ARCHITECTURAL STRUCTURE

Week 11: Structural Considerations for Architects

Photo by Jorge Fernández Salas on Unsplash

Outline

1

INTRODUCTION

Aims

LOs

2

ASSIGNMENTS

- ASSIGNMENT 1- COMMON MISTAKES
- ASSIGNMENT 2

3

LECTURE:

- COMPOSITION OF STRUCTURE
- TYPES OF LOADS
- STRUCTURAL CONSIDERATION
- LIFE CYCLE ANALYSIS

4

~~SUMMARY REFLECTION~~

- IN-CLASS ACTIVITY 2 TO BE SUBMITTED VIA EMAIL

Aims and objectives

- To do a recap on **Assignment 1** submission
- To reiterate **Assignment 2's** submission requirements
- To look at **compositions of structure**
- To expand on **structural considerations** (rule of thumbs)
- To provide **examples** on classical tectonics and digital tectonics

Learning outcomes

Students will be able to..

01 Start to think about Assignment 2

02 Gain understanding on compositions of structure

03 Understand the common rule of thumbs in design practice

Part 1:
Assignments recap

Photo by Ricardo Gomez Angel on Unsplash

Assignment 1: common error

- Misunderstood assignment brief
- Missing grids
- Hatching (in elevation vs section, black colour hatching)
- Triangle on the dashed line (section or elevation) to show where the measurement of level is taken
- Dimension taking (centre-to-centre)
- Labelling ‘void’ convention
- Solid line vs dashed line
- Locations of columns on plan
- Odd measurements
- Missing required drawings

Assignment 2:

ANY QUESTIONS?

REMINDER:
Assignment 1's deadline is on May 8th – Saturday (11:45pm)

Late submission is not tolerable
Note: You had 2x4hr classes to work on this assignment
Via email: mia@miatedjosaputro.com

Live assessments' link:

https://miatedjosaputro.com/2021/04/07/as-2021-assessments/

Documents you need to look at:

- Document **#1**
- Document **#6**
- Document **#7**
- **Fundamentals of academic writing**

Architectural Structure

Protected: AS 2021: Live Assessments Documents

April 7, 2021 0 Comments

Assessment 1 documents:

1- AS_assessment brief_general

2- AS_assessment 1

3- AS_assessment 1- grading rubric

4- AS_assessment 1- example

5- Link to the SketchUp file: https://www.dropbox.com/s/mzflu293nhbx576/5-%20AS_assessment%201-%20sketchup%20file.zip?dl=0

Assessment 2 documents:

