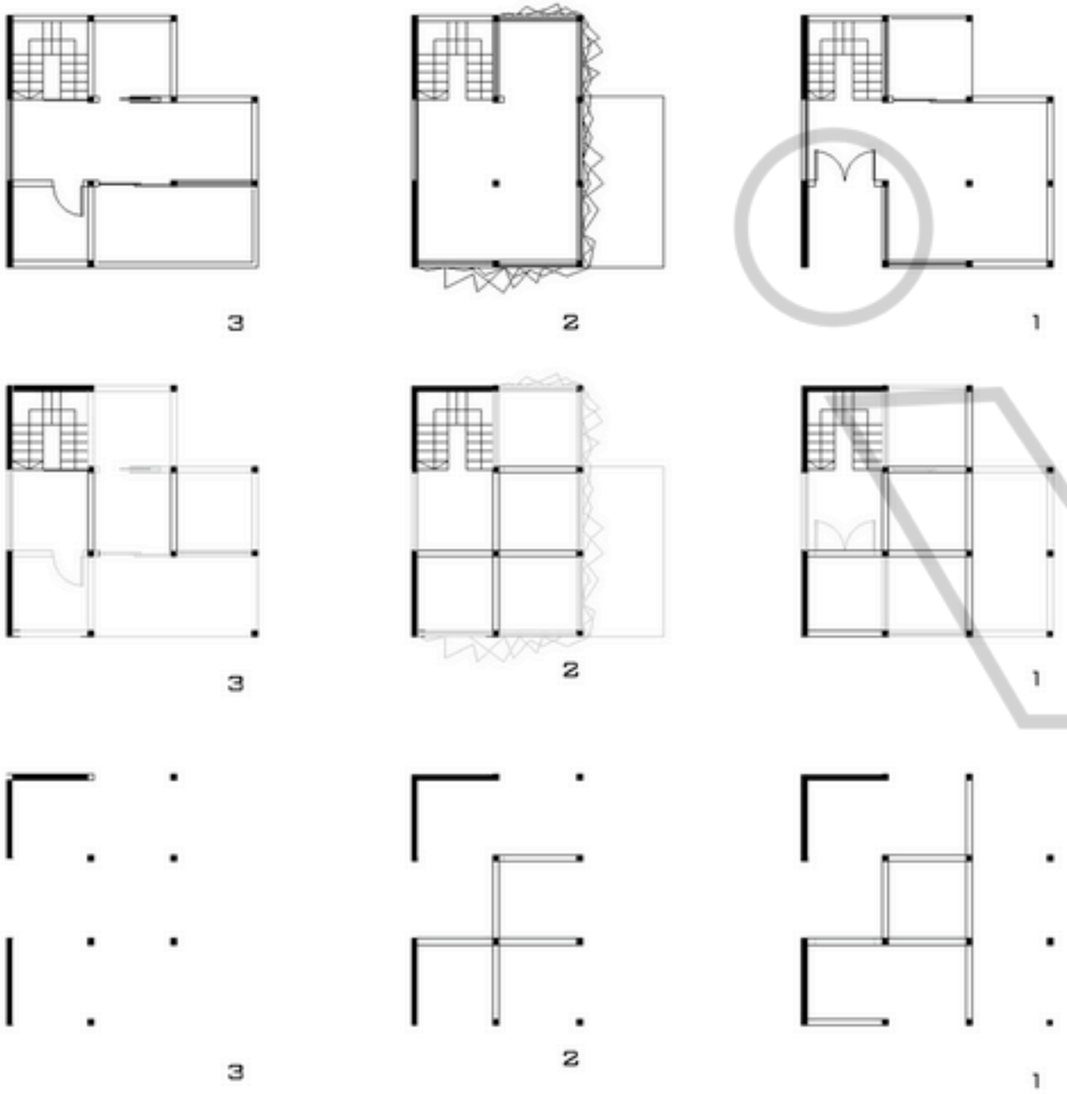
HORIZONTAL ROTATION

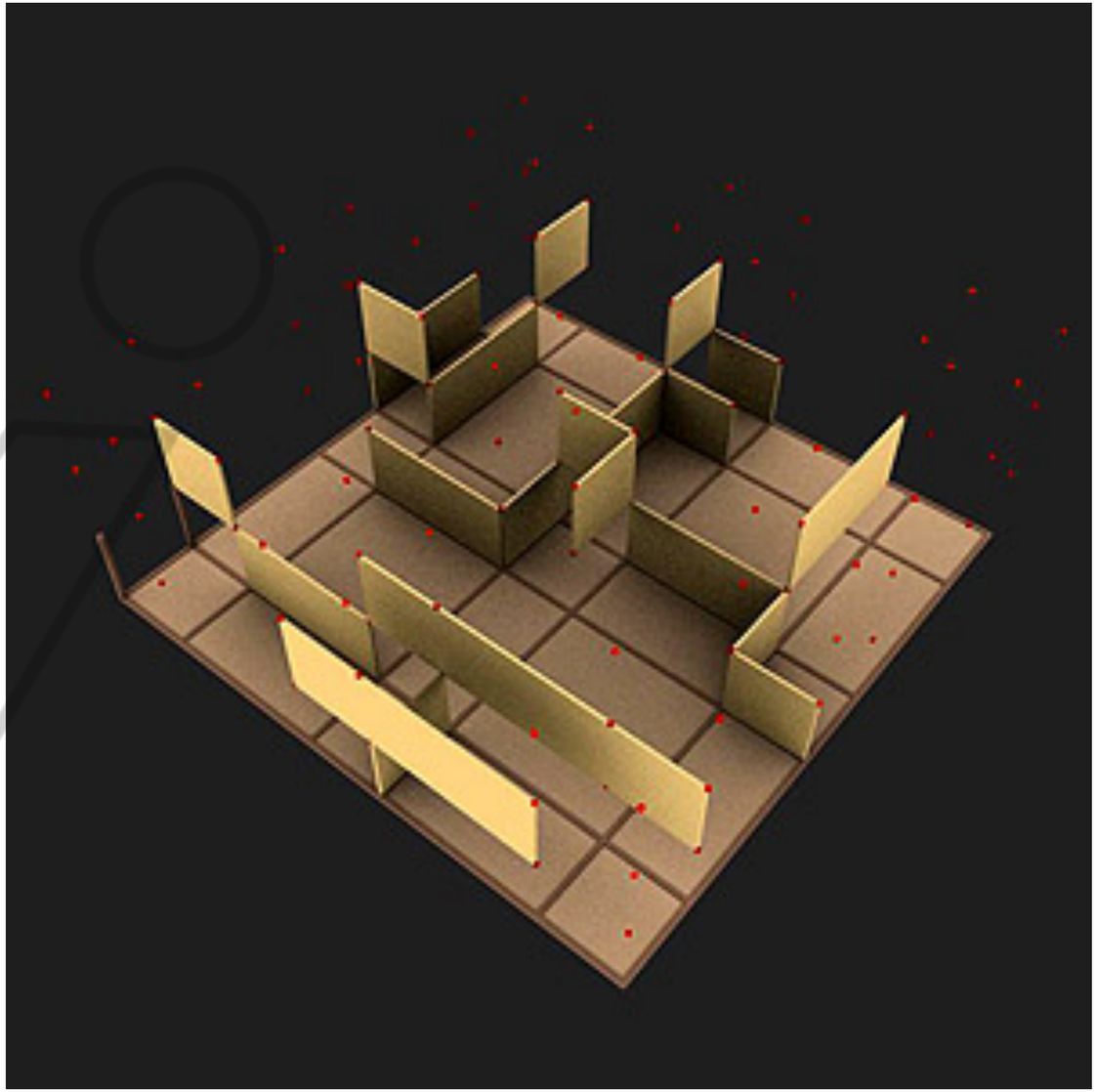


Robert Slutzky, John Hejduk, Colin Rowe and Lee Hirsche, NINE-SQUARE GRID.

PLAYING WITH GRIDS & MODULES

SHIFTING & SUBTRACTION



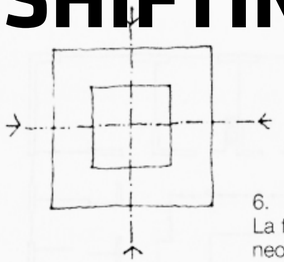


Robert Slutzky, John Hejduk, Colin Rowe and Lee Hirsche, NINE-SQUARE GRID.

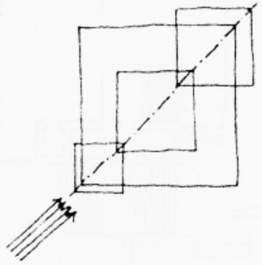
SHIFTING AND VOIDS

Damian Ortega's Cosmic Thing

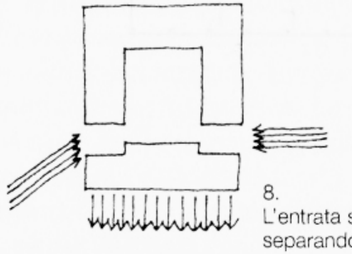
SHIFTING AND VOIDS



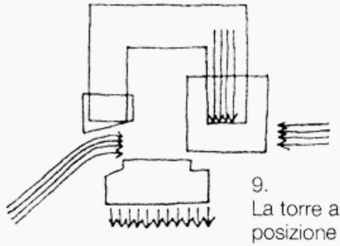
6.
La funzione interna suggerisce un solido rettilineo dal quale è stato estratto il centro.



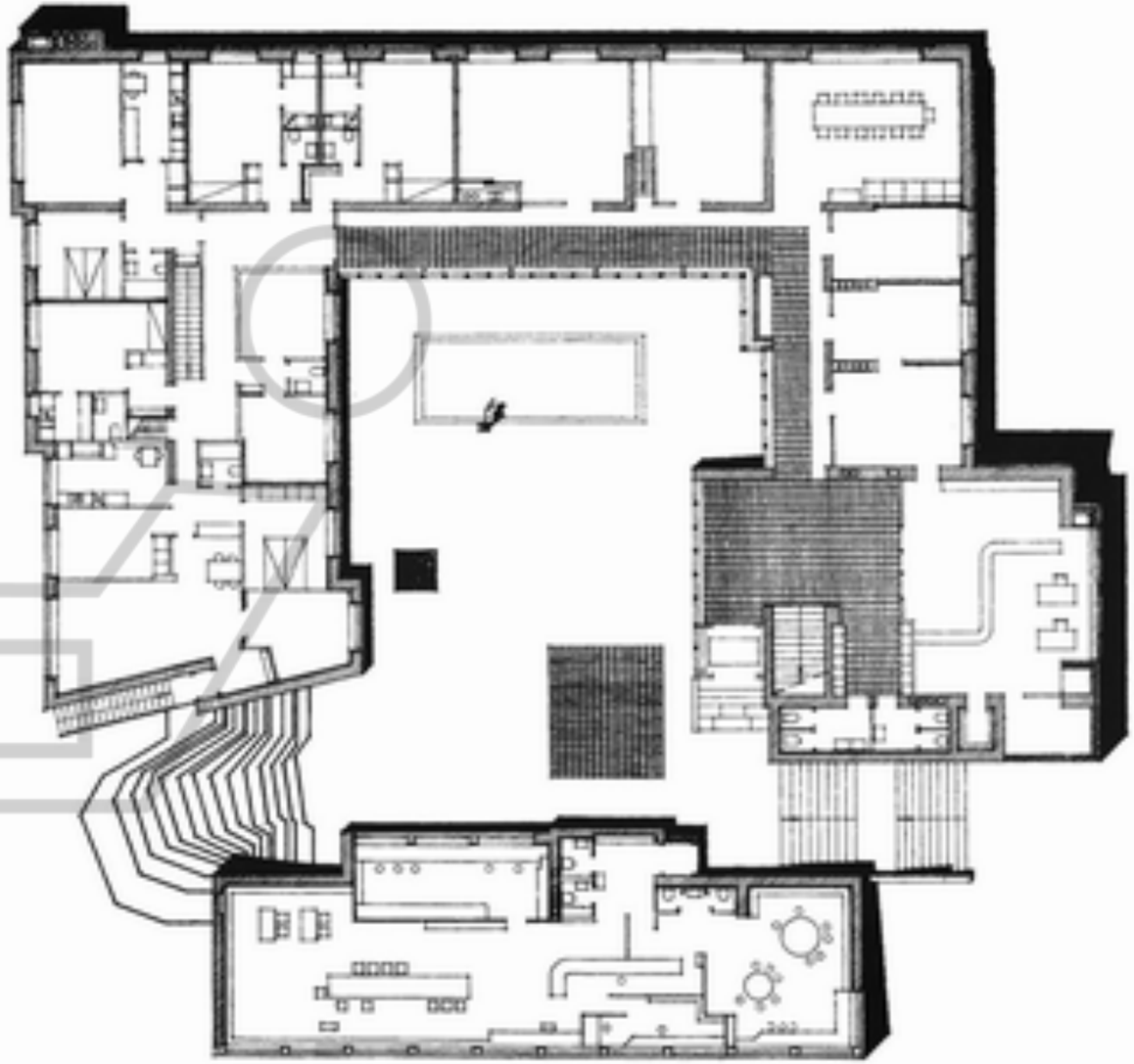
7.
In risposta alle condizioni esterne si possono ipotizzare due proiezioni angolari.



8.
L'entrata sui due angoli taglia un lato, separando la biblioteca.



9.
La torre angolare principale è attratta verso la sua posizione attuale e il vettore esterno si piega per entrare nella corte.

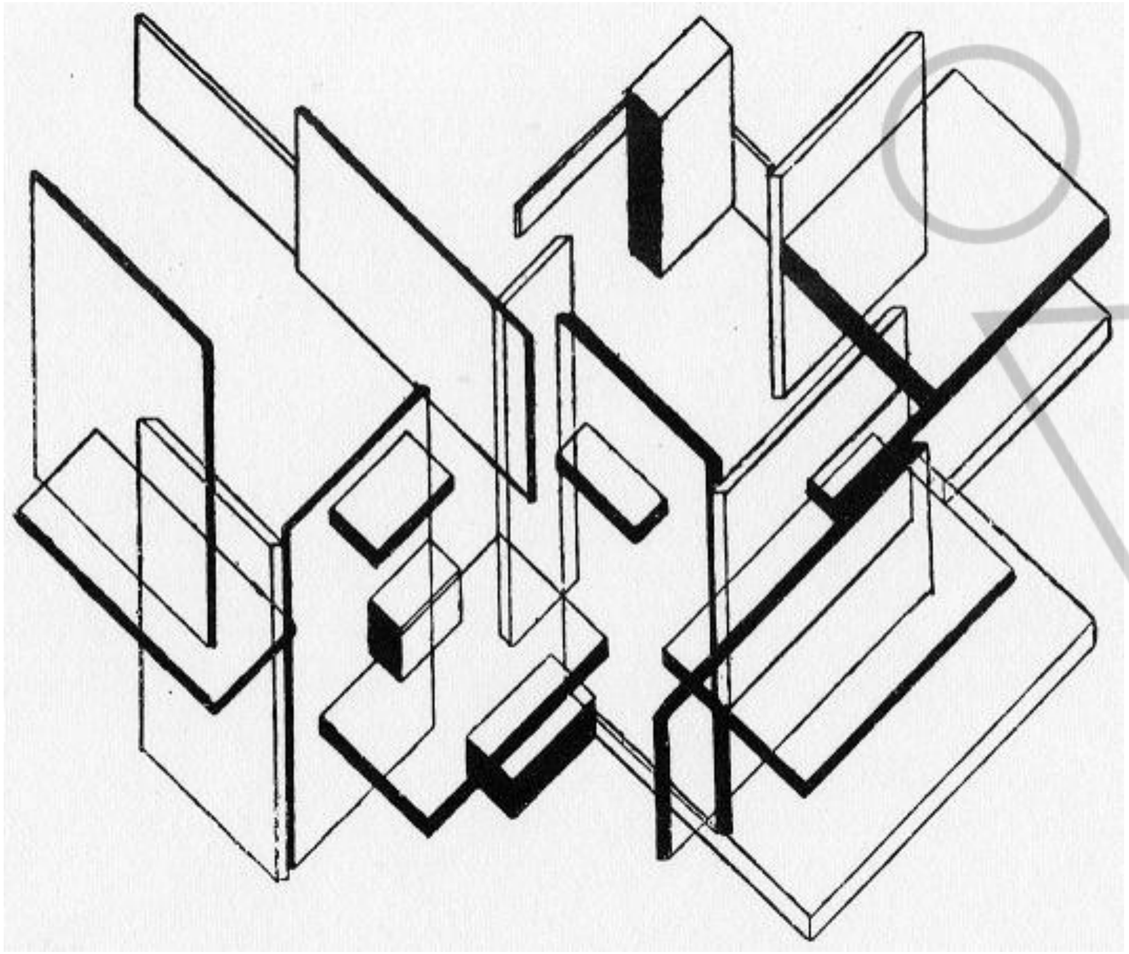


Floor Plan : Säynätsalo Town Hall, Finland (1952) | Alvar Aalto

SHIFTING AND VOIDS

Alvar Aalto, Säynätsalo Town Hall, Finland,1952

SHIFTING AND VOIDS

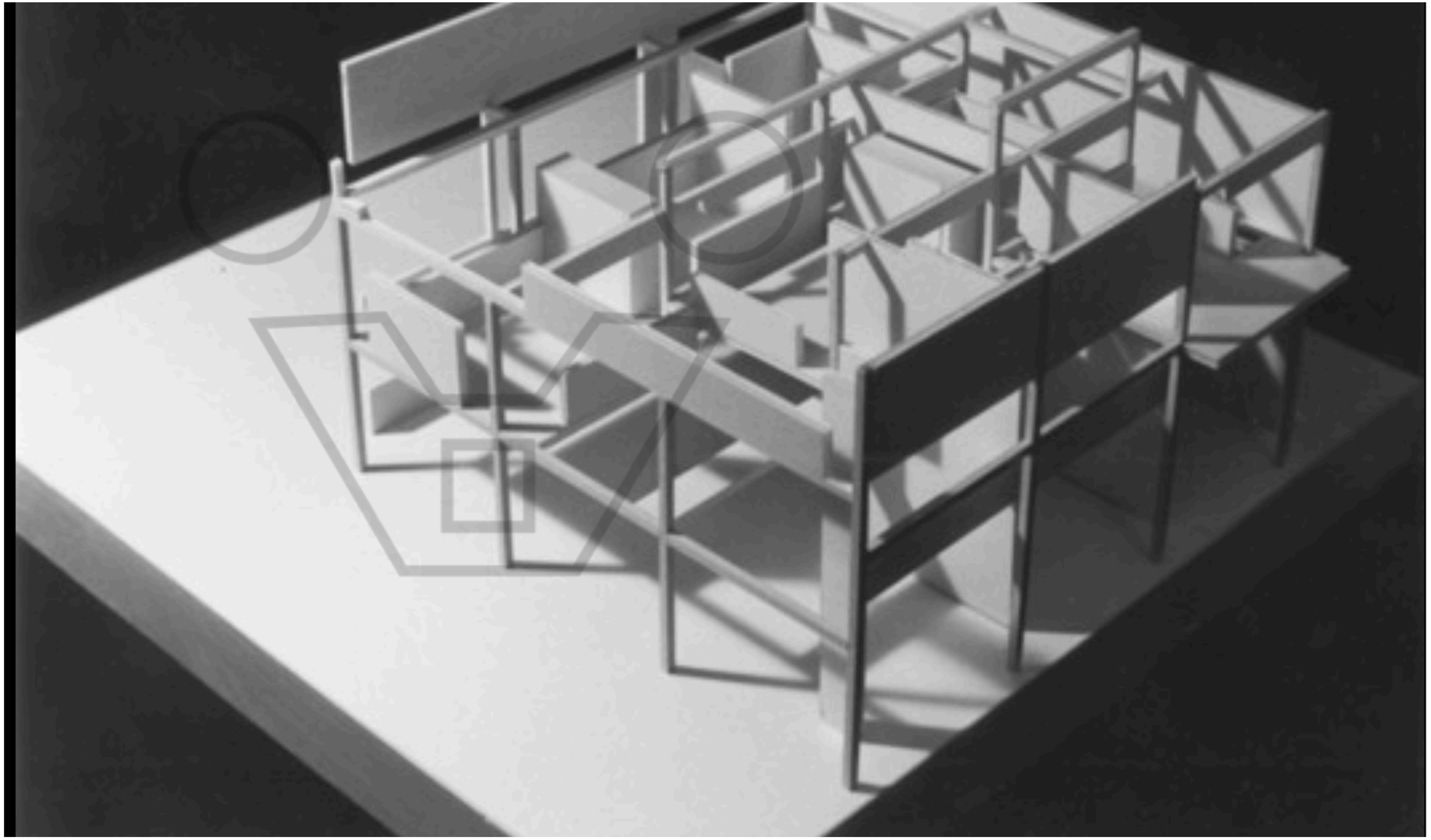


Theo_van_Doesburg,_Architectuuranalyse, 1923

Schoroeder House, Ritvield, 1924 ,_

SHIFTING AND VOIDS

SHIFTING AND VOIDS

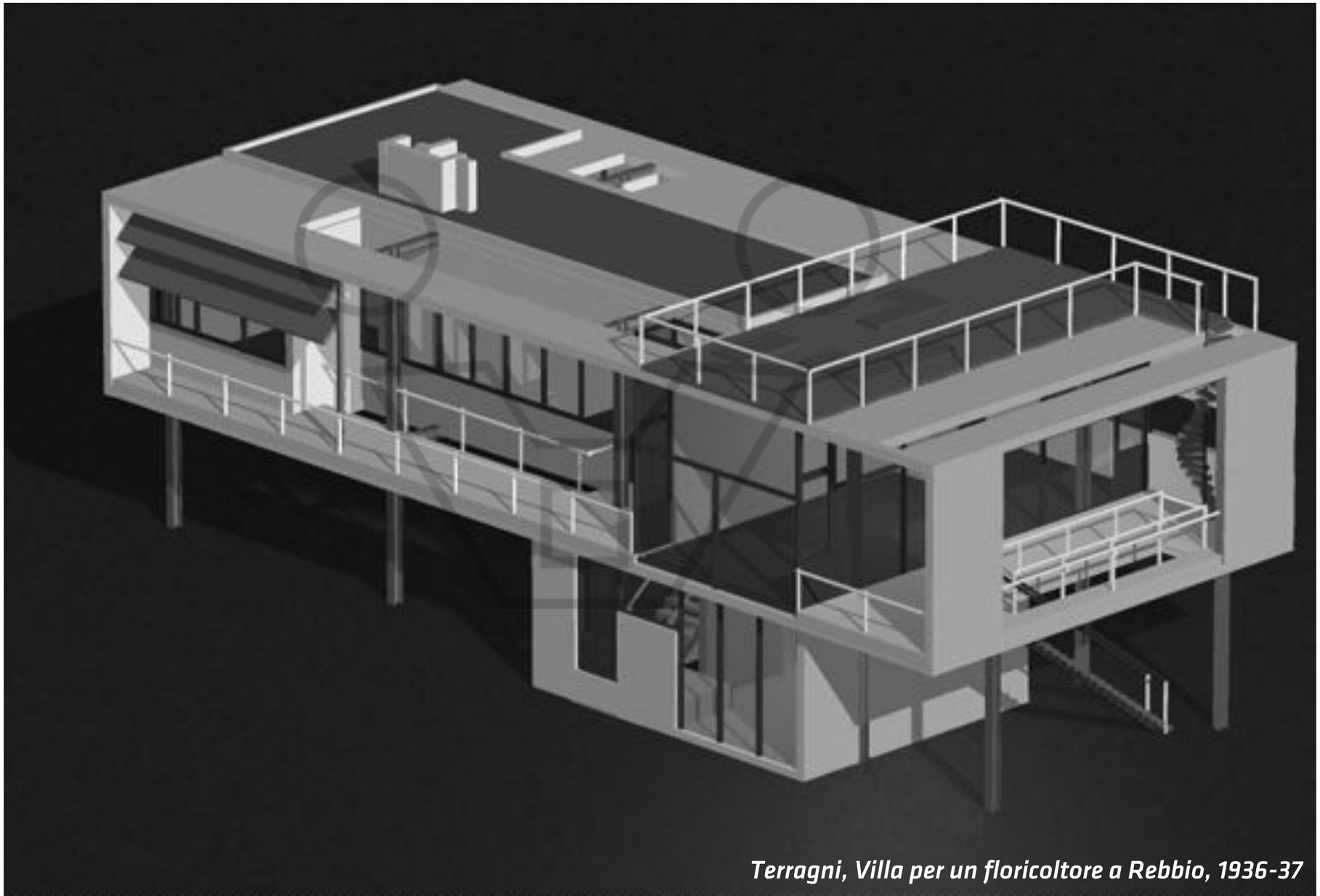


Eisenmann, A Model of House III, 1973

SHIFTING AND VOIDS

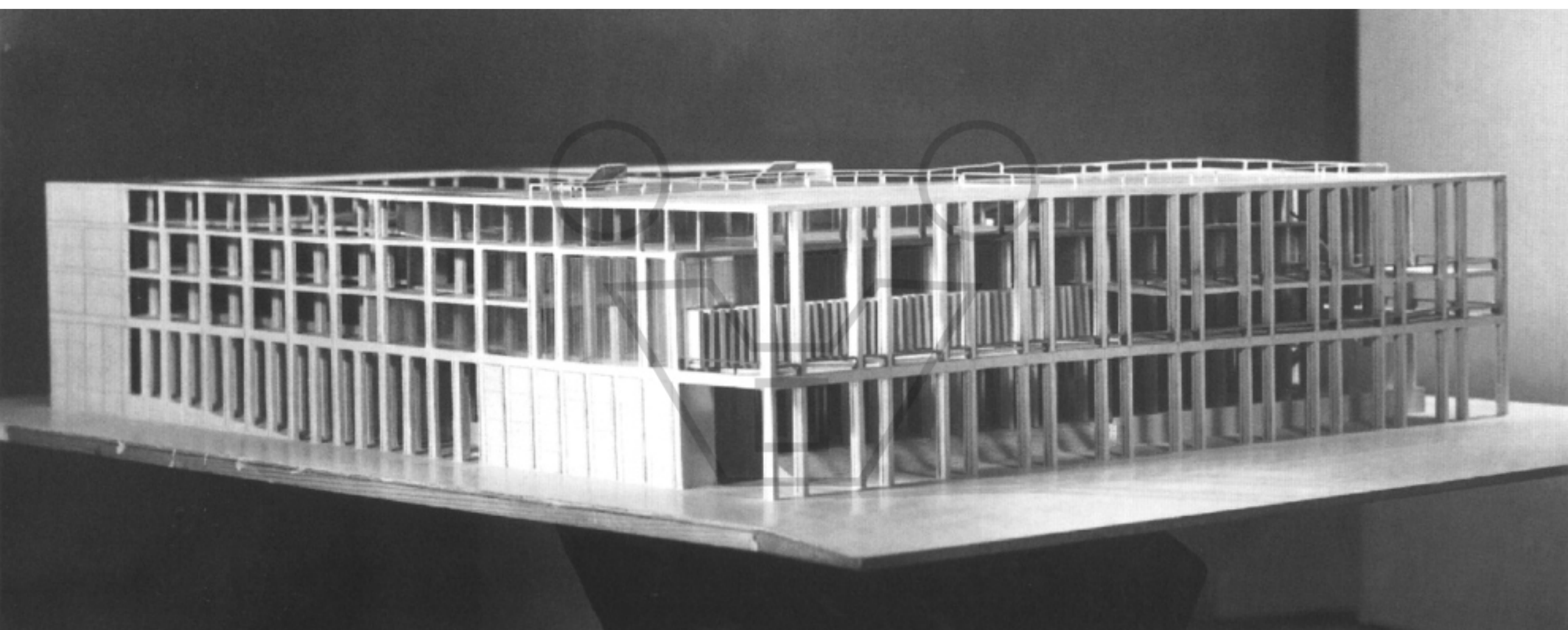
Terragni Villa sul lago, 1936

SHIFTING AND VOIDS



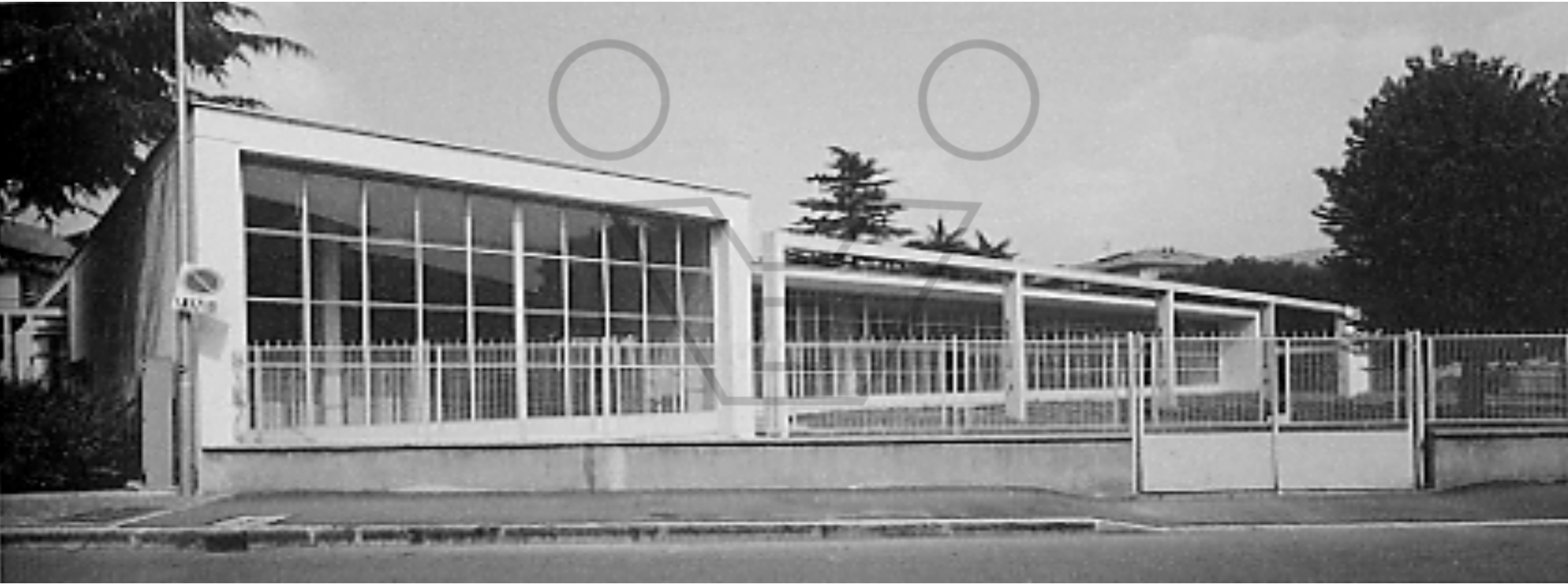
Terragni, Villa per un floricoltore a Rebbio, 1936-37

SHIFTING AND VOIDS

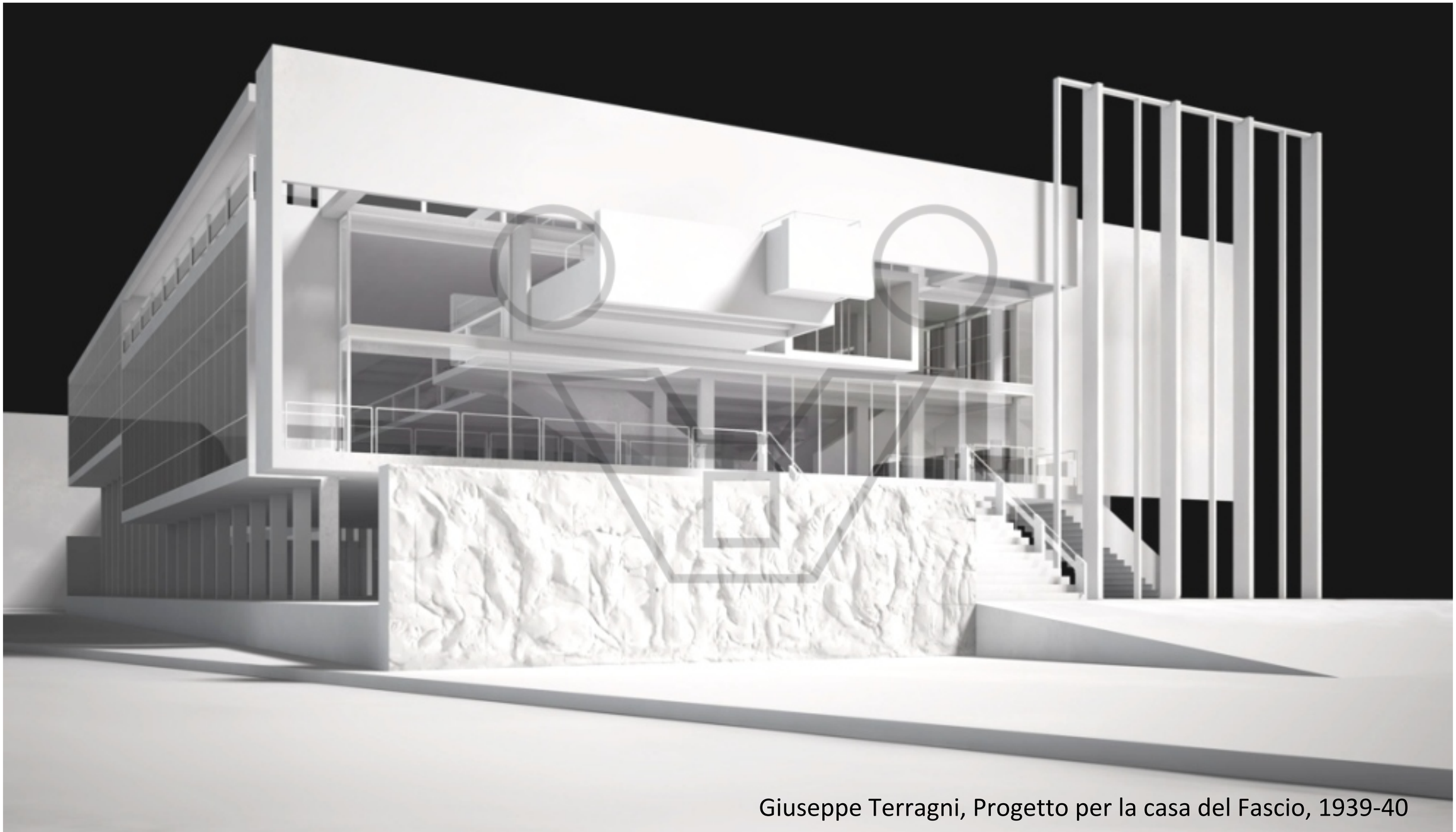


Pietro Lingeri con Cesare Cattaneo e Giuseppe Terragni , Progetto per il Palazzo dei Ricevimenti e dei Congressi all'E.42, concorso nazionale, 193

Terragni, Asilo Sant'Elia, 1936-37



Terragni, Asilo Sant'Elia, 1936-37



Giuseppe Terragni, Progetto per la casa del Fascio, 1939-40

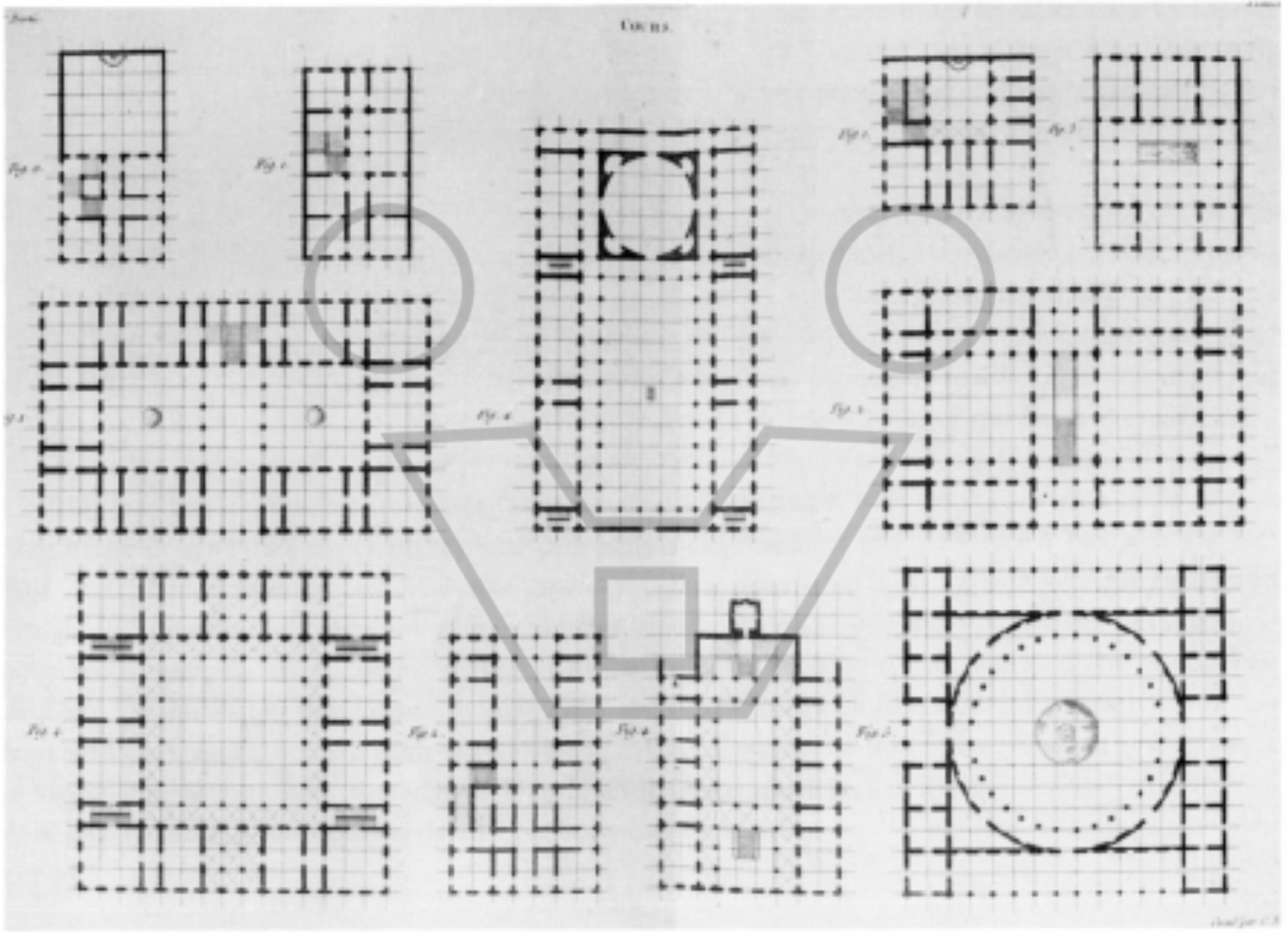
THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

R. Meyer, Bodrum Houses, 2007-2010, Yalikavak, Turkey

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

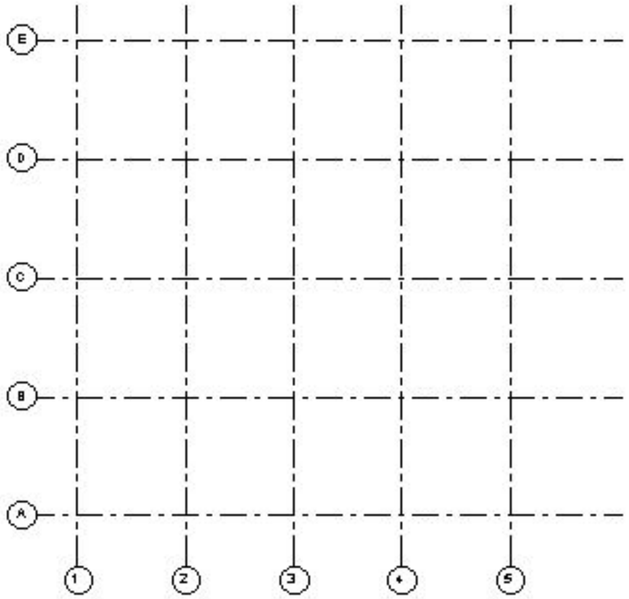
architectural diagram element: the GRID

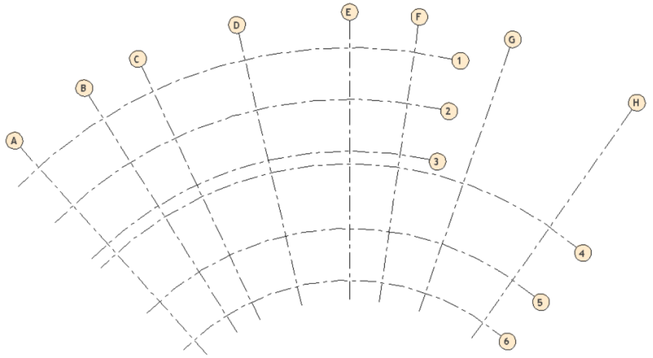
Anticipation of the modern industrialized building construction



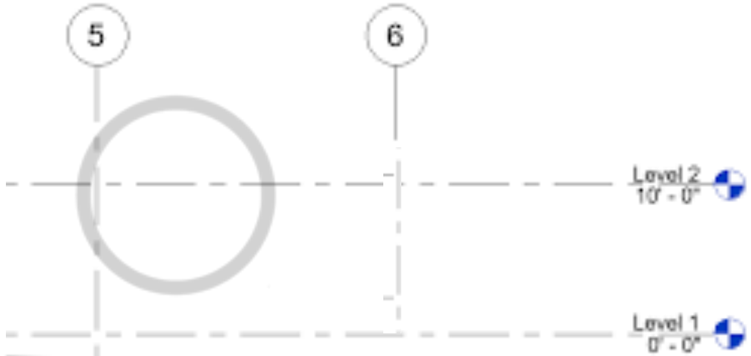
Durand's grid architecture, courtyards

Structural Grid Plan

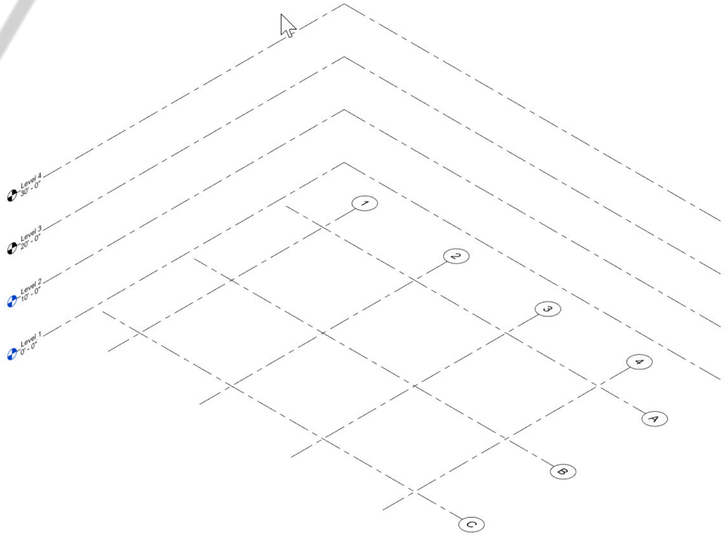




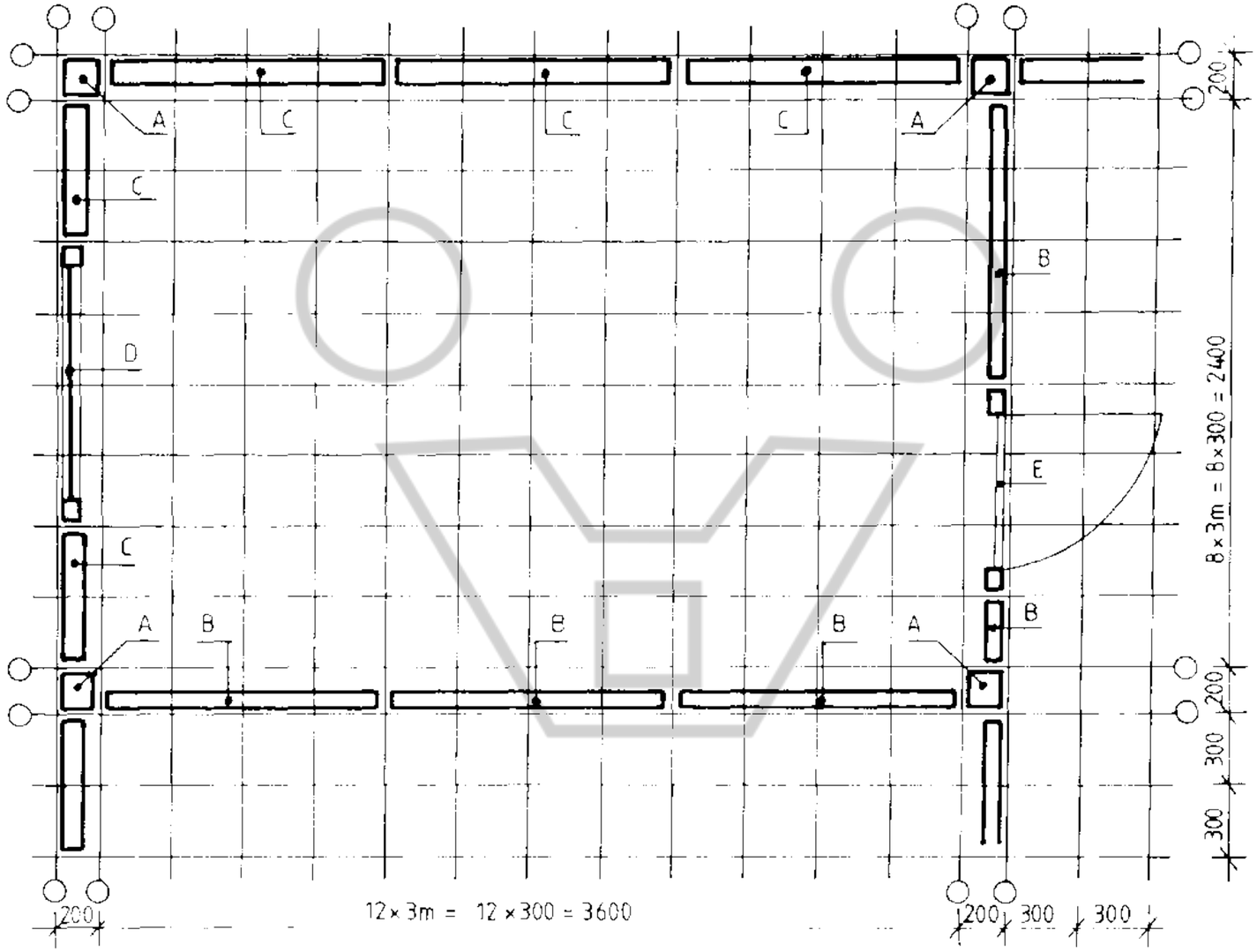
Structural Grid Elevation



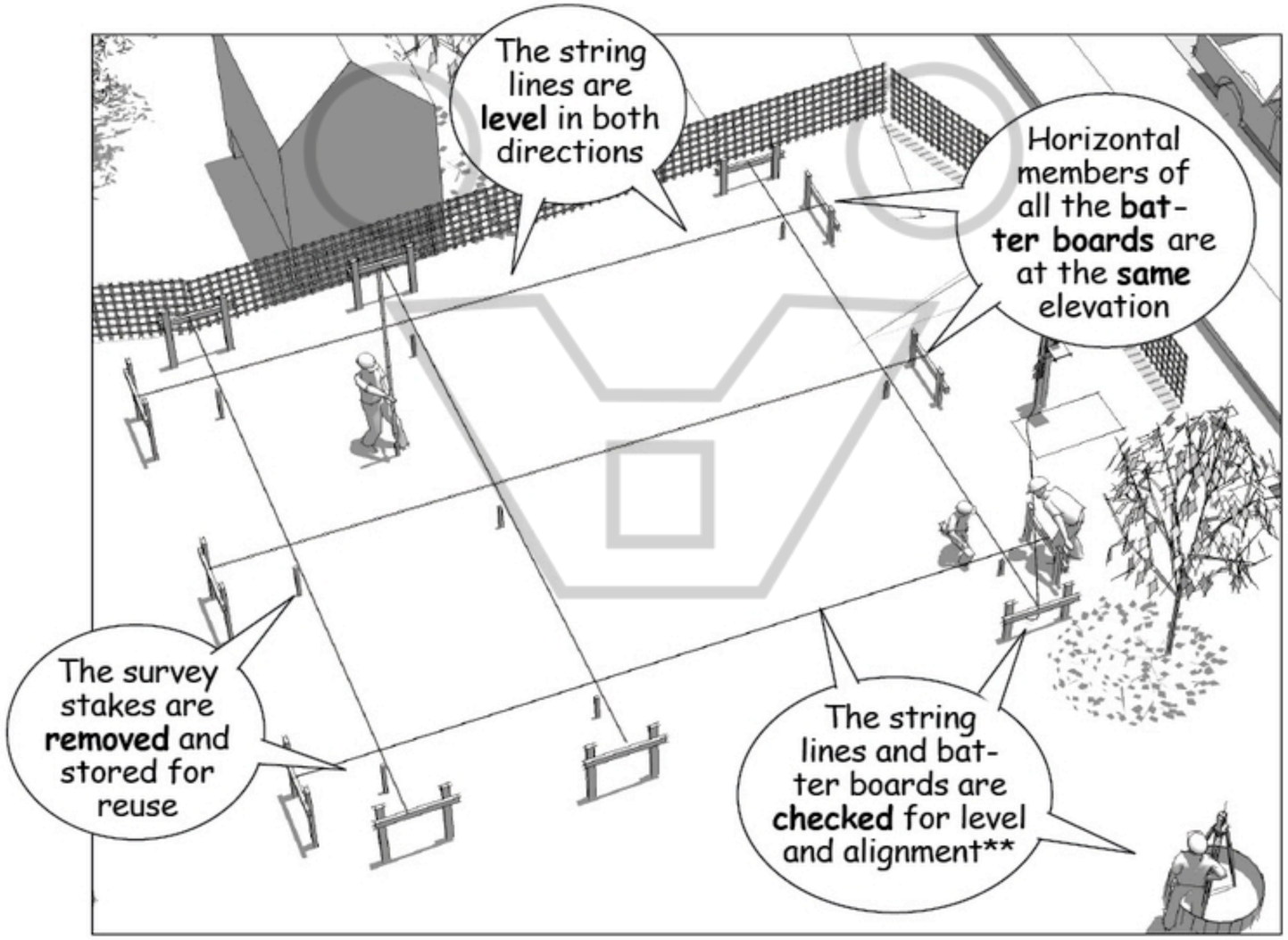
Structural Grid 3D



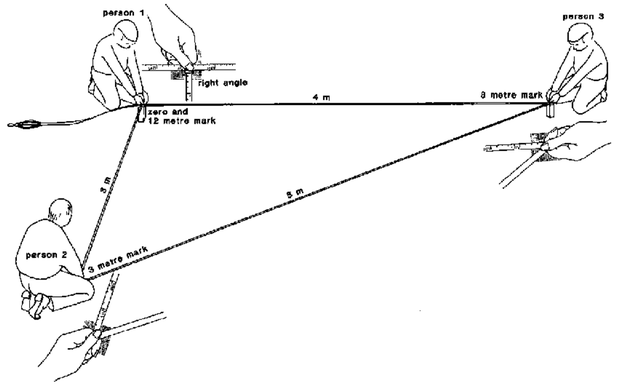
Tartan Grid


A
C
C
C
A
C
B
D
E
C
A
B
B
B
A
B
200
8 × 3m = 8 × 300 = 2400
200
300
300
12 × 3m = 12 × 300 = 3600
200
300
300

FROM DESIGN TO CONSTRUCTION
FROM COMPASSES TO ROPES

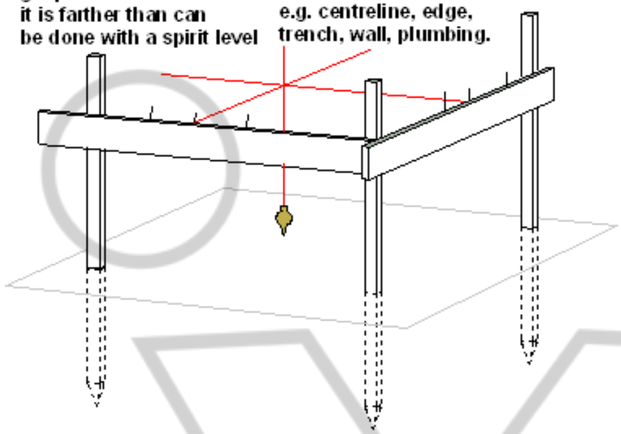


establishing 90 angle

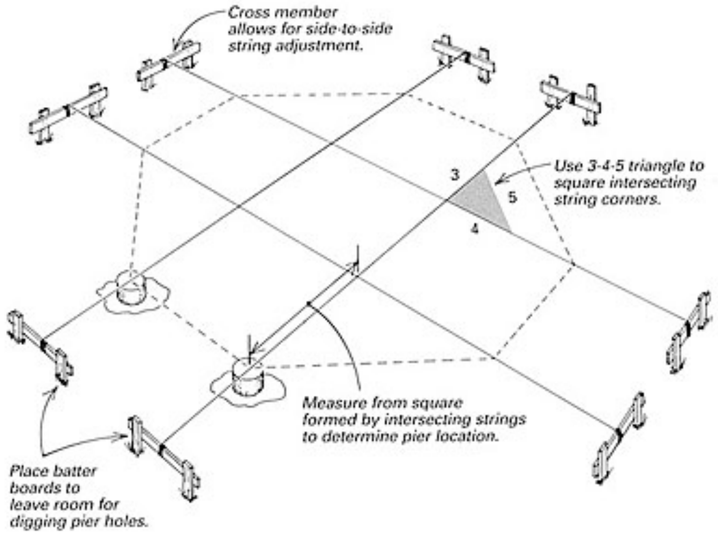


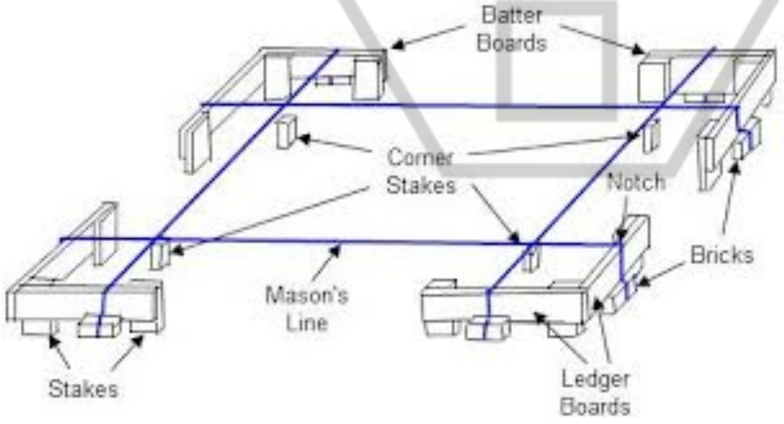
use plumb bob to get point below if it is farther than can be done with a spirit level

clearly mark what the various nails are for. e.g. centreline, edge, trench, wall, plumbing.