6- AS_assessment 2

7- AS_assessment 2- grading rubric

Fundamentals of **academic writing:**

Avoiding Plagiarism

assessments NBU-AStructure

Part 2:
Building system

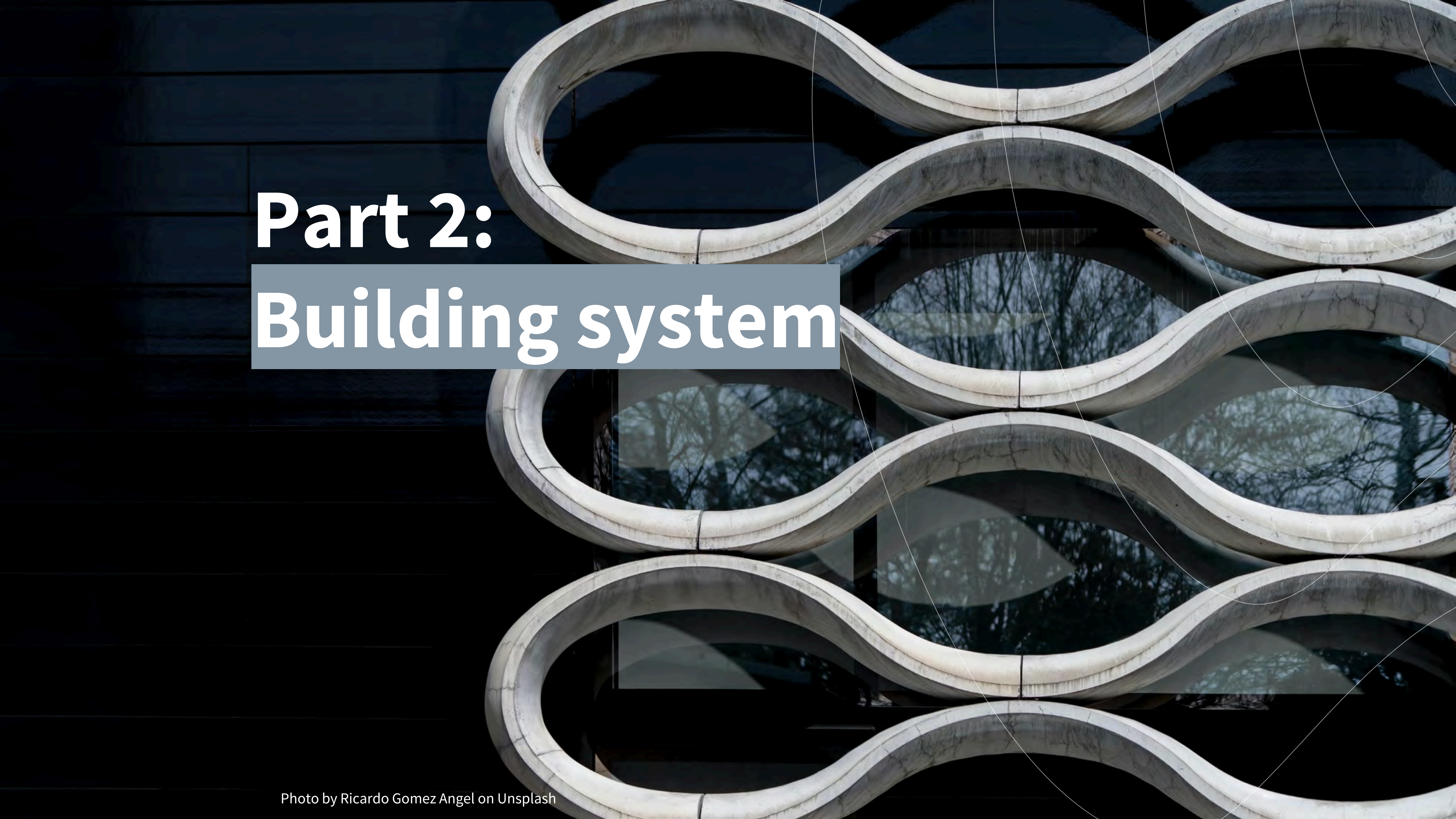
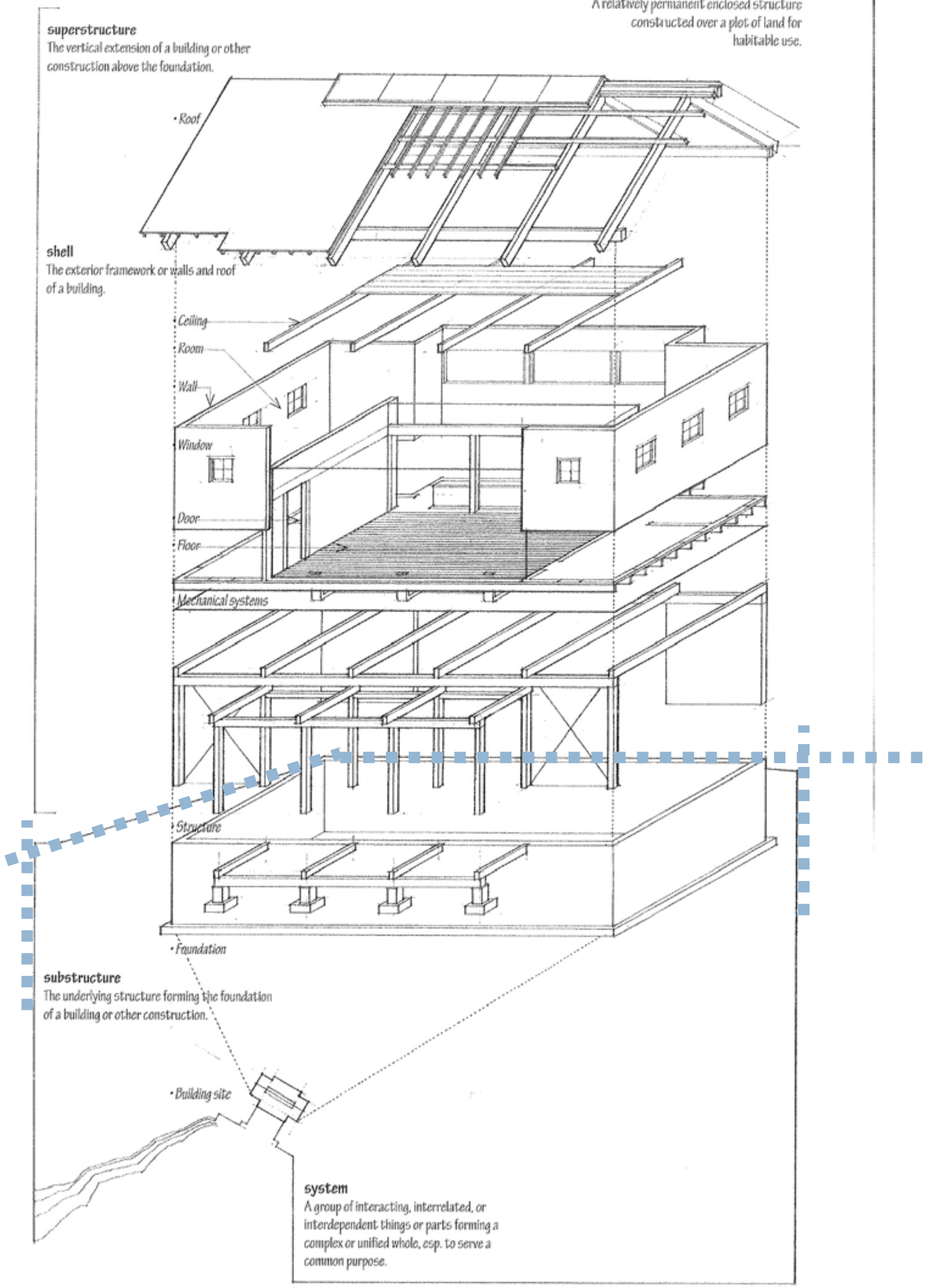