Setting up batter boards for an octagon





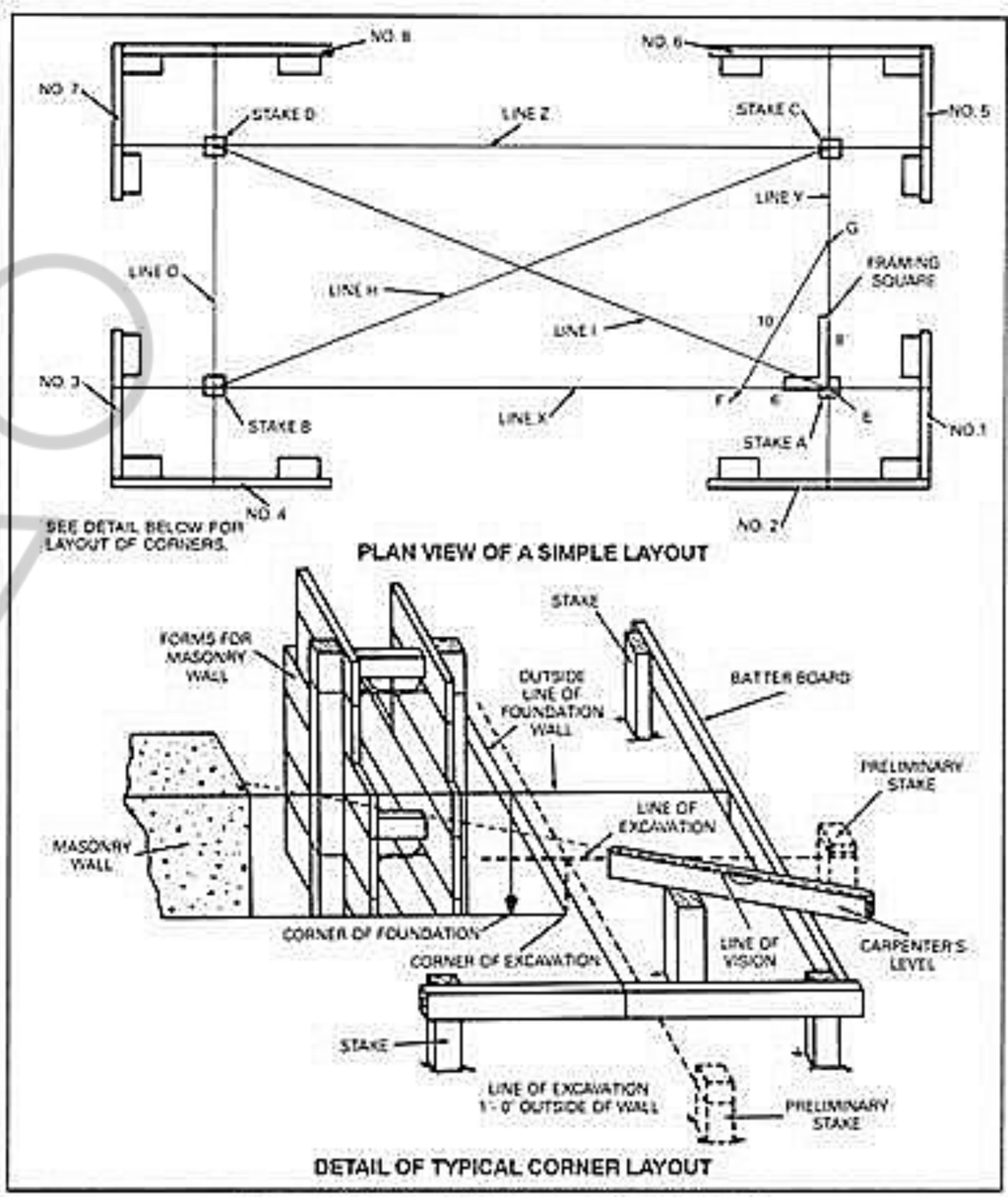
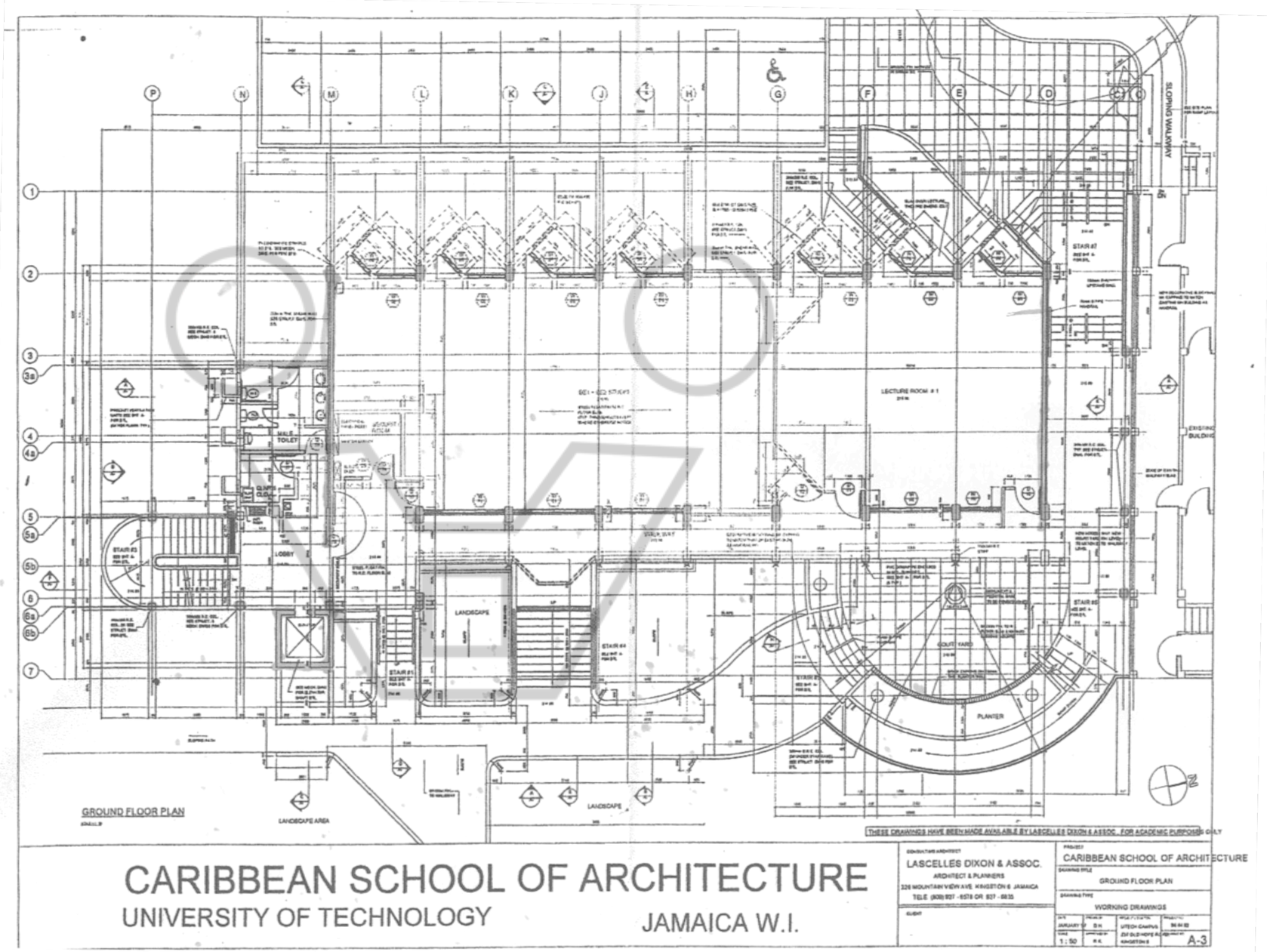
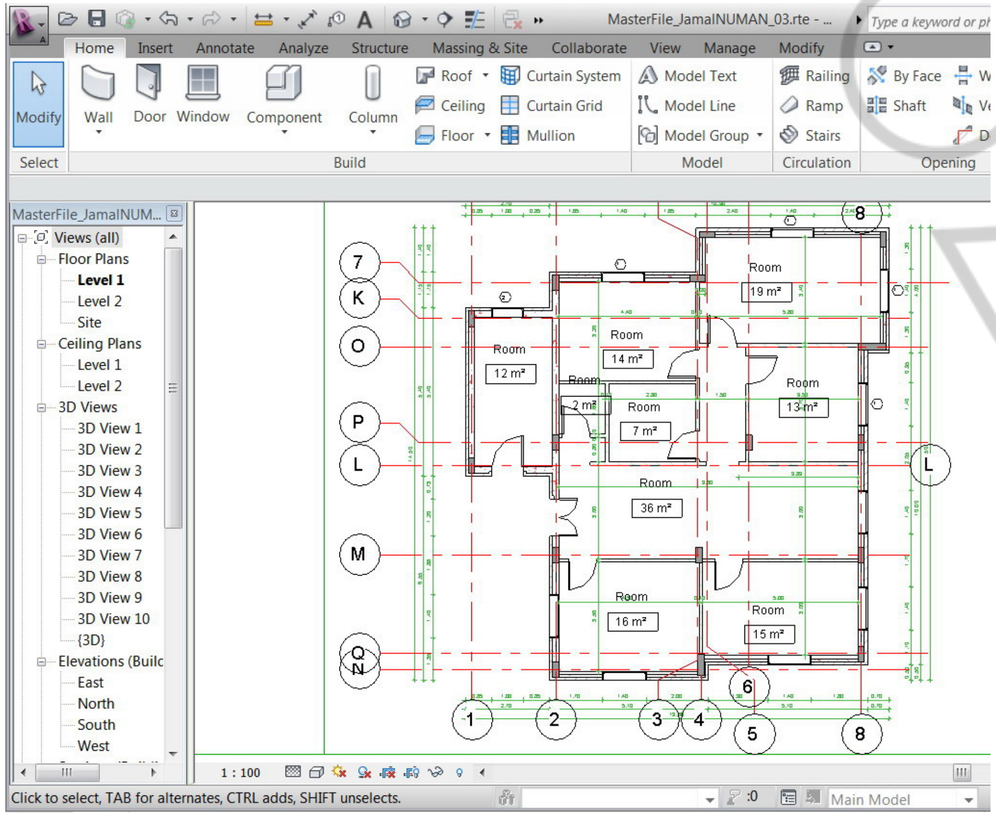


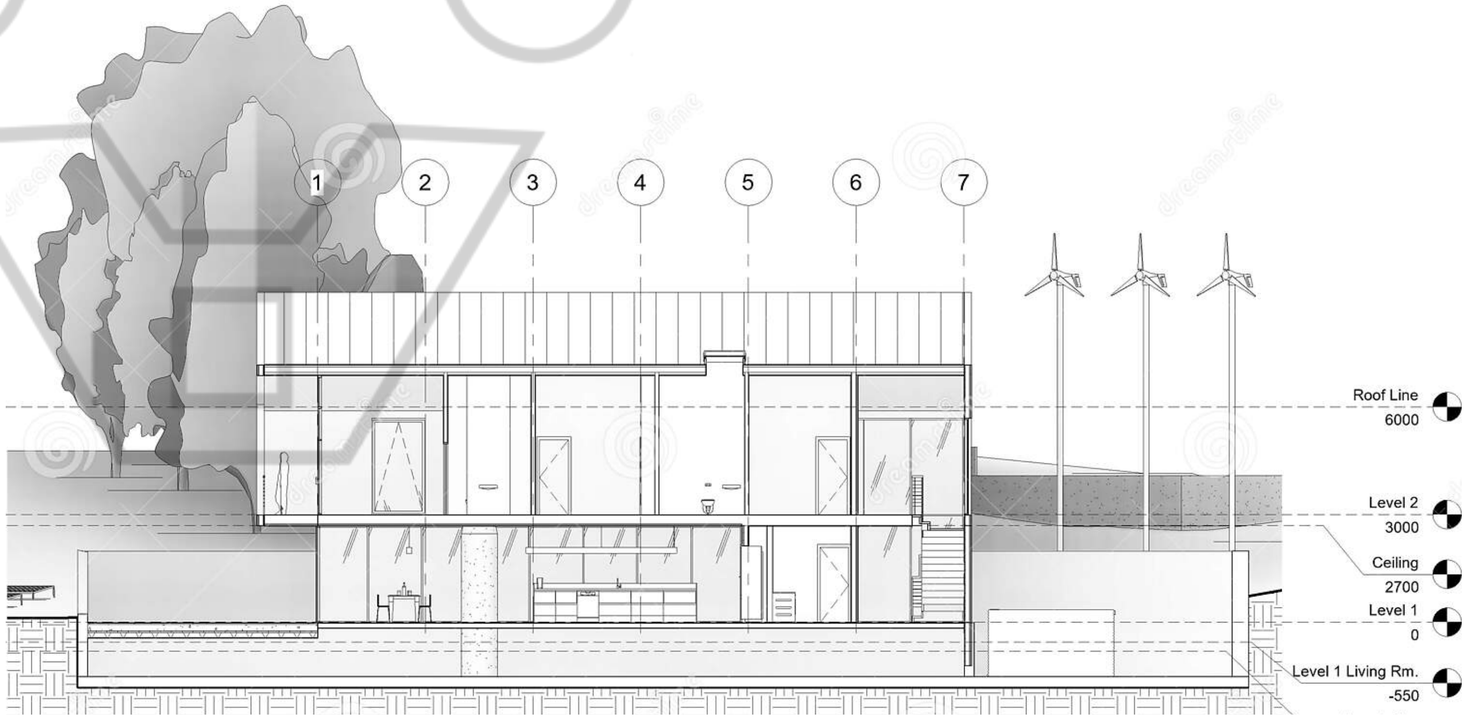
Figure 4-4. Laying out building lines from batter boards

Structural Grid Plan

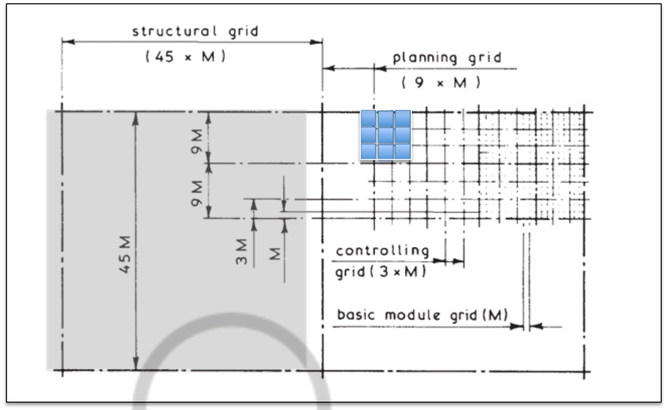


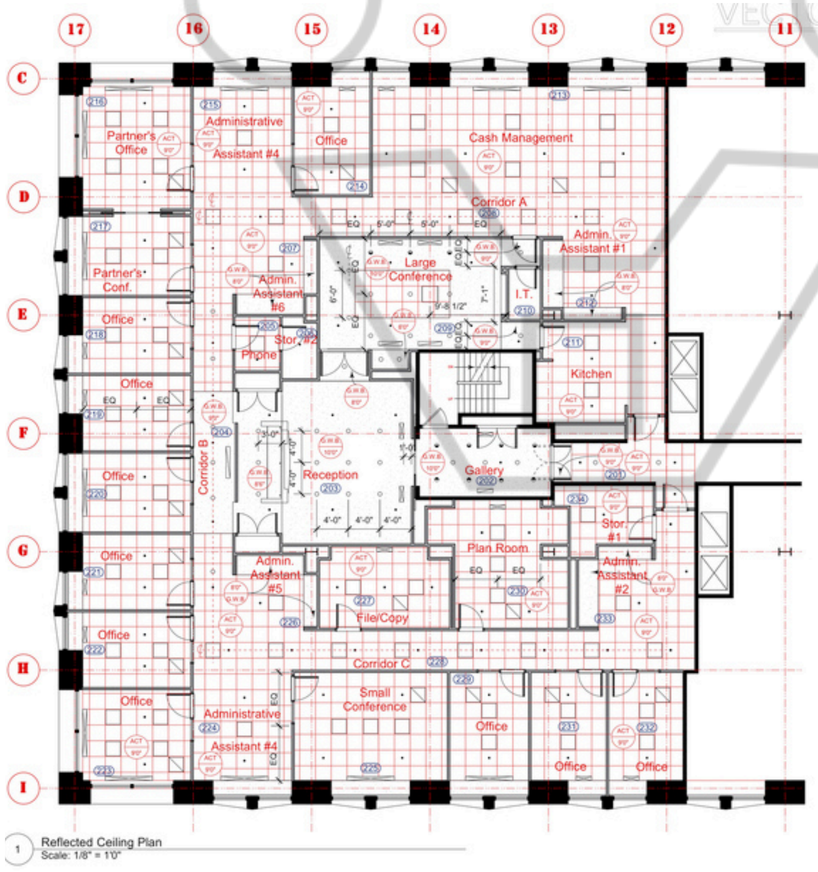
Typical use of Construction Control Lines Grid



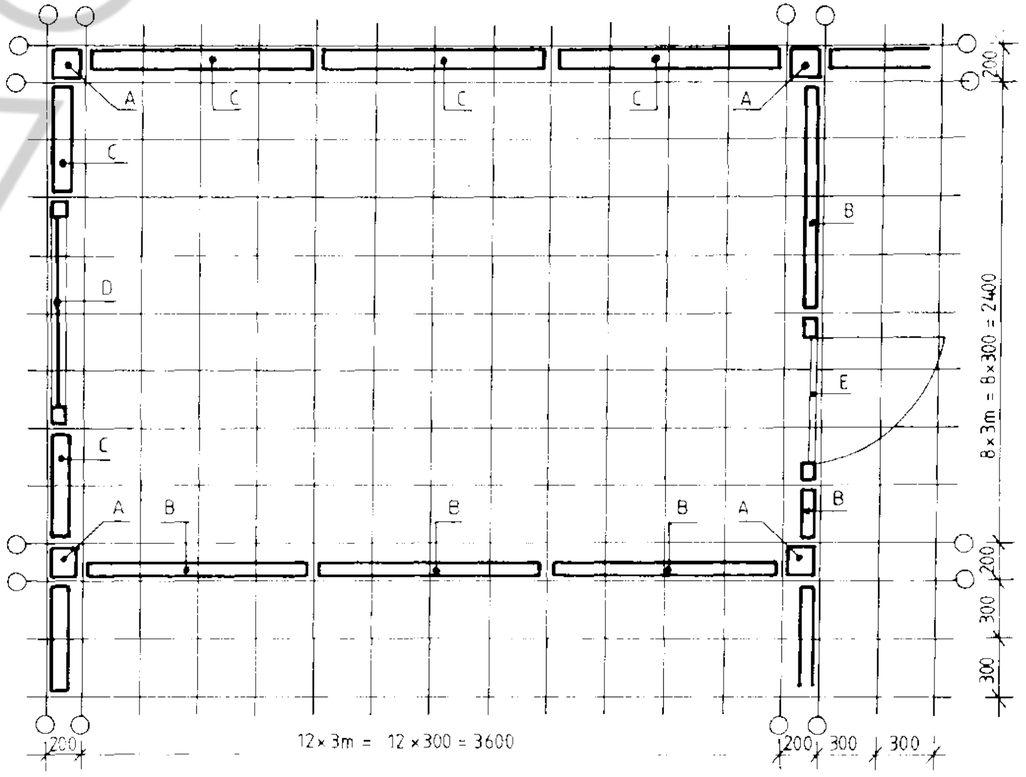


Modular Coordination Grids

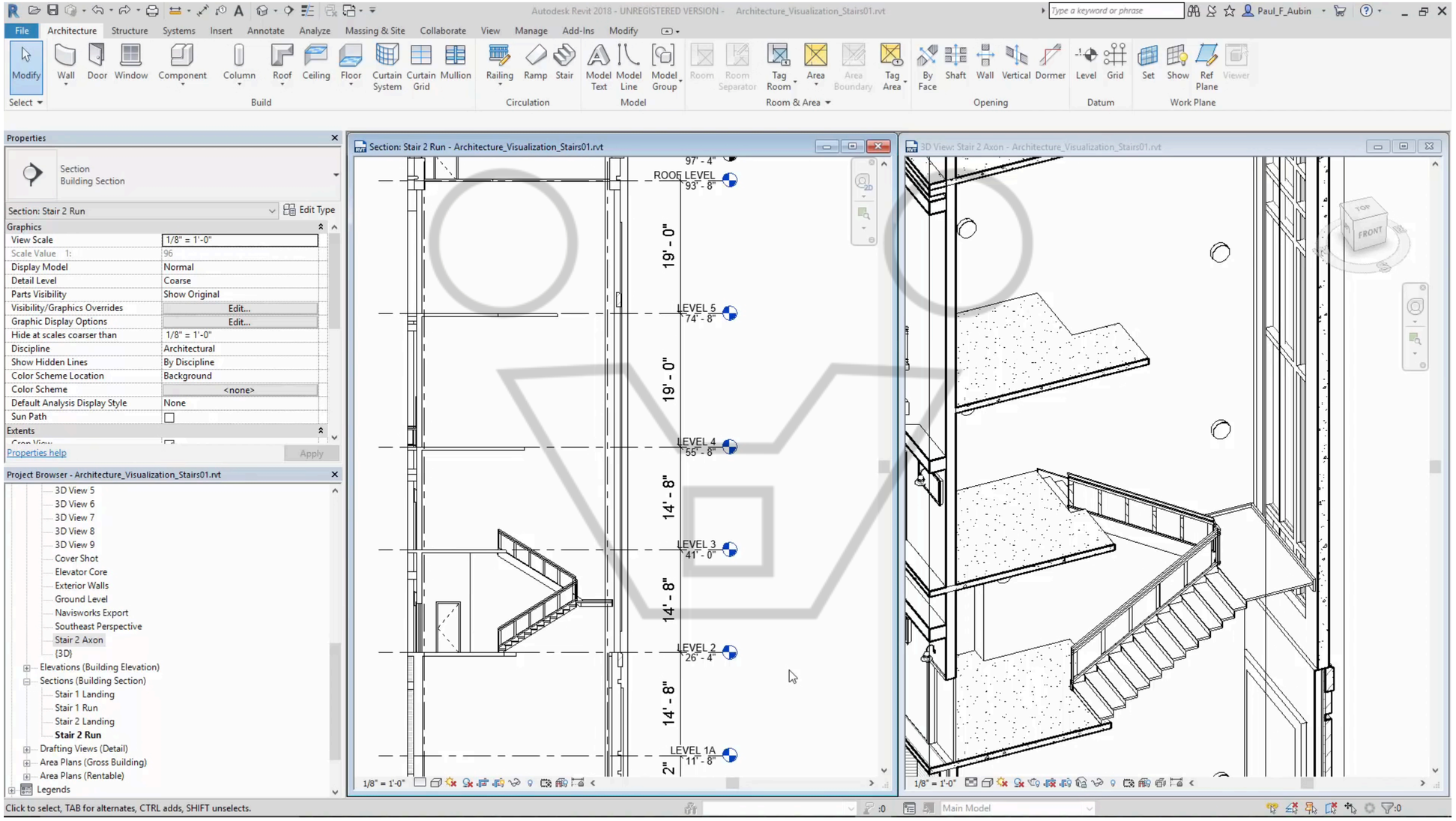




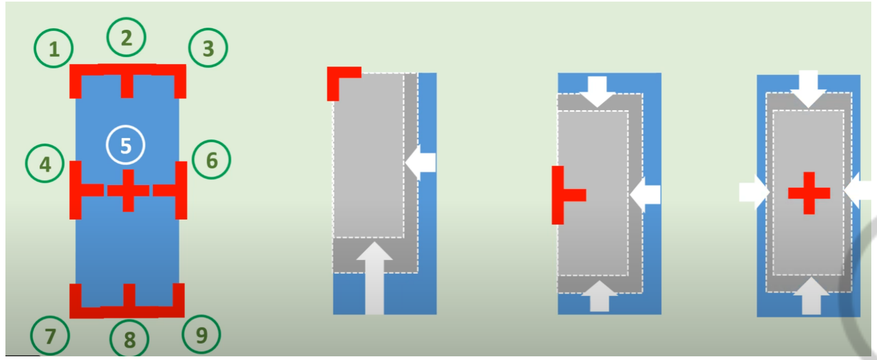
Modular Coordination 'Tartan' Grid

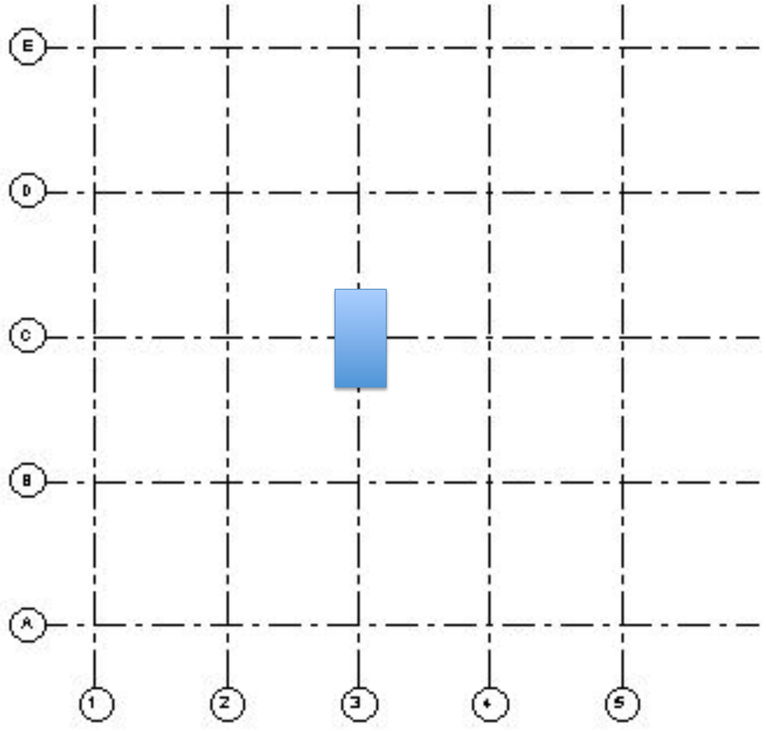


BIM Parametric Grids

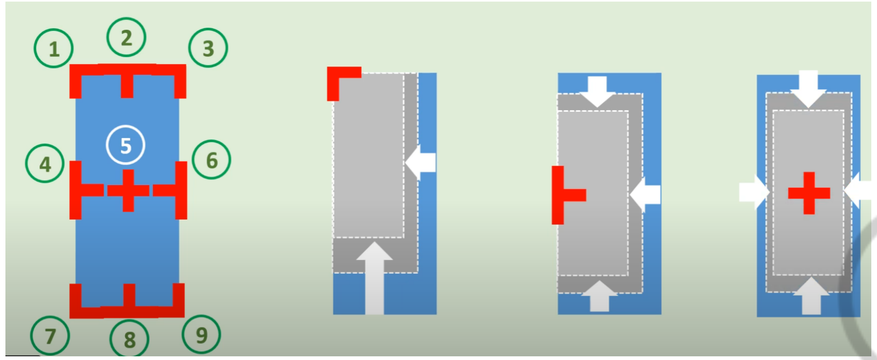


Special Construction Control Lines Grid: Lines of Constraints

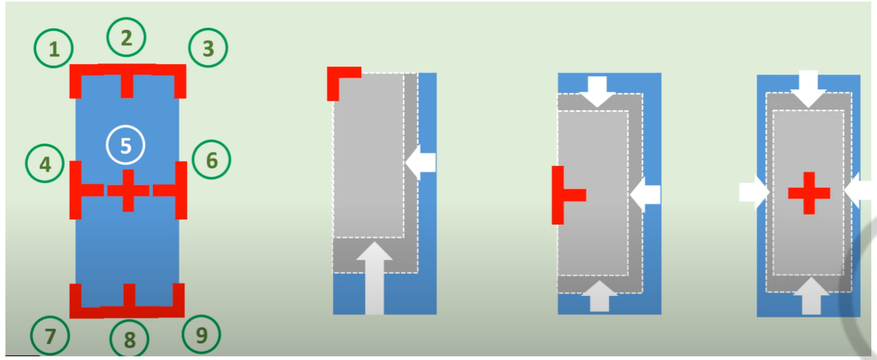


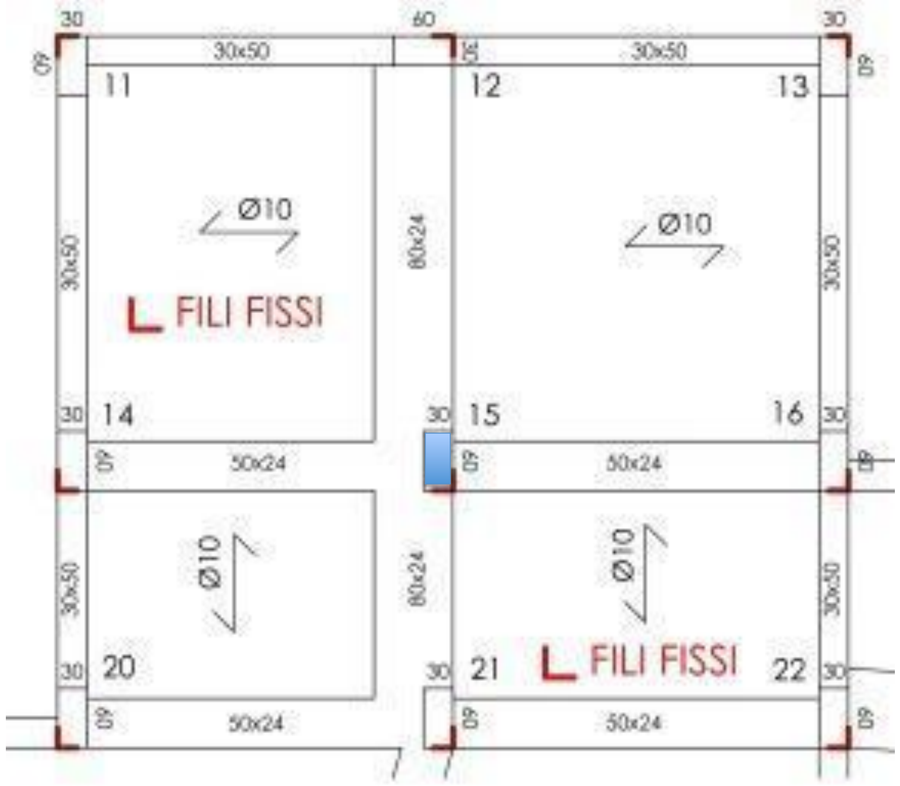


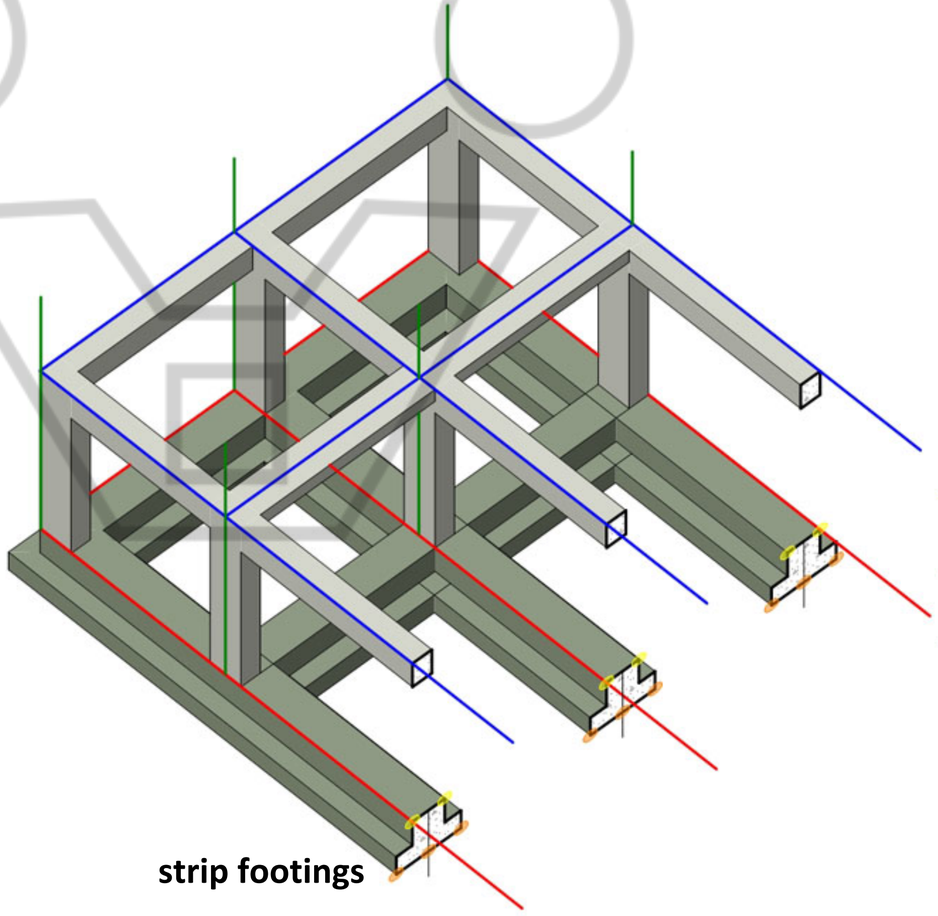
Special Construction Control Lines Grid: Lines of Constraints



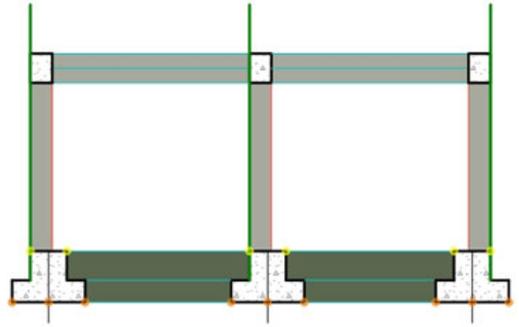
Special Construction Control Lines Grid: Lines of Constraints







strip footings



Filo Fisso Travi

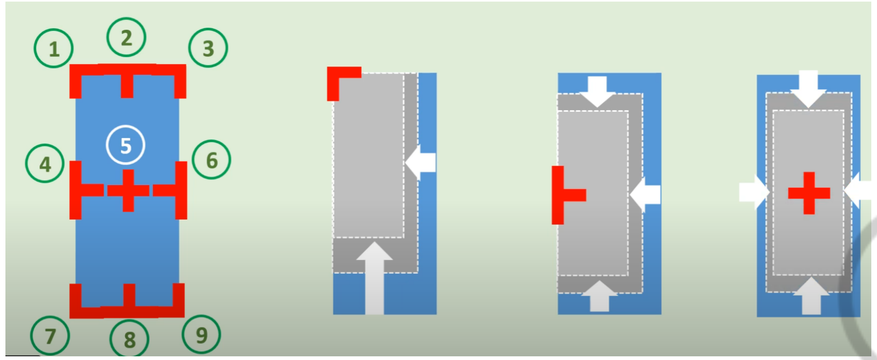
Filo Fisso Travi Rovesce

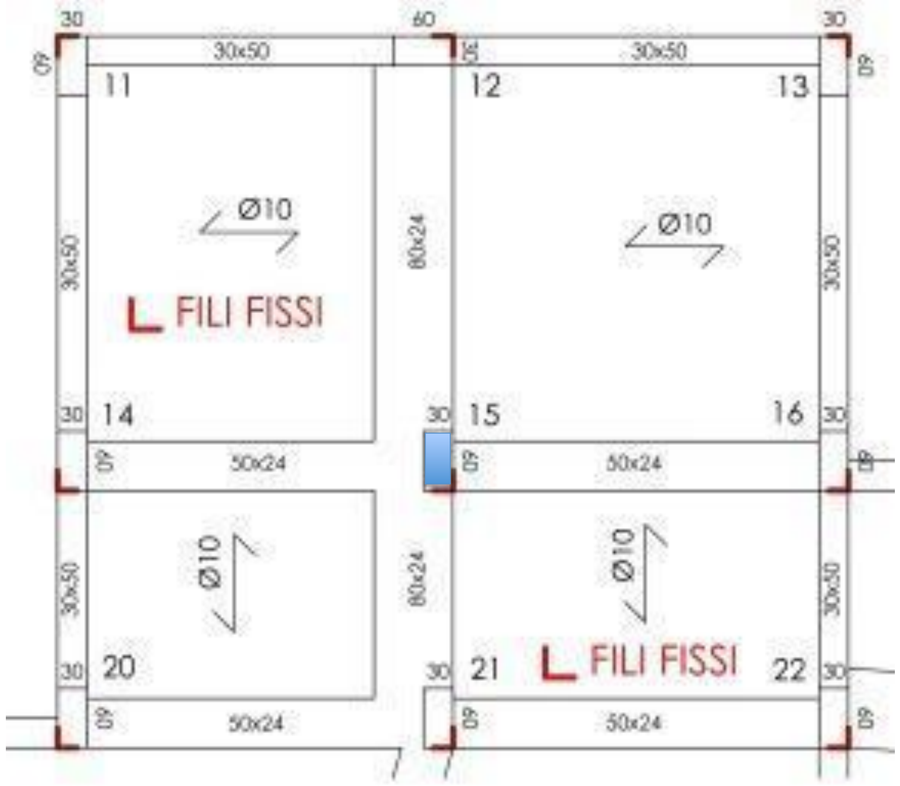
Filo Fisso Pilatri

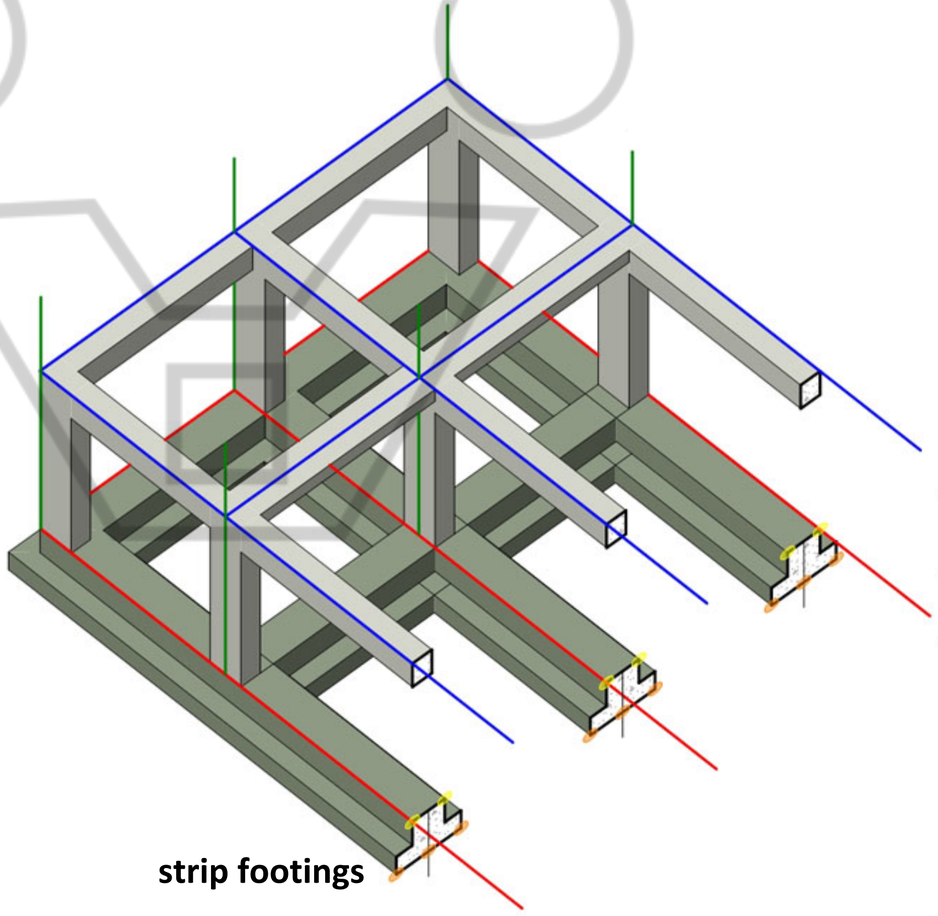
Fili Fissi Disponibili

Fili Fissi Non Disponibili

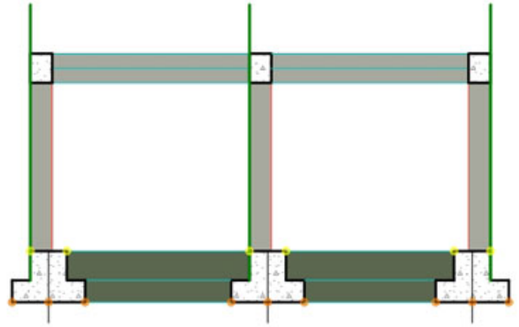
Special Construction Control Lines Grid: Lines of Constraints







strip footings



Filo Fisso Travi

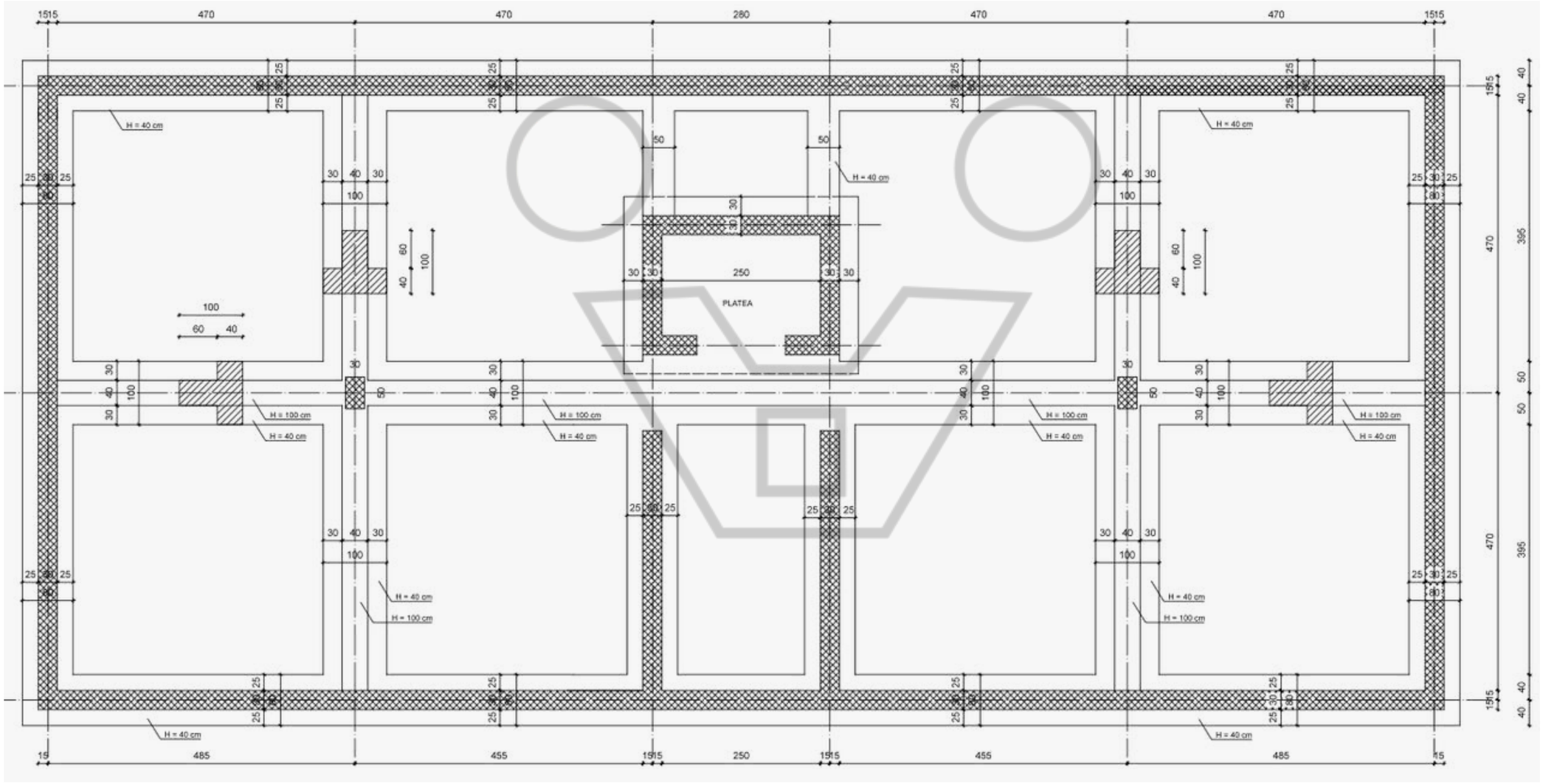
Filo Fisso Travi Rovesce

Filo Fisso Pilatri

Fili Fissi Disponibili

Fili Fissi Non Disponibili

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



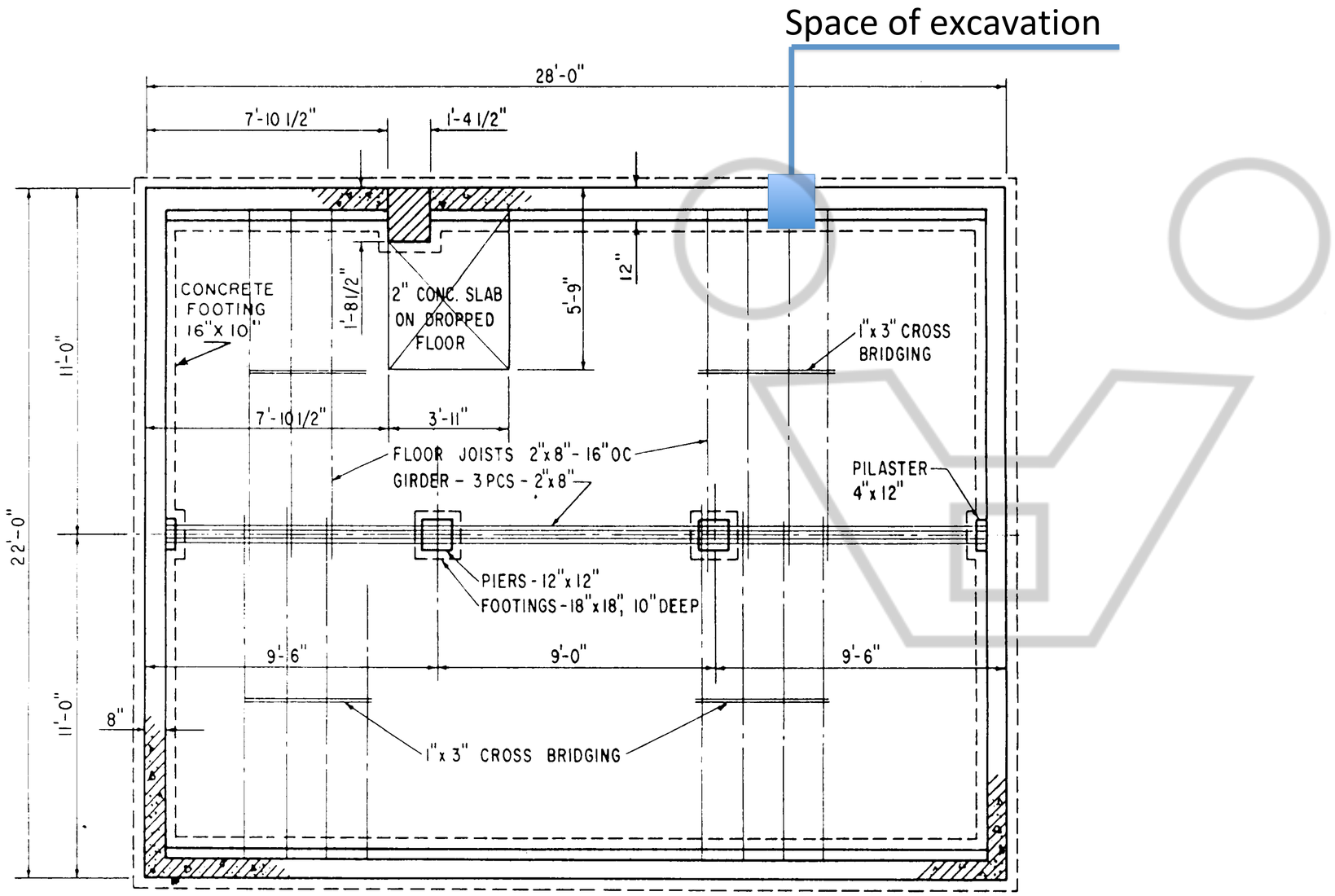


Figure 7-9.—Foundation plan.

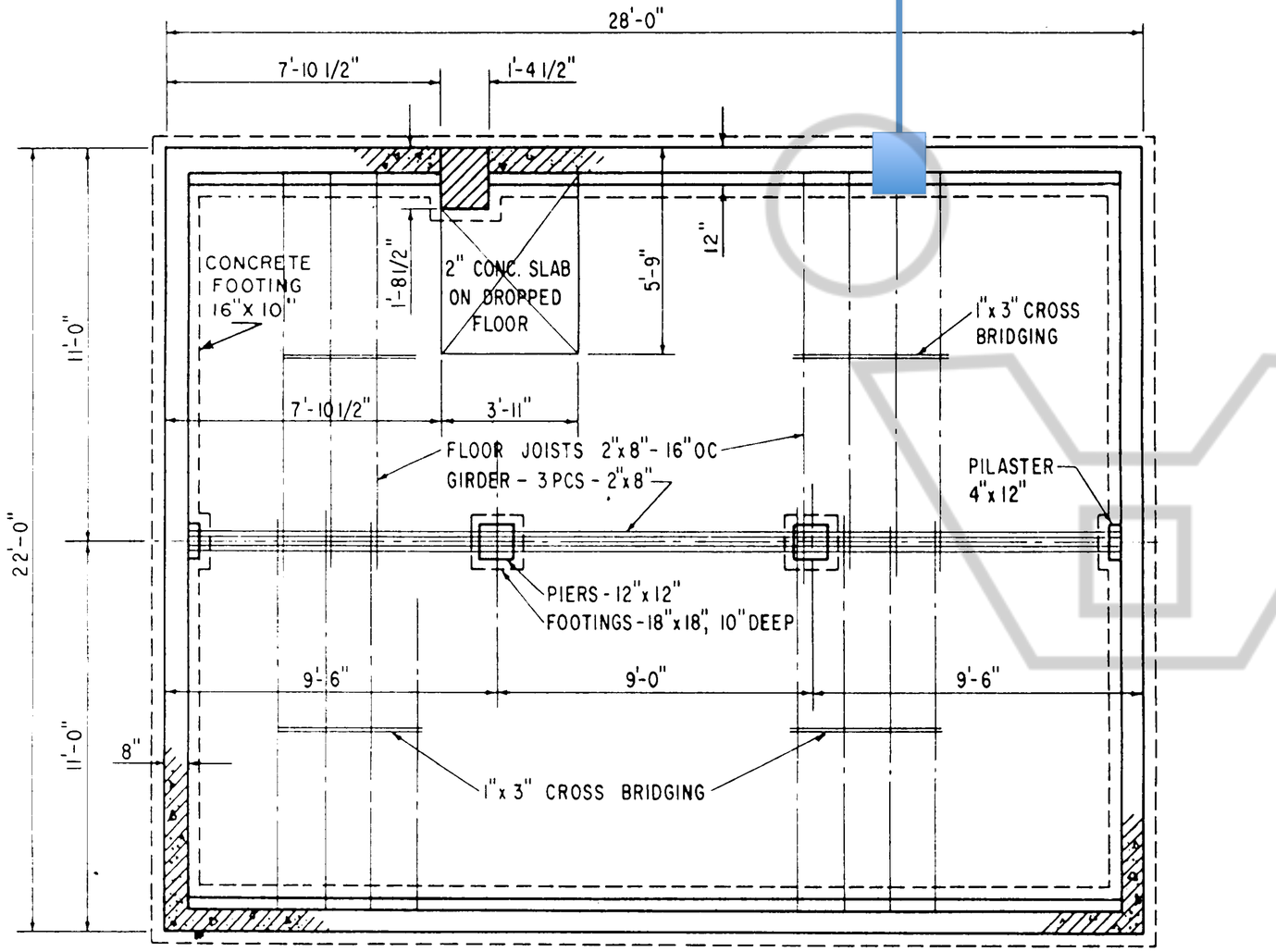
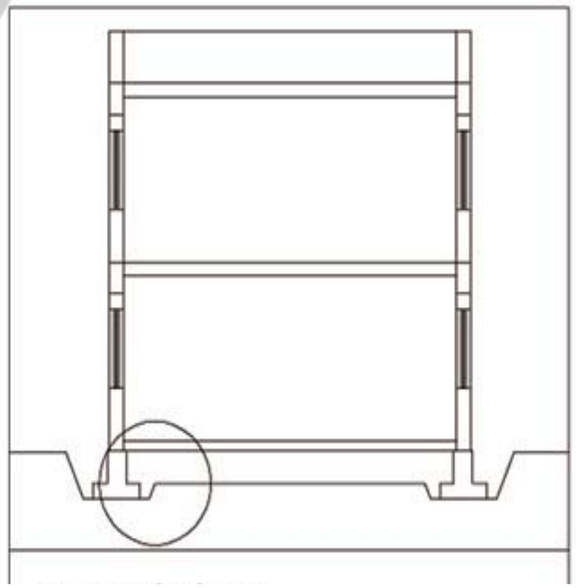
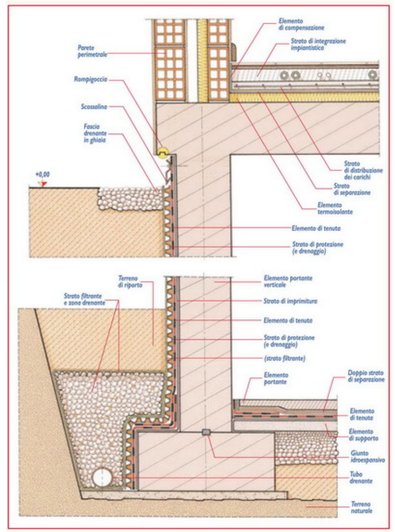


Figure 7-9.—Foundation plan.





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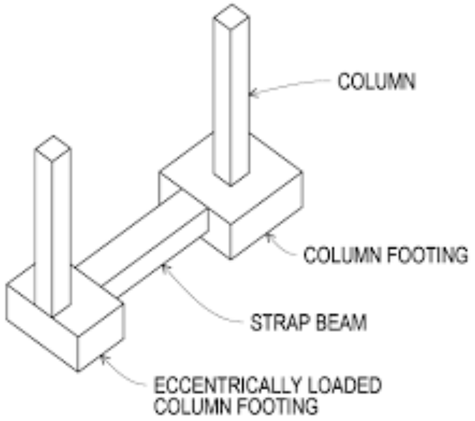
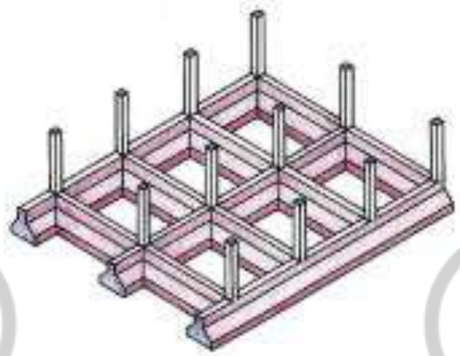
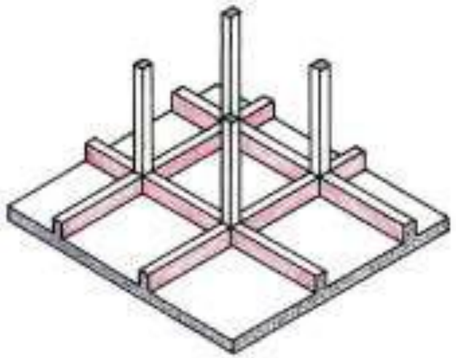
Shallow foundation



: • pad (plinth) footing

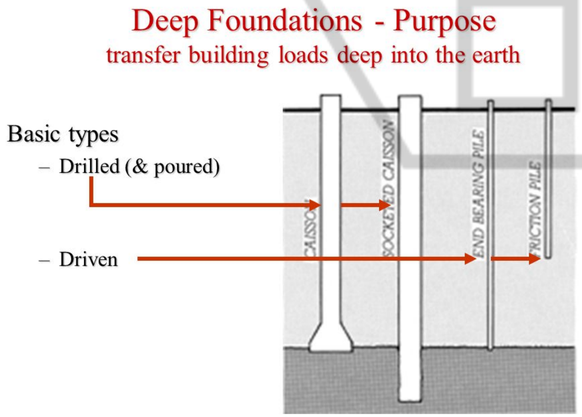


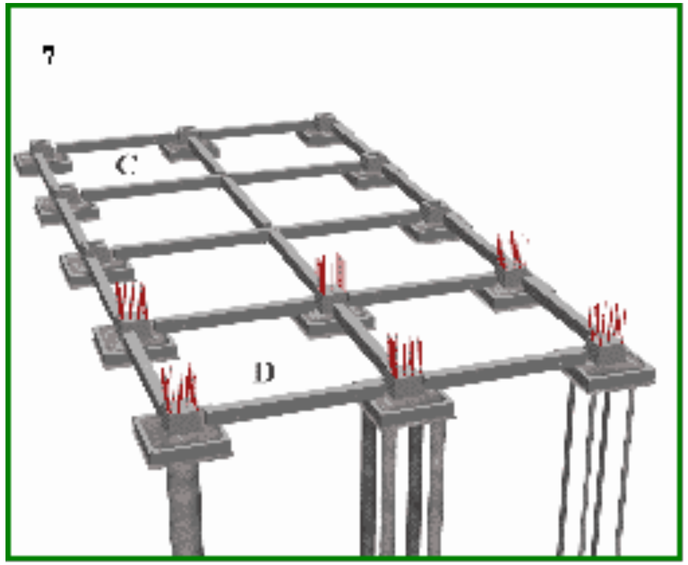
• strip footings



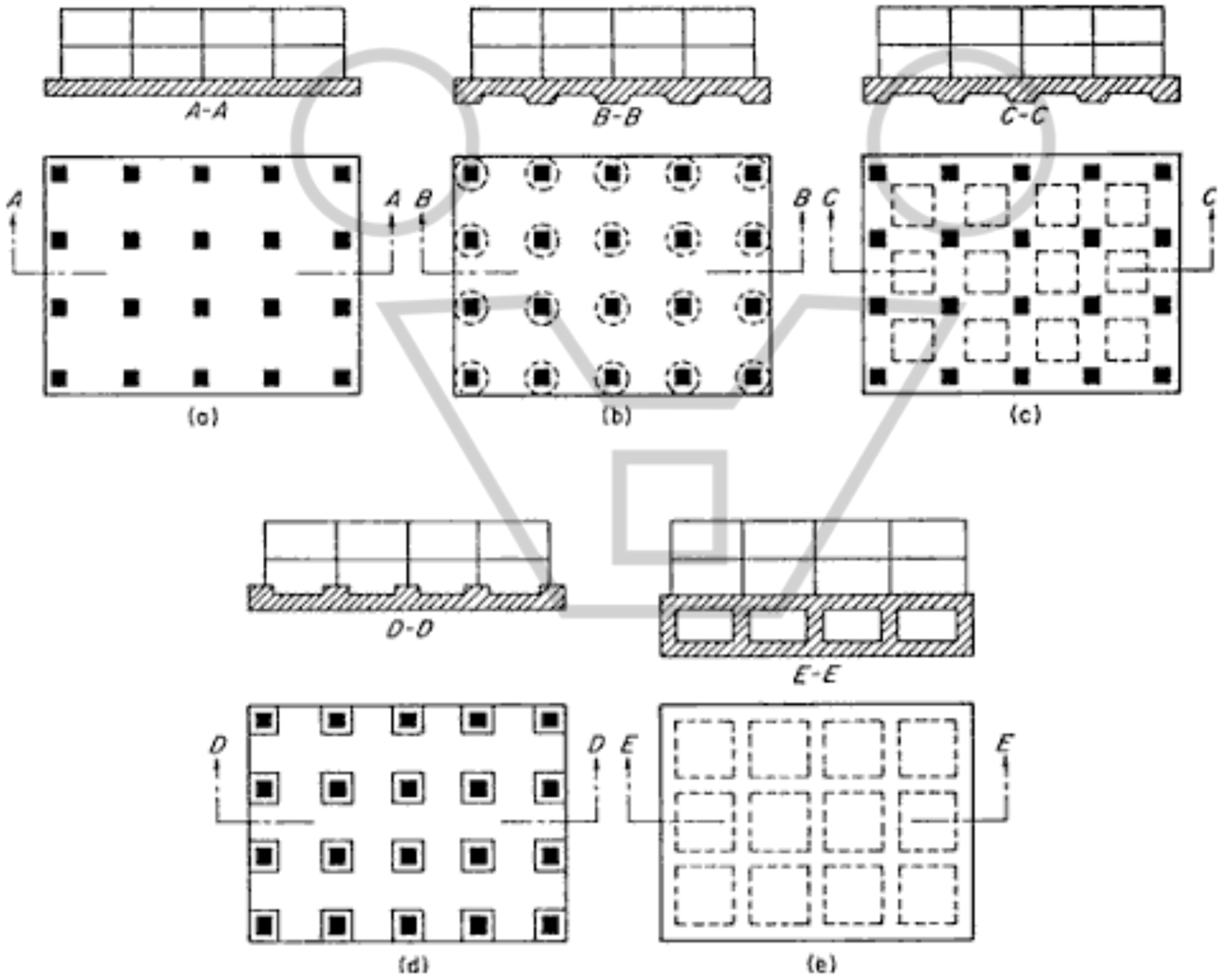
• raft (or mat) foundation (platea)

Deep foundation





The BUILDING FOOTING & FOUNDATIONS



IGURE 5.2 Examples of mat foundations. (a) Flat plate; (b) plate thickened under columns; (c) beam-and-slab; (d) plate with pedestals; (e) basement walls as part of mat.

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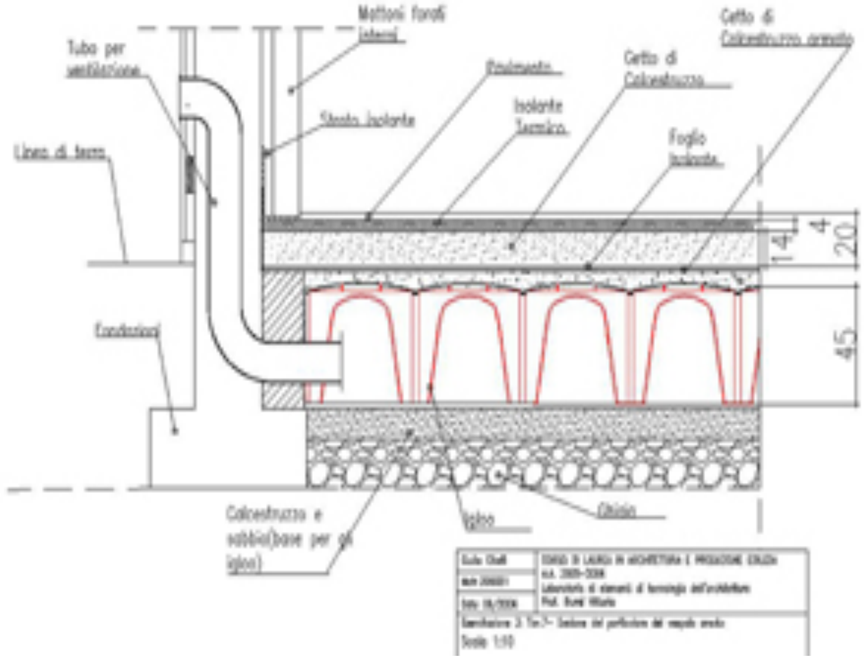
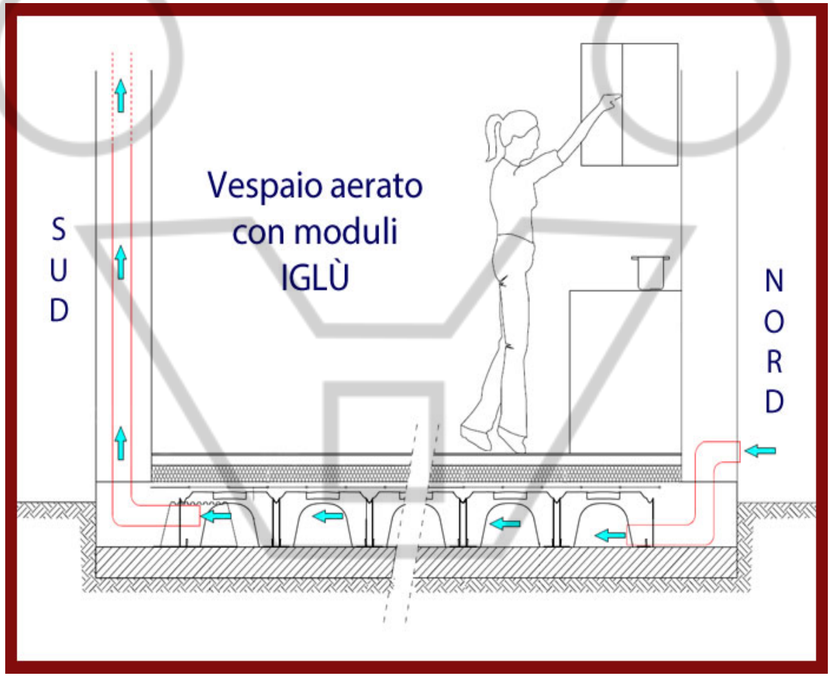
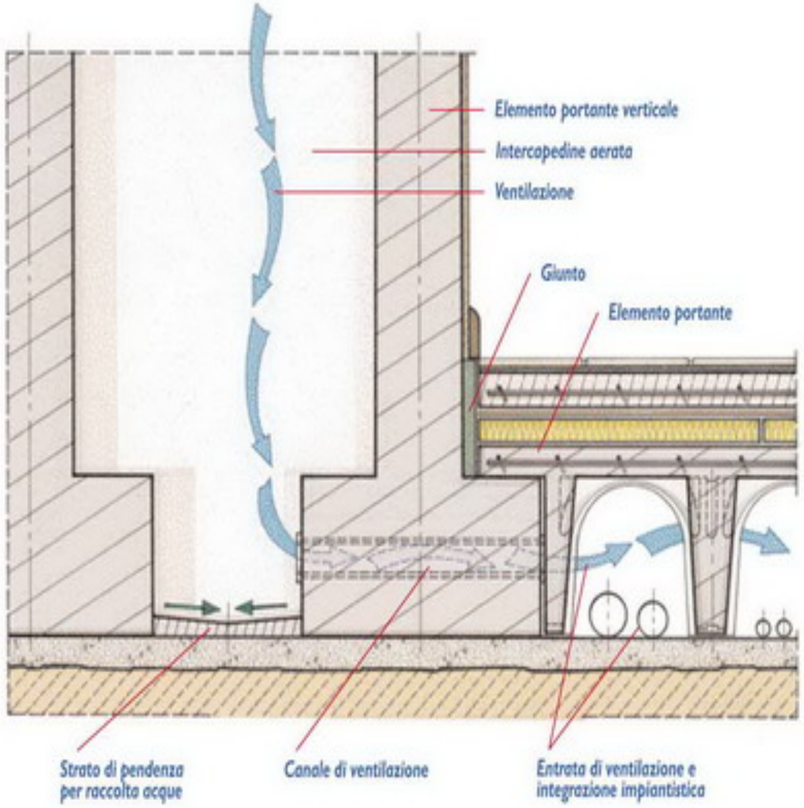
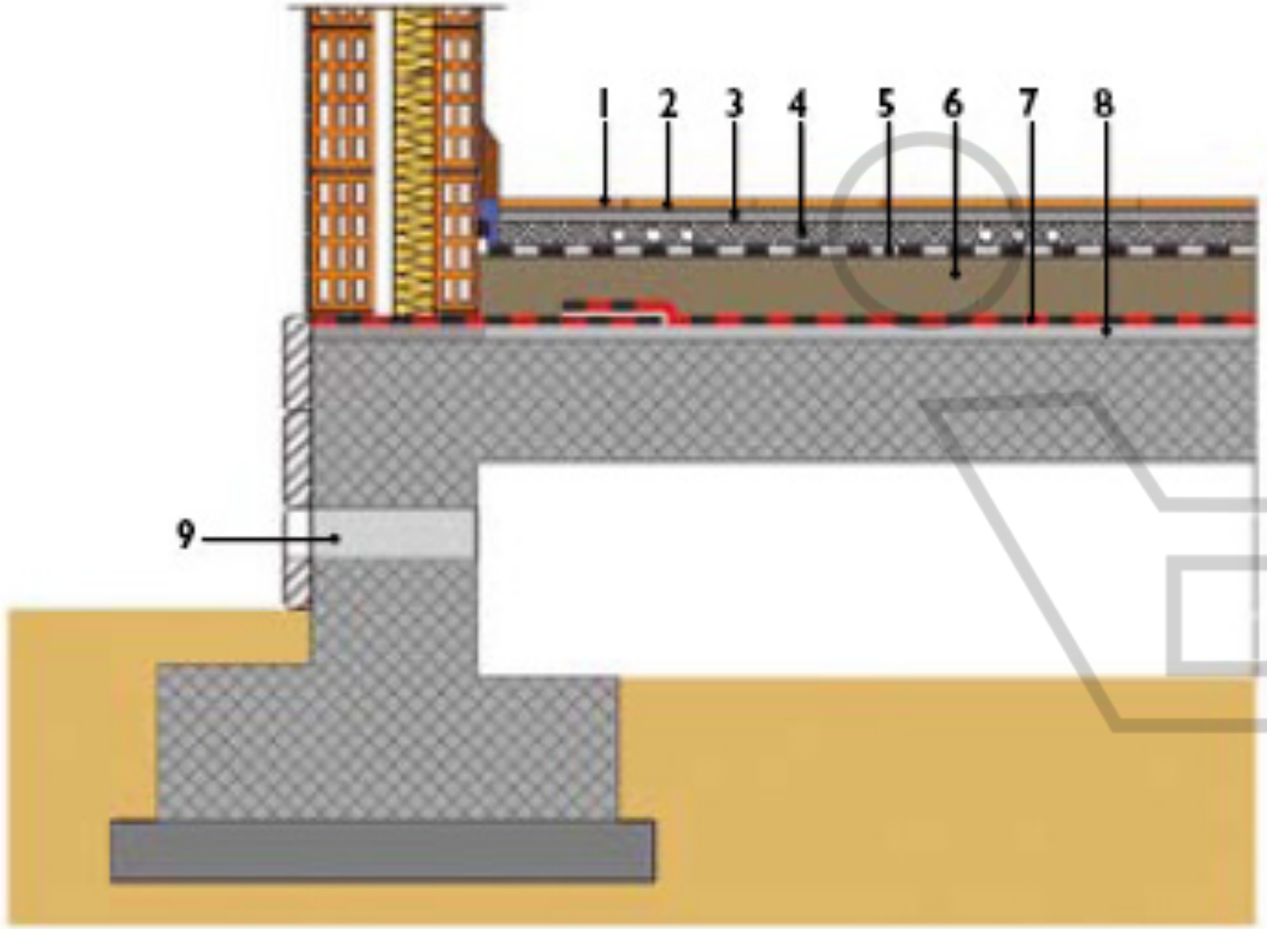




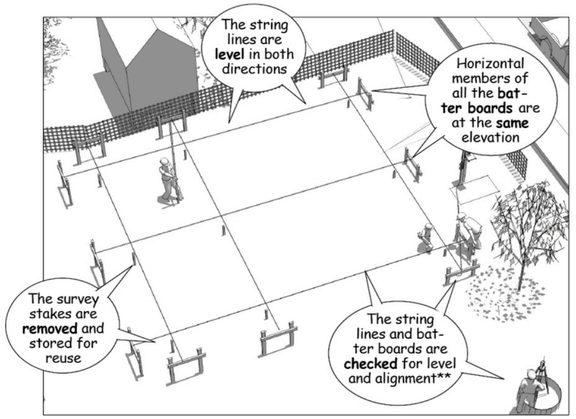


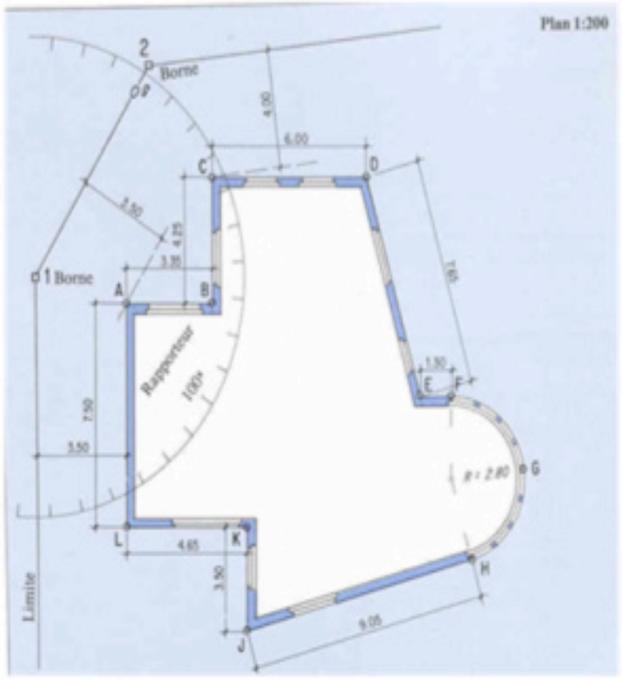
THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

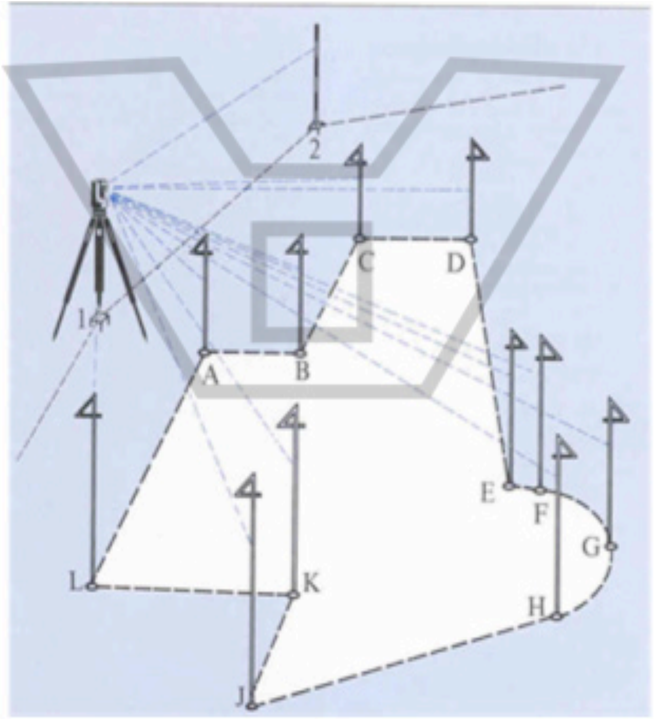
THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

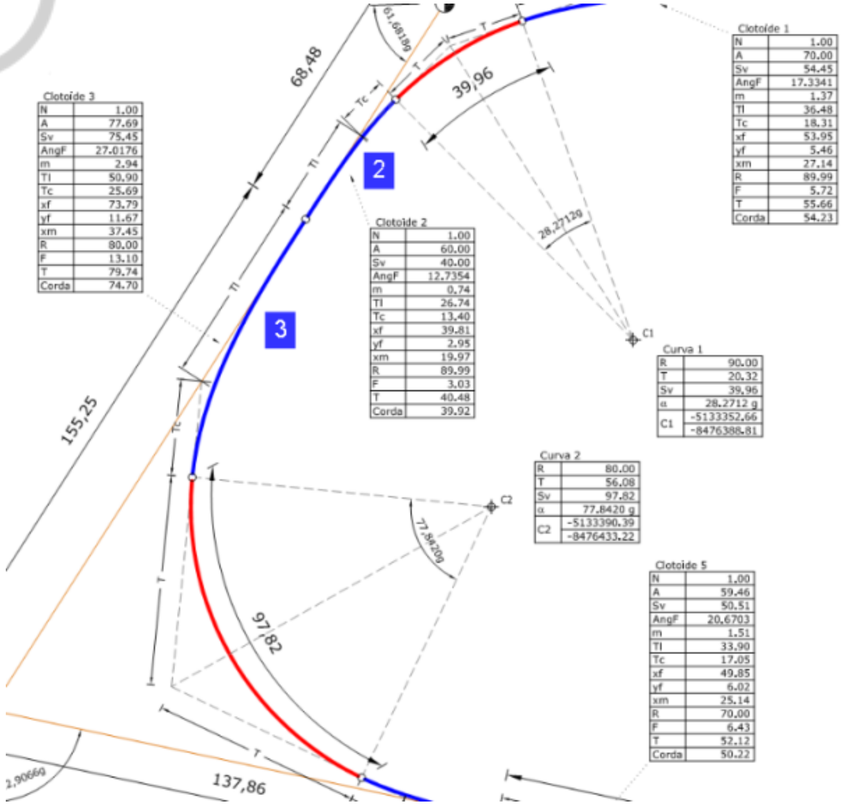


Special Construction Control Lines Grid: Triangulation Rulers

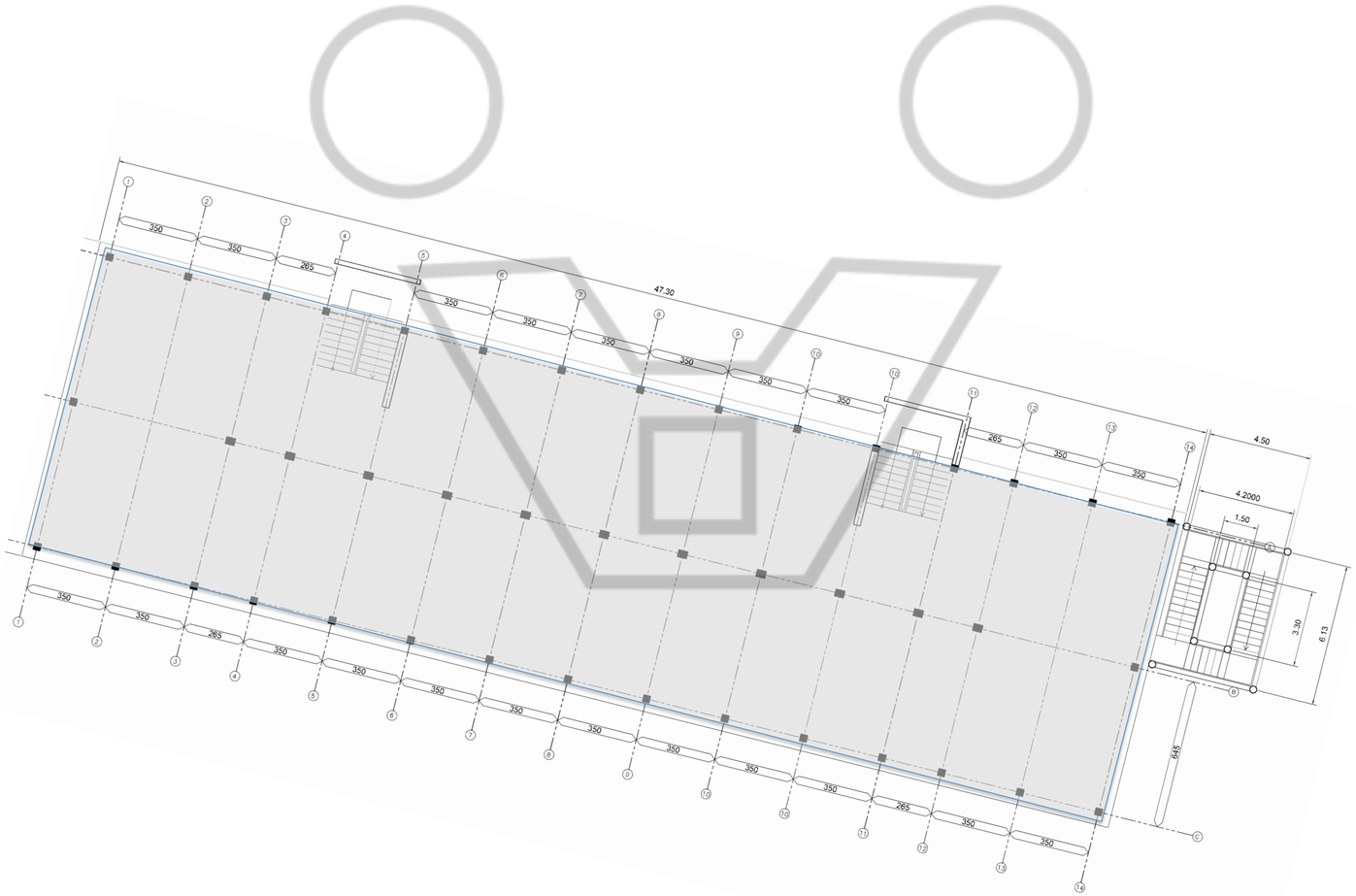




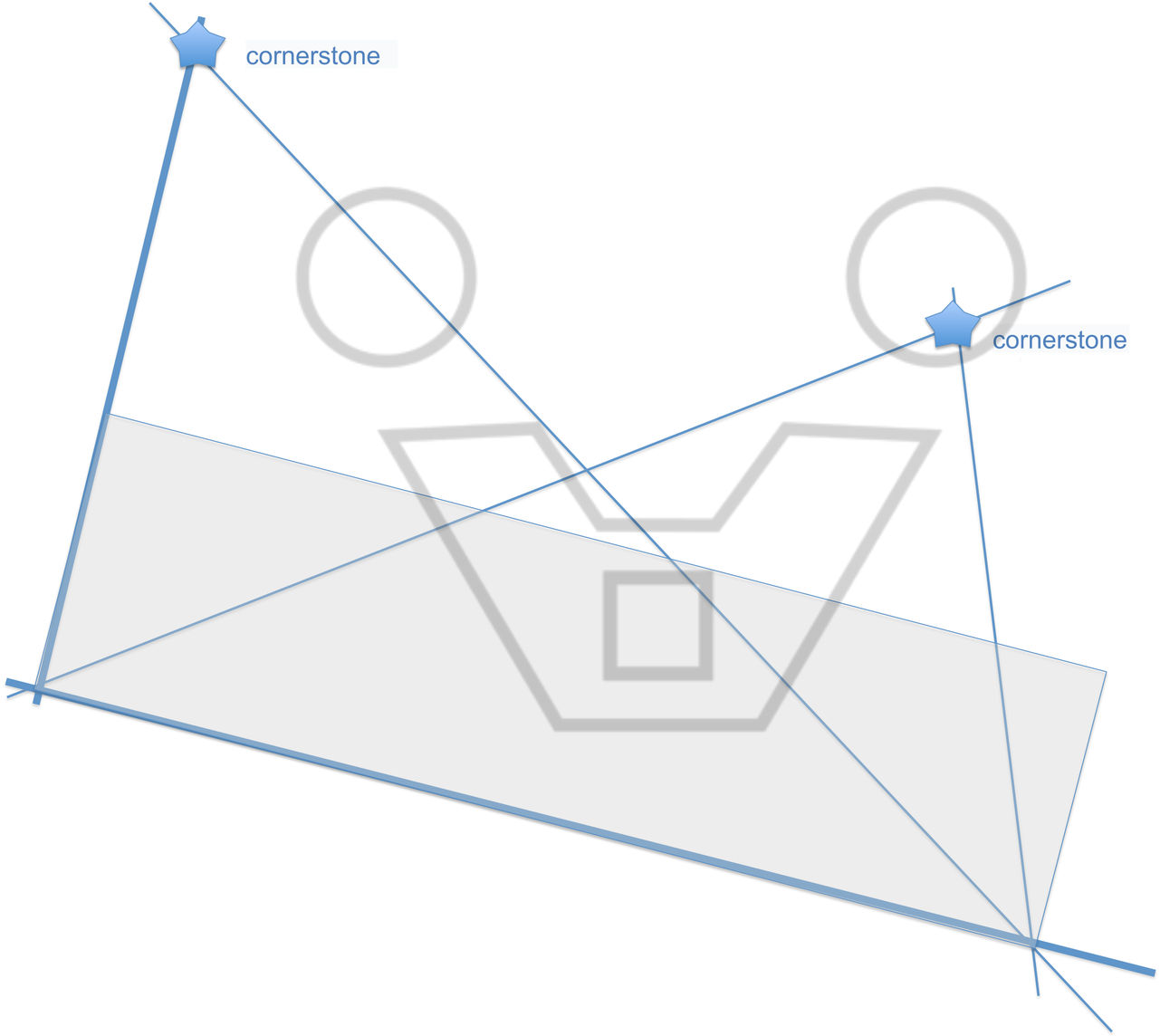




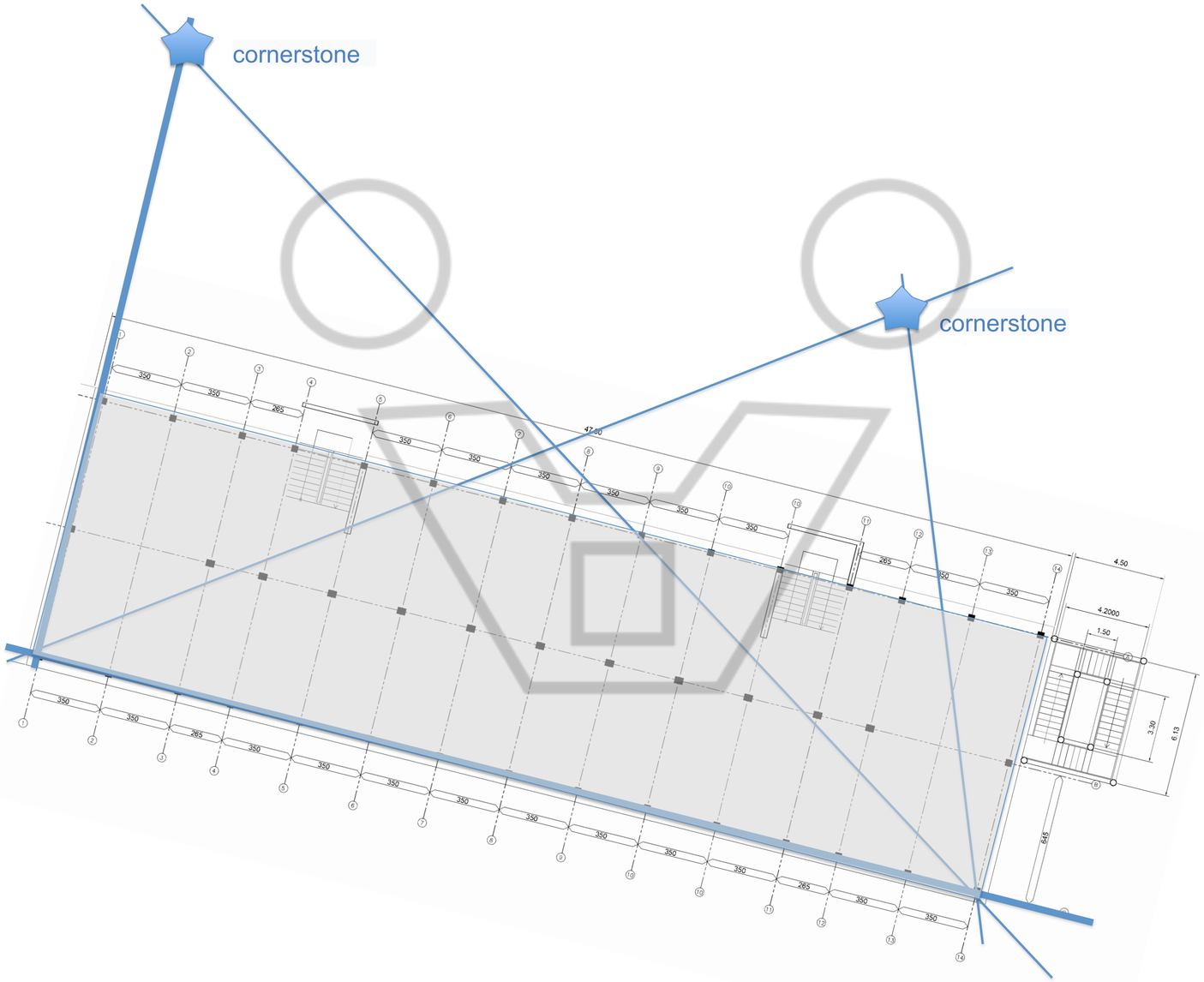
Special Construction Control Lines Grid: Triangulation Rulers for Building Placement



Special Construction Control Lines Grid: Triangulation Rulers for Building Placement



Special Construction Control Lines Grid: Triangulation Rulers for Building Placement



DEFINING GRIDS & 'MEASURES'

WAYS to BUILD & STRUCTURAL STRATEGIES

'SPAN & SPACE' IN RELATION TO MATERIALS AND TECHNOLOGIES

Karnak Temple (Old Tebe) Luxor, Egypt

Pantheon, Rome

Salone dei Cinquecento, Florence

Traditiona North American Natives' Tepee

Trullo

Common wooden slab

'SPAN & SPACE' IN RELATION TO FUNCTIONAL ACTIVITIES

WAYS TO BUILD

subtraction | addition

DIGGING

Zelve in Cappadocia, Turkey

STACKING

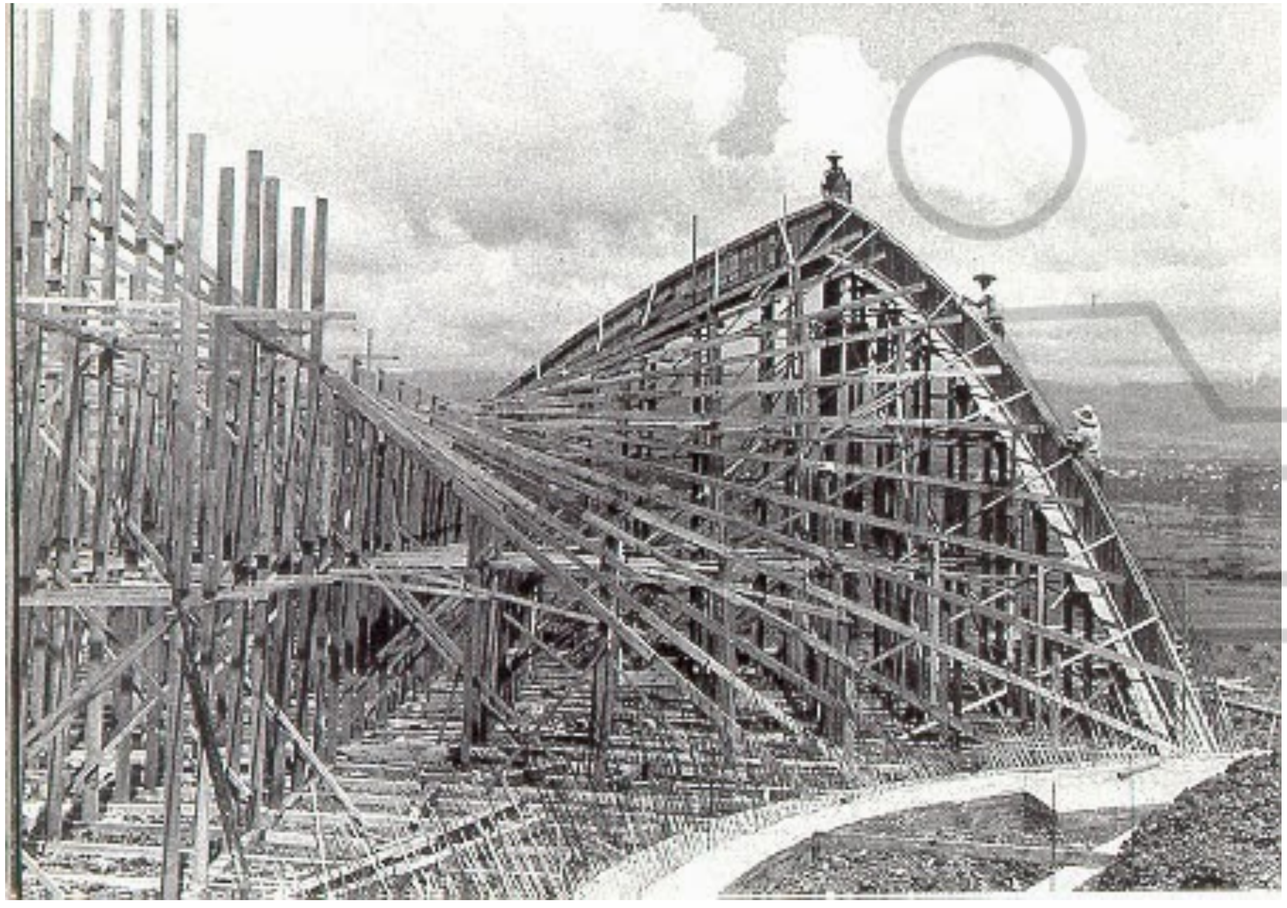
The oldest Piramid of Djoser by Imhotep , 27th Century BC, Egypt

WEAVING

Club House at Maipua in the Gulf of New Guinea

WAYS TO BUILD

WEAVING CAST ELEMENT

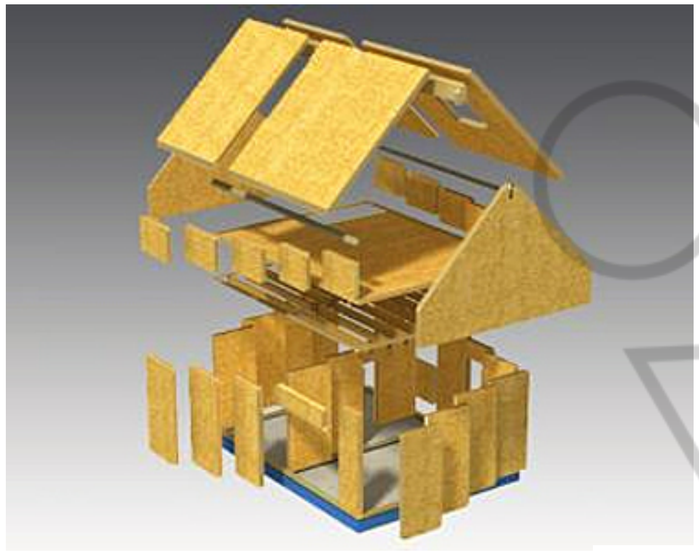


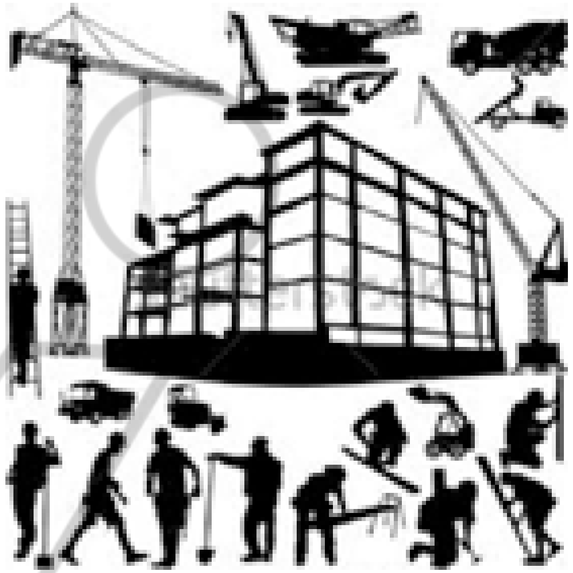
Felix Candela, Formwork of Hyperbolic Paraboloid Vault

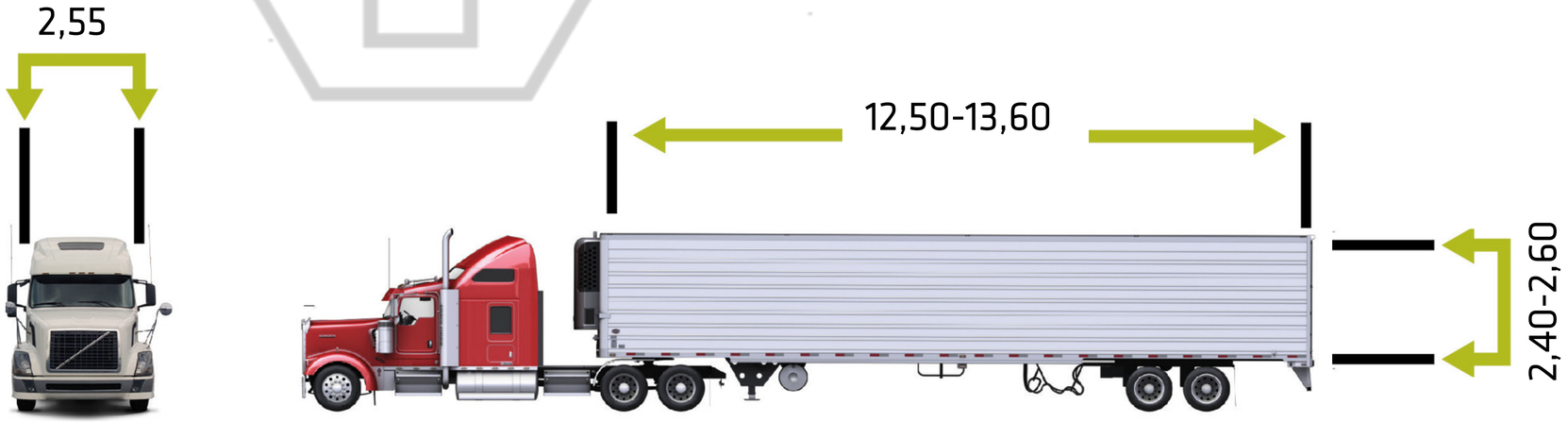
Bridge on River Severn by Abraham Darby III, 1779. A clear example of weaving and how, without scientific knowledge, designer applyed the rules of thumbs from other technologies: in this case from the construction of stone arches since cast iron has the same structural behavior of stone.

JOINING BUILDING ELEMENTS

Building is a big entity that needs to be assembled in different parts and phases.







Dimensions and manouvrability

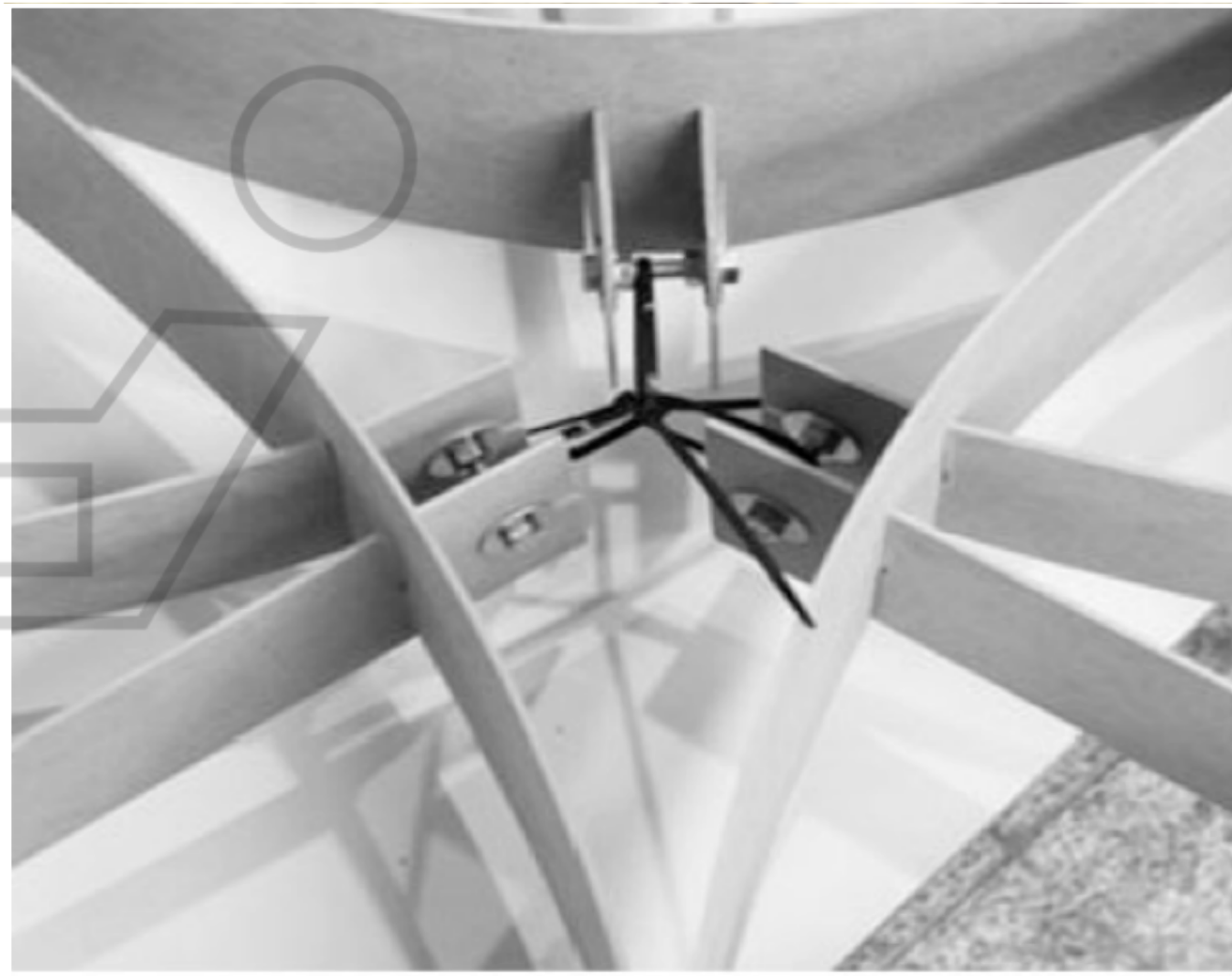
JOINING BUILDING ELEMENTS

STACKING | *GRAVITY & FRICTION*

Cuzco Wall, Peru

JOINING BUILDING ELEMENTS

WEAVING | *STRETCHING AND TYING*



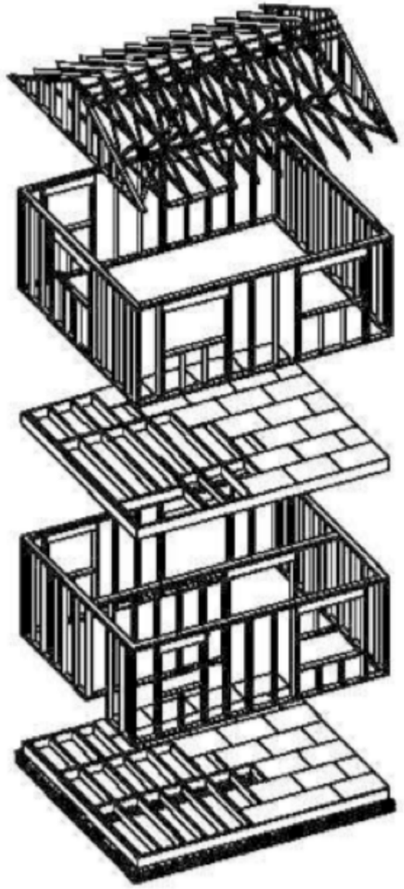
WAYS TO ADD ELEMENTS

PLATFORM STRATEGY

CONTINUOUS POLE STRATEGY

WAYS TO ADD ELEMENTS

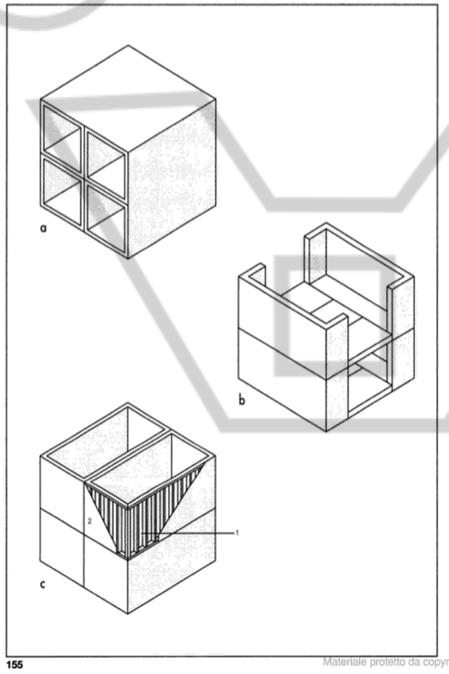
PLATFORM STRATEGY



Construction System based on Precast Slab

WAYS TO ADD ELEMENTS

PLATFORM STRATEGY



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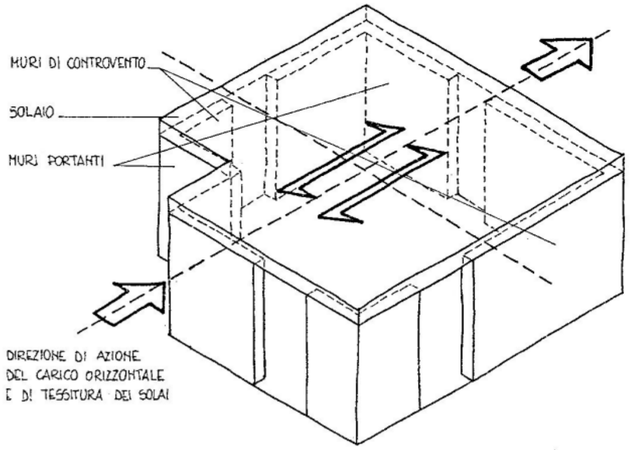
PLATFORM STRATEGY

a box-like structure

Concezione strutturale a "sistema scatolare":

L'edificio a muratura portante deve essere concepito come una *struttura tridimensionale*. I sistemi resistenti di pareti di muratura, gli orizzontamenti e le fondazioni devono essere collegati tra di loro in modo da resistere alle azioni verticali ed orizzontali.