Photo by Ricardo Gomez Angel on Unsplash

SUPERSTRUCTURE

Above the foundation

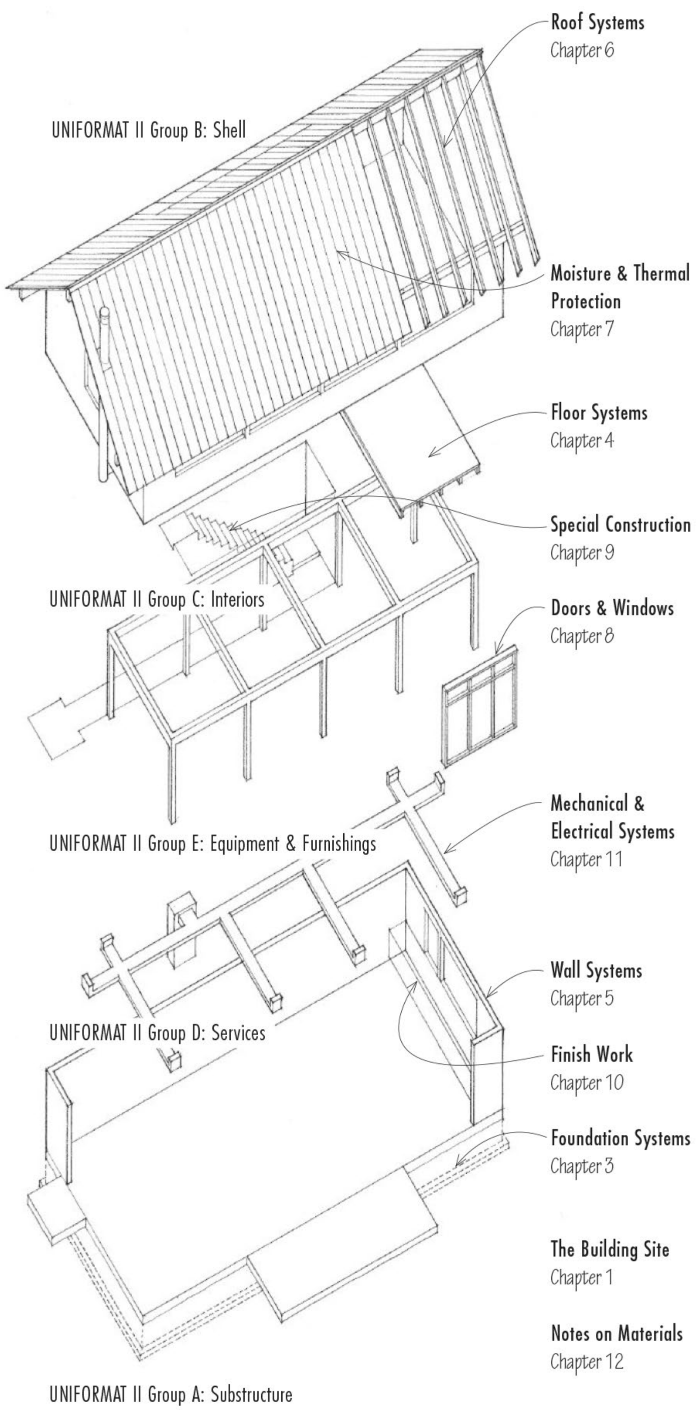


SUBSTRUCTURE

Ching, F. D. (2011). *A visual dictionary of architecture*. John Wiley & Sons.

Building systems

- Structural system
- Enclosure system
- Mechanical system



Ching, F. D. (2020). *Building construction illustrated*, John Wiley & Sons.

Building systems: Structural system

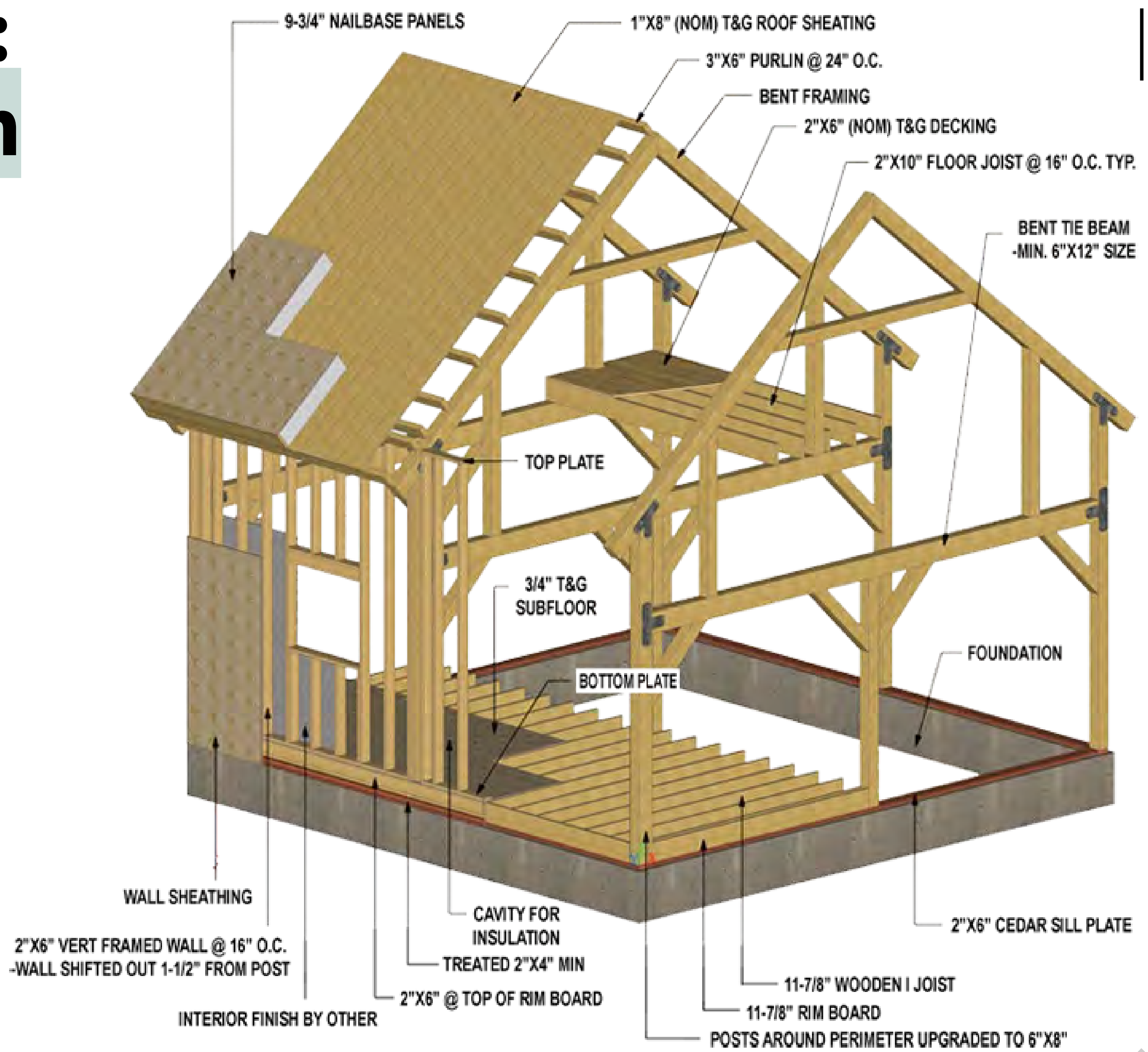
The structural system is designed and constructed to: **support and transmit applied gravity and lateral loads safely to the ground**. Without exceeding the allowable stresses in its members.