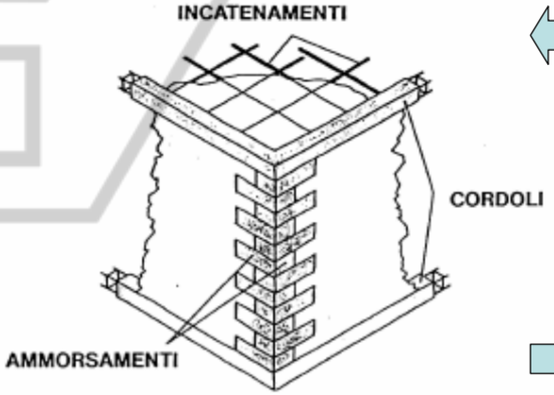


Ai fini di un adeguato comportamento statico e dinamico dell'edificio, tutti le pareti devono assolvere, per quanto possibile, sia la *funzione portante che di controventamento*.

L'organizzazione dell'intera struttura e l'interazione ed il collegamento tra le sue parti devono essere tali da assicurare appropriata resistenza e stabilità, ed un *comportamento d'insieme "scatolare".*

Per garantire il comportamento "scatolare":

muri ed orizzontamenti devono essere opportunamente collegati fra loro. Tutte le pareti devono essere collegate al livello dei solai mediante *cordoli di piano di calcestruzzo armato* e, tra di loro, mediante *ammorsamenti* lungo le intersezioni verticali. Devono inoltre essere previsti opportuni *incatenamenti* al livello dei solai, aventi lo scopo di collegare tra loro i muri paralleli della scatola muraria.

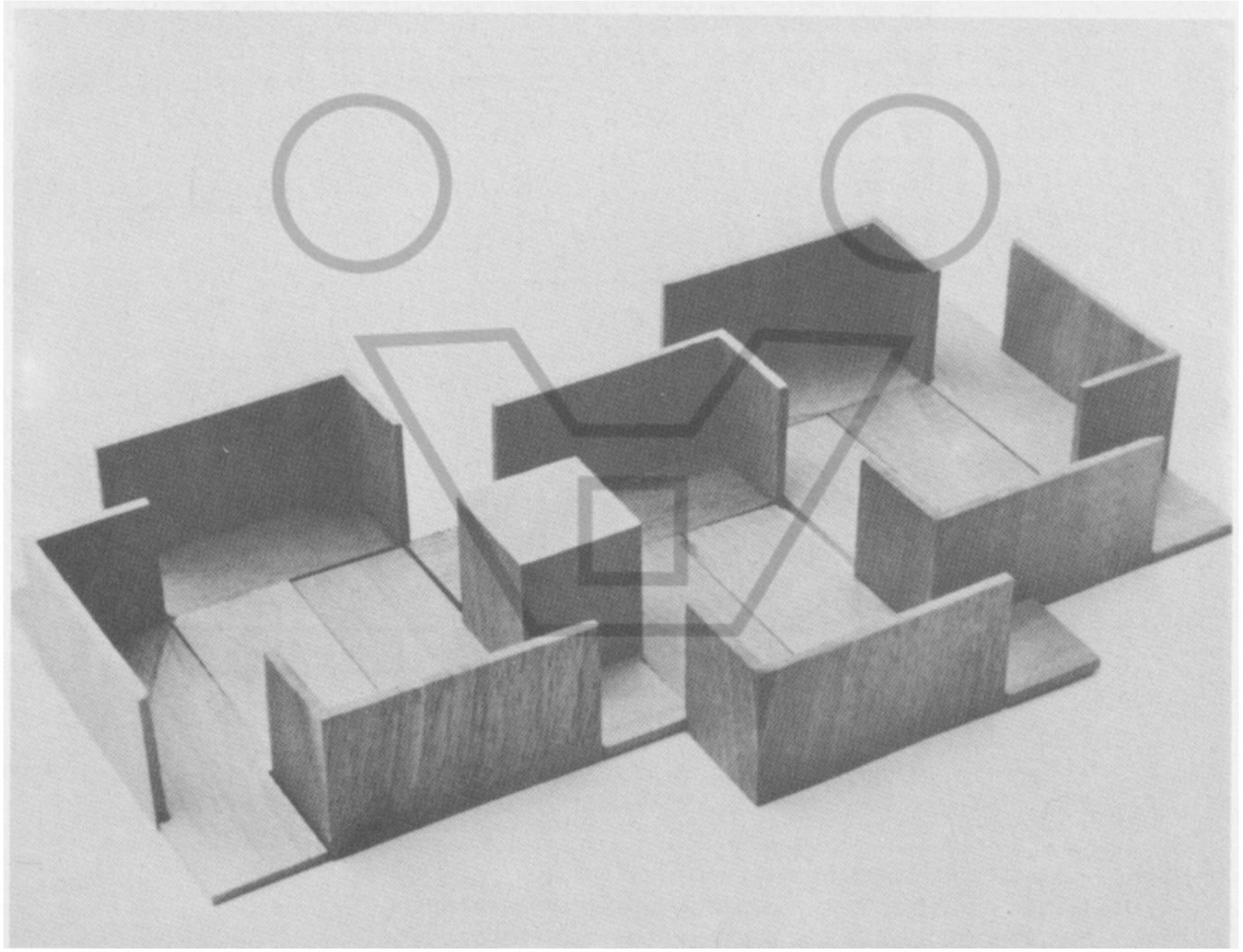


Le pareti portanti sono considerate resistenti anche alle azioni orizzontali quando hanno una lunghezza non inferiore a 0,3 volte l'altezza di interpiano; e devono avere spessore minimo di:

- muratura in elementi resistenti artificiali pieni	150 mm
- muratura in elementi resistenti artificiali semipieni	200 mm
- muratura in elementi resistenti artificiali forati	240 mm
- muratura di pietra squadrata	240 mm
- muratura di pietra listata	400 mm
- muratura di pietra non squadrata	500 mm

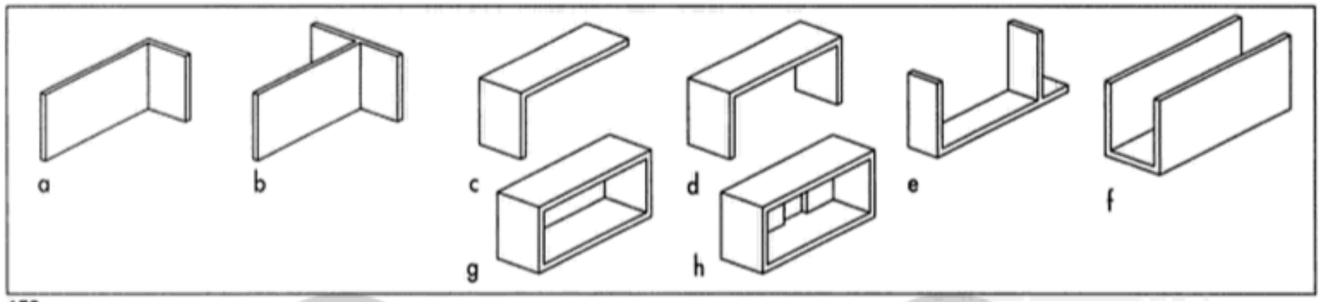
La buona concezione strutturale ed una corretta realizzazione dei dettagli strutturali garantisce un adeguato comportamento strutturale. Ciò è riconosciuto dalle NTC: *'edifici semplici'*.

ELEVATION



Triedro System

ELEVATION



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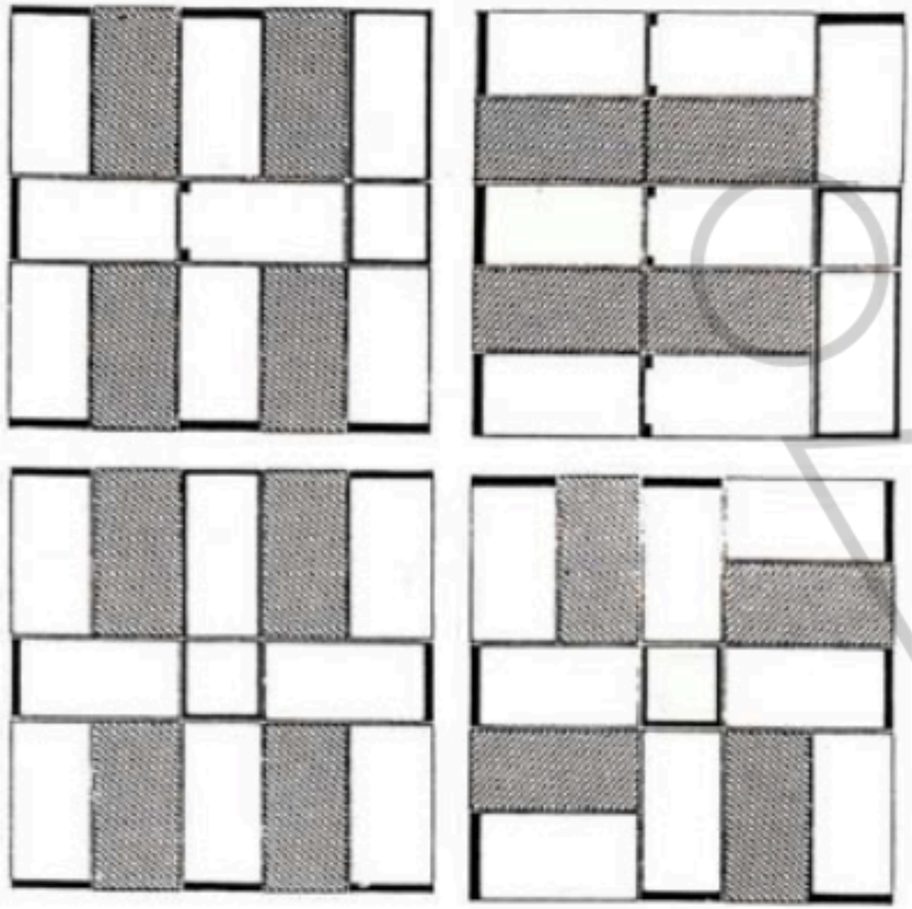
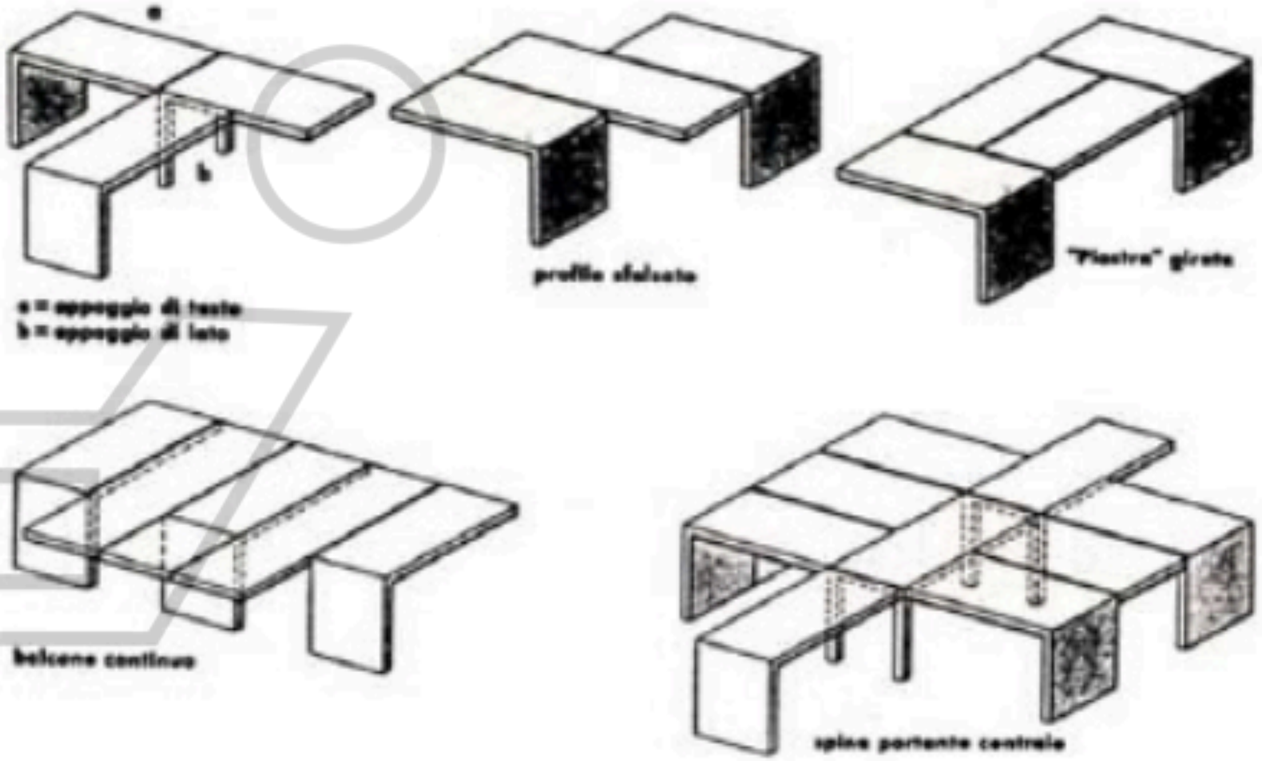
Triedro System

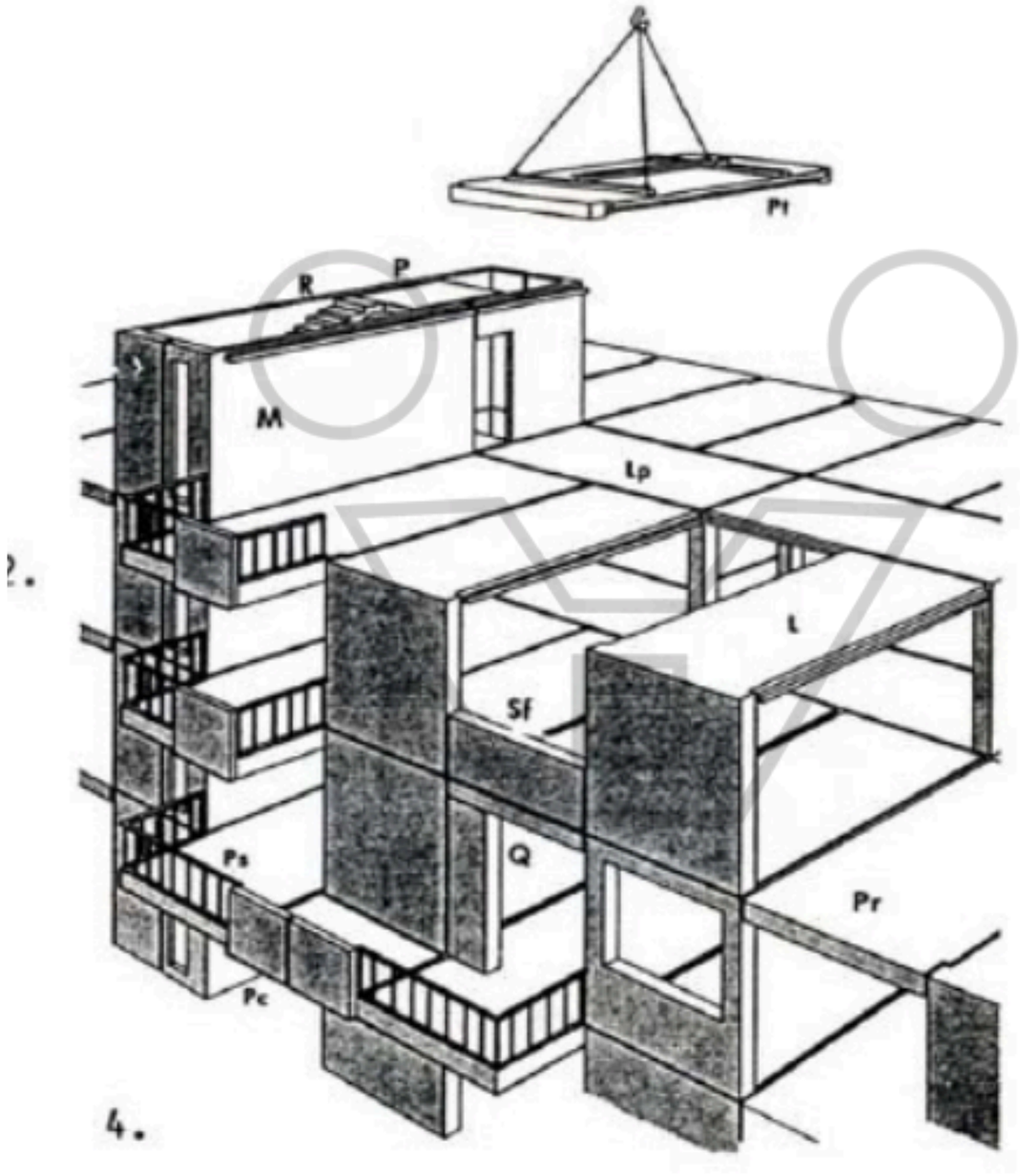


2.

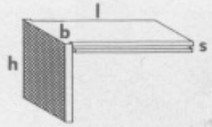
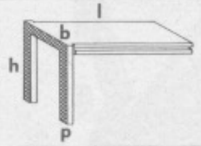
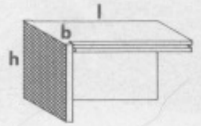
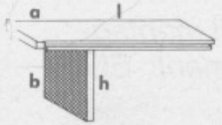
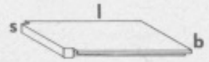
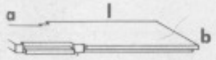
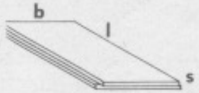
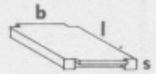


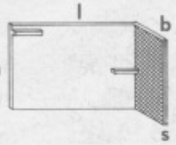
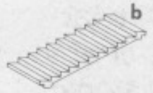
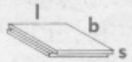
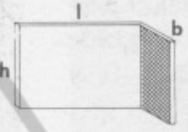
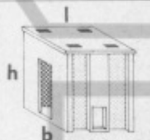
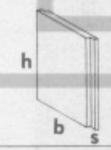
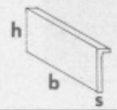
Not bearing element

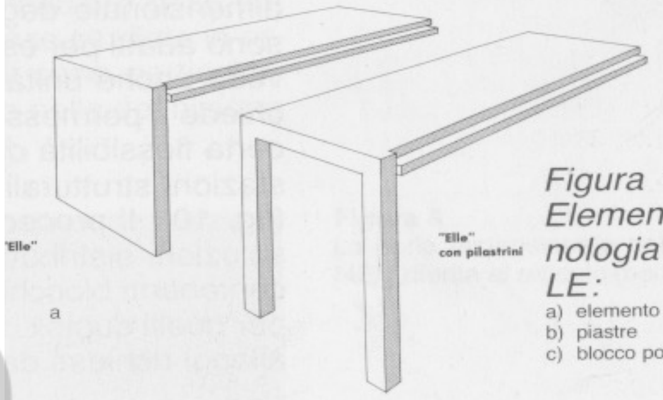
Elle System | Diagrammatic composition

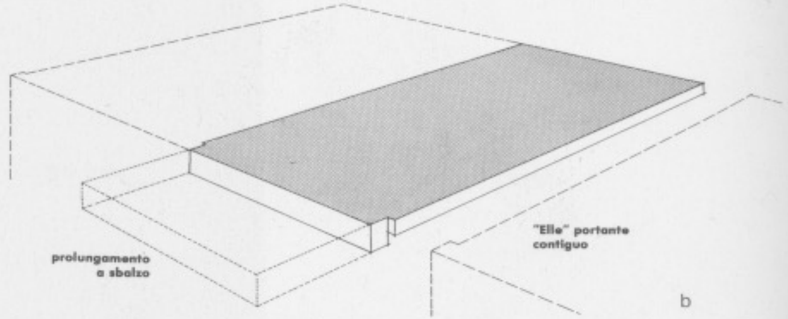


Elle System | Assembling

L	elemento "Elle"		l = 240 ÷ 600 b = 240 s = 25 h = 280 ÷ 360
Lp	"Elle" con pilastrini		l = 240 ÷ 600 b = 240 p = 30 min. h = 280 ÷ 360
La	"Elle" d'angolo		l = 240 ÷ 600 b = 240 h = 280 ÷ 360
Ls	"Elle" a sbalzo		l = 240 ÷ 600 a = 120 ÷ 240 b = 240 h = 280 ÷ 360
Pt	"Piastra"		l = 240 ÷ 600 b = 120 ÷ 300 s = 25
Ps	"Piastra" a sbalzo		l = 240 ÷ 600 a = 120 ÷ 240 b = 120 ÷ 300
Pg	"Piastra" girata		l = 240 ÷ 600 b = 120 ÷ 300 s = 25
Pc	"Piastra" di collega-mento		l = 240 b = 120 ÷ 240 s = 25

blocchi portanti	**M** muro scala		l = 480 ÷ 600 b = 120 ÷ 240 h = 280 ÷ 360 s = 15
	R rampa scala		b = 100/115/130 n. alzate 9 ÷ 11 n. pedate 8 ÷ 10
	P pianerottolo		l = 75/105/135 b = 210 ÷ 450 s = 25
	A angolo		l = 240 ÷ 600 b = 240 h = 280 ÷ 360
	B blocco bagno		l = 180/240 b = 240 h = 280 ÷ 360
elementi complementari	**Q** quinta		h = 255 ÷ 335 b = 60/120 s = 25
	Sf sottofinestra		h = 95 b = 120 ÷ 300 s = 13
	Pr parapetto		h max = 95 b max = 480 s = 8





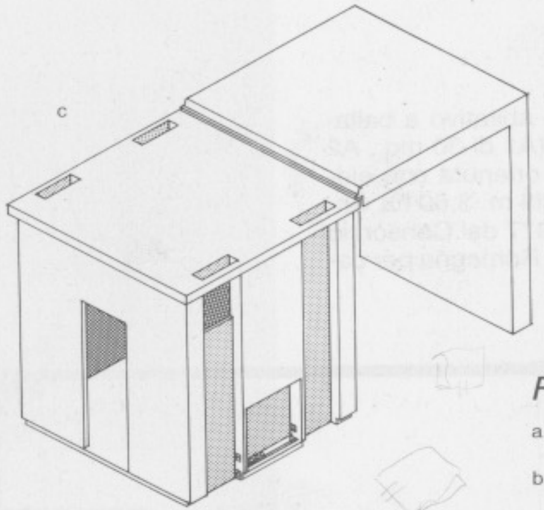


Figura 1: Elementi tipo della nologia costruttiva LE:

a) elemento tradizionale a «L»
b) piastre
c) blocco portante

Figura 2:

a. Schema di ciclo produttivo a fissi
b. Schema di ciclo produttivo a mobili.

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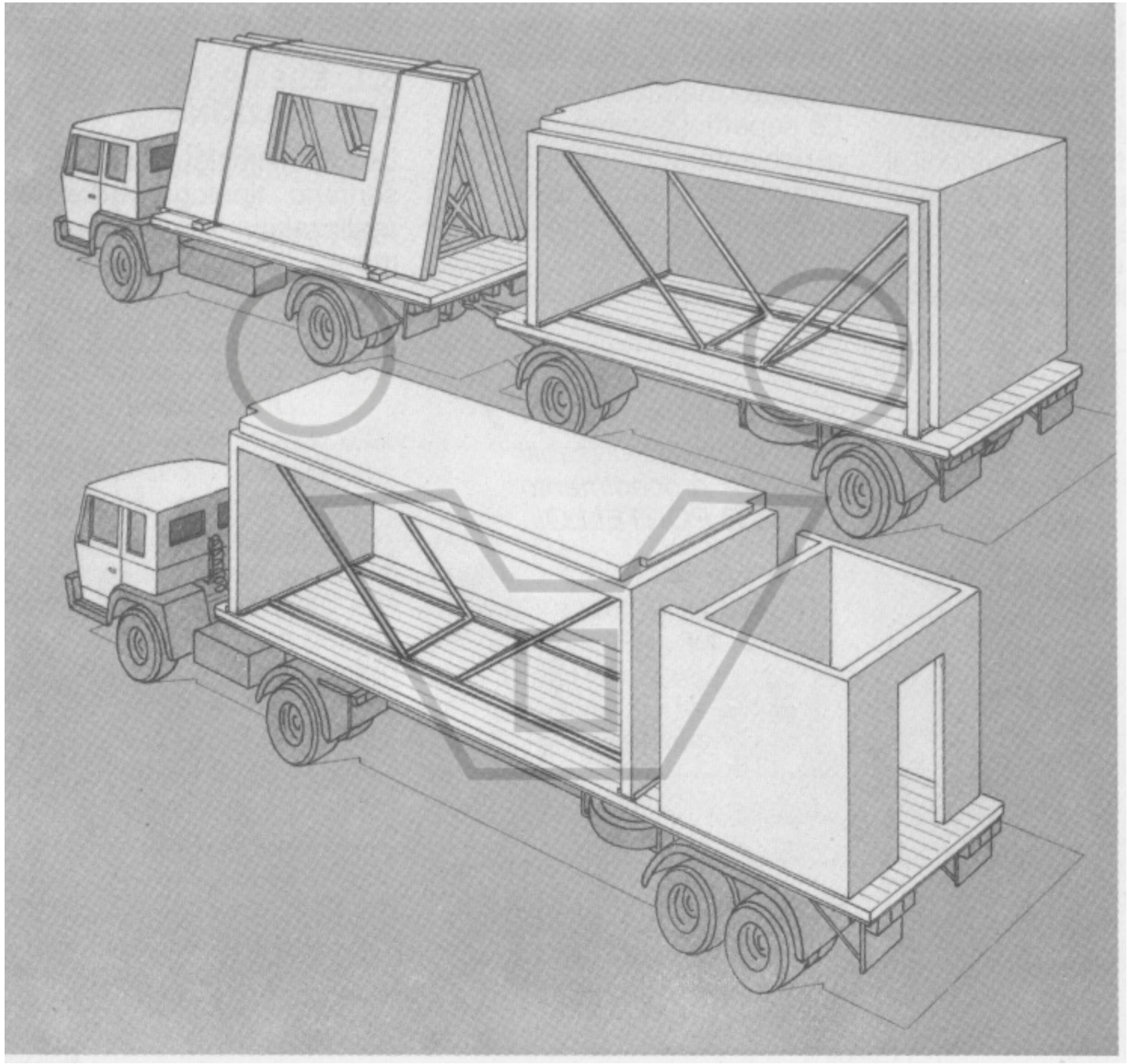


Dolmen System- Transportation

PLATFORM STRATEGY

not necessarily monotonous boxes

Habitat 67, by Moshe Safdie, Montreal

WAYS TO ADD ELEMENT

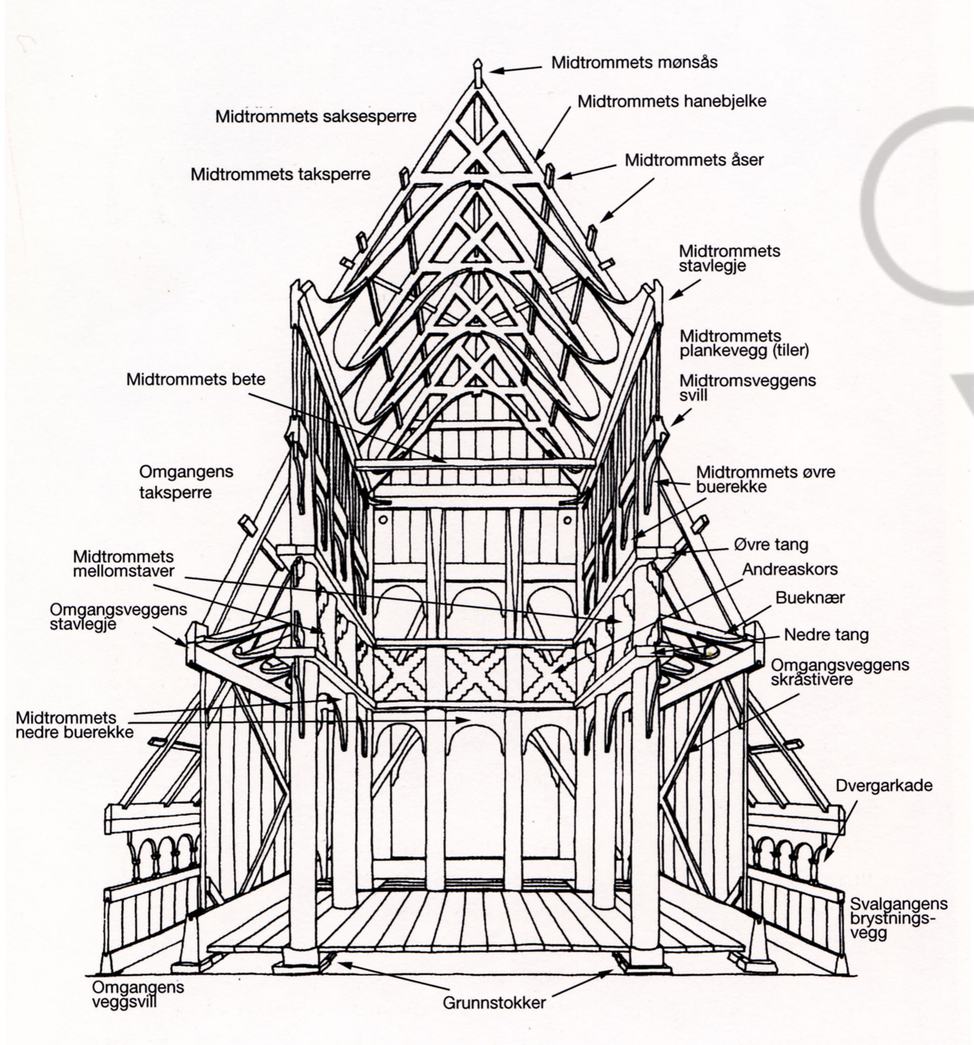
CONTINUOUS POLE STRATEGY

Borgund stavkyrkje (1180 and 1250 AD), Norway

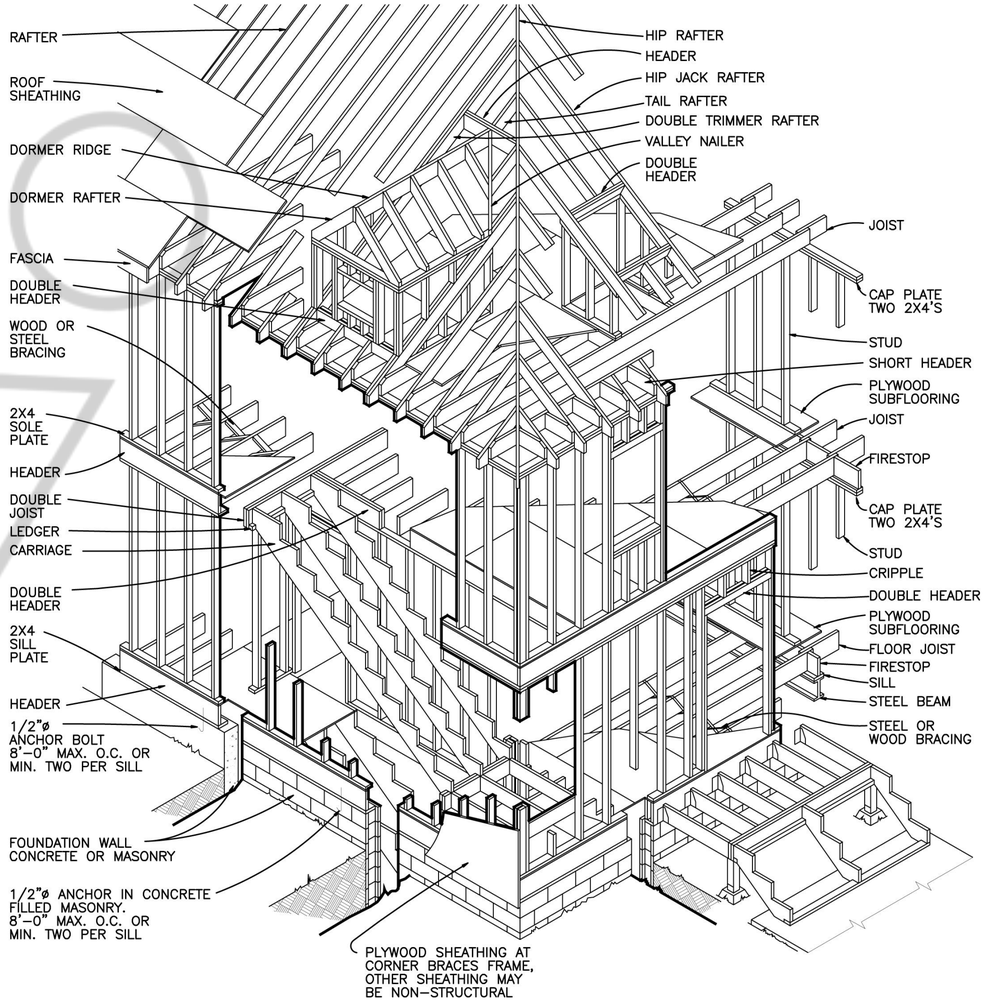
Akademie-du-Mont-Cenis, Herne, Germany

WAYS TO ADD ELEMENTS

CONTINUOUS POLE STRATEGY



Borgund stavkyrkje (1180 and 1250 AD), Norway

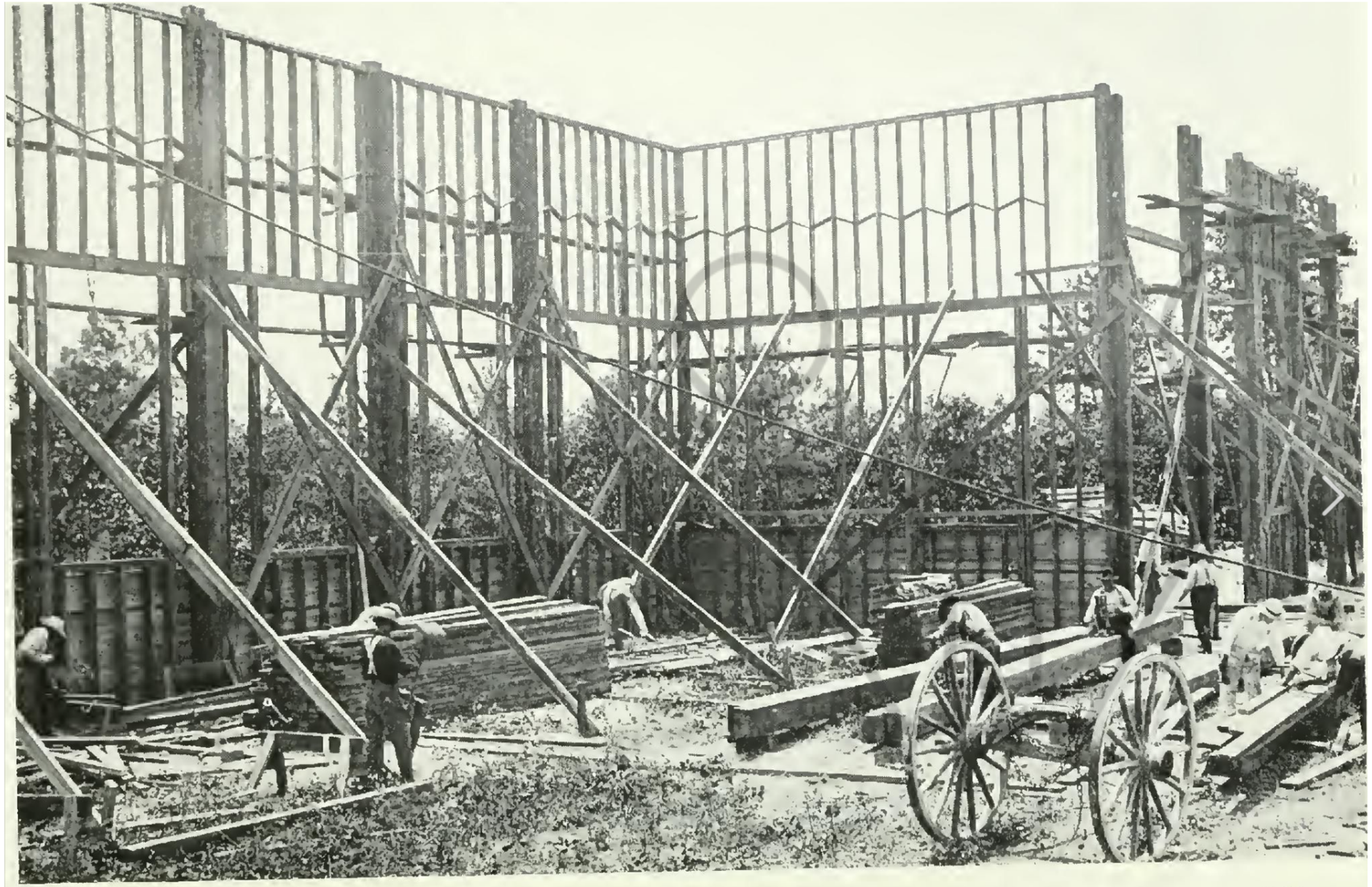


Ballon Frame, from **Augustine Taylor's idea in Chicago in 1833**

HEAVY FRAMING STRUCTURE

LIGHT FRAMING STRUCTURE *use of standardized and uniform elements of reduced dimensions*

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



ERECTING FRAMEWORK FOR ONE OF THE BUILDINGS OF THE JAMESTOWN EXPOSITION OF 1907.

This exposition commemorated the 300th anniversary of the founding of the first permanent settlement of English-speaking people in America, which occurred at Jamestown, Virginia, May 13, 1607.

Examples of machine cut (or square) nails

St. Mary's Catholic Church nearby Fort Dearborn
by Augustine Taylor (1833)

STEEL FRAMED & TALL BUILDINGS

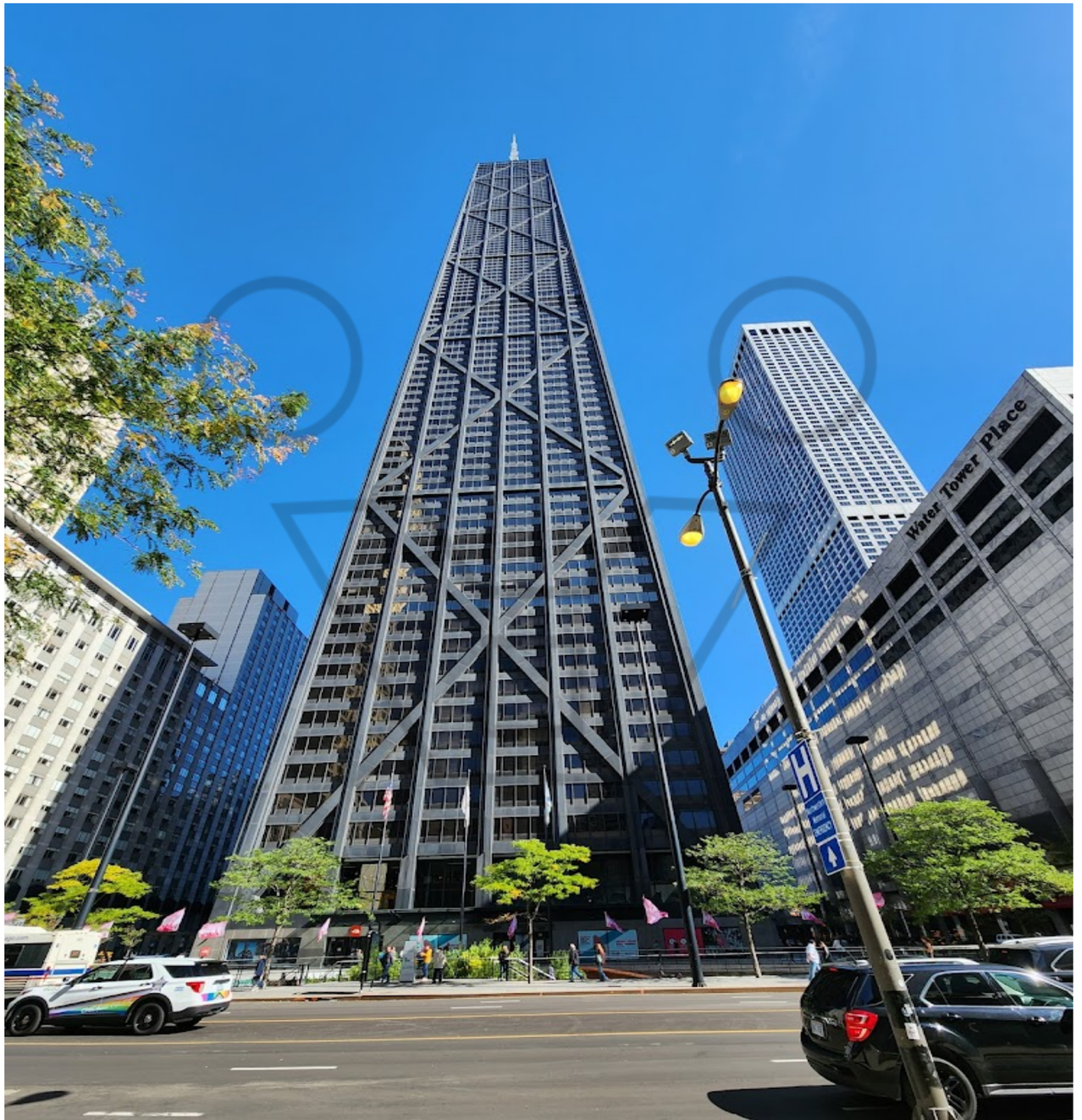
Marshall Store, di Henry Hobson Richardson, Chicago 1885-87

Leiter Building, William Le Baron Jenney, Chicago 1879

FIRST 'STEEL' FRAMED BUILDING

Chocolaterie Menier by Julies Saulnier in Moisiel-su-Marne (1871) pressi Parigi

BRACING

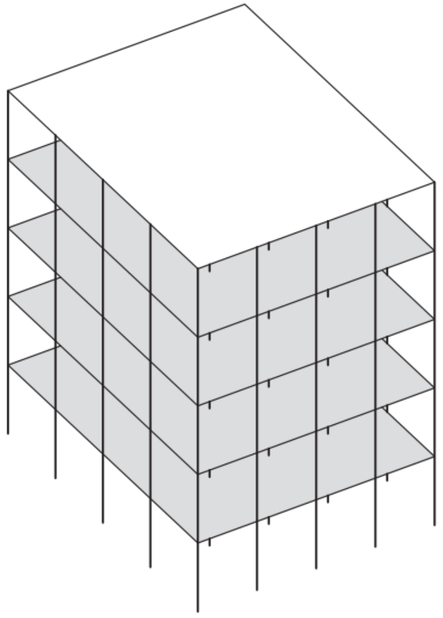


John Hancock Center, Bruce Graham e Fazlur Khan, Skidmore, Owings, & Merrill, Chicago, 1969

BRACING

15.7.2 Rigid Frame

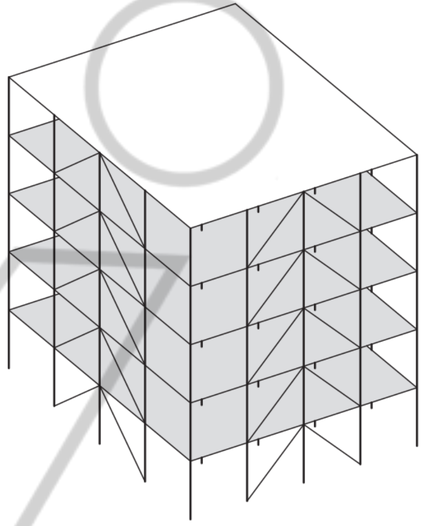
Moment frames can be designed to about 30 stories in height. Above that, member sizes become too large to make the design practical. The primary advantage to a moment frame is the unobstructed view it allows when used with a curtain wall system. Although moment frames are often called rigid frames, they are actually more flexible than braced frames. They are called rigid frames because the system transfers moment from the beams to the columns via rigid connections.



15.21
Rigid frame

15.9.3 Braced Frames

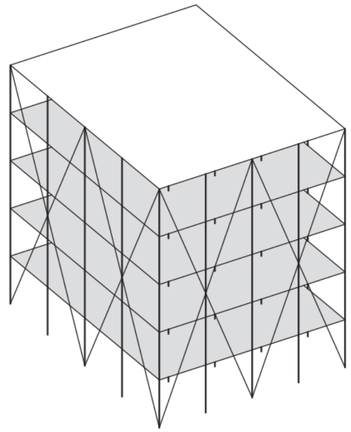
Braced frames work well to a height of about 80 stories. Beyond that, the forces accumulated in the diagonals make the member sizes bulky. Diagonals help reduce the moment in individual members and reduce drift (lateral deflection). Diagonals in braced frames span only one floor level.
The disadvantages of braced frames include the possible obstruction of view at window locations and the expense of fabrication and installation of the diagonal connections.



15.22
Braced frames

15.9.4 Trussed Tube

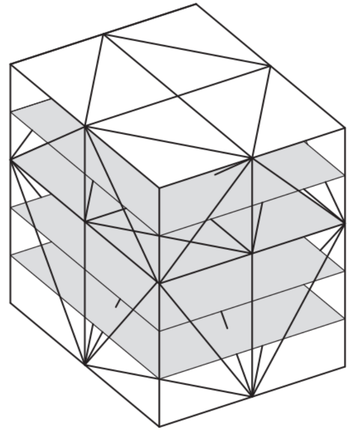
In a trussed tube, sometimes called a braced tube, the tube is braced with diagonals that span multiple stories creating a giant truss system. There may be columns in the core, but they support gravity loads only and not lateral loads. The John Hancock Building in Chicago by Fazul Kahn is a good example of a trussed tube.



15.23
Trussed tube

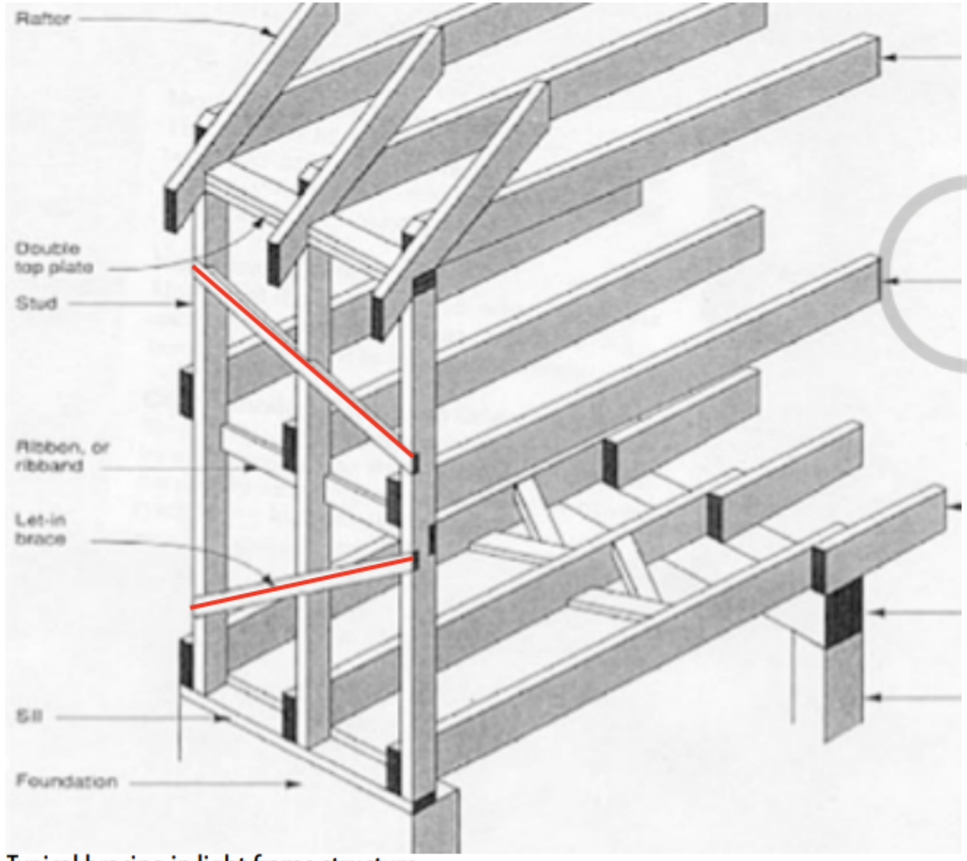
15.7.5 Space Truss

Space trusses in high-rise systems follow the same logic as discussed in section 15.5 but at a very large scale. Space truss components can vary from single floor height to multiple floor height. The floor loads are transferred to the truss components, which in turn transfer loads vector-actively to the ground.

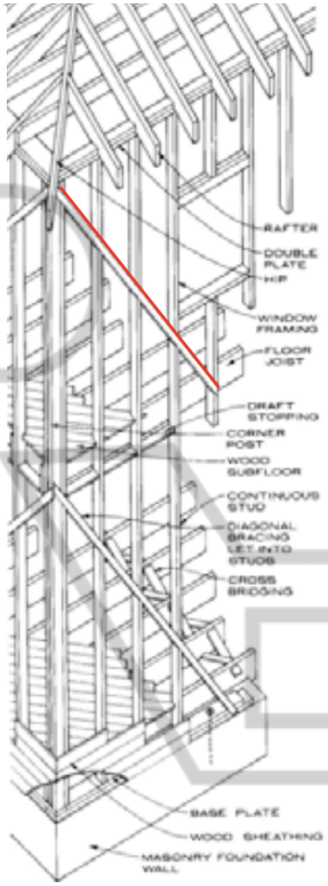


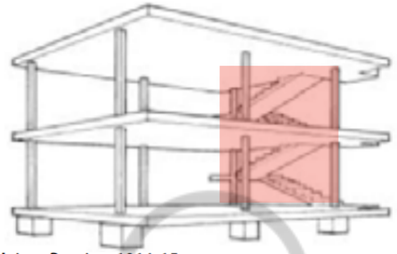
15.24
Space truss

BRACING



Typical bracing in light frame structure



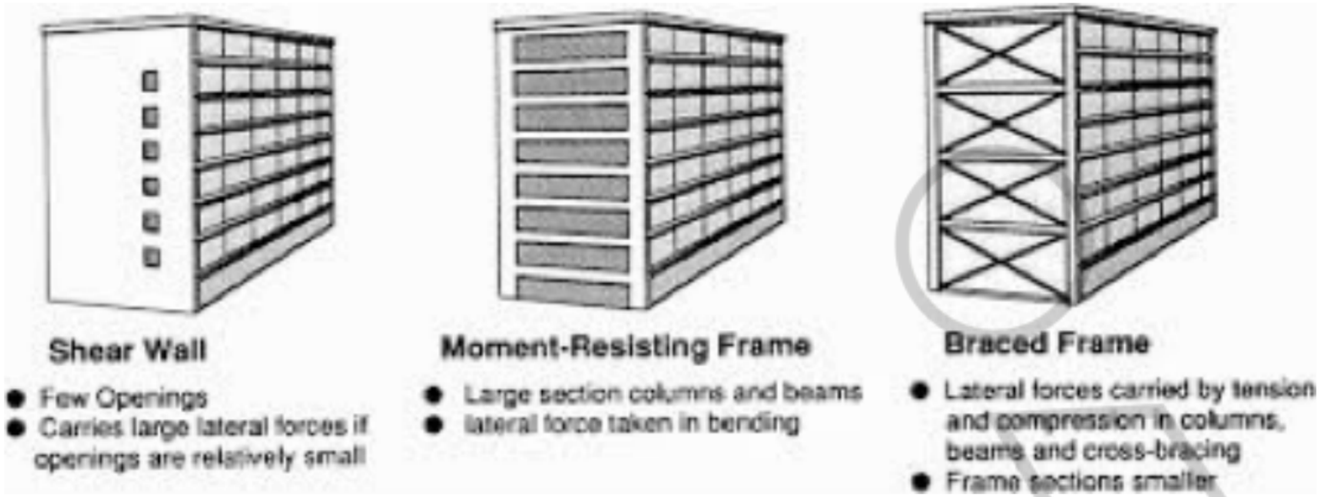


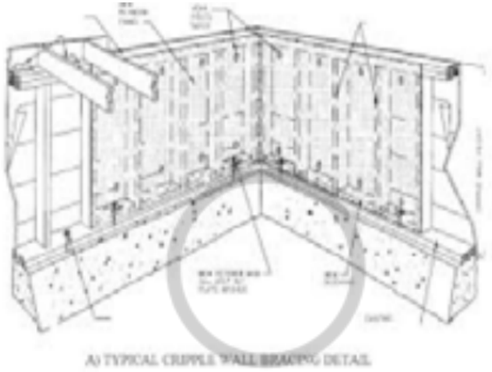
Maison Domino 1914-15

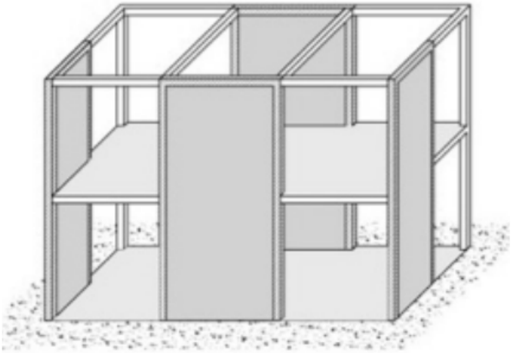
G. Terragni 1932-36

Different bracing devices

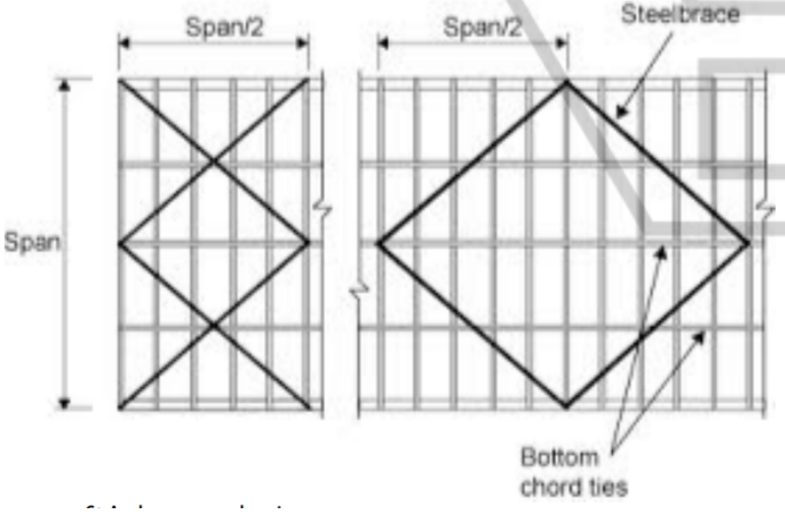
BRACING

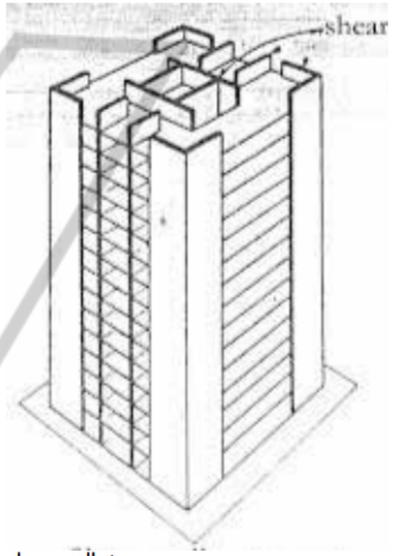






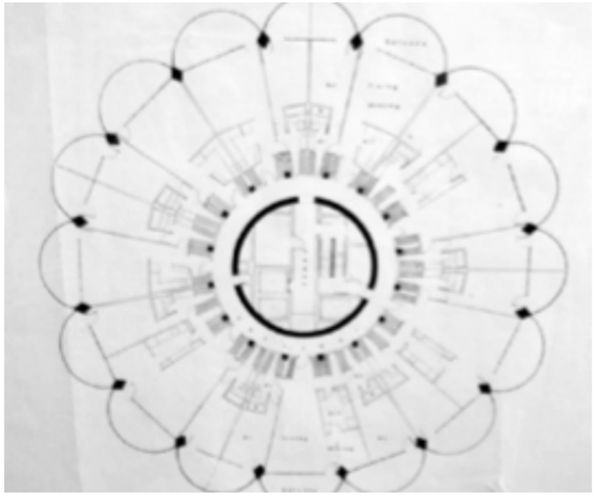
overlapping rigid boards to the frame elements.





shear walls type

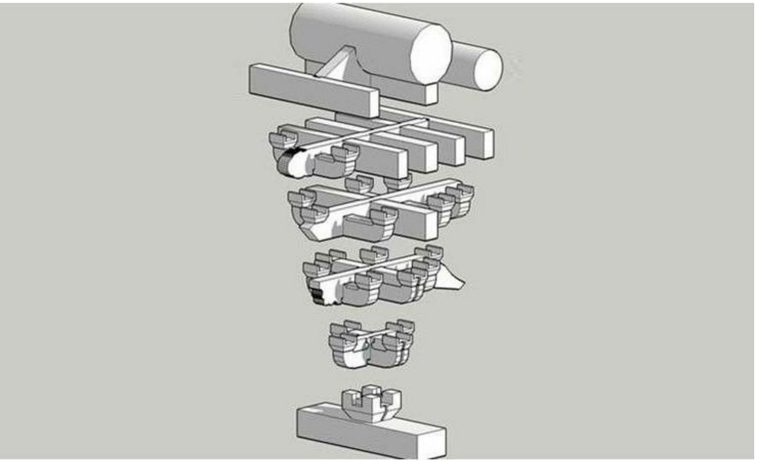
St.Andrews cross-bracing

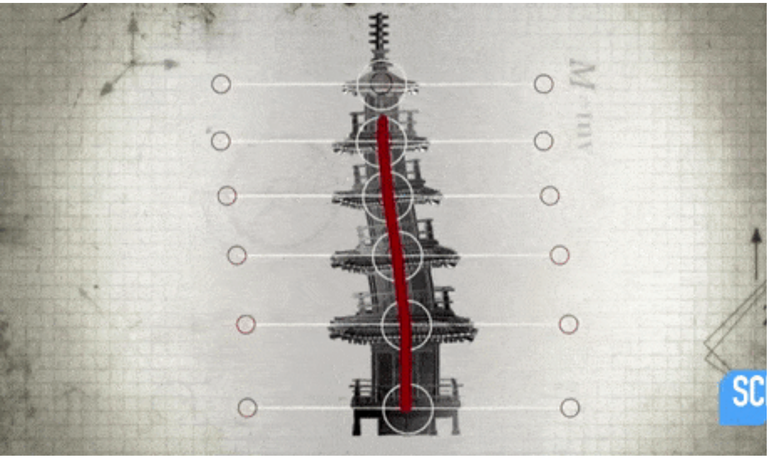


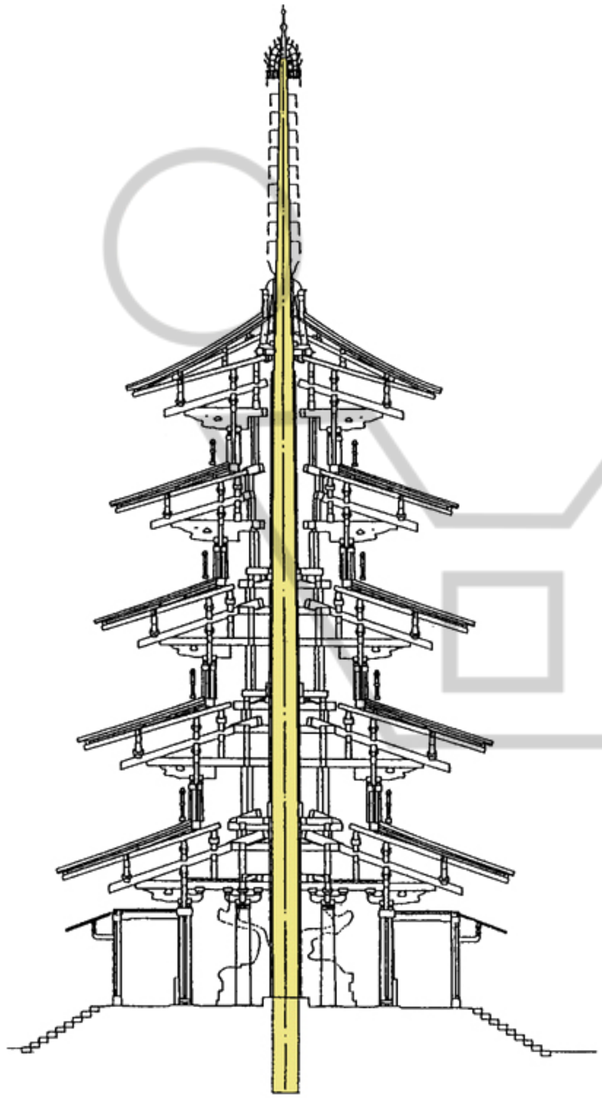
shear core type Bertrand Goldberg , Marina City Apartments, 1959-64

One of the most important aspects to take in account in designing framing structure is the *bracing* to prevent the

RESIST USING FORCE OR MOVEMENTS







TYPES OF STRUCTURAL ELEMENTS

CONTINUOUS

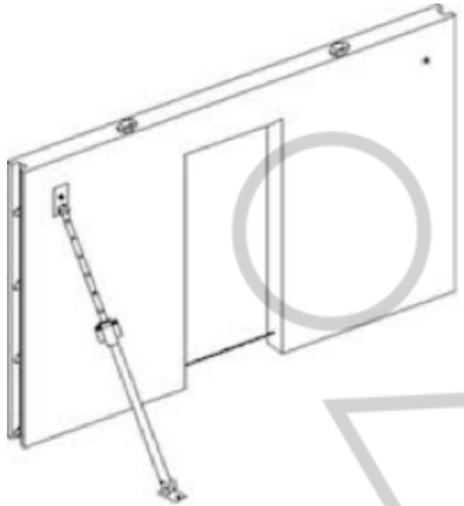
DISCRETE

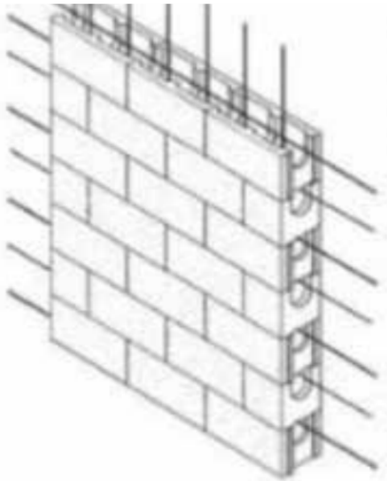
Efficiency versus complexity

TYPES OF STRUCTURAL ELEMENTS: CONTINUOUS

Palazzo Medici Riccardi, Michelozzo, Firenze 1444-1464

TYPES OF STRUCTURAL ELEMENTS: CONTINUOUS





TYPES OF STRUCTURAL ELEMENTS: CONTINUOUS

TYPES OF STRUCTURAL ELEMENTS: CONTINUOUS

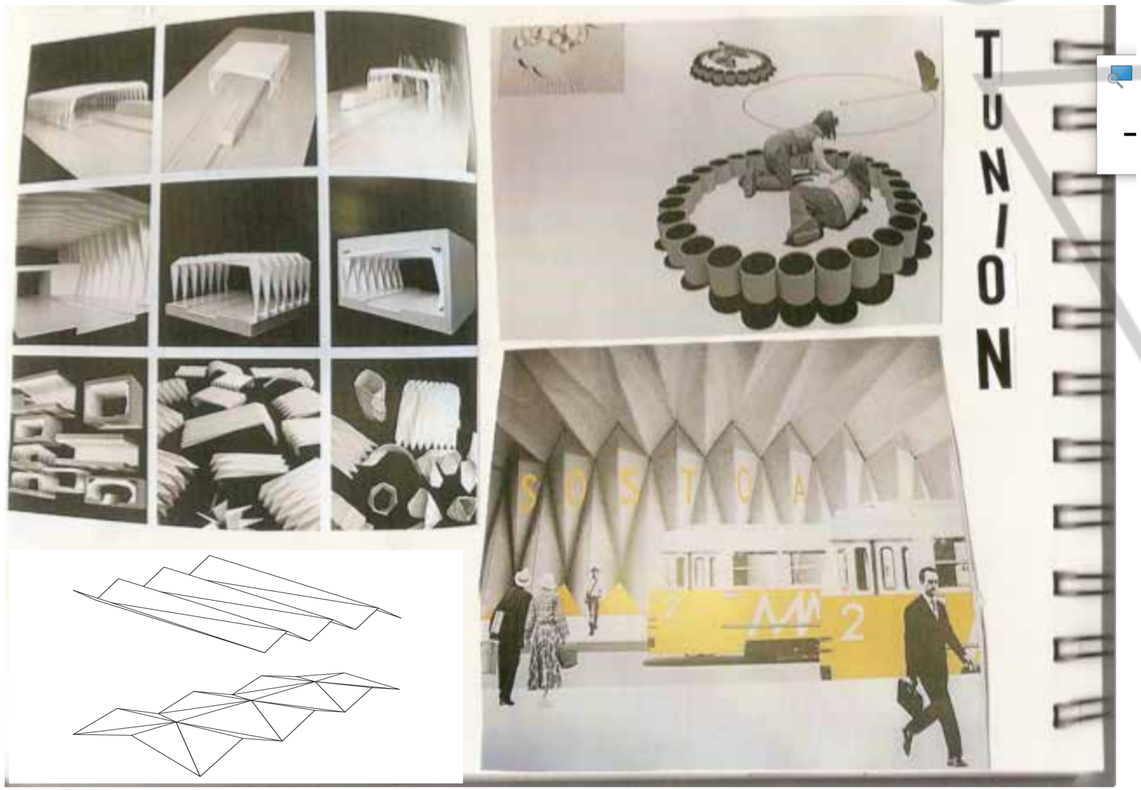
STRUCUTRAL INSULATED PANELS

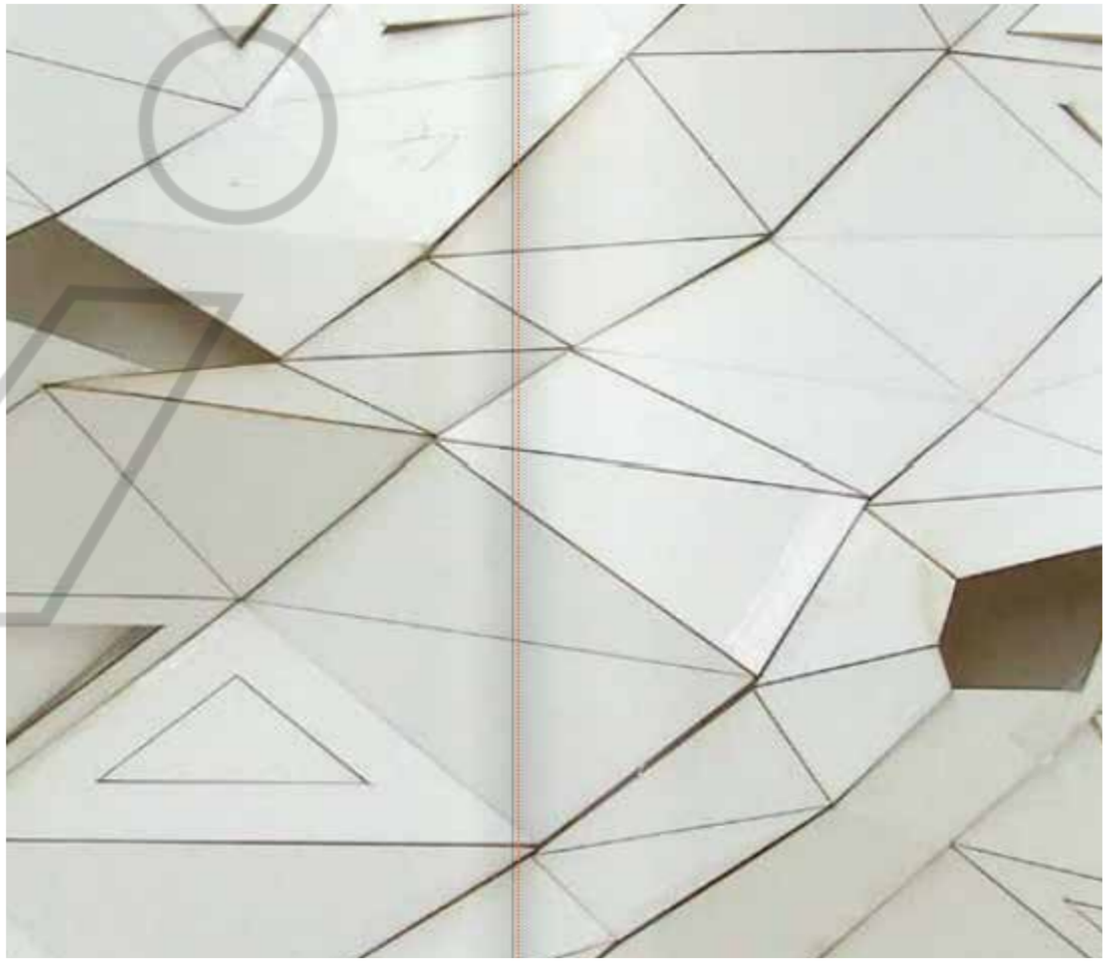
CROSS LAMINATED TIMBER (CLT) / CROSS-LAM (XLam)

Cross Laminated Timber (CLT) or briefly Cross-Lam (Xlam) is a new generation of engineered massive wood product started from 1990 in Austria and Germany, that has been gaining popularity in residential and mid span buildings. This technology offers rapidity and easiness in assembling, good thermal and sound insulation, good fire resistance and a standardized technique for the connection of its elements. The X-Lam is also high valuable for its high level of prefabrication allowing the application of the state-of-the art CNC manufacturing technologies and, as a consequence, an effective implementation of the file-to-factory process and a very high accuracy in production.

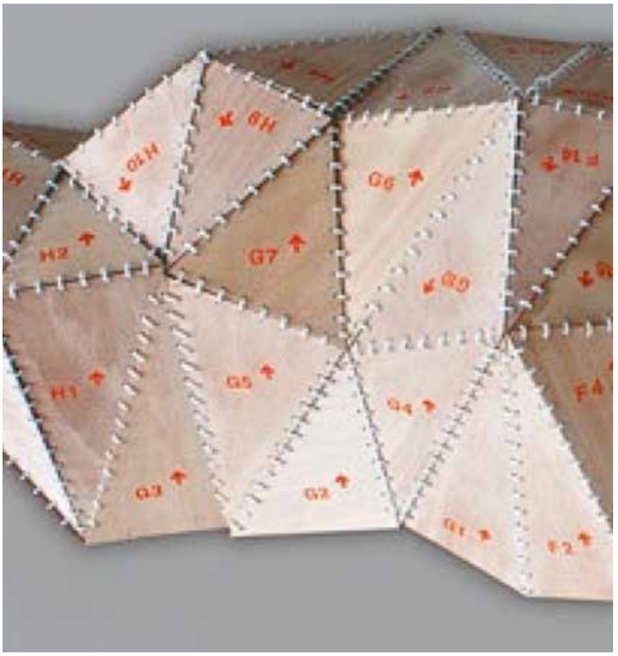
TYPES OF STRUCTURAL ELEMENTS: CONTINUOUS

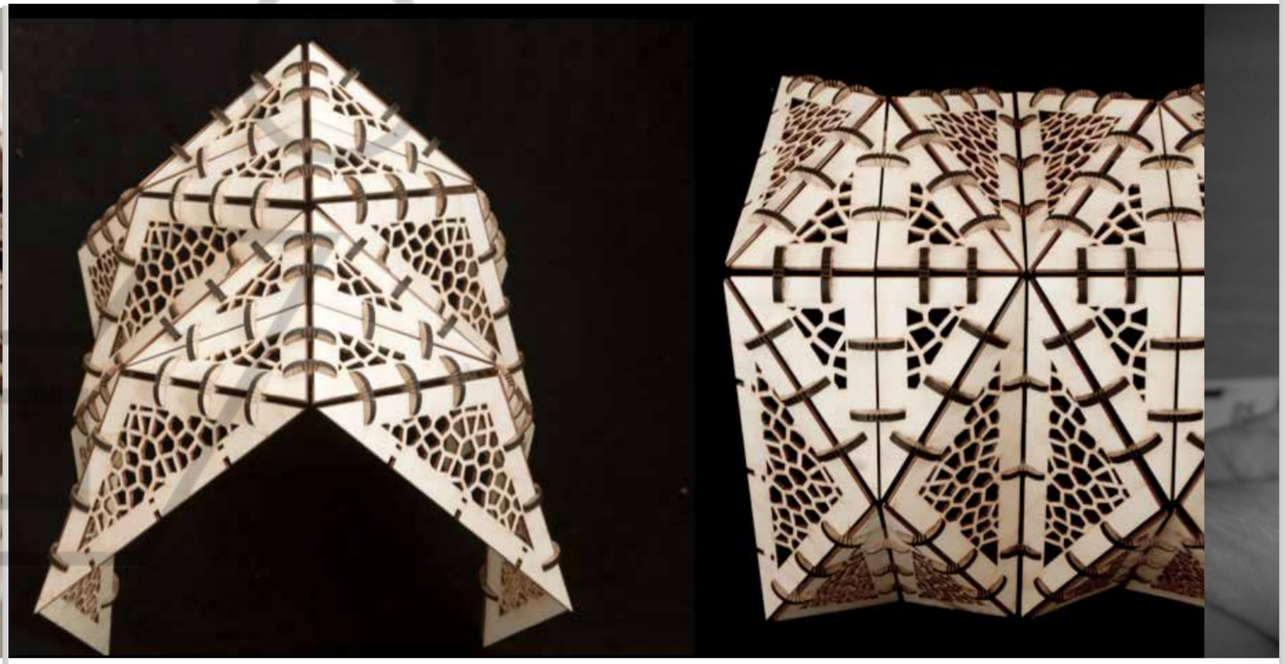
folded plate structure





TYPES OF STRUCTURAL ELEMENTS: CONTINUOUS

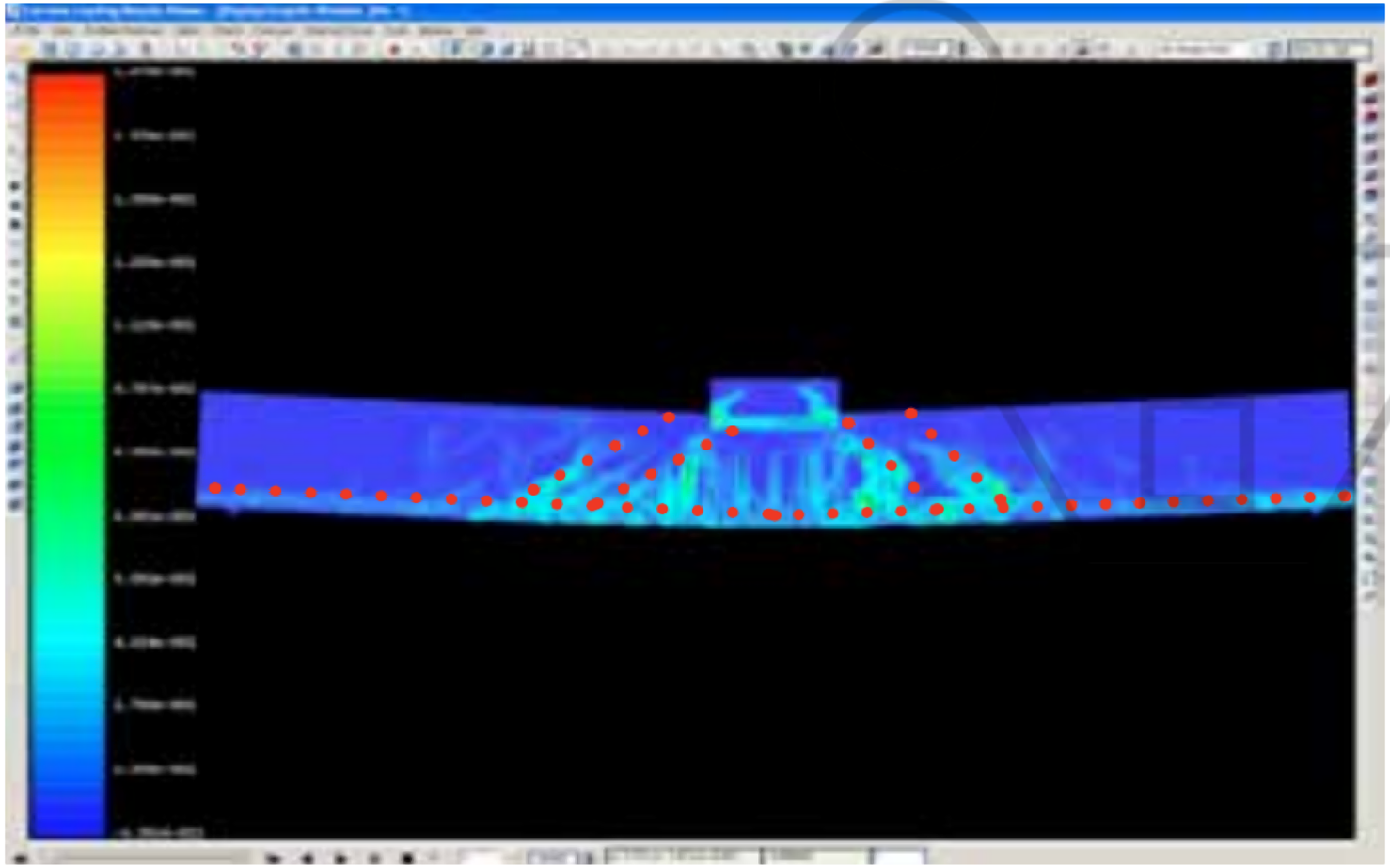


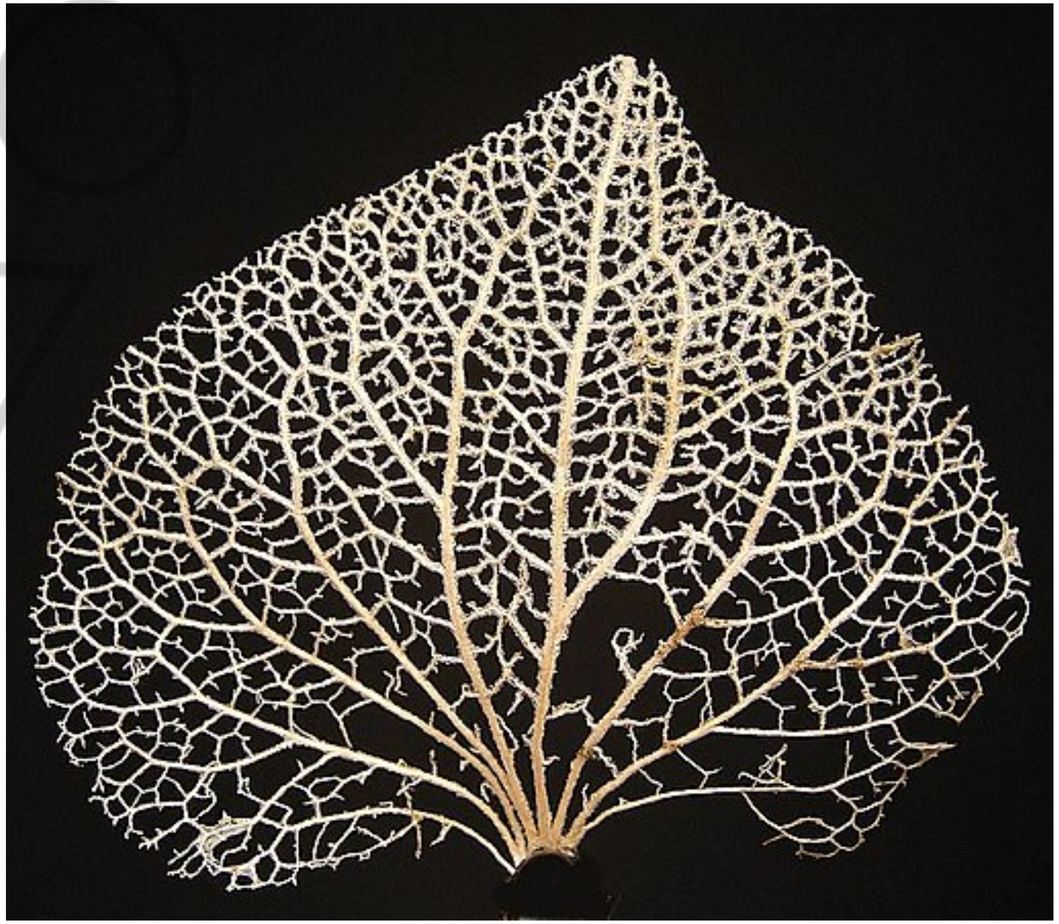


Students' Models from iCAD Master course G. Ridolfi 2013-14

TYPES OF STRUCTURAL ELEMENTS: DISCRETE

materials optimization search for stiffness and strength through structural form and geometry rather than through mass and dimension.





TYPES OF STRUCTURAL ELEMENTS: DISCRETE

2.15 Sawmill at Tunhovd, Norway.

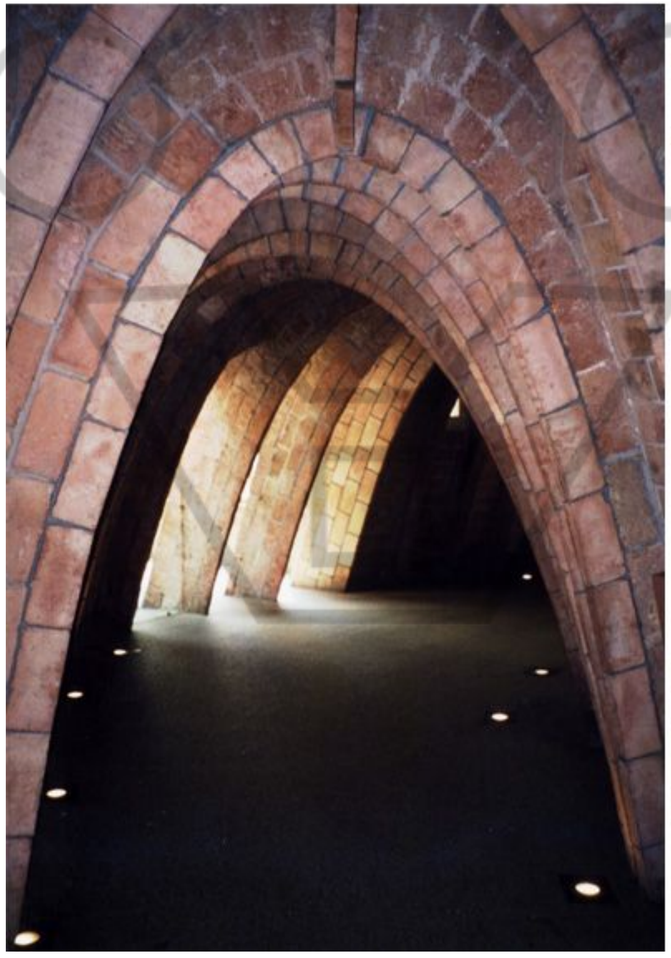
2.16 Structures. Architects Foster Associates, engineers Ove Arup and Partners: the Century Tower (1991), Tokyo.

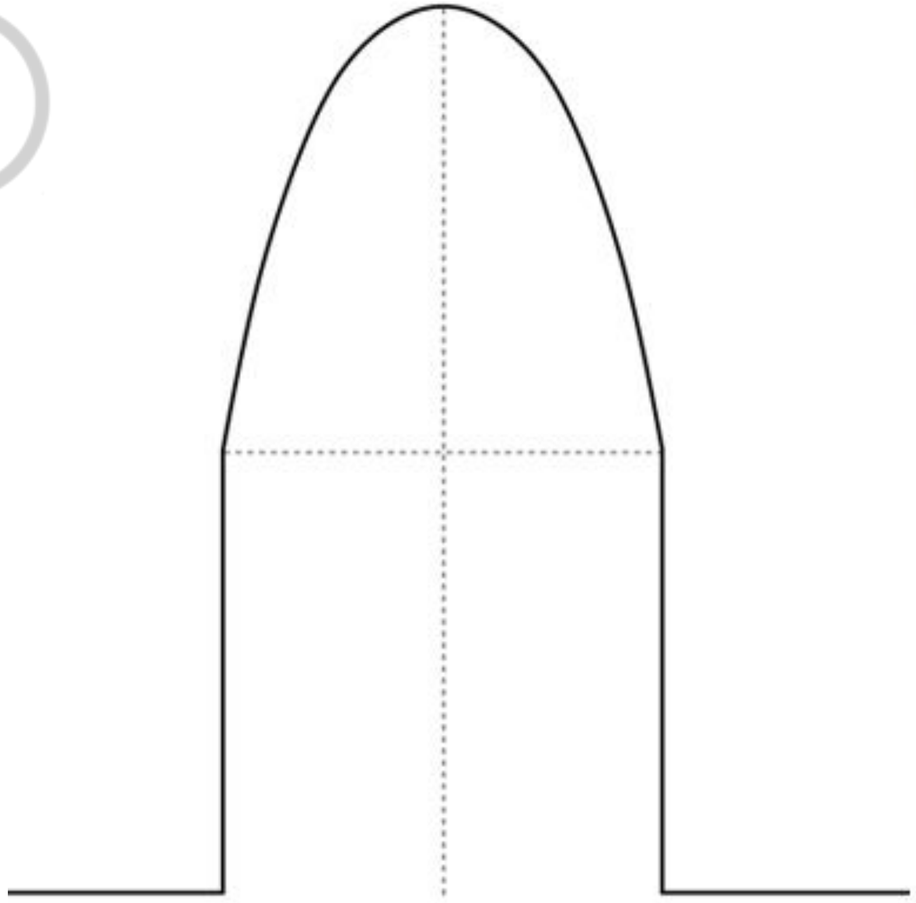
TYPES OF STRUCTURAL ELEMENTS: DISCRETE

Palazzo Medici Riccardi, Michelozzo, Firenze 1444-1464

TYPES OF STRUCTURAL ELEMENTS: DISCRETE

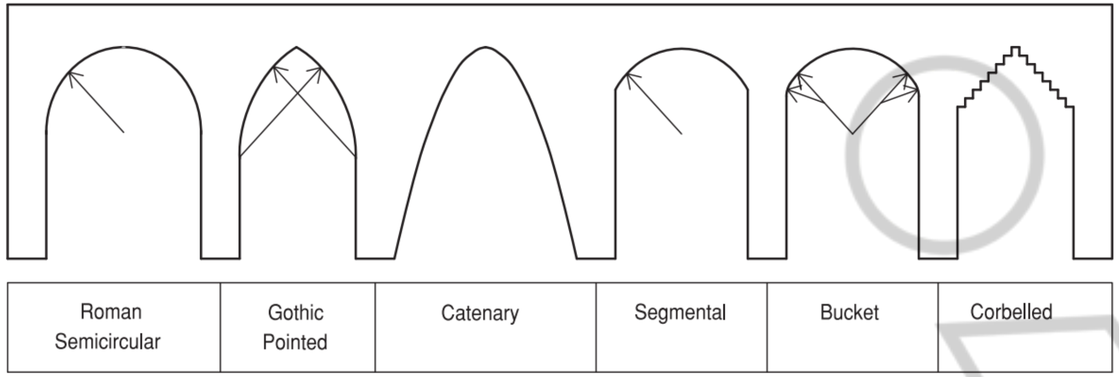
The catenary

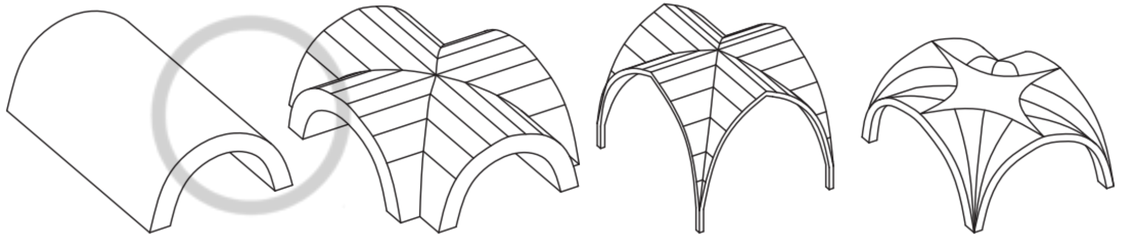




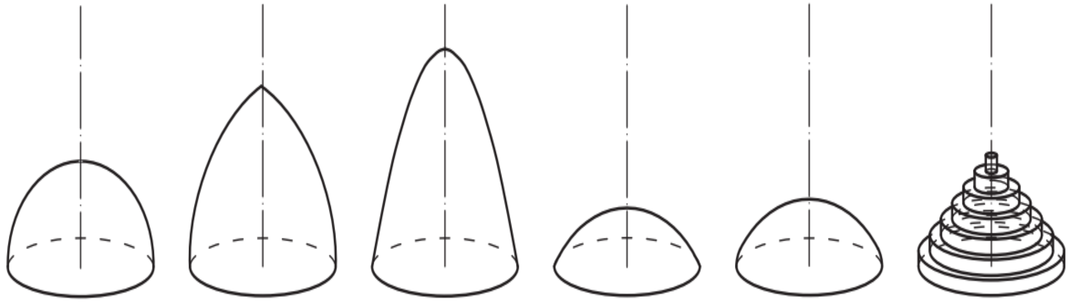
TYPES OF STRUCTURAL ELEMENTS: DISCRETE

The form-resistant structures (semiactive)

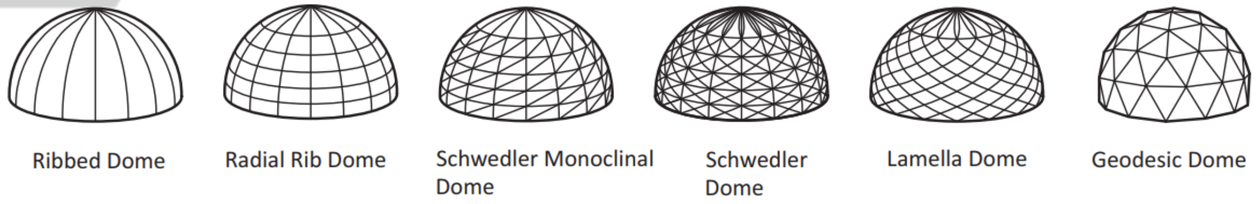




VOLTE

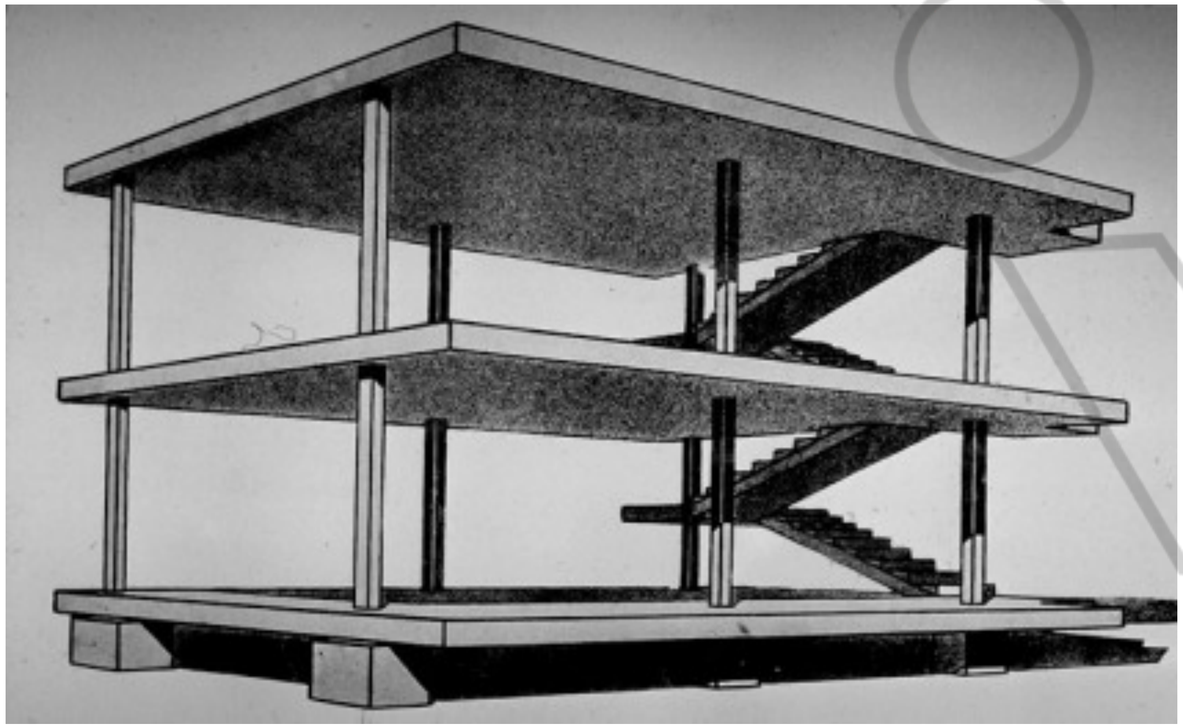


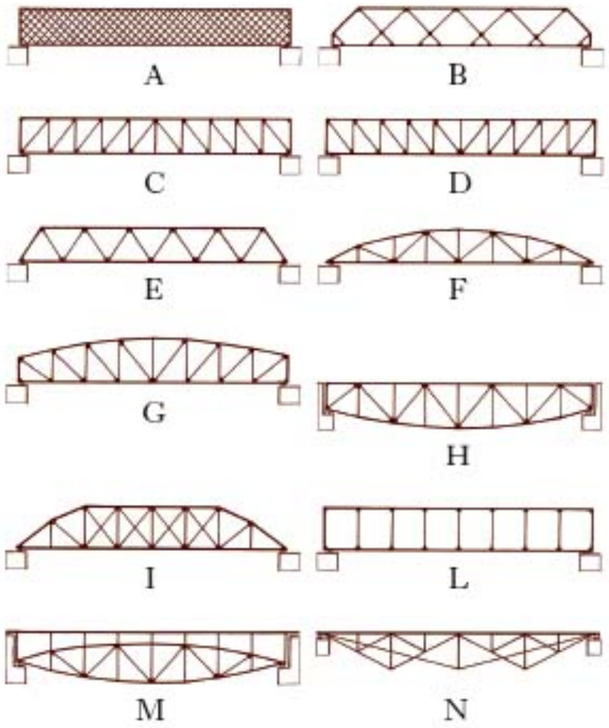
CUPOLE: SUPERFICI



CUPOLE: LINEE RESISTENTI

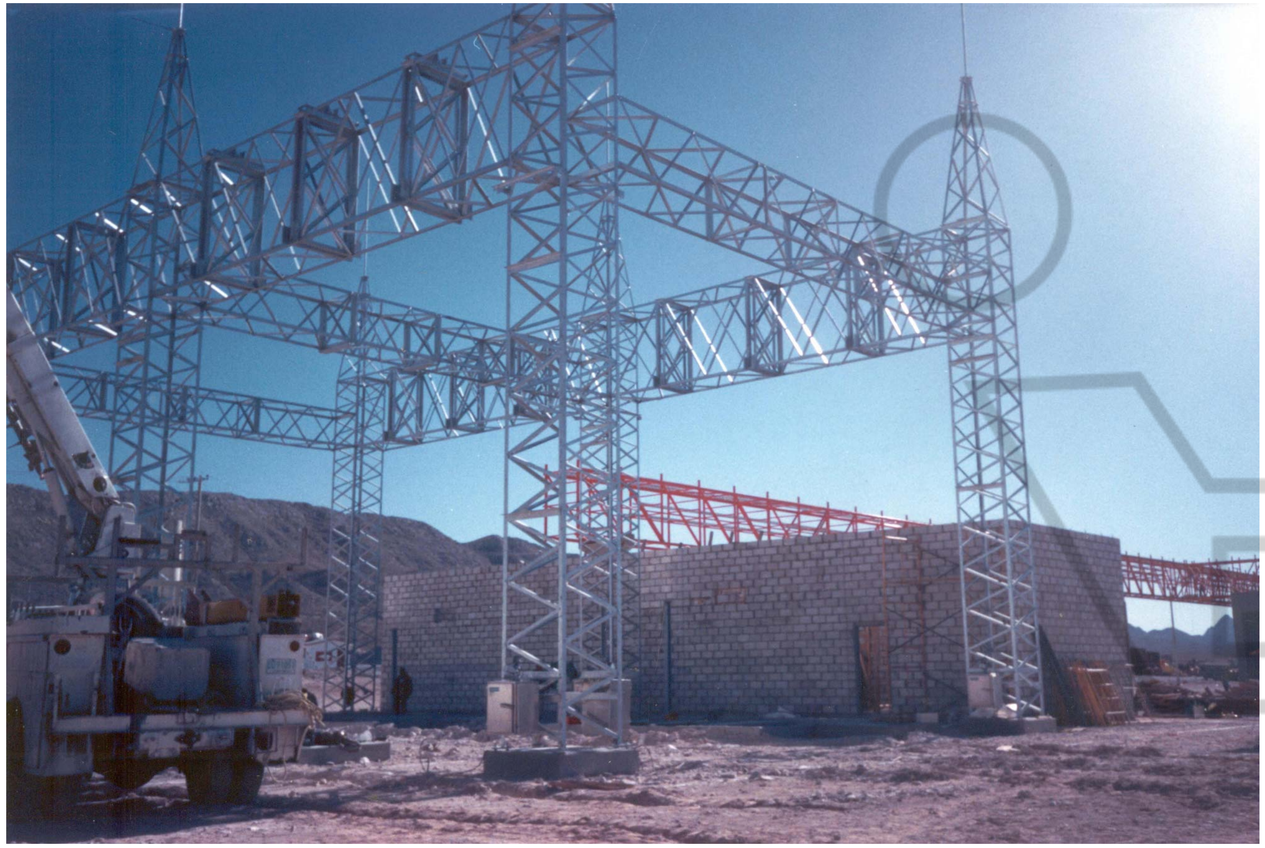
TYPES OF STRUCTURAL ELEMENTS: DISCRETE

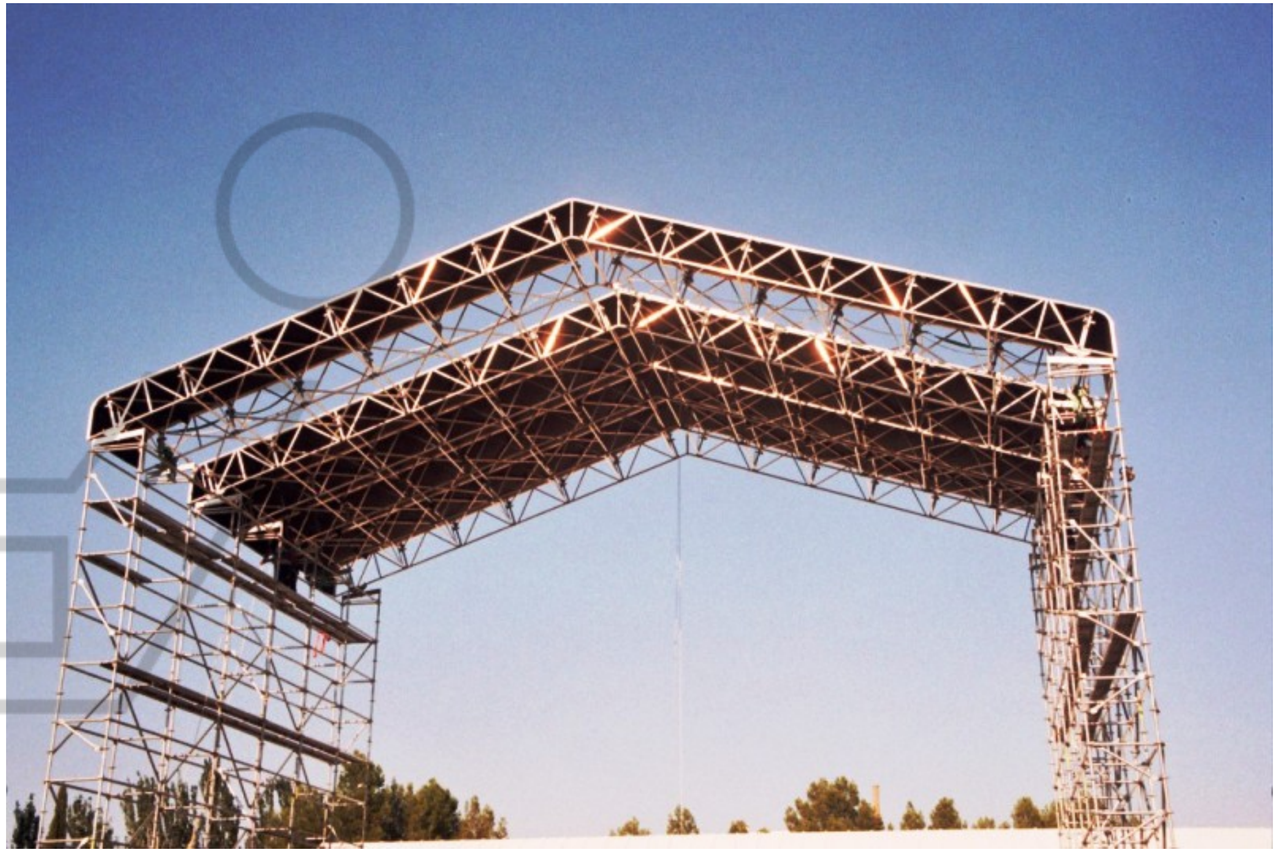




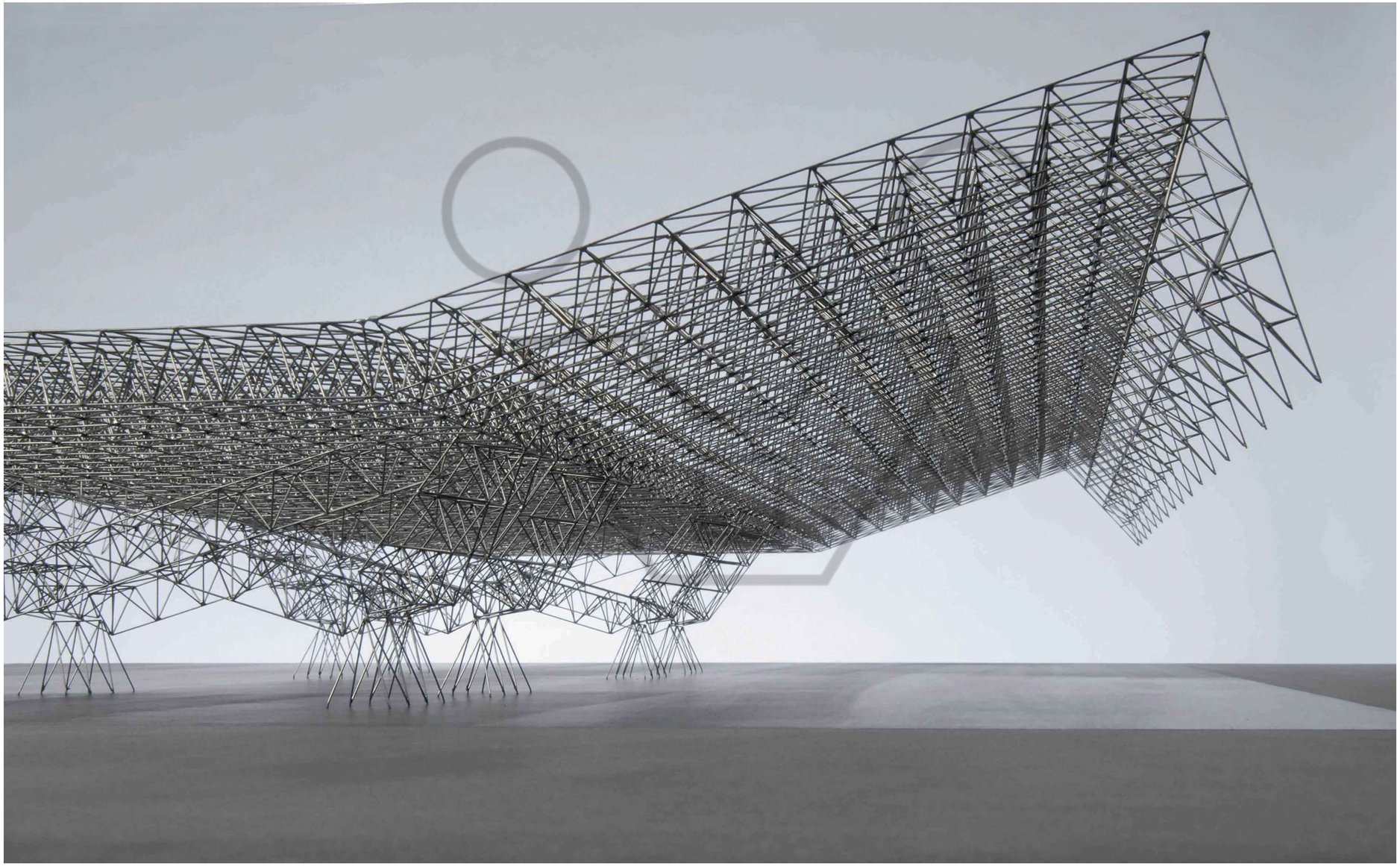
MAISON DOMINO 1914

TYPES OF STRUCTURAL ELEMENTS: DISCRETE





TYPES OF STRUCTURAL ELEMENTS: DISCRETE



USAF Aircraft Hangar
by Konrad Wachsmann

TYPES OF STRUCTURAL ELEMENTS: DISCRETE

B&B Italia Offices, R. Piano-R.Rogers, 1973

Chile's showcase at Expo Milano 2015

TYPES OF STRUCTURAL ELEMENTS: DISCRETE

Japanese Pavilion : EXPO 2000, Hanover Germany | Shigeru Ban

STRUCTURAL GEOMETRY TYPES

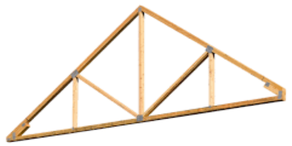
1D-LINE

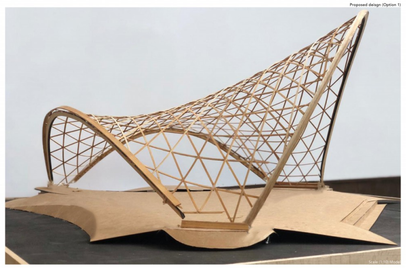
2D- PLANE

3D-VOLUME

CONTINUOUS

DISCRETE





Hans Wilsdorf bridge - Genève, Switzerland - SCIA

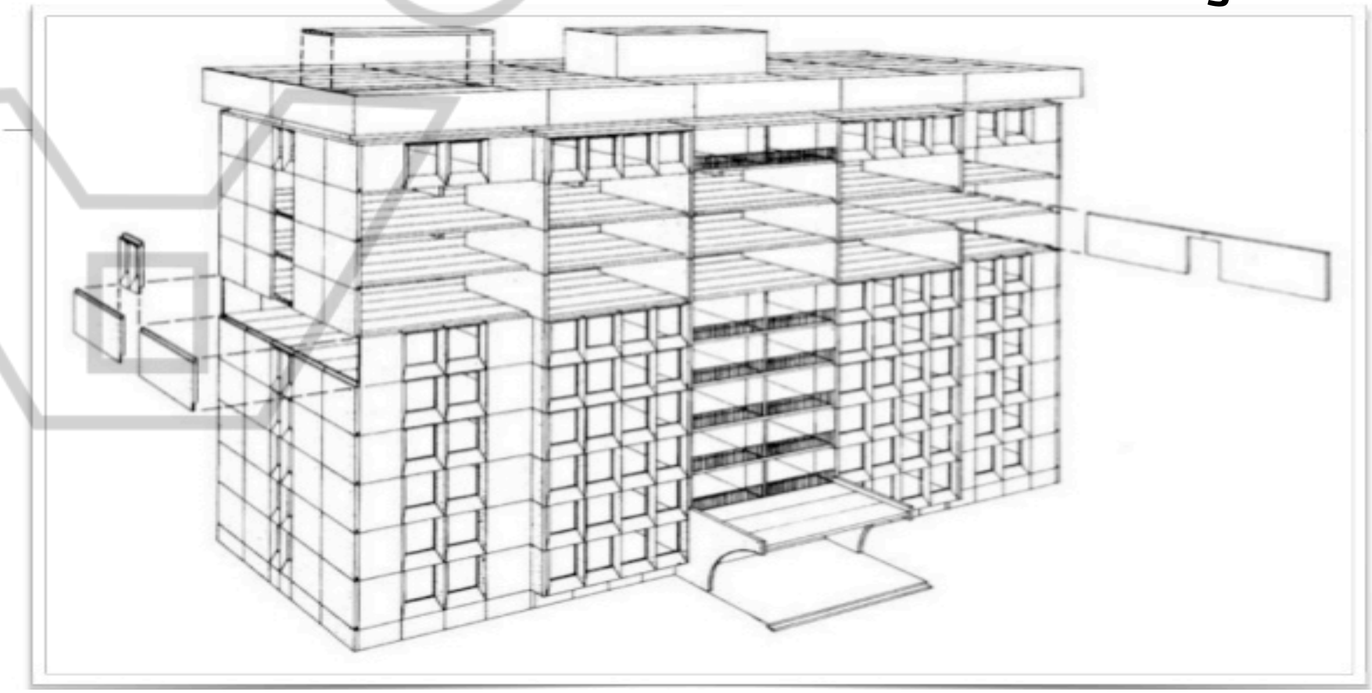
ELEVATION SYSTEM

WAYS to BUILD & STRUCTURAL STRATEGIES

ELEVATION | PLATFORM STRATEGY

Pilasters/Columns

Load Bearing Wall

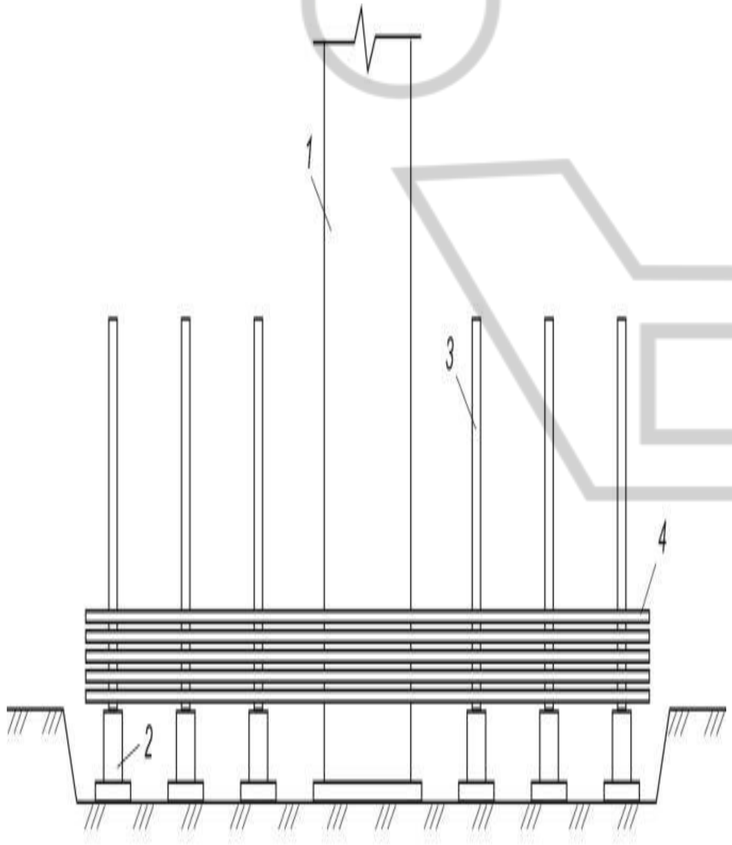


ELEVATION | LONG POLE STRATEGY

ELEVATION | LONG POLE STRATEGY

Lift slab construction

also called the Youtz-Slick Method



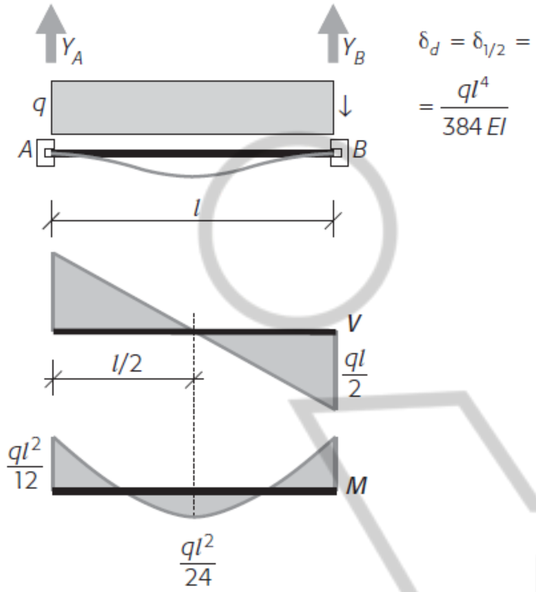
HORIZONTAL SYSTEM

WAYS to BUILD & STRUCTURAL STRATEGIES

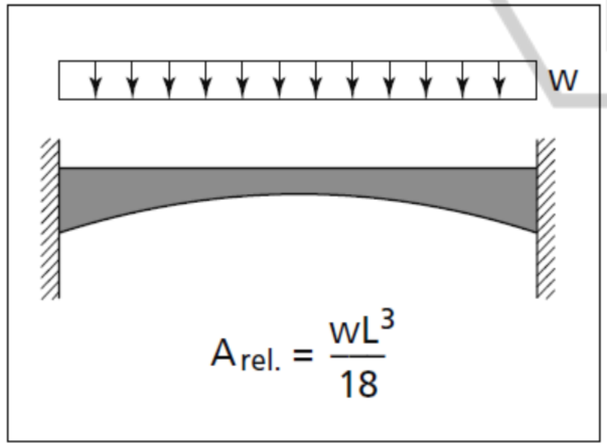
'PONTOS' CHALLENGING THE ABYSS

Structures are more efficient when loads cause axial forces in the system rather than bending.