Elements of structural system:

- The superstructure (vertical extension of a building above the foundation)
- Columns, beams and load bearing walls, supporting floor and roof structure
- The substructure

Building systems: Structural system

Structural + envelope systems



[You'll Want To Live In A Barn After Seeing These Barn Homes! | Home Design, Garden & Architecture Blog Magazine (goodshomedesign.com)]

Building systems: Structural system

Timber Frame Kits CT, MA, RI, Shipped & Raised Nationwide: The Barn Yard & Great Country Garages (thebarnyardstore.com)

Building systems: Enclosure system

The enclosure system is the shell or envelope of a building. It consists of:

- Roof
- Exterior walls
- Windows
- Doors

Building systems: Enclosure system

Case Studies

HelioTrace Façade System

SOM, Permasteelisa, and Adaptive Building Initiative, a co-venture between Buro Happold and Hoberman and Associates.

- **Integration**
  - *Kinetic shades*
  - *Building enclosure*
  - *Internal mechanicals*
- ***Shading***
  - *Opaque panels from the mullions*
  - *50% perforated panels parallel to the envelope*
  - *Effective shading: 78%*
  - *Annual solar gain reduction: 81%*

Source: Hoberman

Building systems: Enclosure system

Case Studies

building: **Kiefer Technic Showroom**
architect: **Ernst Giselbrecht + Partner**
location: **Steiermark**

- **Dynamic Facade**
  - *Automated control of folding panels*
  - *Manual override by occupants*