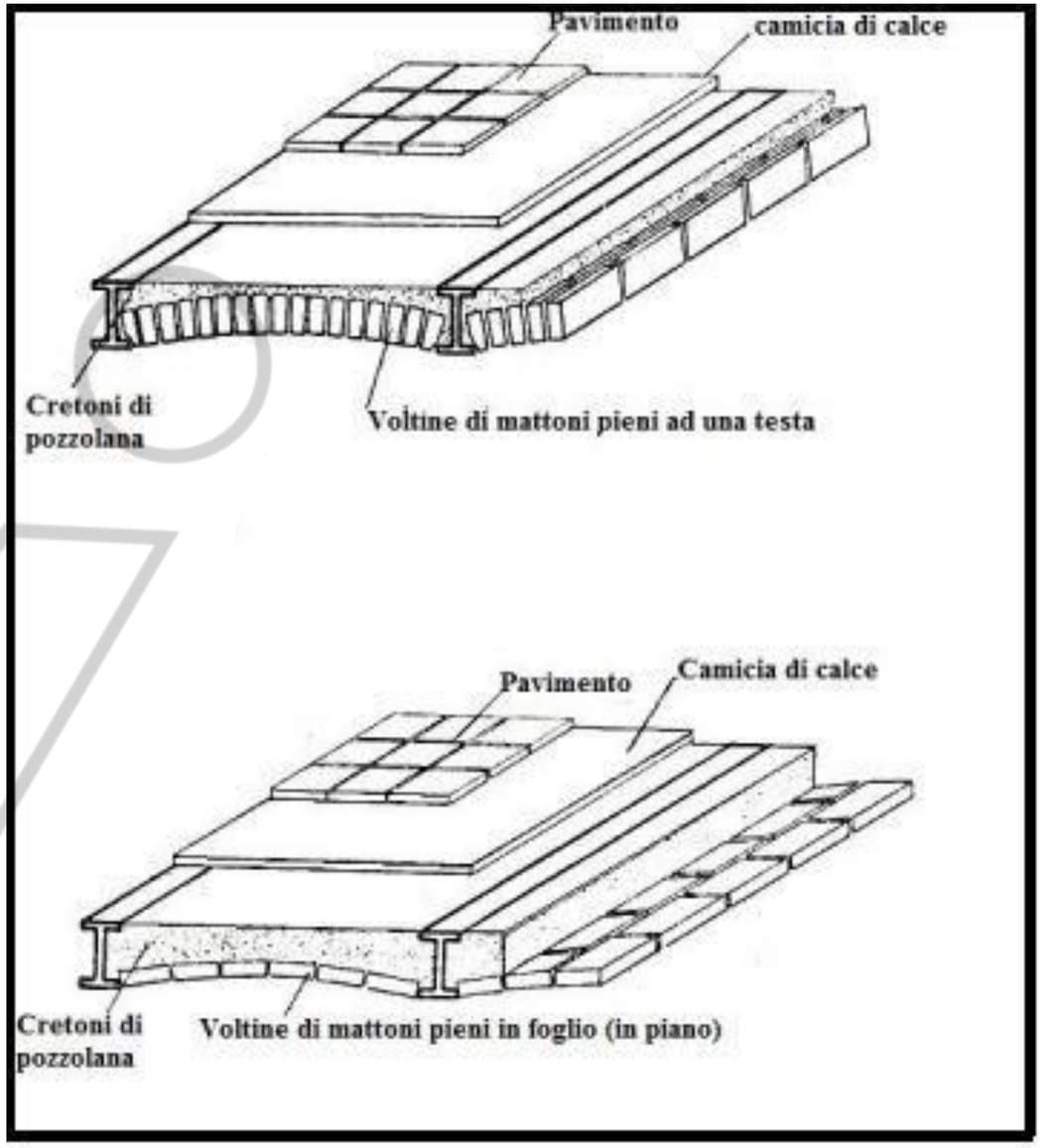
Adapting the Shape to the Stress



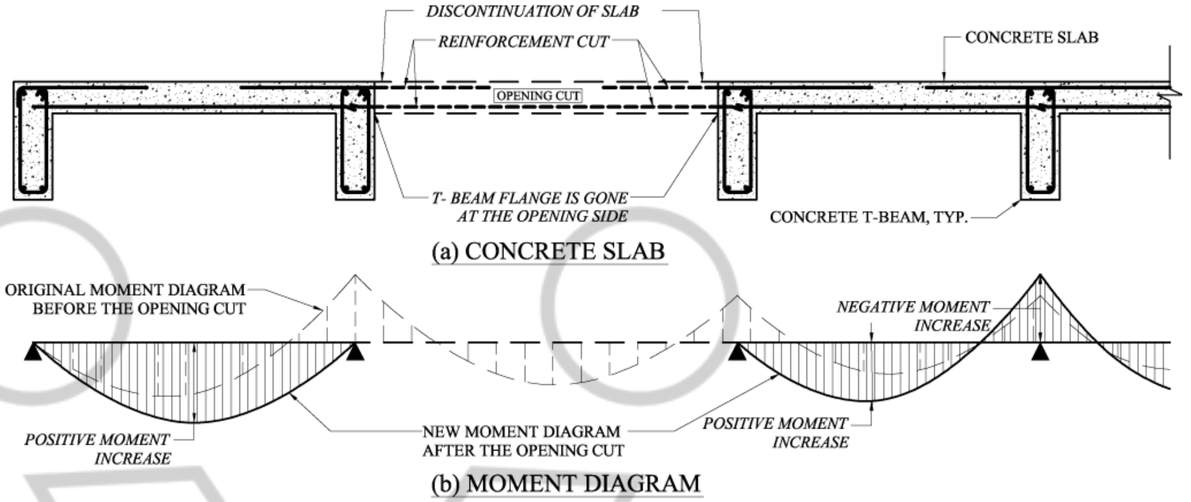
$$\delta_d = \delta_{l/2} = \frac{ql^4}{384\,EI}$$

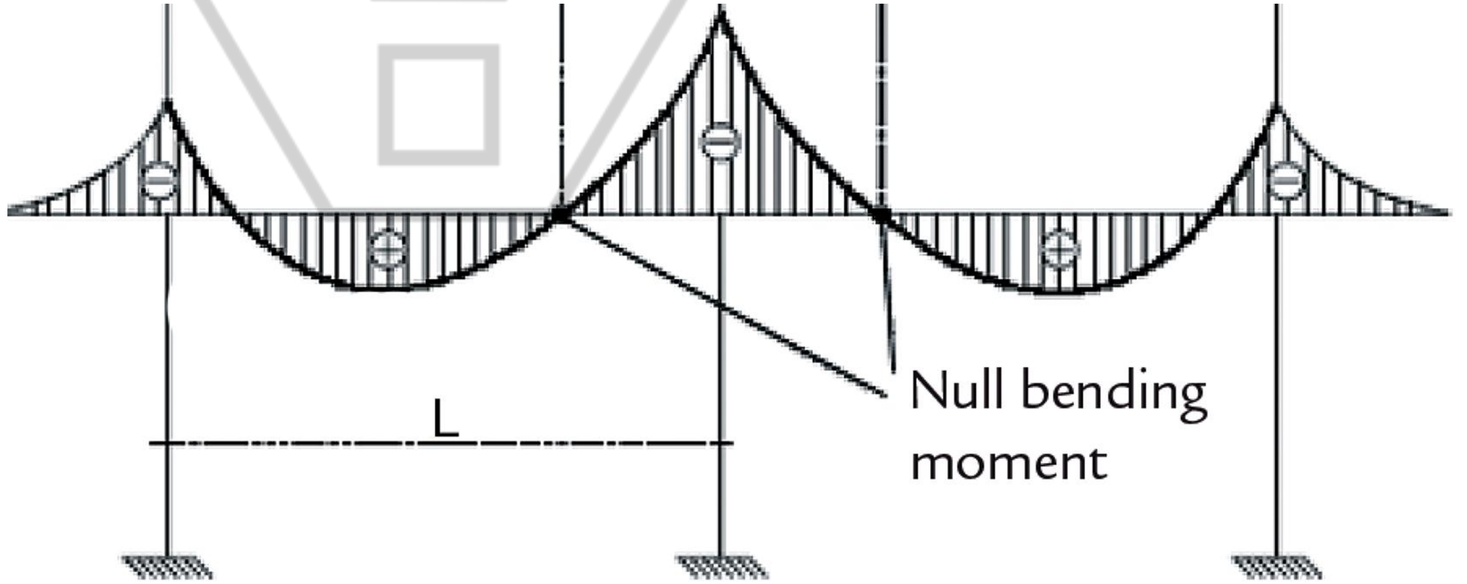


2.47 Beam with fixed ends shaped according to the bending moment diagram.

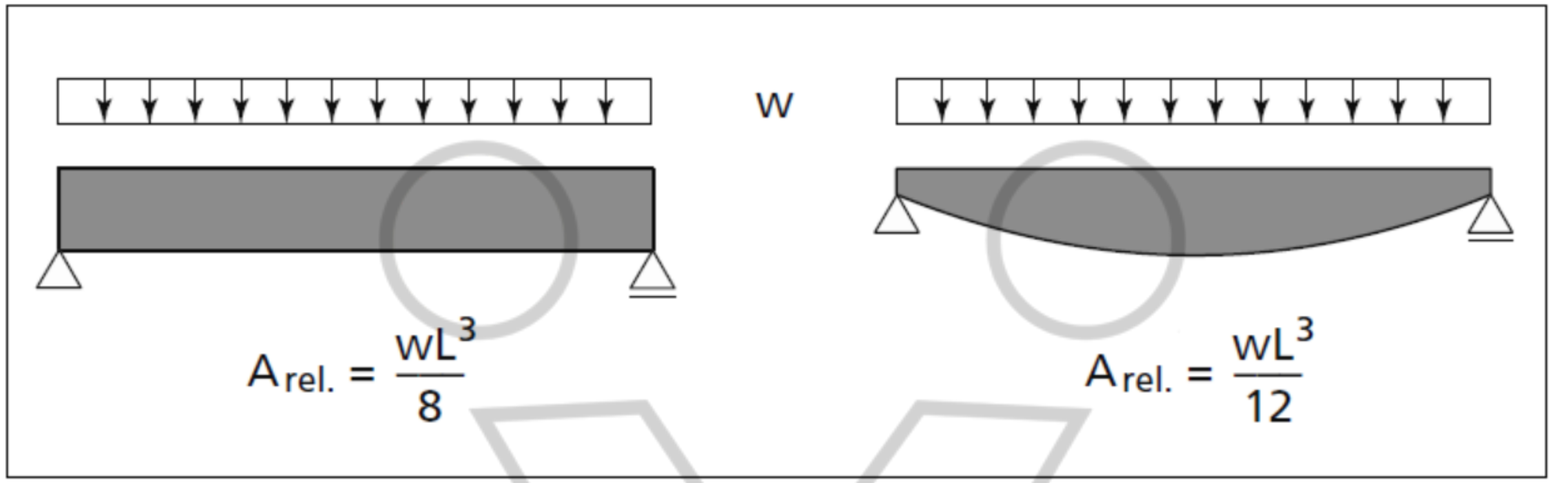


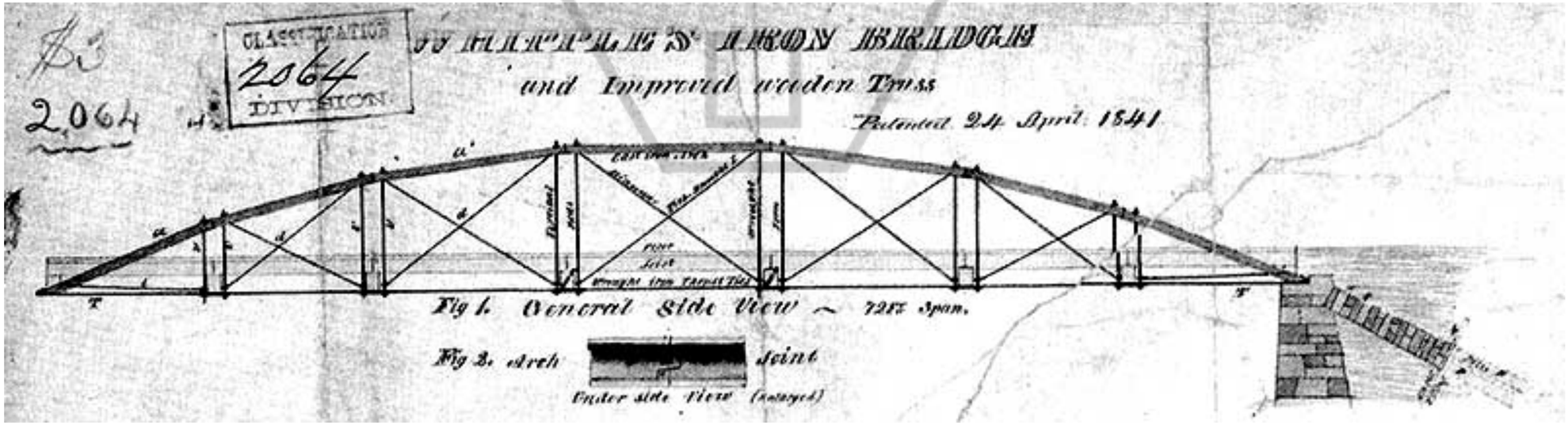
Adapting the Shape to the Stress





Adapting the Shape to the Scale

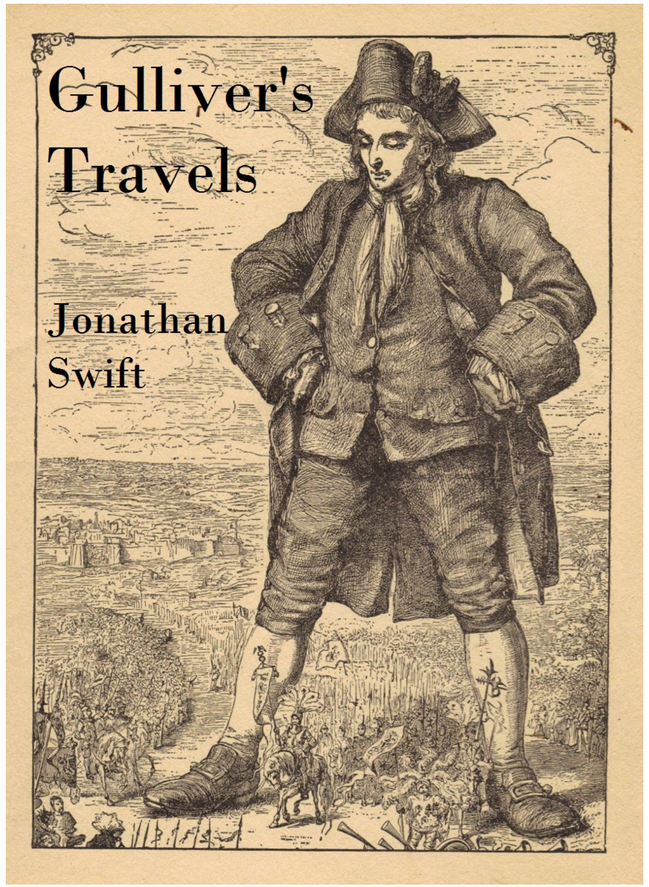


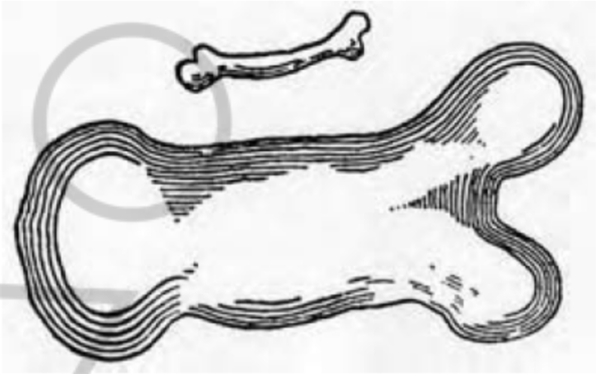


PROPORTIONS vs SCALE

THE LAW OF SCALE: DIFFERENT PRINCIPLES AND SOLUTION FOR DIFFERENT SCALE

What happen when as a giant he tries to adapt to a world of dwarfs



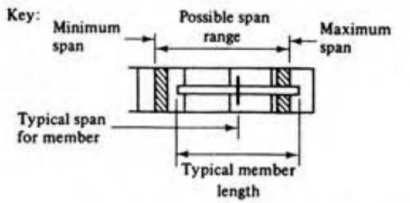


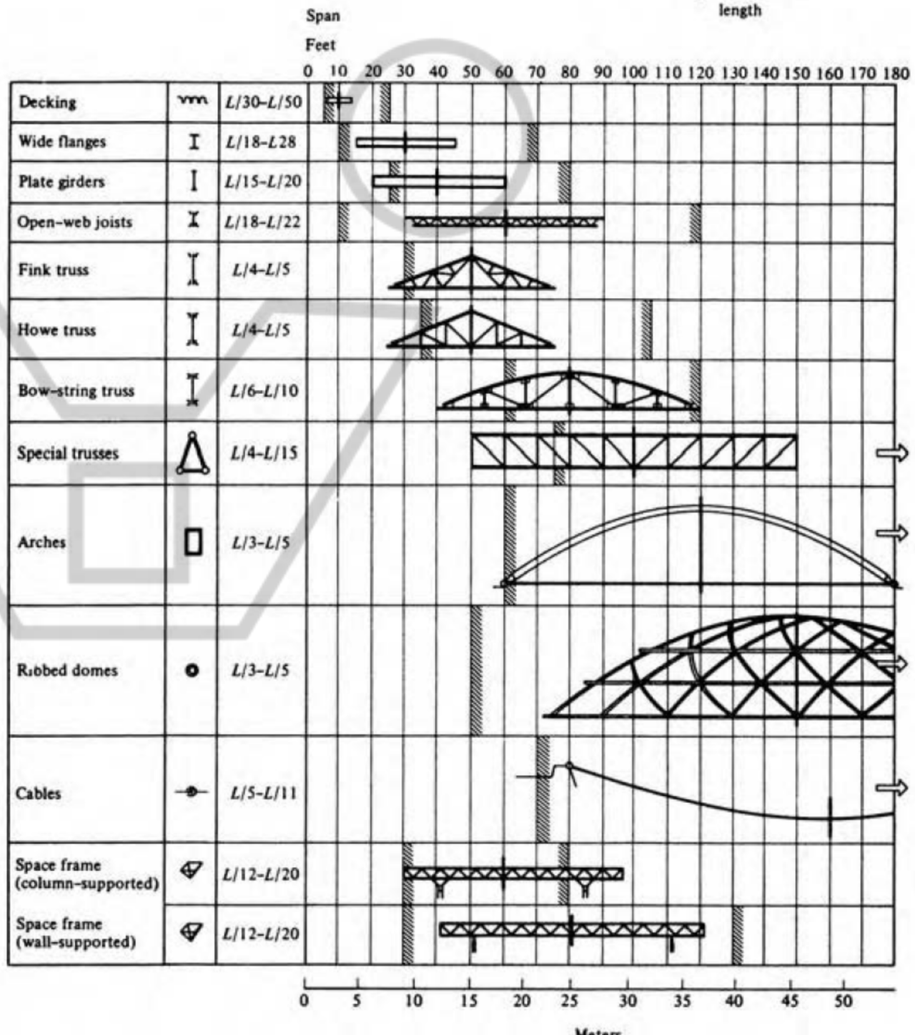
2.64 Animal bone magnified × 3, after Galileo.

'Everywhere Nature works true to scale, and everything has its proper size accordingly.
Men and trees, birds and fishes, stars and star- systems, have their appropriate dimensions, and their more or less narrow range of absolute magnitudes. | d'Arcy Thompson

Adapting the Shape to the Scale

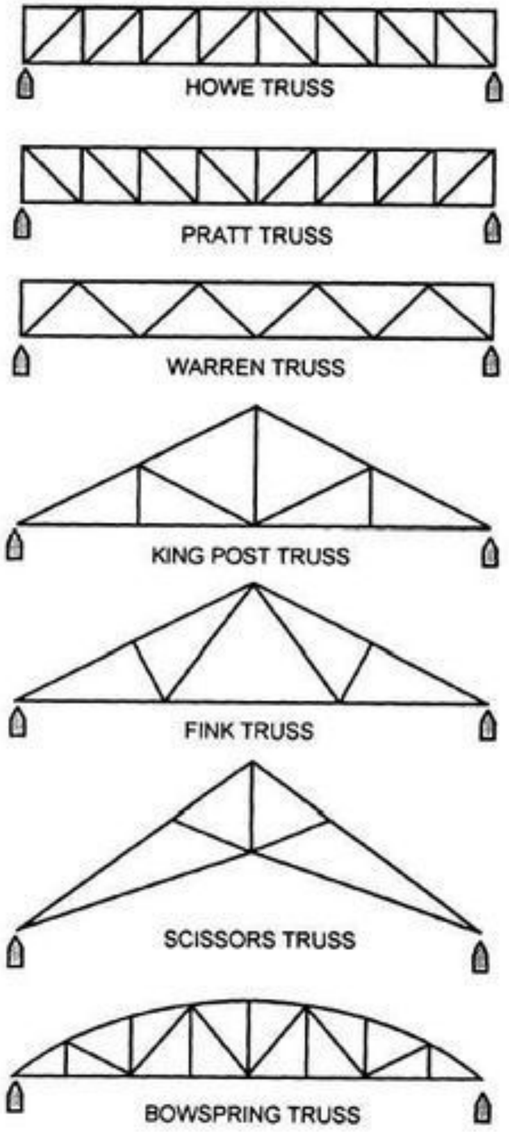
to reduce the influence of the dead- weight of the structure.

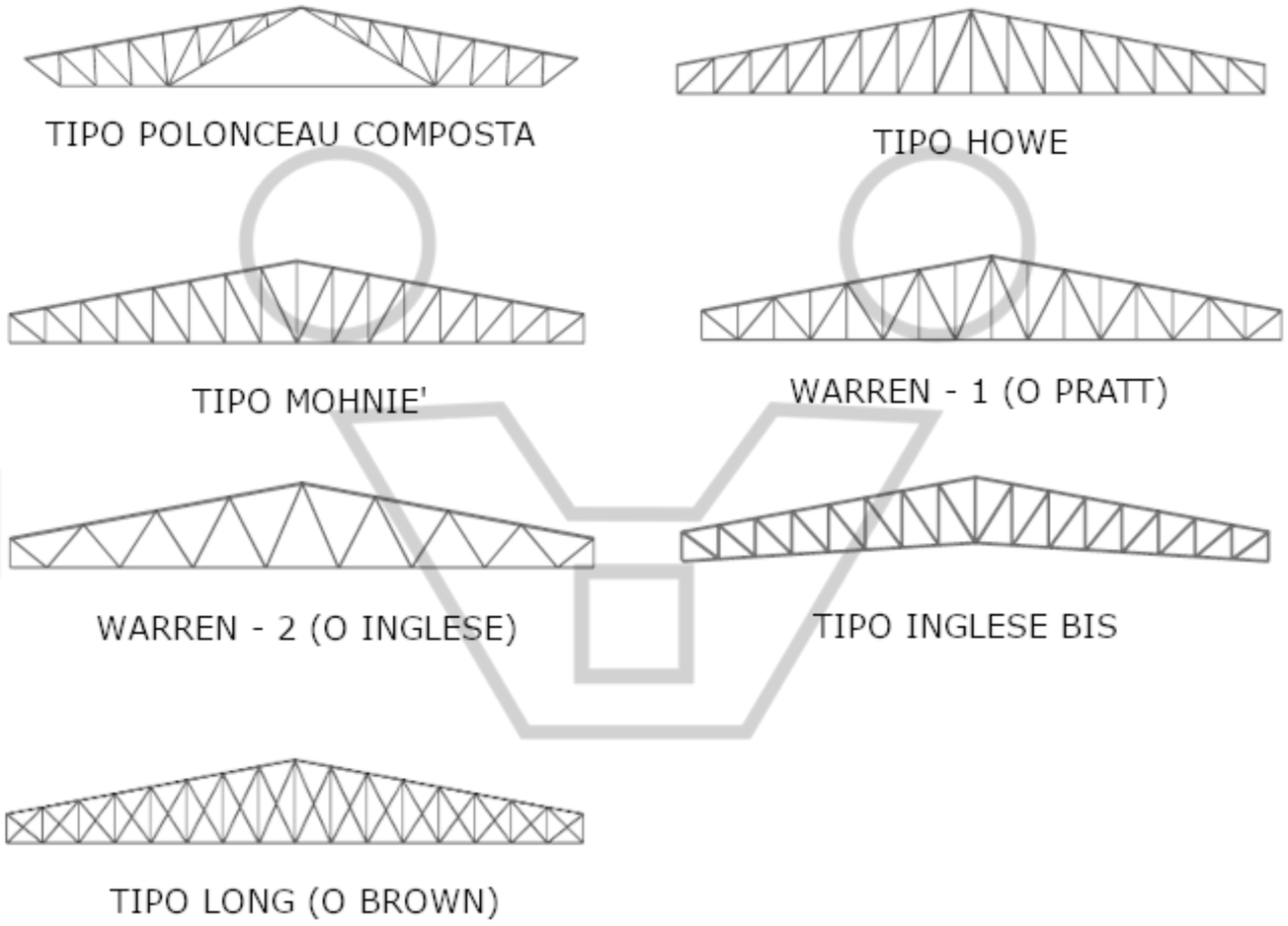


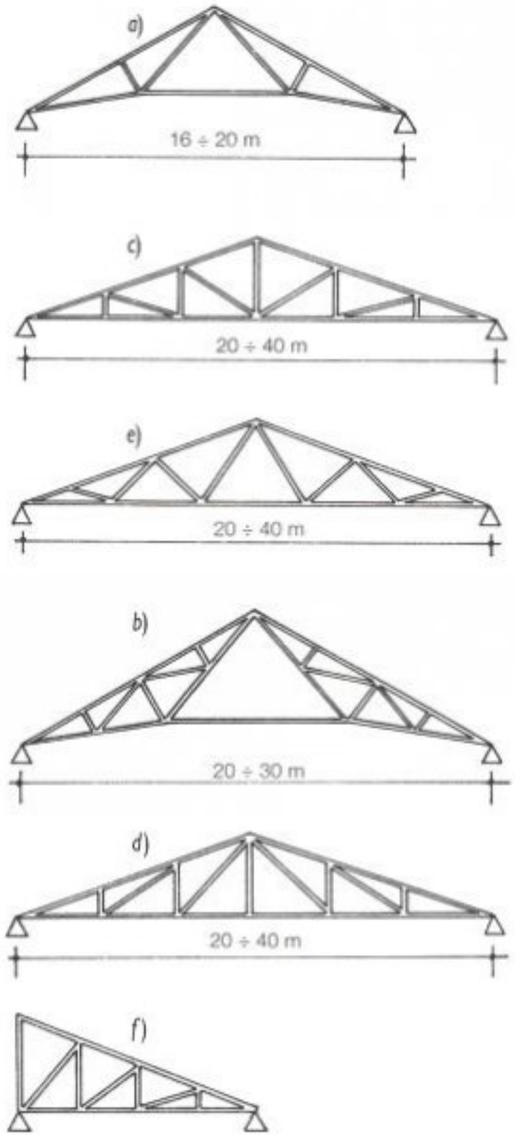


2.65 Span ranges of structural systems of steel, after Schodek.[103]

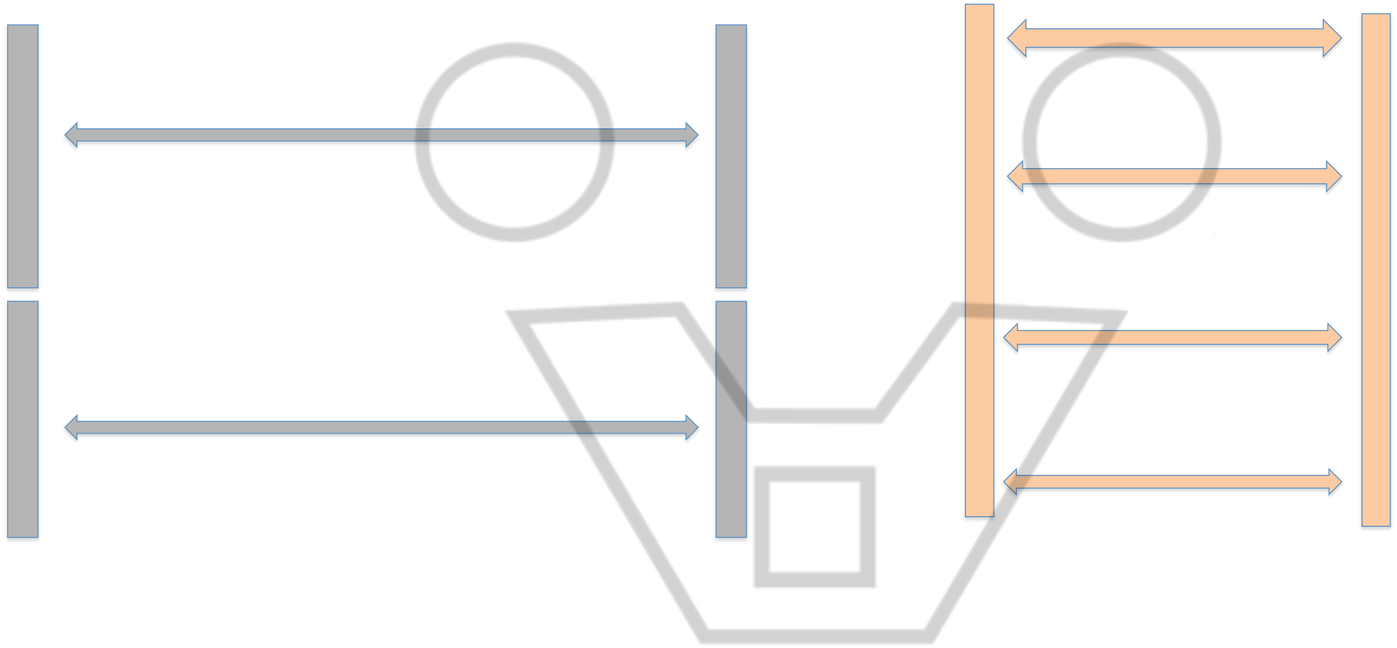
Adapting the Shape to the Scale







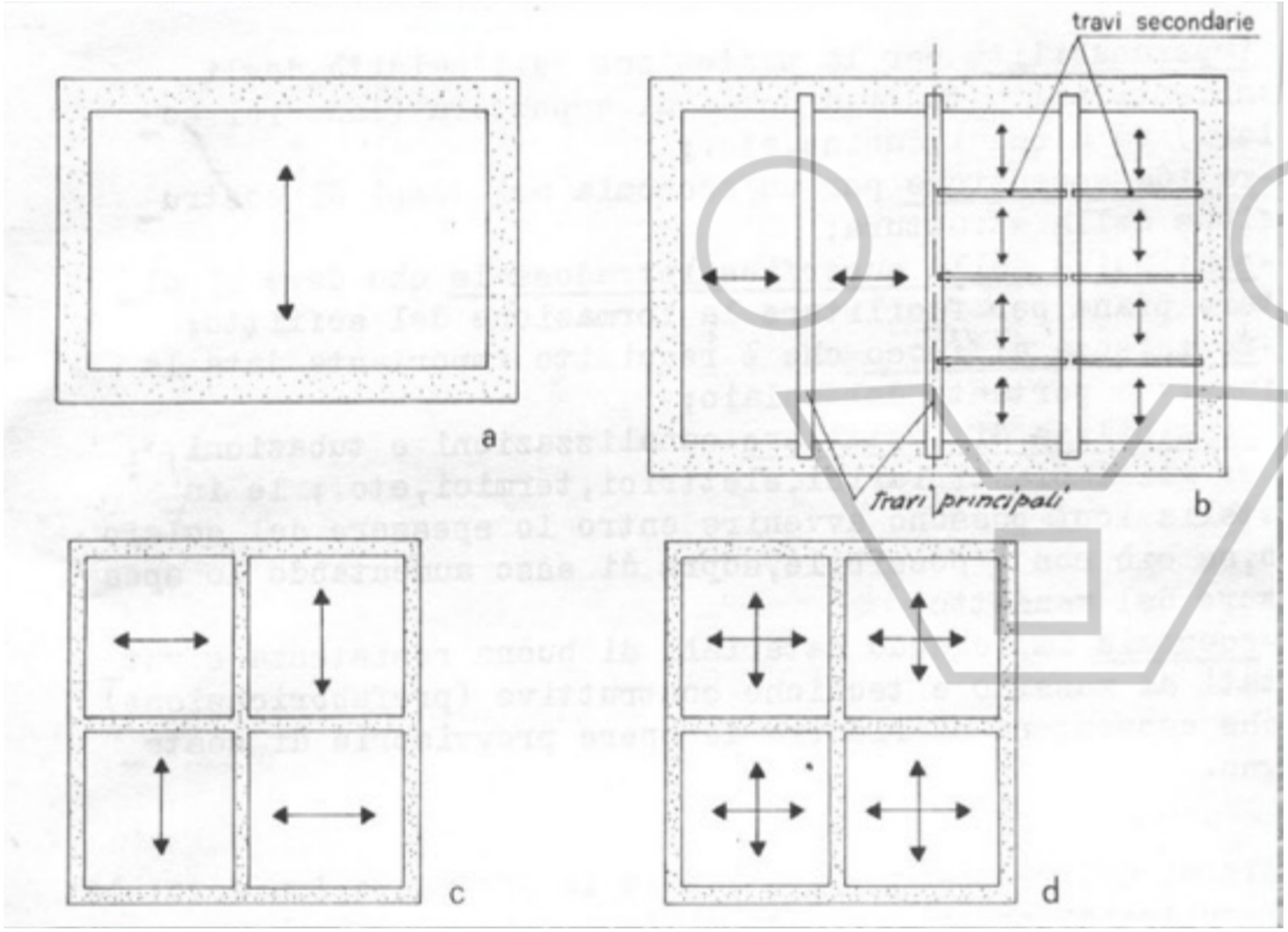
Adapting the Shape to the Materials

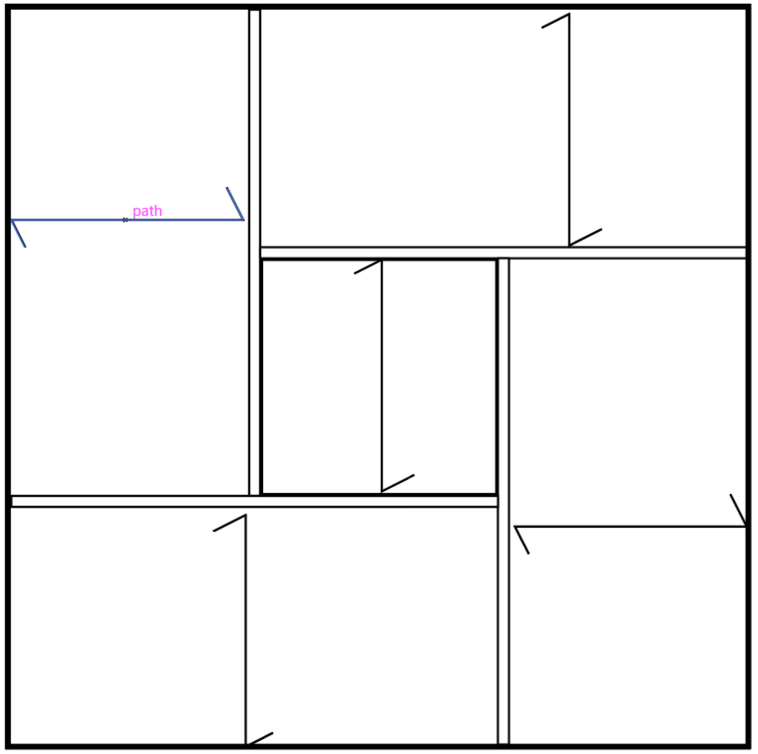


CONCRETE
short beam-long slab

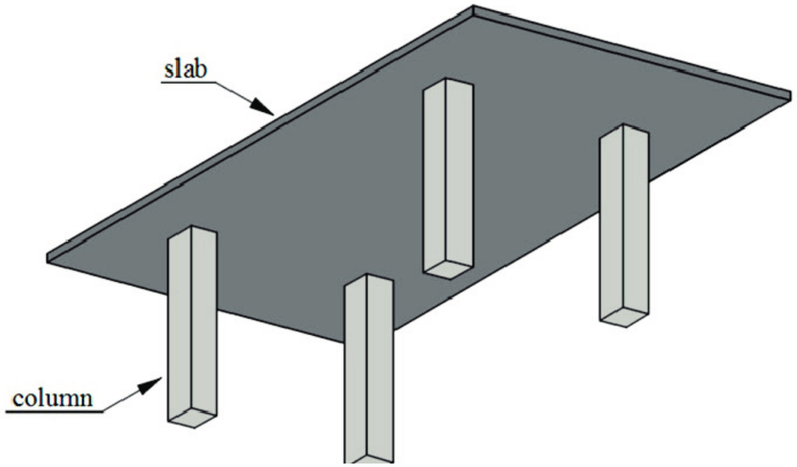
WOOD
long beam-short slab

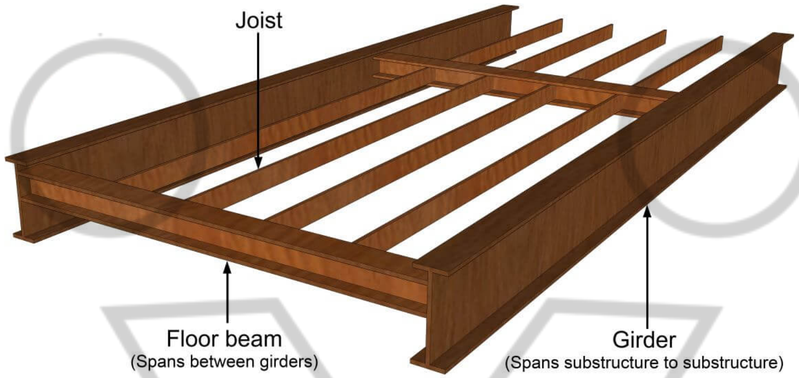
BEAMS DIAGRAM ORIENTATION

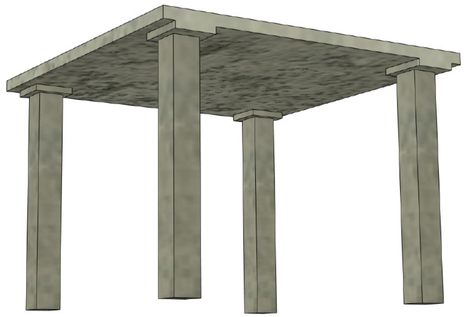


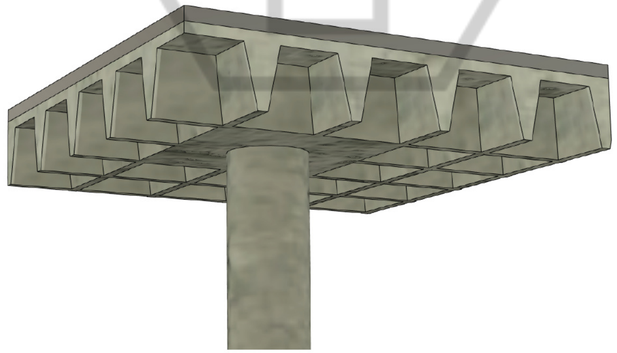


CHOISE OF TYPE OF FLAT SLAB



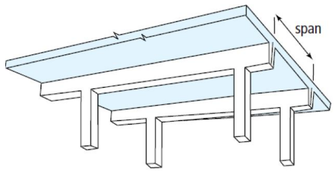


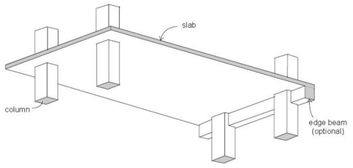


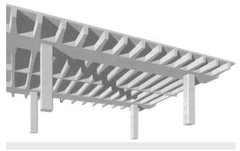


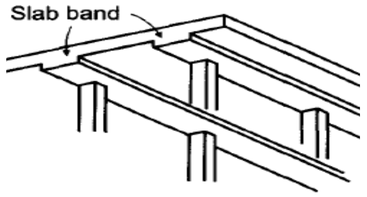
Flat slab: a two-way reinforced structural system that uses a slab of uniform thickness with additional depth at columns

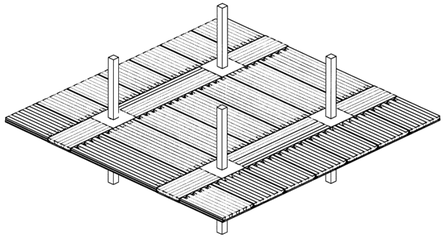
CONCRETE SLAB SPAN COMPARISON

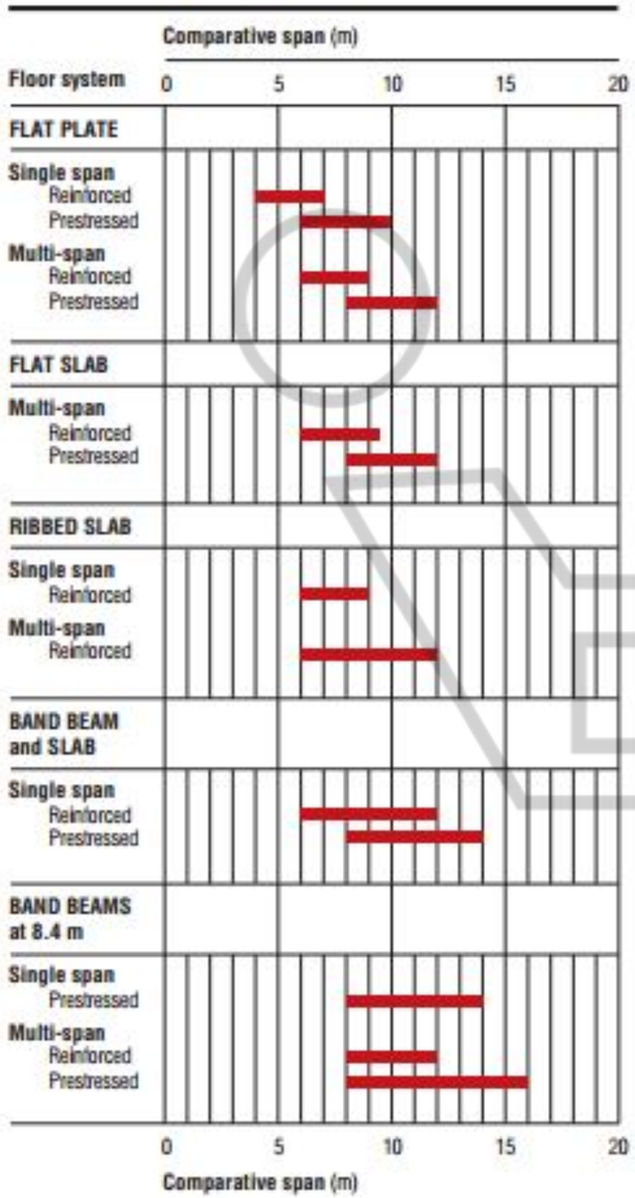










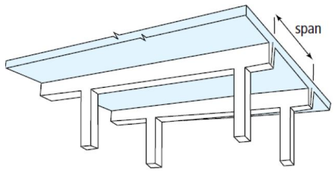


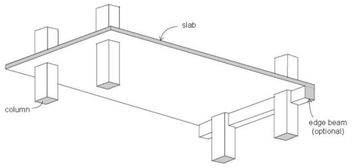
The **flat plate** is a two-way reinforced concrete **framing system** utilizing a slab of uniform thickness, the simplest of structural shapes. 4-6 ml

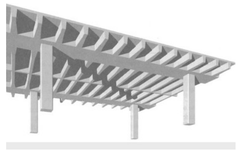
A flat slab is a two-way reinforced concrete **slab** that usually does not have bea and girders, and the loads are transferred directly to the supporting concrete columns

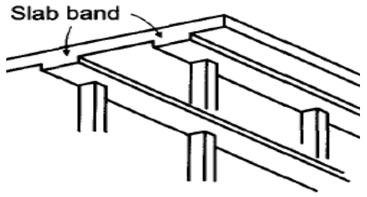
Ribbed or waffle slab is a slab system which consists of series of parallel reinfo concrete T beams framing into reinforced concrete girders

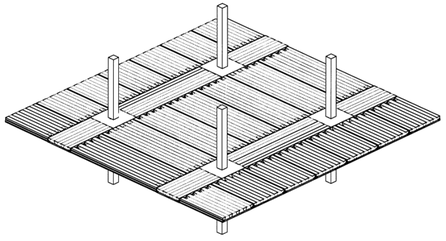
CONCRETE SLAB SPAN COMPARISON

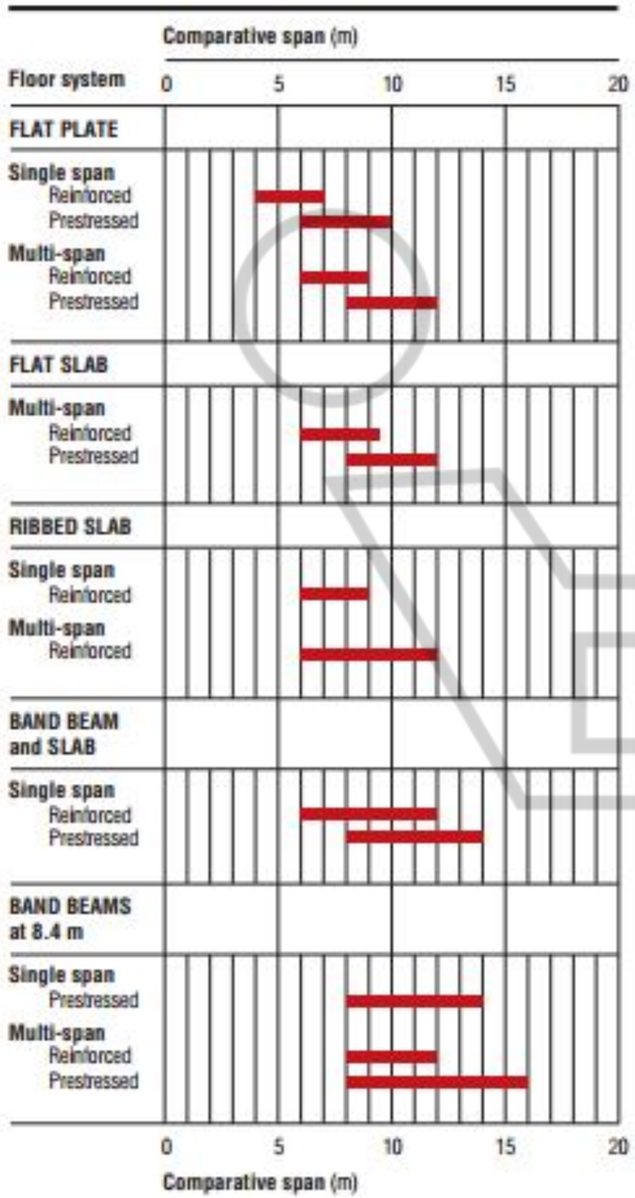












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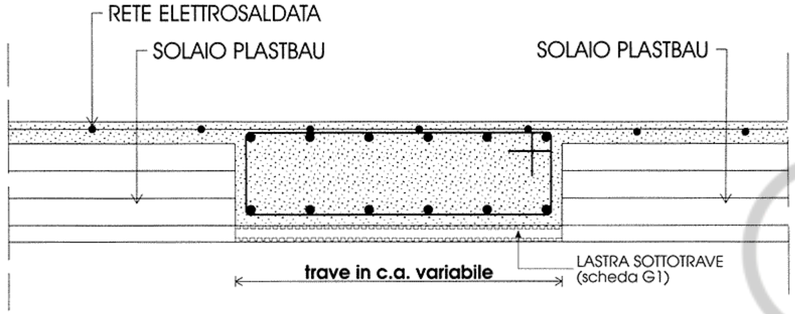
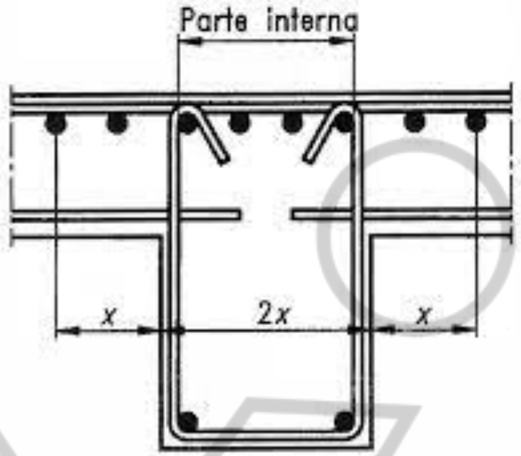
TRUSS SPAN COMPARISON

	Span (m)					
	6	8	10	13	16	20
Reinforced concrete flat slab						
Integrated beams and deep composite slab						
Integrated beams with precast slabs						
Composite beams and slab						
Fabricated beams with web openings						
Cellular composite beams						
Composite trusses						

IN SITU REINFORCED CONCRETE SLAB DIMENSIONING





Quick selection guide

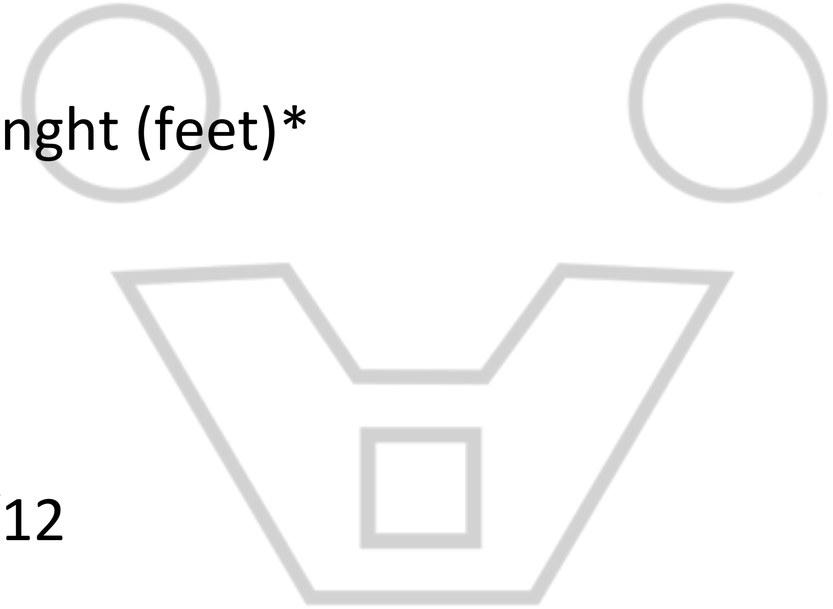
Luce [m]	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
Trave a spessore b x h [cm]	25 x 12	34 x 12	42 x 12	50 x 12	60 x 14	68 x 16	75 x 18	84 x 20	92 x 22	100 x 24
Trave emergente b x h [cm]	30 x 15	30 x 20	30 x 25	30 x 30	30 x 35	30 x 40	30 x 45	30 x 50	30 x 55	30 x 60

IN SITU REINFORCED CONCRETE SLAB DIMENSIONING

RULES OF THUMB (L/12)

Beam high (inch) = Beam lenght (feet)*

*) USA (ACI) 318-14



in meters

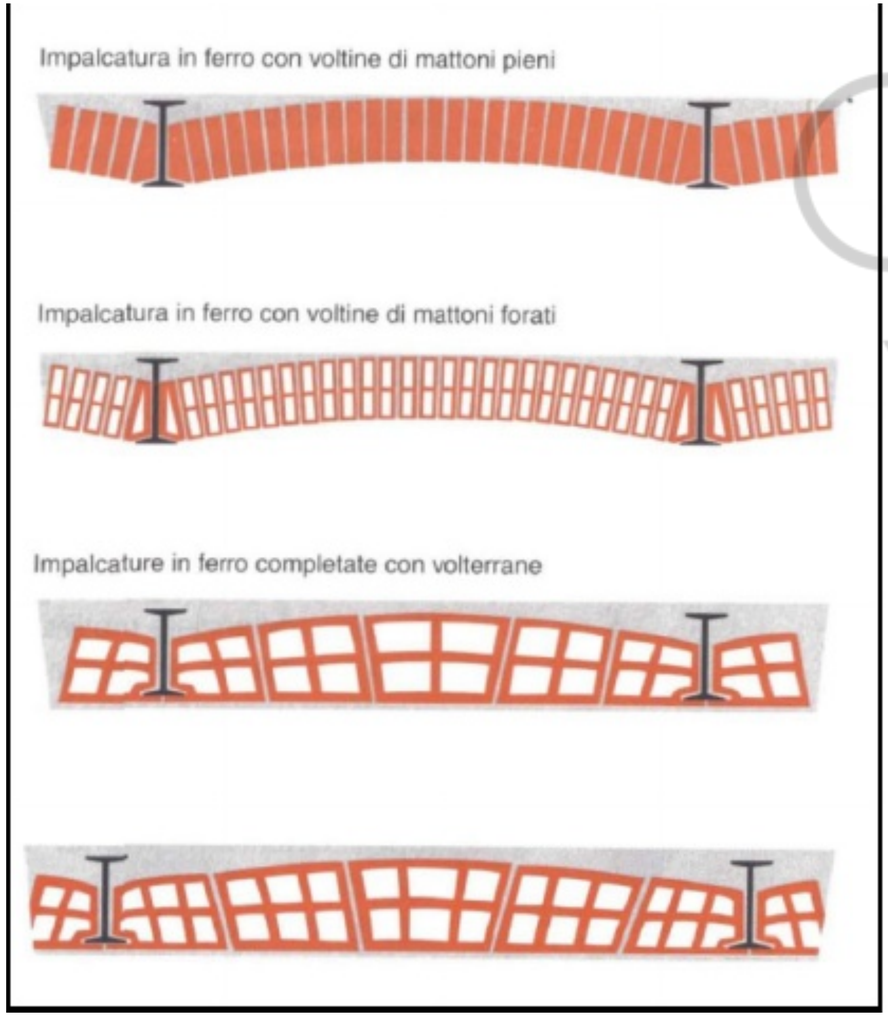
Beam hight = Beam Length/12

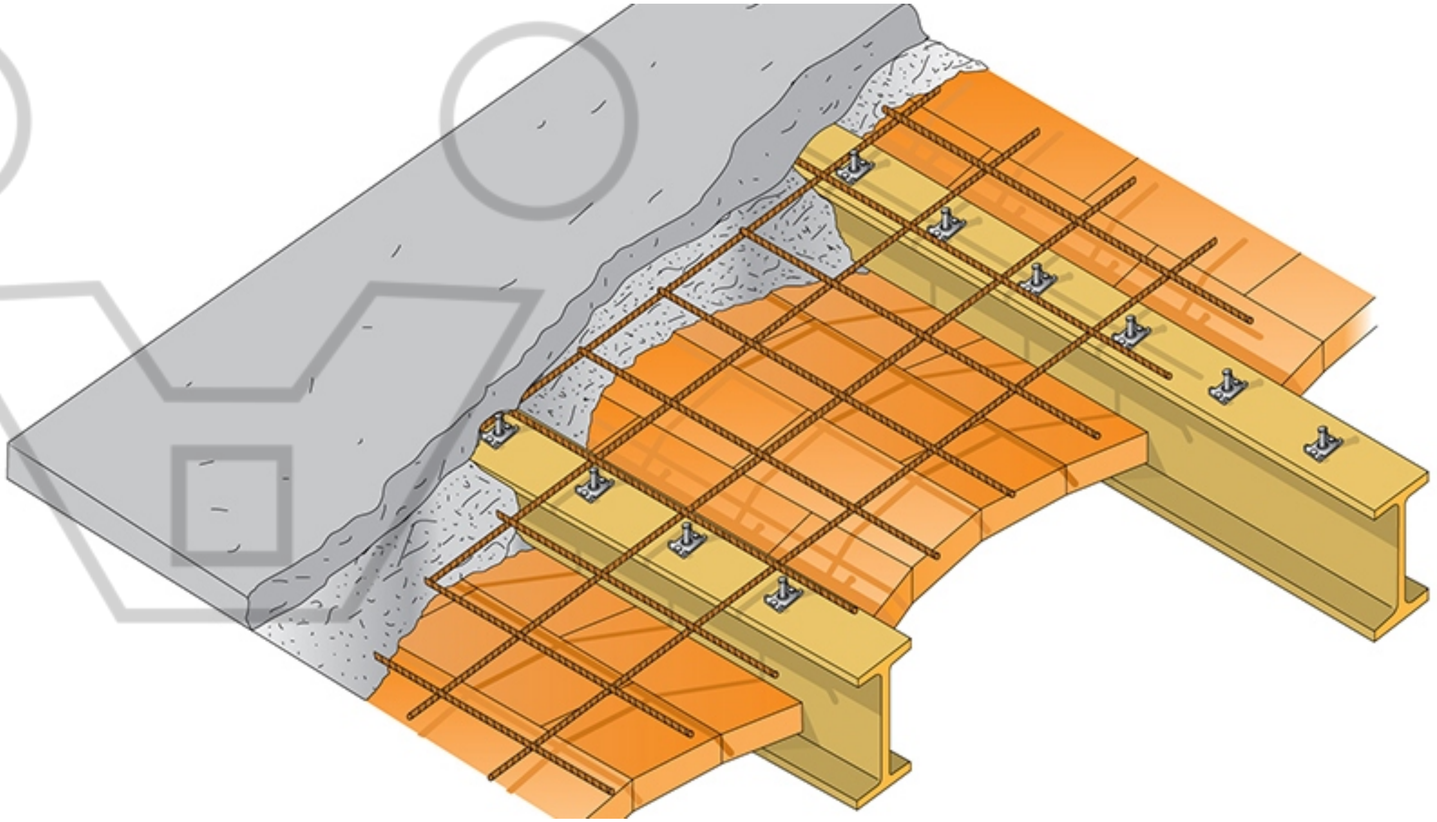
1 inch = 2,54 cm

1 foot = 30,48 cm

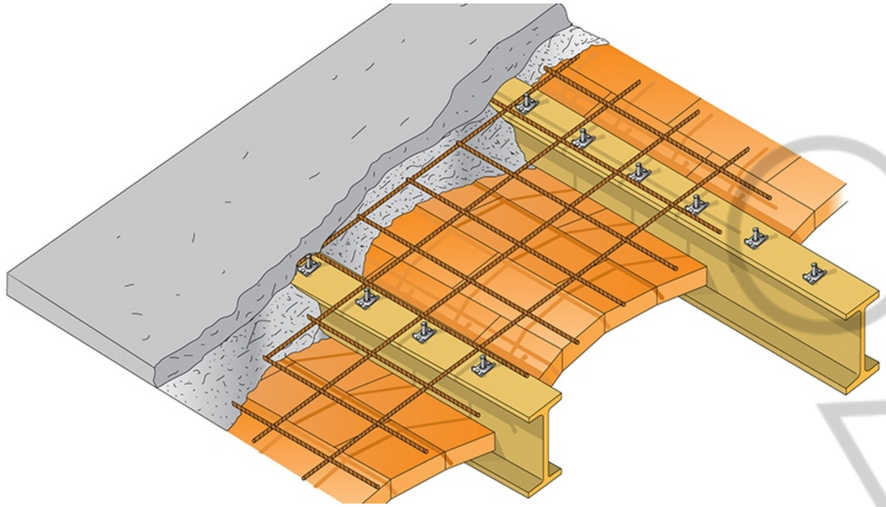
WOODEN SLAB TYPES

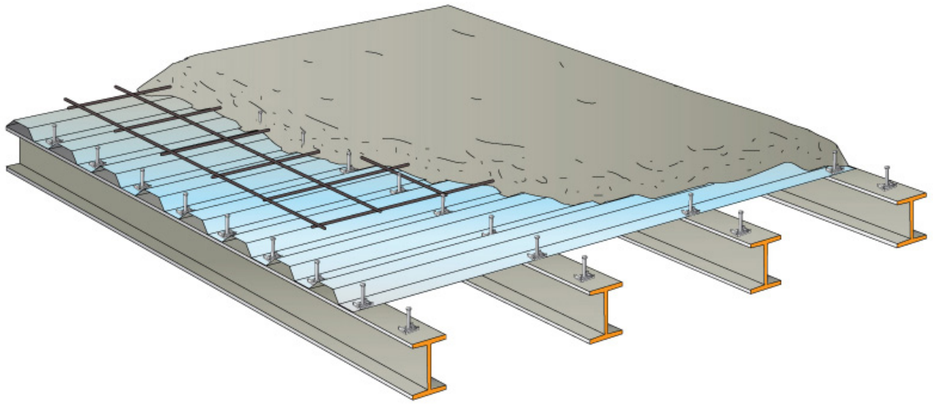
TRADITIONAL SLAB TYPES: Brick & Steel Slab





TRADITIONAL SLAB TYPES: Steel Slab





HORIZONTAL DEPTH DIMENSIONING: STEEL & WOOD

Girders, Beams & Joists

STEEL	
Floor Beam/Joist	L / 20
Floor Beam - Vibrating Machinery or Track Support	L / 16
Composite Floor Beam	L / 22
Roof Beam/Joist	L / 24
Joist Girder	L / 12
Truss	L / 12
Space Frame	L / 12 to L / 20
Girts	L / 60
WOOD	
Nominal Joist	L / 24
Nominal Scissor Truss	3:12 Diff. Between Top & Bot. Chord or Bot. Chord Pitch 1/2 of Top Chord Pitch
Nominal Flat Truss	L / 14
Timber Bowstring Truss	L / 6 to L / 8
Timber Gable Truss	L / 6 Min.
Timber Flat Truss	L / 8 to L / 10

STEEL BEAMS DEPTH DIMENSIONING

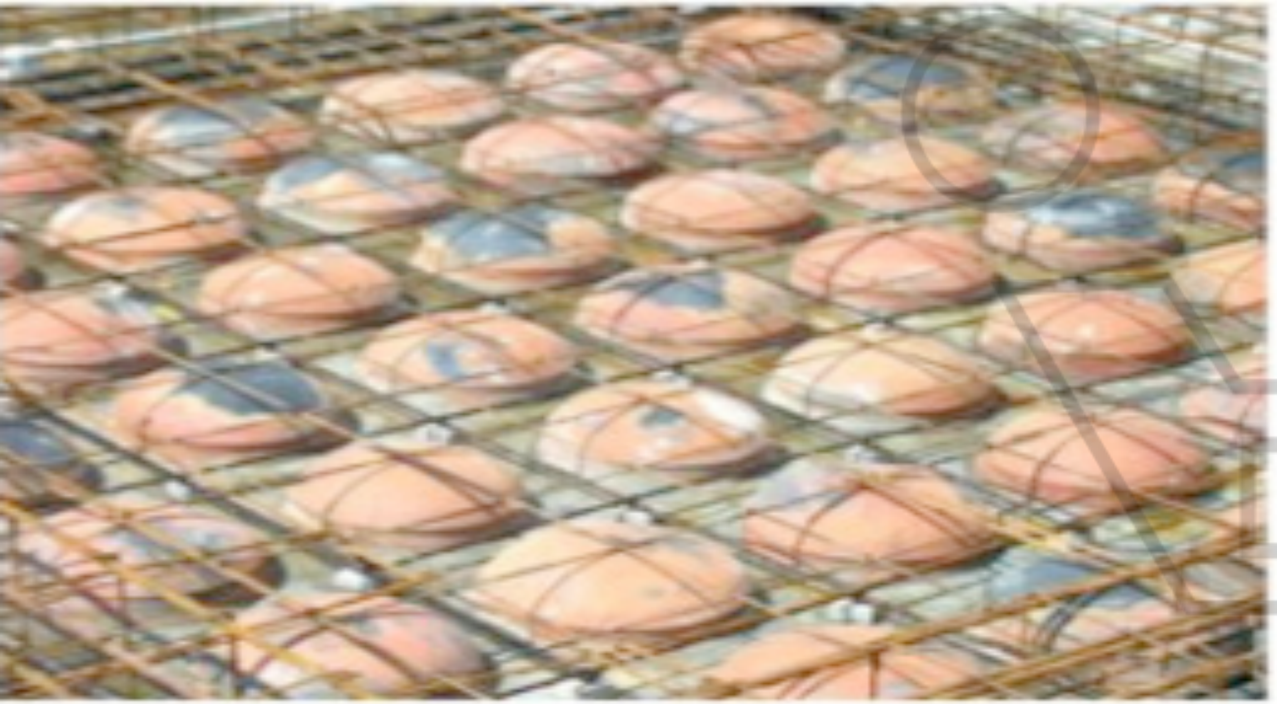
Span to depth ratios for different steel beam solutions

Non-composite primary beams	Floor = span/20	Roof = span/25
Non-composite secondary beams	Floor = span/25	Roof = span/30

Composite beams Span/16 to span/18 (note depth is steel beam plus slab)

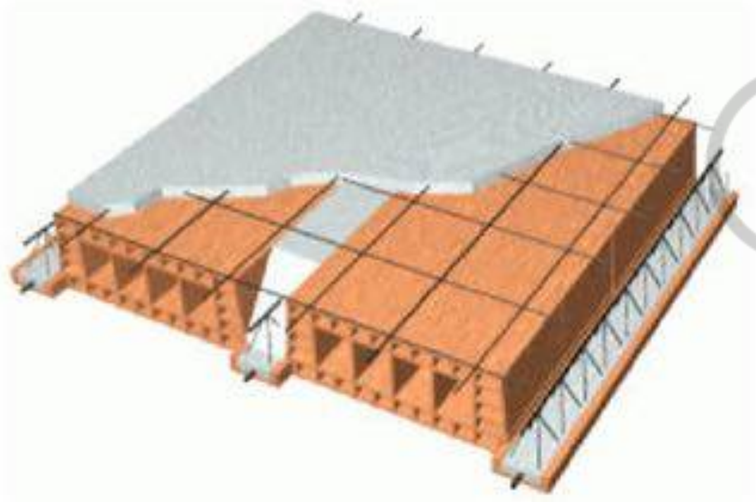
Long span solutions tend to be shallower, up to span/20

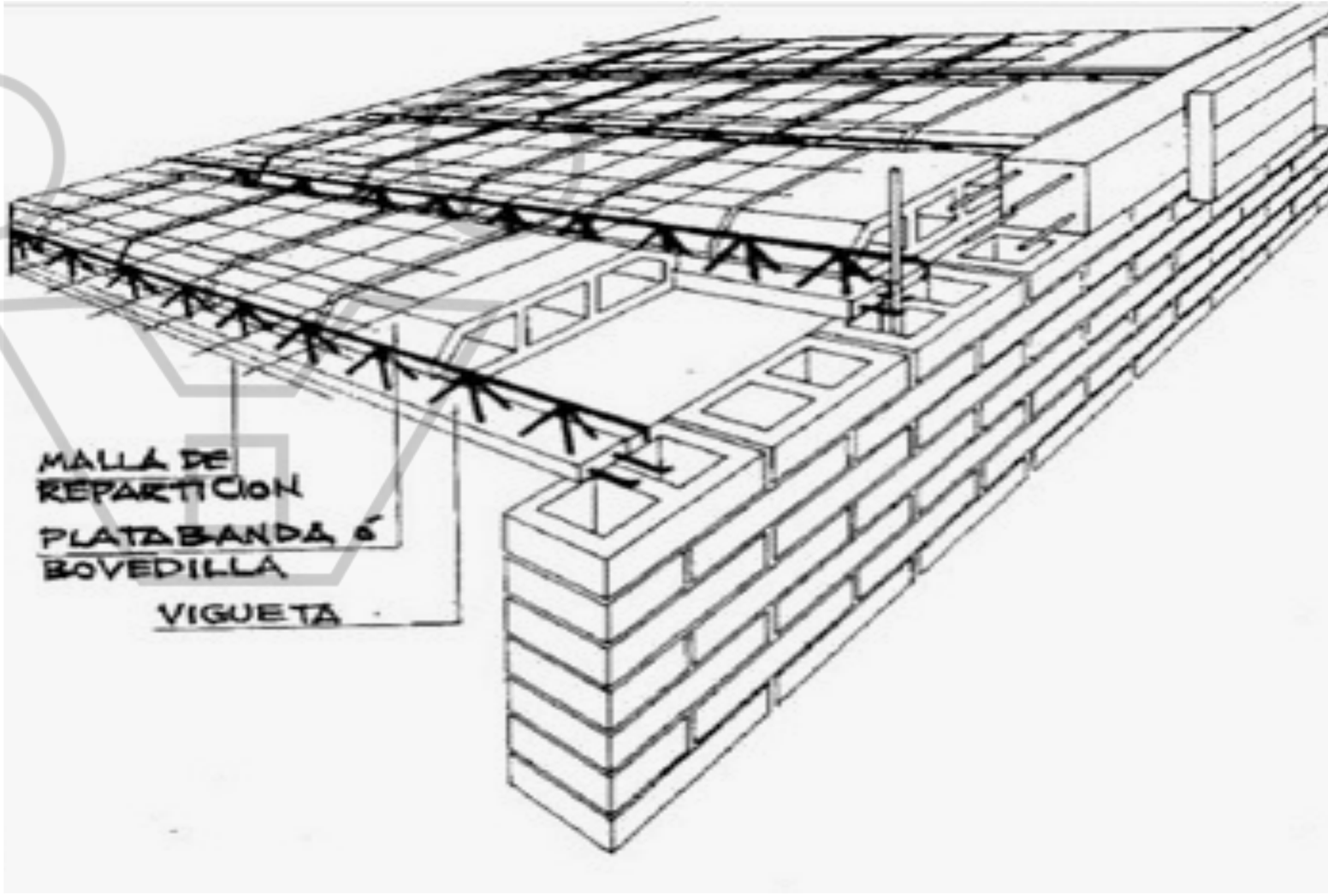
TRADITIONAL SLAB TYPES: Brick Slab



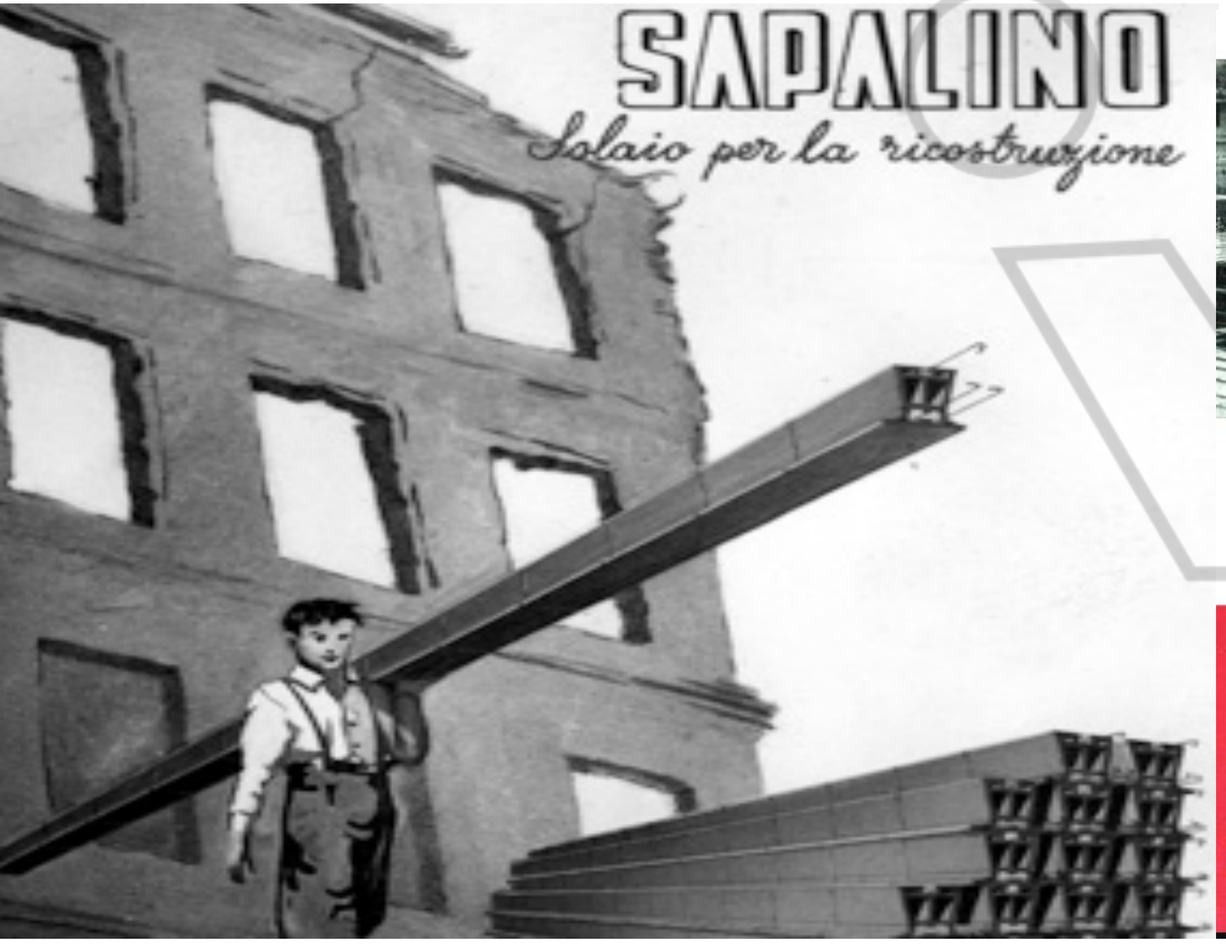
Earthen pots and Mangalore tiles used as filler materials between the steel reinforcements in the filler slabs

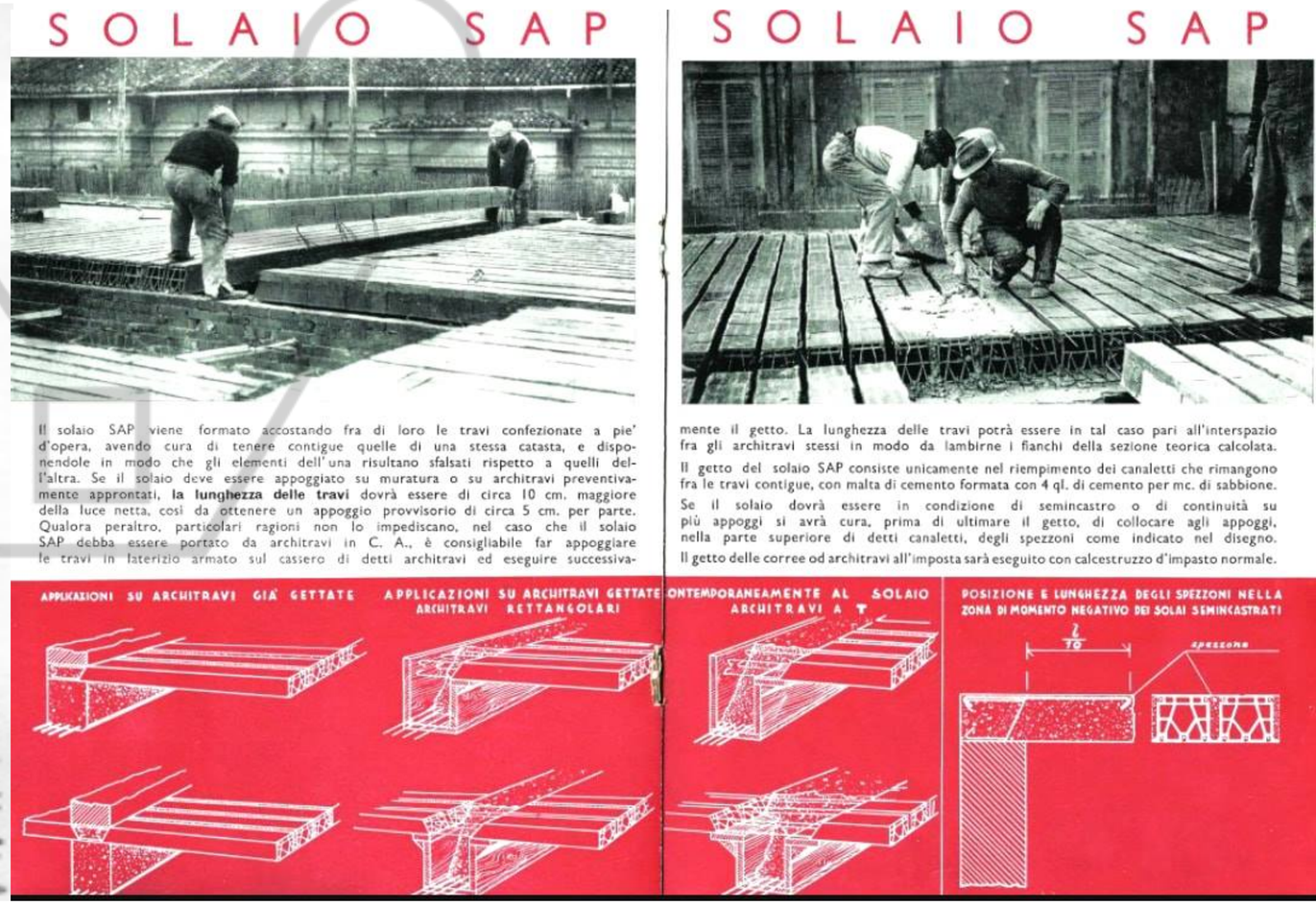
TRADITIONAL SLAB TYPES: Brick Slab





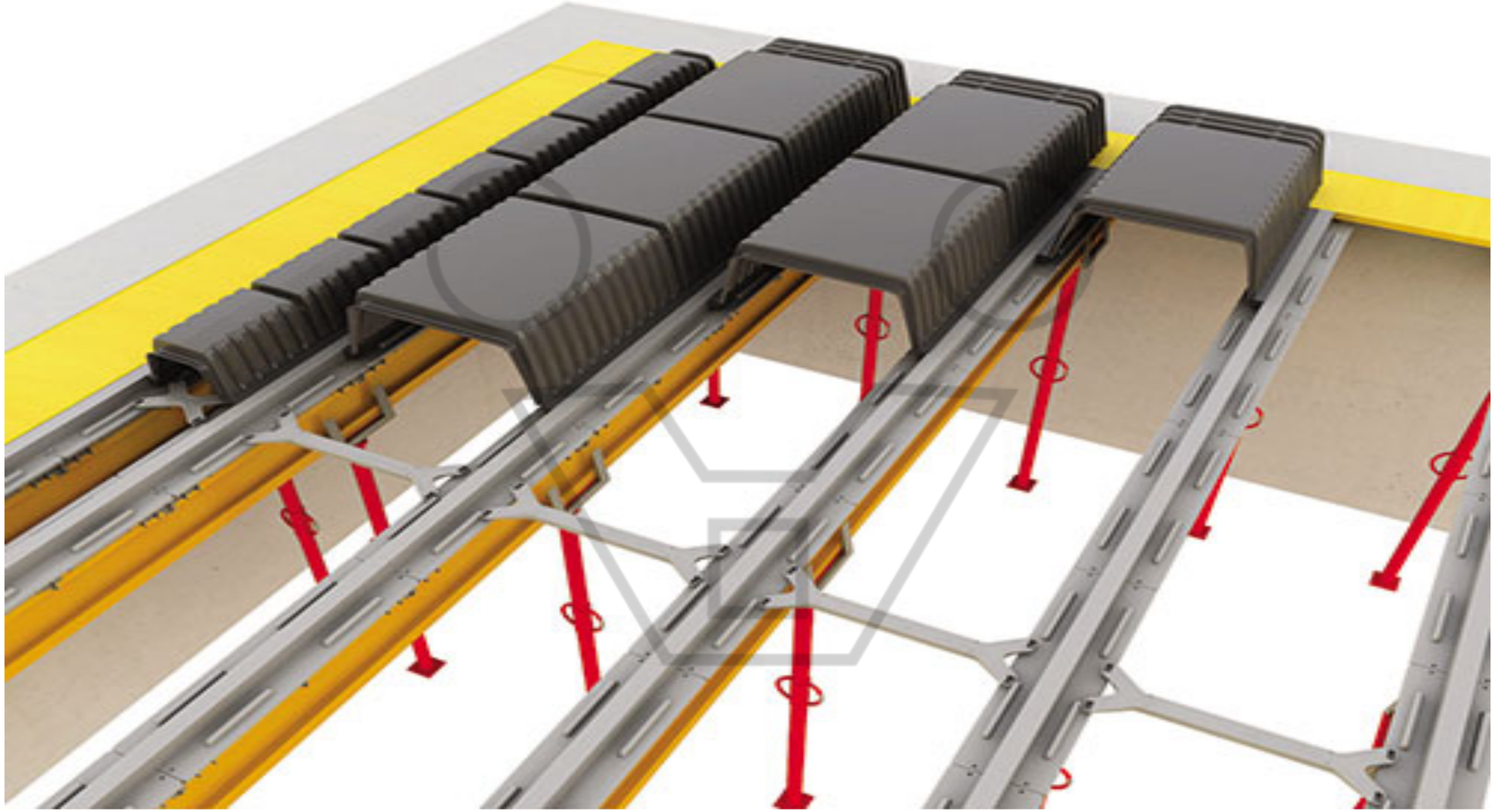
TRADITIONAL SLAB TYPES: Brick Slab





TRADITIONAL SLAB TYPES: Brick Slab

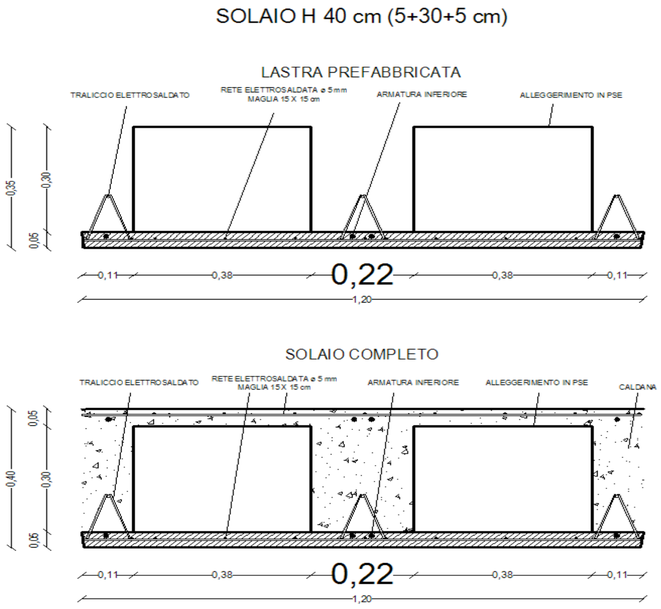
IN SITU SLAB INDUSTRIALIZED SYSTEM

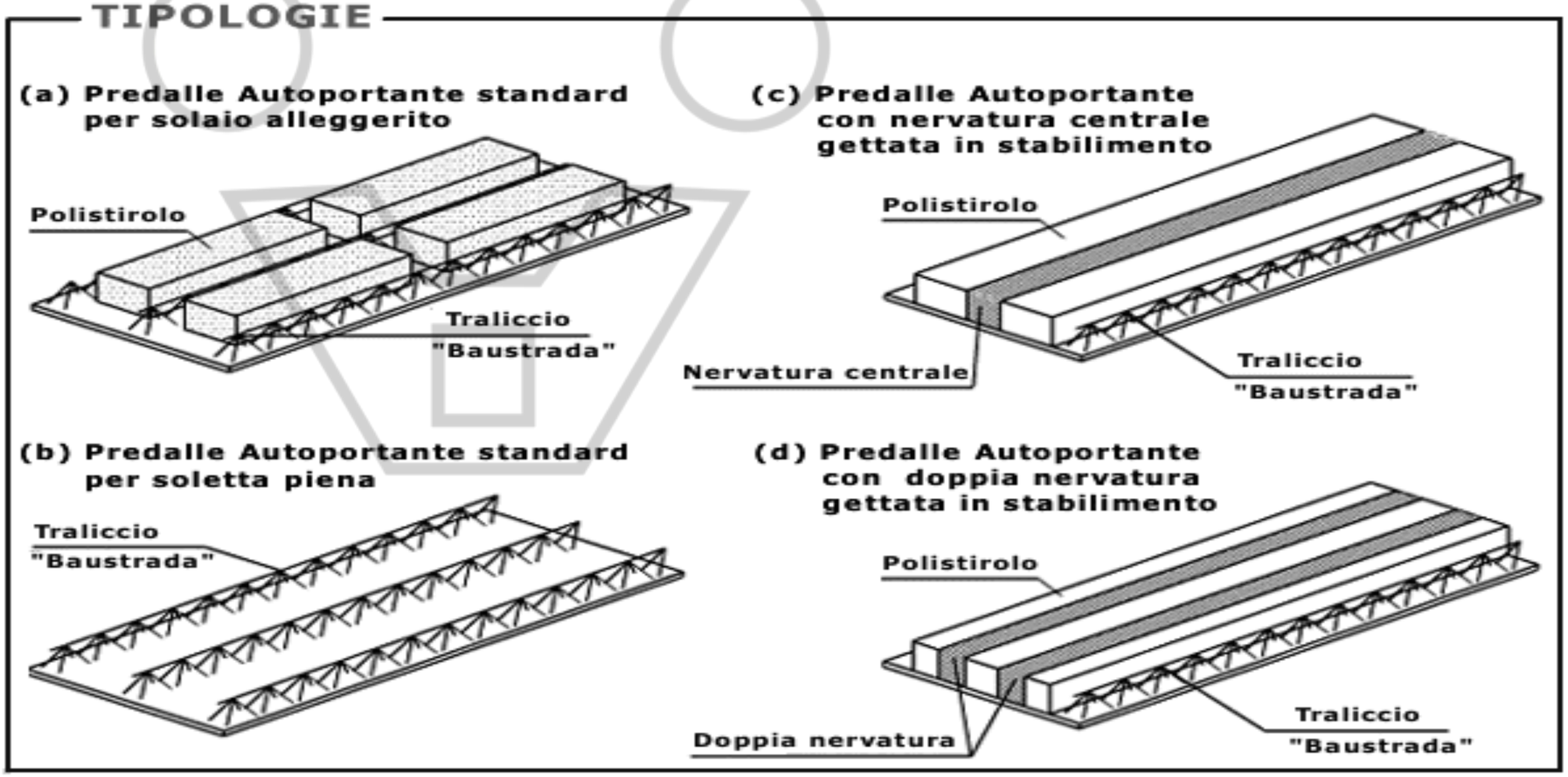


SKYRAIL: An Industrialized formwork for concrete

PREFAB SLAB TYPES: Disposable FormWork Slab

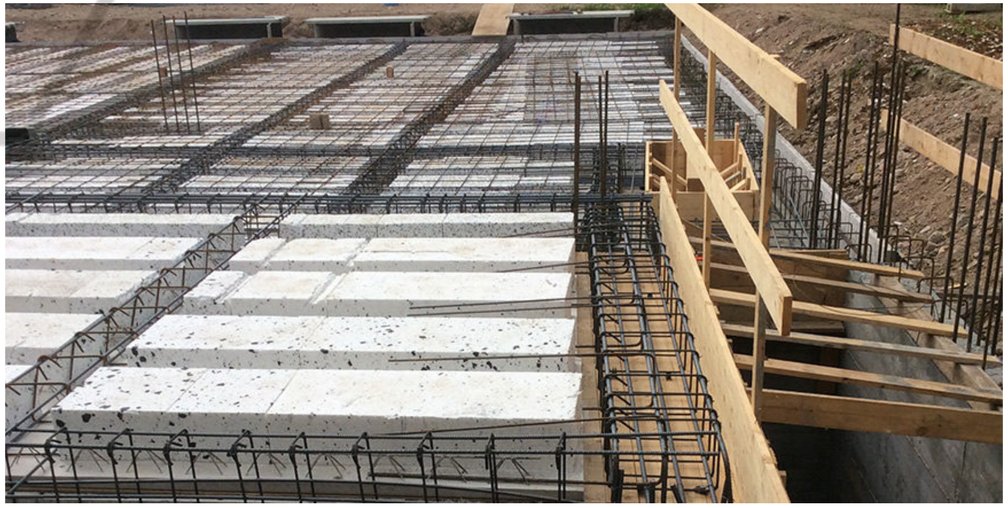
PREDALLES





PREFAB SLAB TYPES: Disposable FormWork Slab

PREDALLES

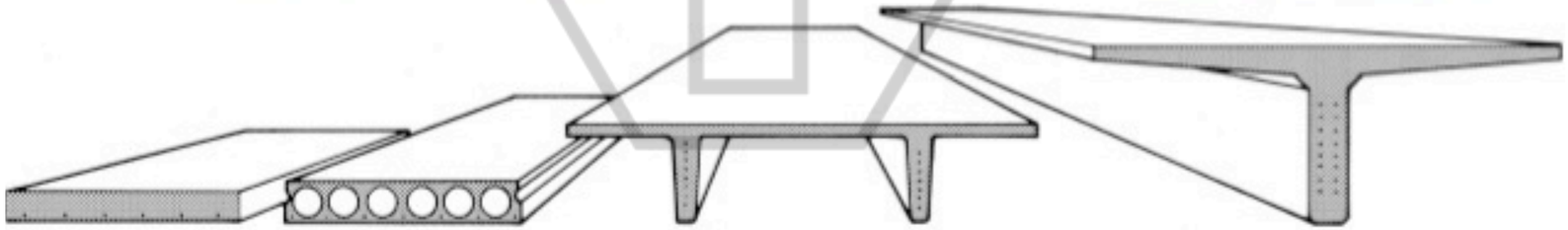


PREFAB SLAB TYPES

PRECAST, PRESTRESSED CONCRETE STRUCTURAL ELEM

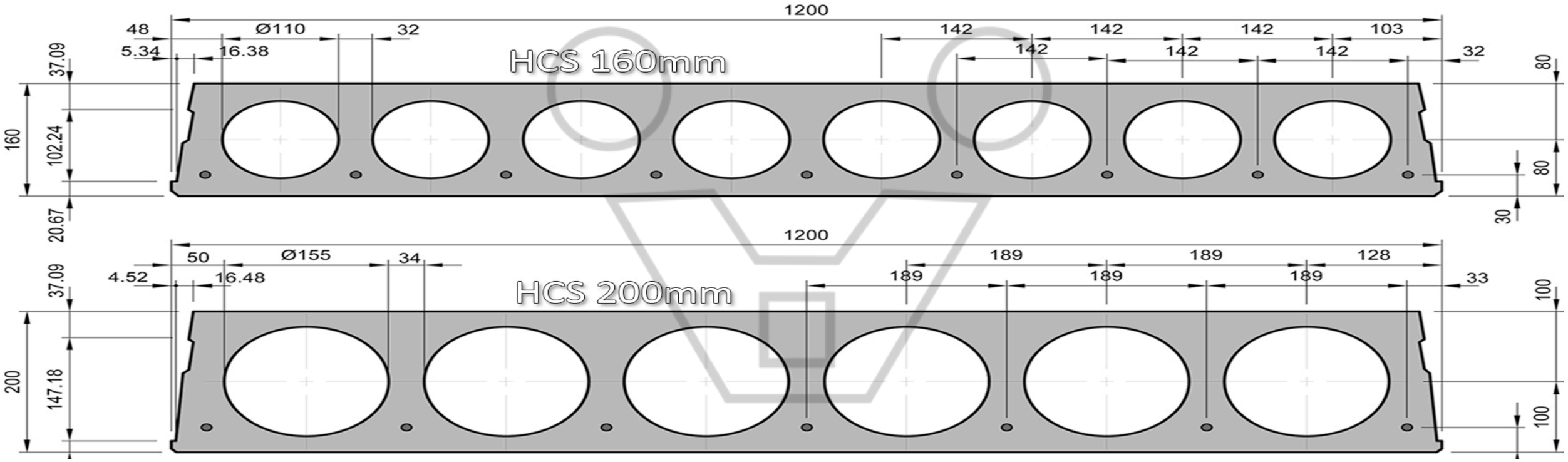
Precast Concrete Slabs

- *Used for floor and roof decks.*
- *Deeper elements (toward the right below) span further than those that are shallower (toward the left).*
- *Right: Hollow core slabs stacked at the precasting plant.*



SOLID FLAT SLAB	*HOLLOW CORE SLAB*	*DOUBLE TEE*	*SINGLE TEE*
Widths vary	*2', 4', 8' wide (610, 1220, 2440 mm)*	*8', 10' wide (2440, 3050 mm)*	*8', 10' wide (2440, 3050 mm)*
	(1'4", 3'4" some manufacturers)		

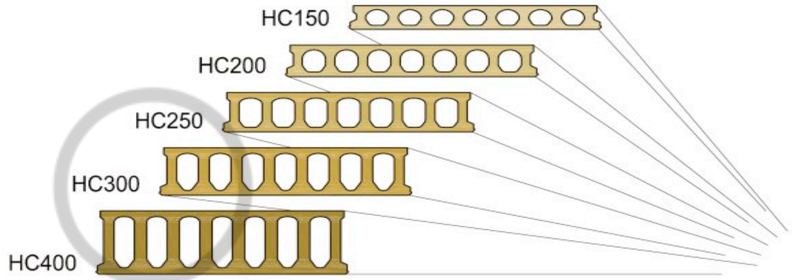
PREFAB SLAB TYPES: Hollow Core Slab



PREFAB SLAB TYPES: Hollow Core Slab

Load/span dimensioning

Precast Hollowcore Slab

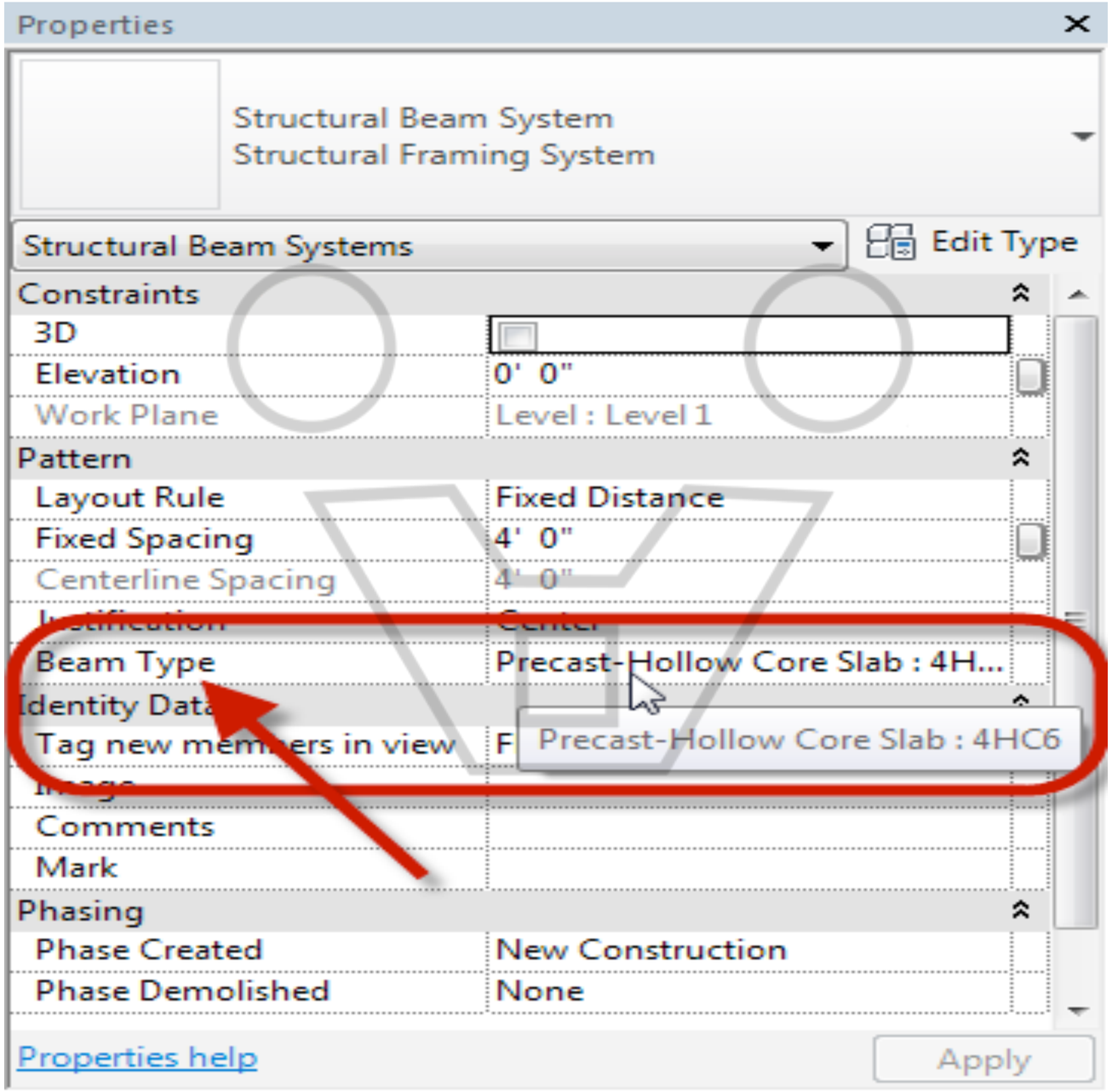


Hollowcore Load Spans

Unfactored Live Load (kn/sqm) - including self weight and screed

CLEAR SPAN (m) ⇨	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5
HC-150																														
Without structural screed	48.1	36.5	27.5	20.2	15.1	11.5	9.0	7.1	5.7	4.5	3.6	2.9	2.4	1.8	1.4	1.1	0.8													
With 75mm structural screed	46.3	35.8	28.9	24.0	20.5	17.3	13.5	9.8	7.1	5.0	3.3	1.9	0.8																	
75mm Structural screed + Temporary propping	46.3	35.8	28.9	24.0	20.5	17.7	14.6	11.5	9.1	7.3	5.8	4.4	3.2	2.3	1.4	1.1	0.8													
HC-200																														
Without structural screed			42.4	35.6	30.6	25.5	20.3	16.4	13.4	11.1	9.3	7.8	6.5	5.5	4.7	3.9	3.3	2.8	2.3											
With 75mm structural screed			40.9	34.0	29.0	25.2	22.1	19.6	17.6	15.4	12.4	9.9	7.9	6.2	4.8	3.6	2.6	1.8	0.9											
75mm Structural screed + Temporary propping			40.9	34.0	29.0	25.2	22.1	19.6	17.6	15.9	13.8	11.4	9.3	7.7	6.2	5.1	4.0	3.1	2.4											
HC-250																														
Without structural screed							31.0	25.2	20.8	17.4	14.6	12.4	10.6	9.1	7.8	6.8	5.8	5.0	4.4	3.7	3.2									
With 75mm structural screed							30.4	27.0	24.3	22.0	19.5	16.1	13.4	11.1	9.2	7.6	6.2	5.0	3.9	3.0	2.2	1.5	0.9							
75mm Structural screed + Temporary propping							30.4	27.0	24.3	22.0	19.8	17.3	14.5	12.2	10.3	8.7	7.3	6.1	5.1	4.1	3.3	2.6	2.0							
HC-300																														
Without structural screed											23.0	19.6	16.8	14.5	12.3	10.7	9.3	8.2	7.2	6.3	5.5	4.8	4.2	3.6						
With 75mm structural screed											27.4	24.2	21.6	18.6	15.3	13.0	11.0	9.3	7.8	6.6	5.4	4.4	3.5	2.7	2.0	1.4	1.8			
75mm Structural screed + Temporary propping											27.4	24.2	21.6	19.4	16.3	14.0	12.0	10.3	8.8	7.6	6.4	5.4	4.5	3.7	3.0	2.4	1.8			
HC-400																														
Without structural screed															19.3	16.8	14.7	12.9	11.4	10.0	8.8	7.7	6.8	6.0	5.2	4.5				
With 75mm structural screed															22.7	20.5	17.7	15.2	13.1	11.2	9.6	8.2	6.9	5.7	4.7	3.8	3.0	2.2	1.5	0.9
75mm Structural screed + Temporary propping															22.7	20.5	18.0	15.8	13.8	12.0	10.4	9.0	7.7	6.5	5.5	4.6	3.8	3.0	2.3	1.7