Source: Ernst Giselbrecht + Partner

Building systems: Mechanical system

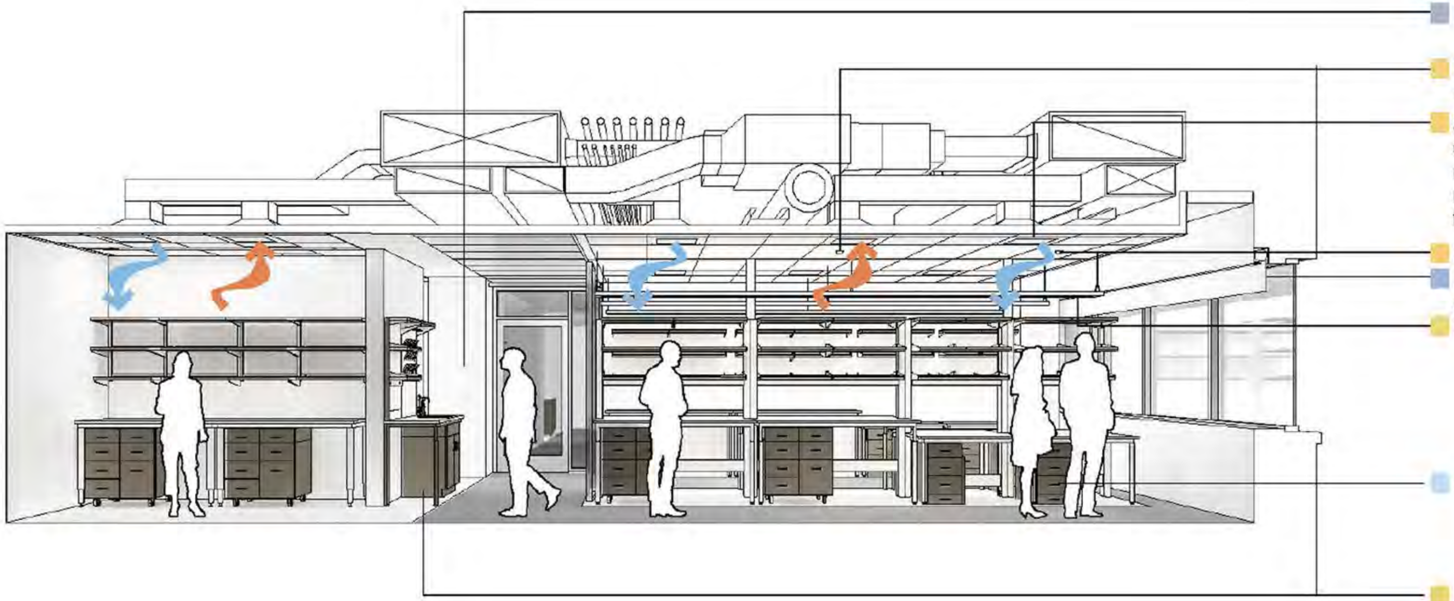
The mechanical system provides important services to a building. It consists of:

- The water supply system
- Sewage disposal system
- Heating, ventilating and air conditioning systems
- Electric system
- Vertical transportation system
- Fire-fighting system

Building systems: Mechanical system

WEILL CORNELL MEDICAL COLLEGE MRB
ennead architects LLP

The building's high performance envelope and careful lighting design reduce conditioning loads, which are then met with an efficient mechanical system design. The mechanical systems, including variable speed drives on the chillers, AHU fans, and pumps, air-side heat recovery, water-side economizer and premium efficiency motors on chilled water and hot water pumps, reduce the energy required to remove the large heat loads and condition the building.