Note:	Self Weight (Incl. screed)	Reinforcement	Cores
HC-150	2.23 kn/sqm + 1.8 kn/sqm screed	8 nos. 9.3mm diameter strands	7 nos. 110mm wide cores
HC-200	2.74 kn/sqm + 1.8 kn/sqm screed	6 nos. 12.5mm + 2 nos. 9.3mm diameter strands	7 nos. 110mm wide cores
HC-250	3.10 kn/sqm + 1.8 kn/sqm screed	6 nos. 12.5mm + 4 nos. 9.3mm diameter strands	7 nos. 109mm wide cores
HC-300	3.80 kn/sqm + 1.8 kn/sqm screed	8 nos. 12.5mm + 4 nos. 9.3mm diameter strands	7 nos. 103mm wide cores
HC-400	4.92 kn/sqm + 1.8 kn/sqm screed	8 nos. 12.5mm + 4 nos. 9.3mm diameter strands and 2 nos. 9.3mm diameter top strands	7 nos. 97mm wide cores

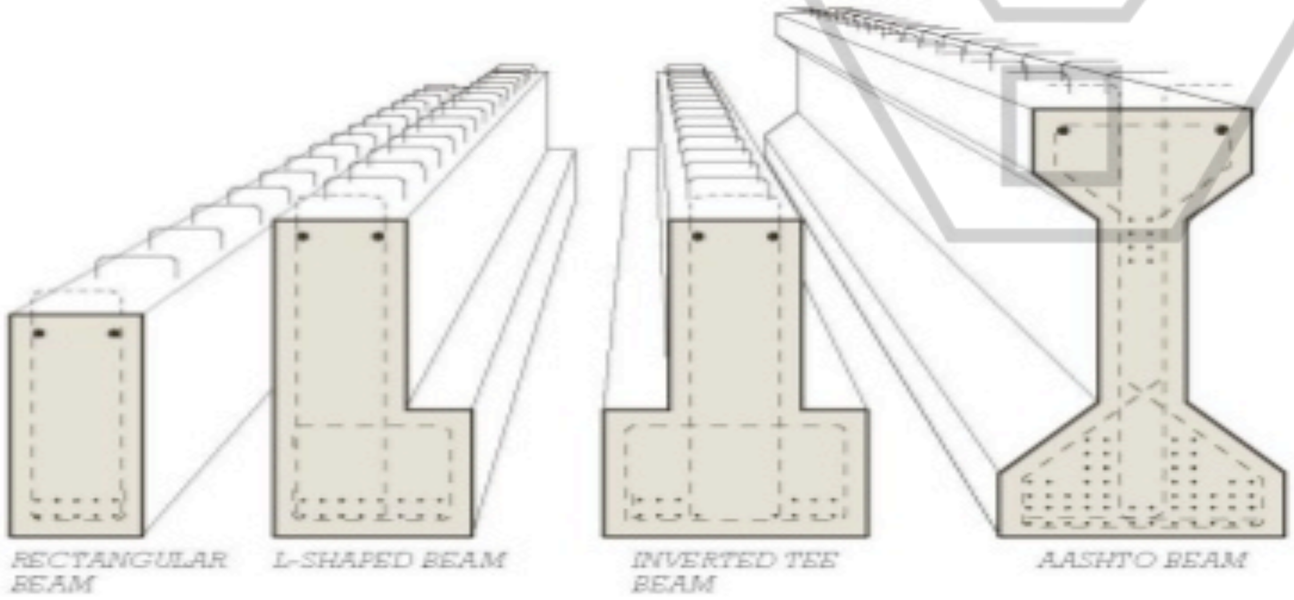

Properties
Structural Beam System
Structural Framing System
Structural Beam Systems
Edit Type
Constraints
3D
Elevation
0' 0"
Work Plane
Level : Level 1
Pattern
Layout Rule
Fixed Distance
Fixed Spacing
4' 0"
Centerline Spacing
4' 0"
Beam Type
Precast-Hollow Core Slab : 4H...
Precast-Hollow Core Slab : 4HC6
Comments
Mark
Phasing
Phase Created
New Construction
Phase Demolished
None
Properties help
Apply

LONG SPAN: PREFAB CONCRETE GIRDERS & BEAMS

PRECAST, PRESTRESSED CONCRETE STRUCTURAL ELEM

Precast Concrete Beams and Girders

- *Provide support for slabs.*
- *The projecting reinforcing bars will bond with concrete cast on site.*
- *Right: Inverted tee beams supported by precast columns.*

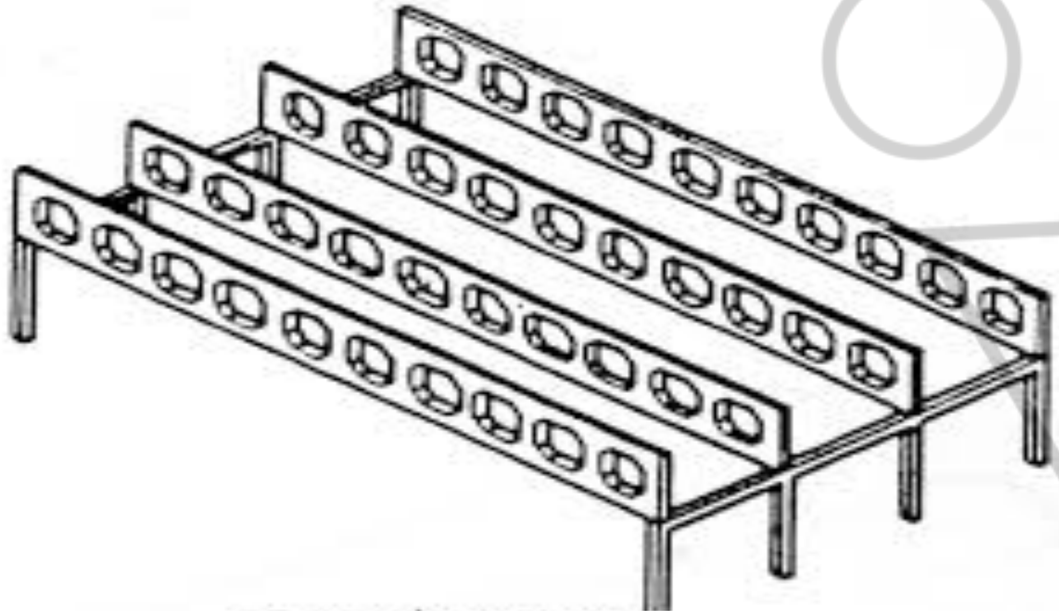


LONG SPAN: PREFAB CONCRETE GIRDERS & BEAMS

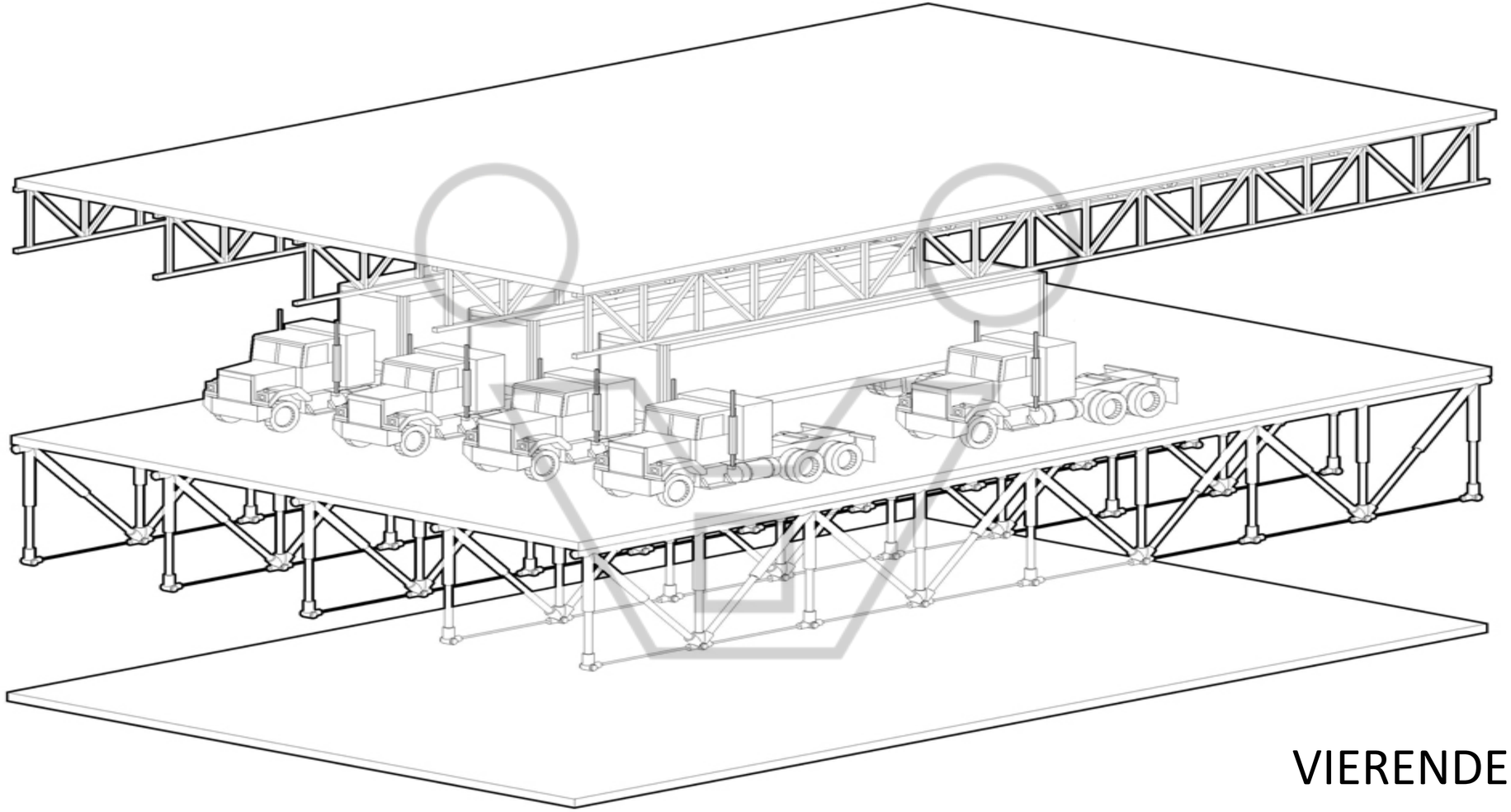
Beams

- Made in different sizes
- Rectangular beams, L shaped beams, inverted T beams and AASHTO beams

LONG SPAN: HALLOW BEAMS



LONG SPAN: SPATIAL & CELLULAR TRUSS



VIERENDEL

LONG SPAN: SPATIAL & CELLULAR TRUSS

Catwalk truss

LONG SPAN: PARAPET BEAM

Single tee slabs

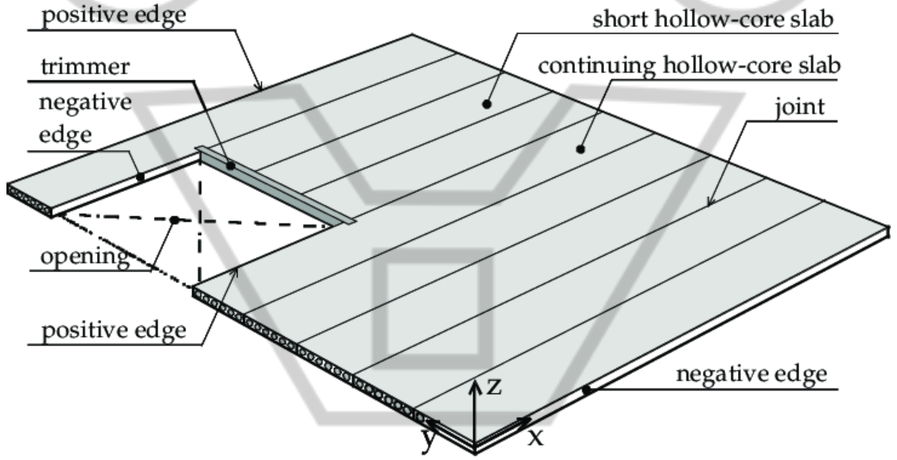
LONG SPAN: WALL BEAM

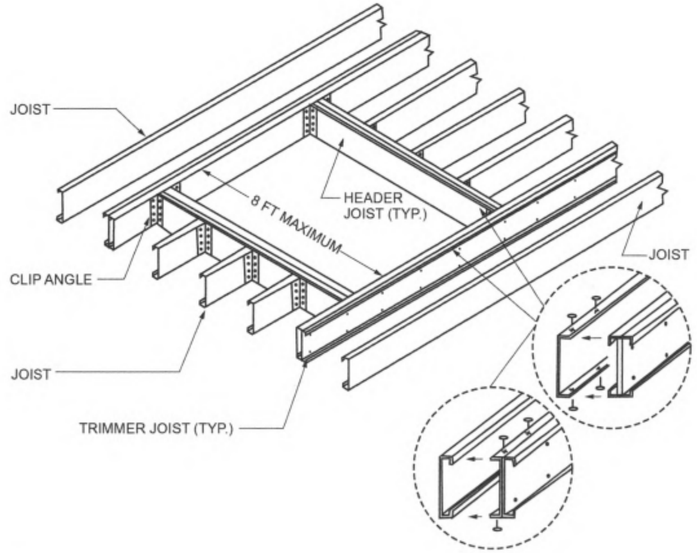
Milstein Hall, designed by OMA.

STRUCTURAL DISCONTINUITY & LOCAL WEAKNESS

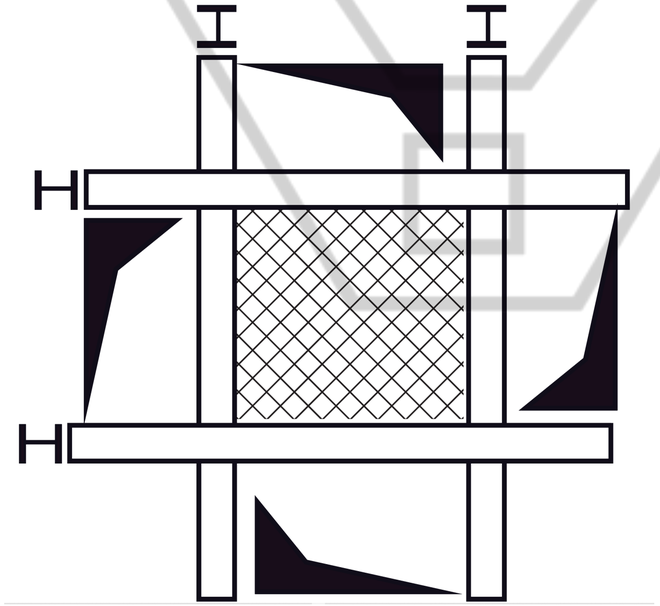
Joints
Opening Slab
Aggetti

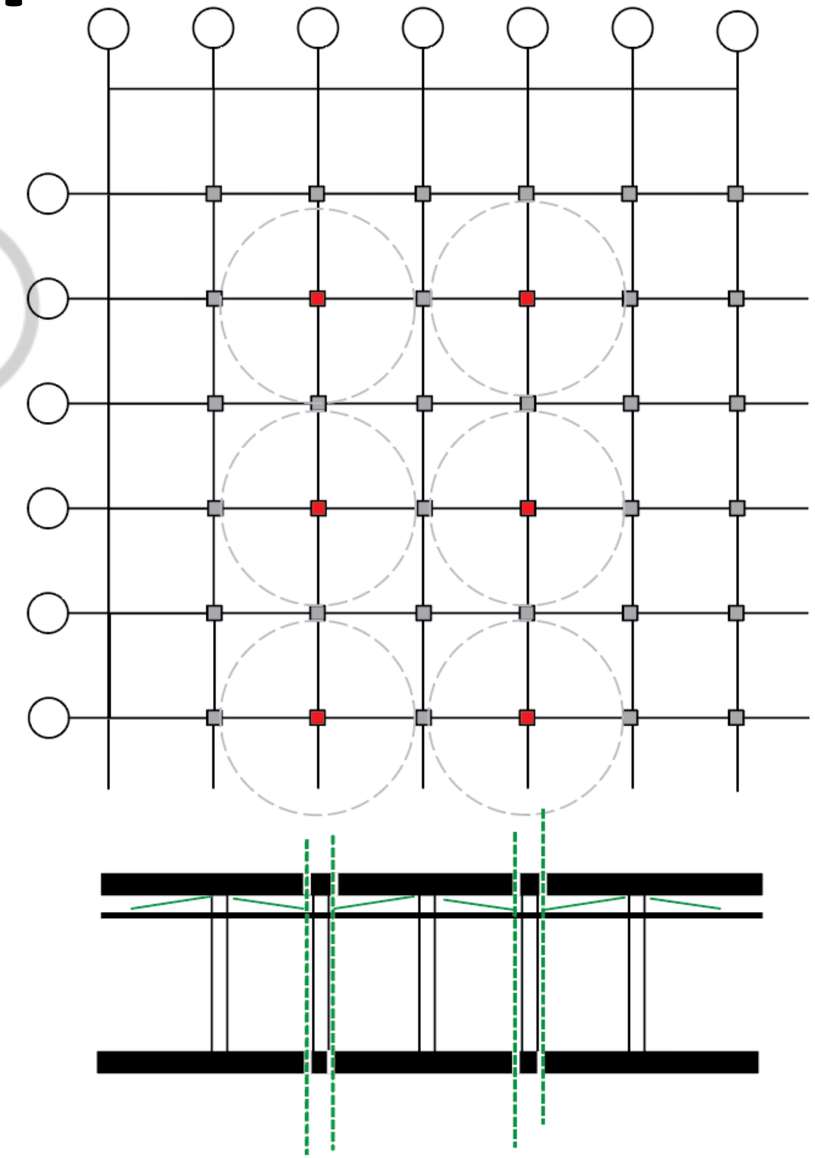
STRUCTURAL DISCONTINUITY & LOCAL WEAKNESS: FLOOR OPENINGS



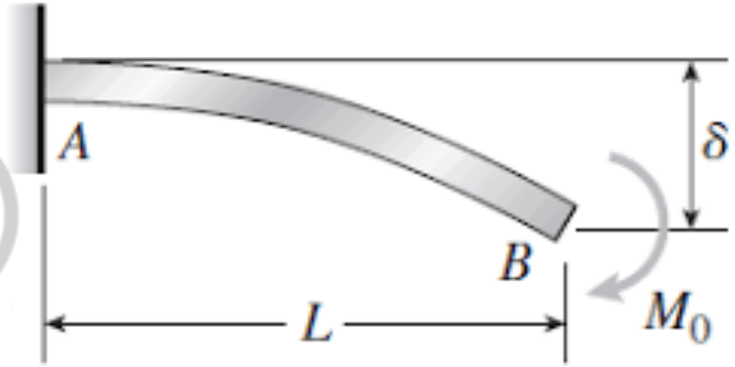


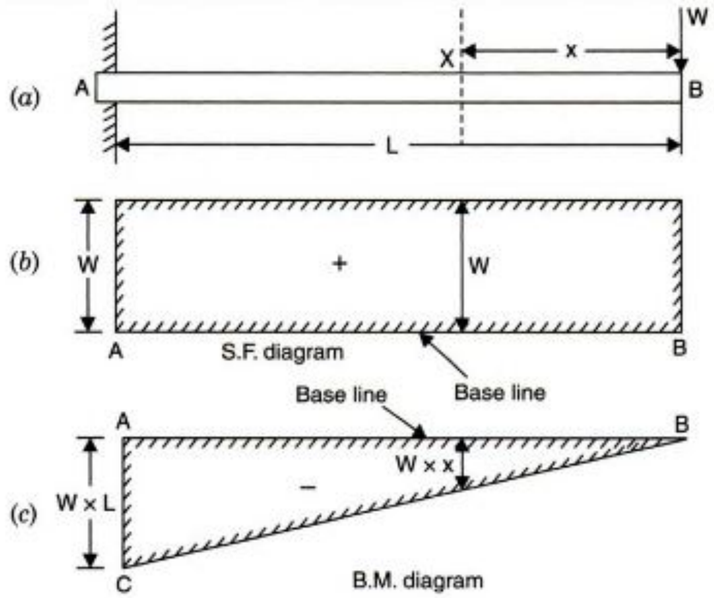
STRUCTURAL DISCONTINUITY & LOCAL WEAKNESS: FLOOR OPENINGS





STRUCTURAL DISCONTINUITY & LOCAL WEAKNESS: CANTELIVERED ELEMENTS





Shifting space on the air: the cantelivered structure

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

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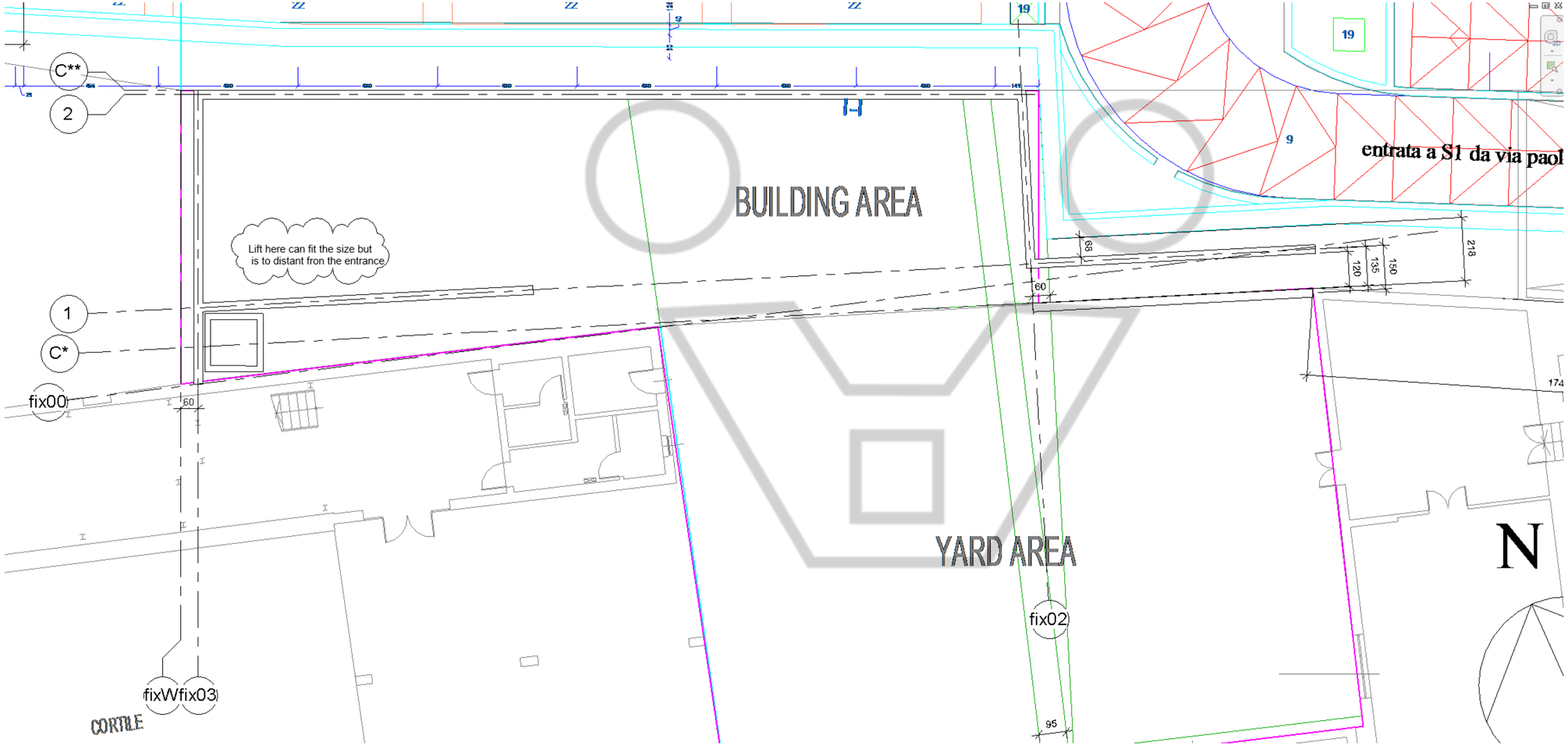
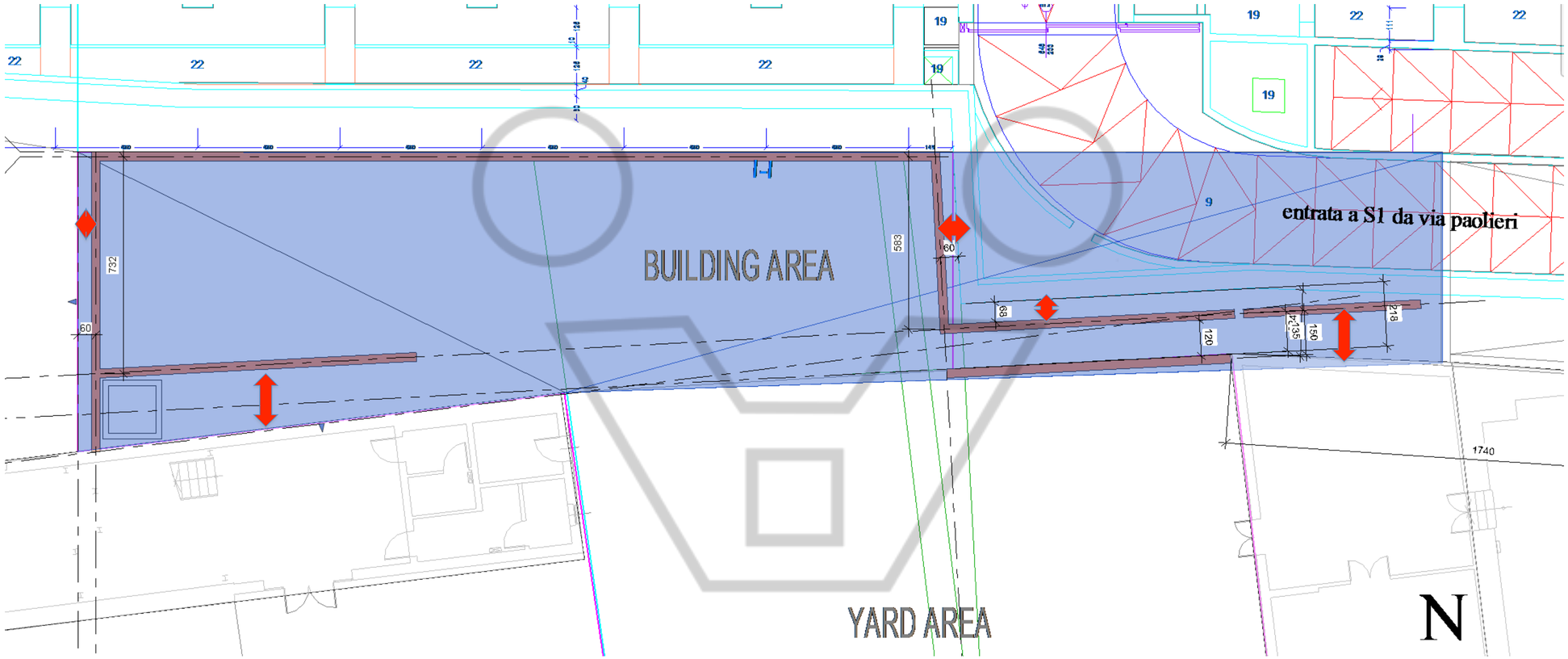

C**
2
1
C*
fix00
fixW
fix03
CORTILE
BUILDING AREA
YARD AREA
Lift here can fit the size but is to distant fron the entrance
entrata a S1 da via paol
19
9
fix02
N
60
68
120
135
150
218
174
95

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



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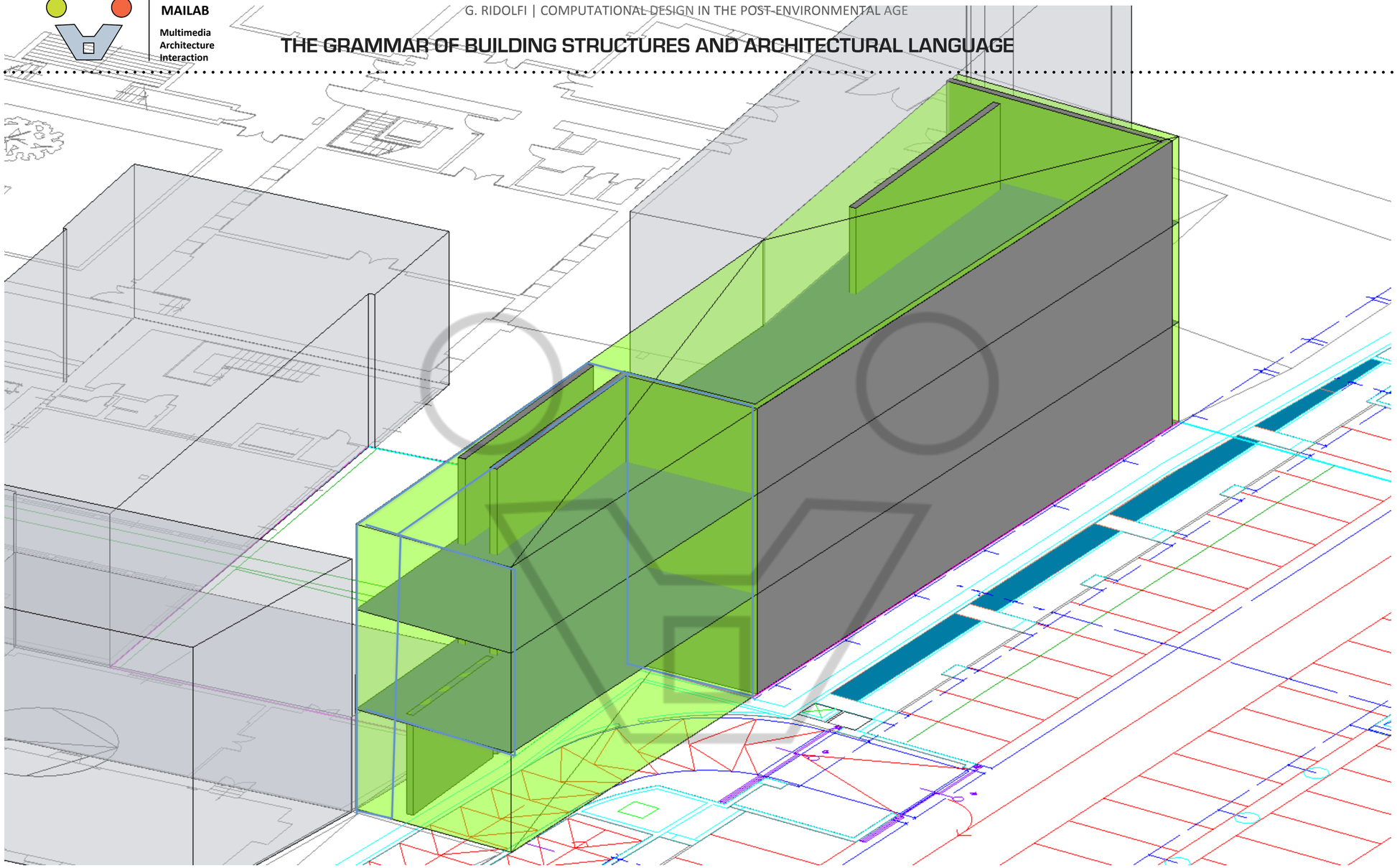
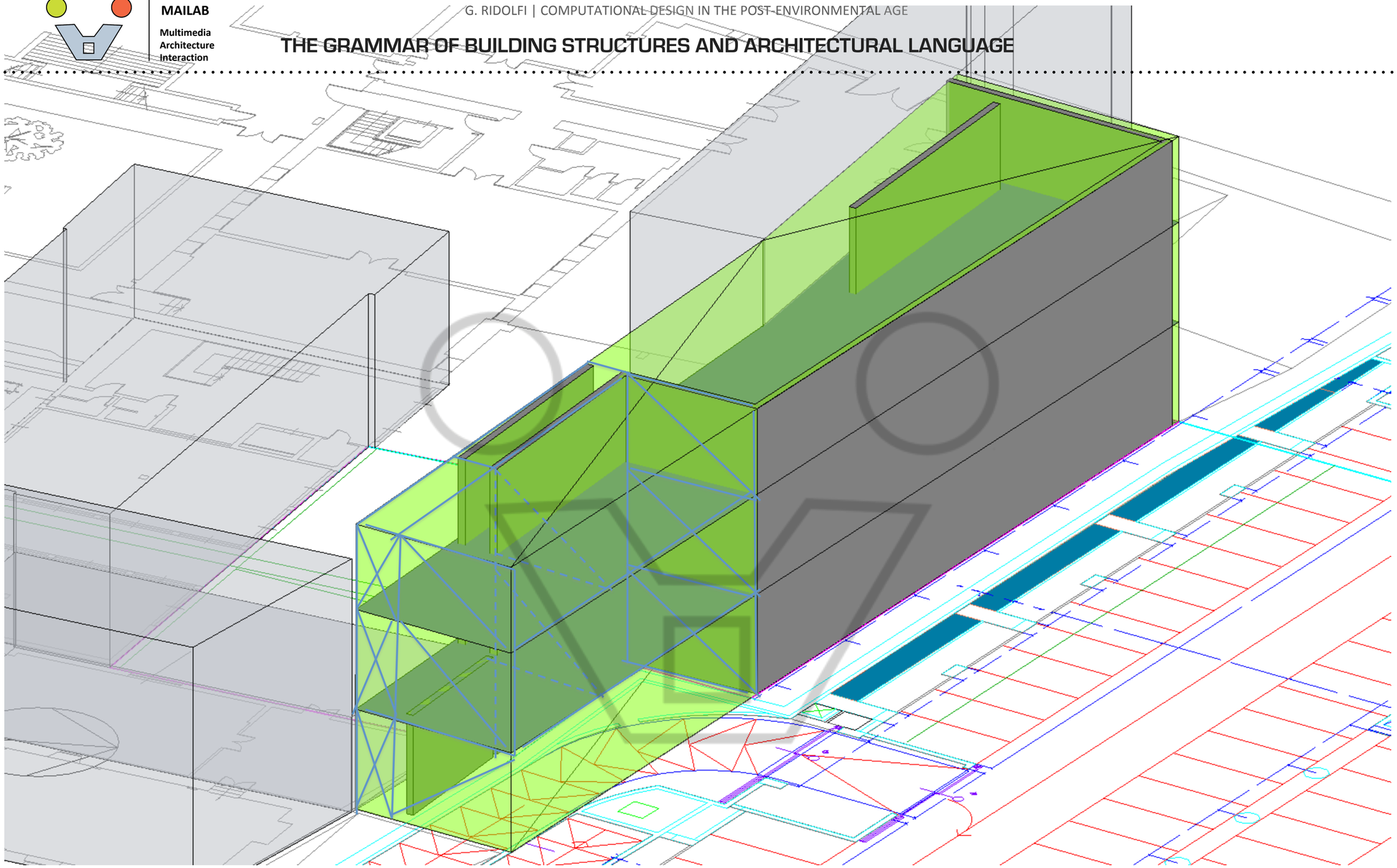


THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE



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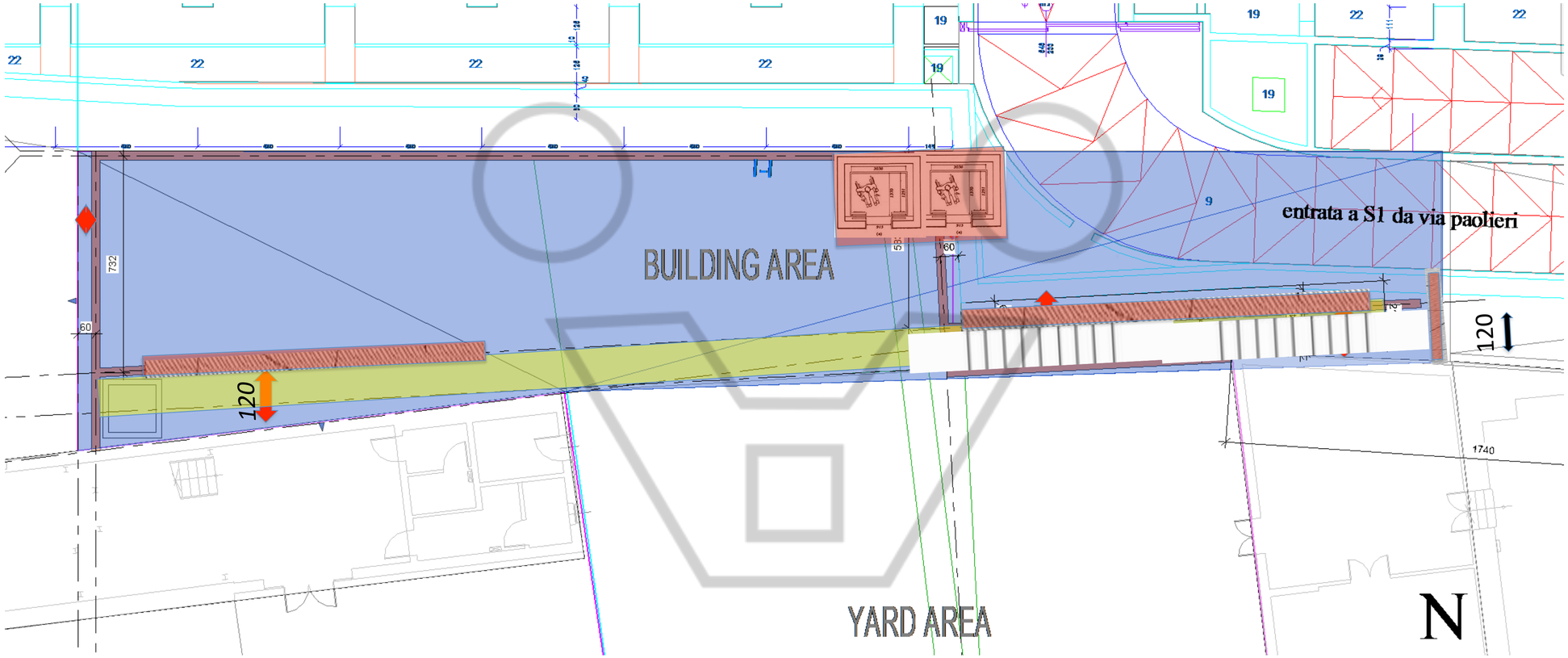

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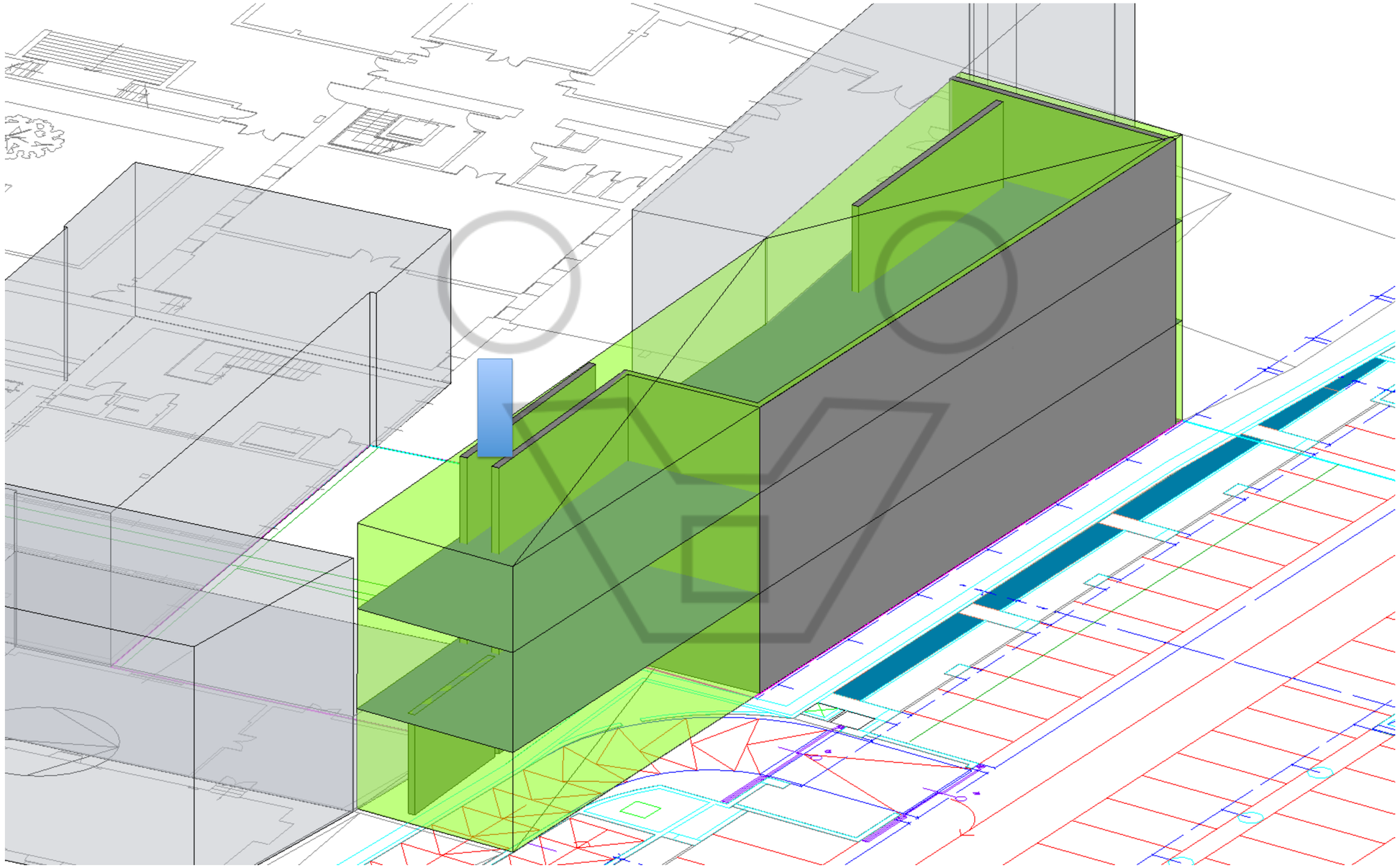
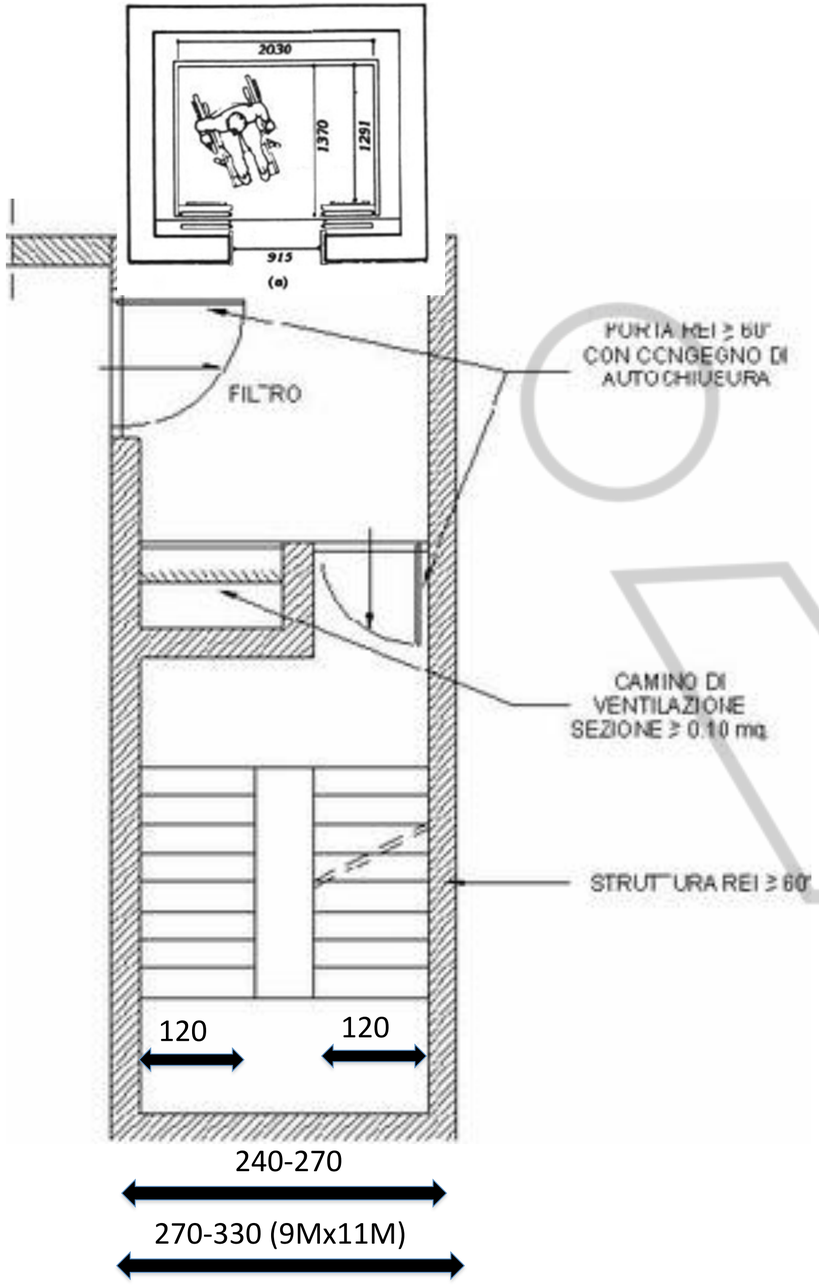
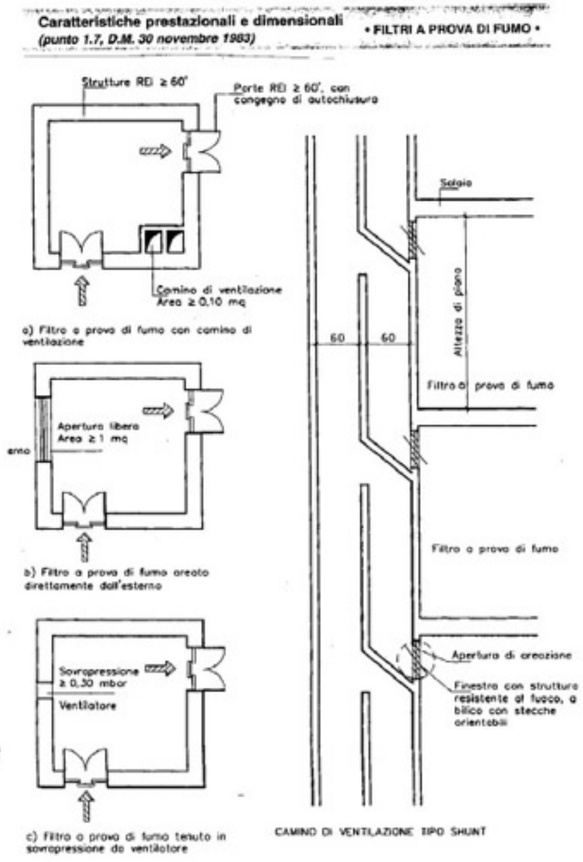




Interno ventilato 0,10 mq

Esterno

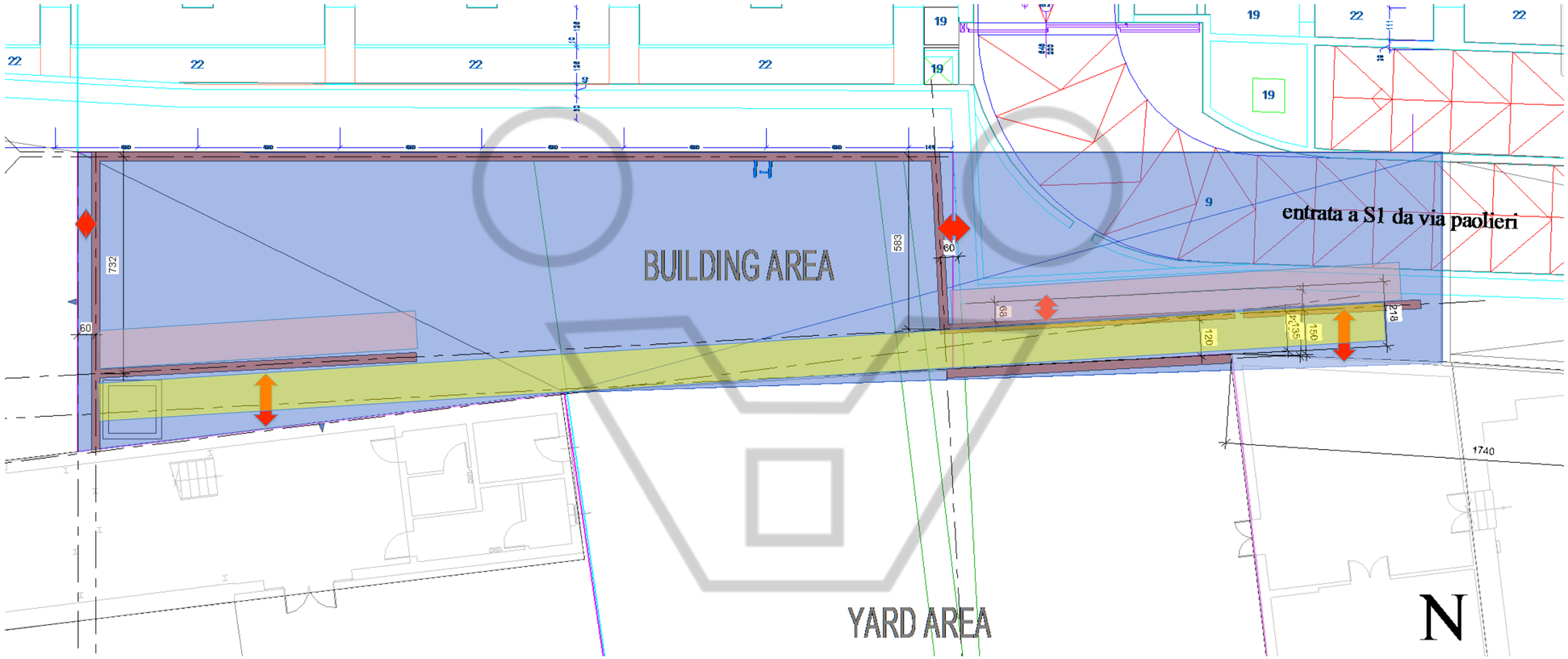
Interno in sovrapressione

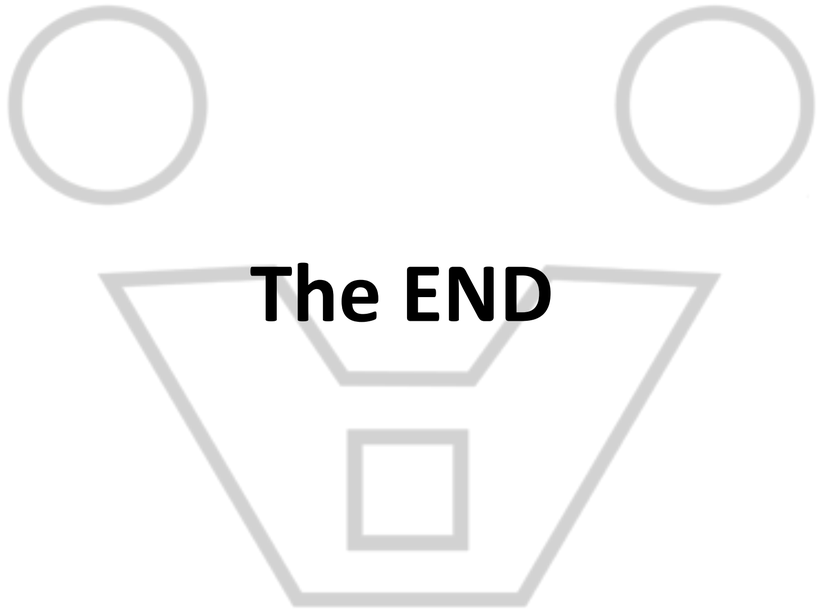


Filtri a prova di fumo

Canna di ventilazione Shunt

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE





The END

THE GRAMMAR OF BUILDING STRUCTURES AND ARCHITECTURAL LANGUAGE

Auto SW
Dimensioni (LxLxH): 1,70x1,00x1,00 **Capacità in Q.li:** 6

SCUDO
Dimensioni (LxLxH): 2,59x1,43x1,41 **Capacità in Q.li:** 8

FURGONE
Dimensioni (LxLxH): 3,03x1,50x1,88 **Capacità in Q.li:** 10

FURGONE CENTINATO
Dimensioni (LxLxH): 4,20x2,20x2,23 **Capacità in Q.li:** 10

MOTRICE
Dimensioni (LxLxH): 6,20x2,12x2,45 **Capacità in Q.li:** 25

MOTRICE
Dimensioni (LxLxH): 8,00x2,44x2,60 **Capacità in Q.li:** 50/100

BILICO
Dimensioni (LxLxH): 13,60 x 2,44 x 2,60 **Capacità in Q.li:** 240

MEGA
Dimensioni (LxLxH): 13,60 x 2,50 x 3,00 **Capacità in Q.li:** 240

AUTOTRENO
Dimensioni (LxLxH): (7,7+7,7) x 2,5 x 3 **Capacità in Q.li:** 240

AUTOTRENO
Dimensioni (LxLxH): (7,5+7,5) x 2,44 x 2,70 **Capacità in Q.li:** 240

AUTOTRENO
Dimensioni (LxLxH): (7,4+8,20) x 2,5 x 2,90 mt o 3 mt
Capacità in Q.li: 240