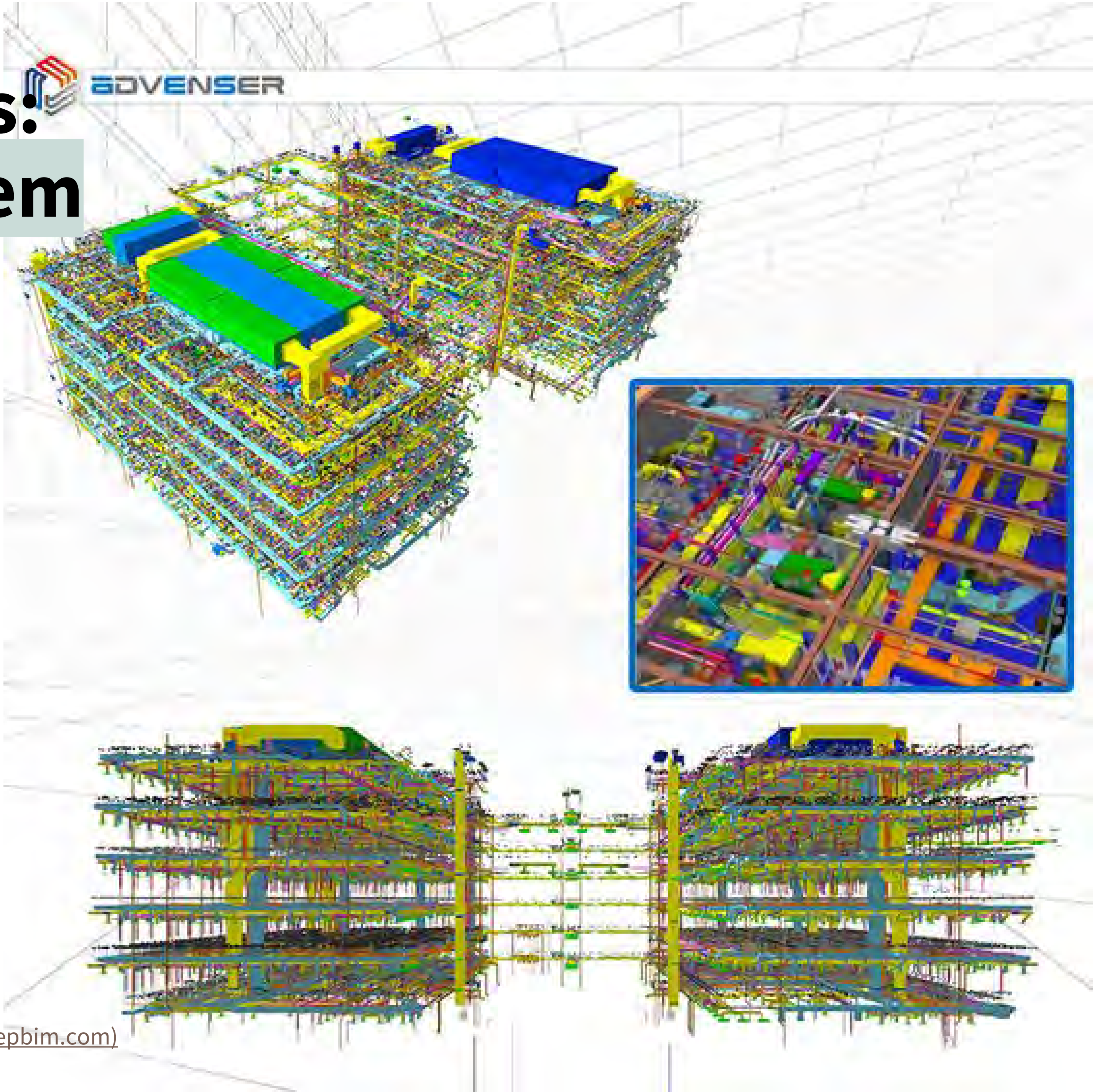
MECHANICAL SYSTEMS

MECHANICAL SYSTEMS ENERGY SAVINGS
-MRB reduces annual energy use 21% below ASHRAE 90.1-2004

VERIFICATION
-Measurement and verification of all HVAC and lighting systems
-Post-occupancy thermal comfort survey

SUSTAINABLE SITES
WATER EFFICIENCY
ENERGY / ATMOSPHERE
MATERIALS / RESOURCES
INDOOR ENVIRONMENTAL QUALITY
INNOVATION & DESIGN PROCESS

Building systems:
Mechanical system



MEP Building Information Modeling (BIM) Services (mepbim.com)

Basic structural elements

1. **Hangers, suspension cables-** axially loaded members in tension
2. **Columns**- axially loaded members in compression
3. **Beams**- members carrying bending moment and shear
4. **Planar Trusses-** all members axially loaded
5. **Arches**- curved members stressed mainly in direct compression
6. **Cables**- flexible members stressed in tension
7. **Rigid frames-** members stressed by moment and axial load
8. **Plates or slabs-** load carried by bending
9. **Thin shells** (curved surface elements)- stresses acting primarily in plane of element

Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

Basic structural elements

Columns- axially loaded members in compression

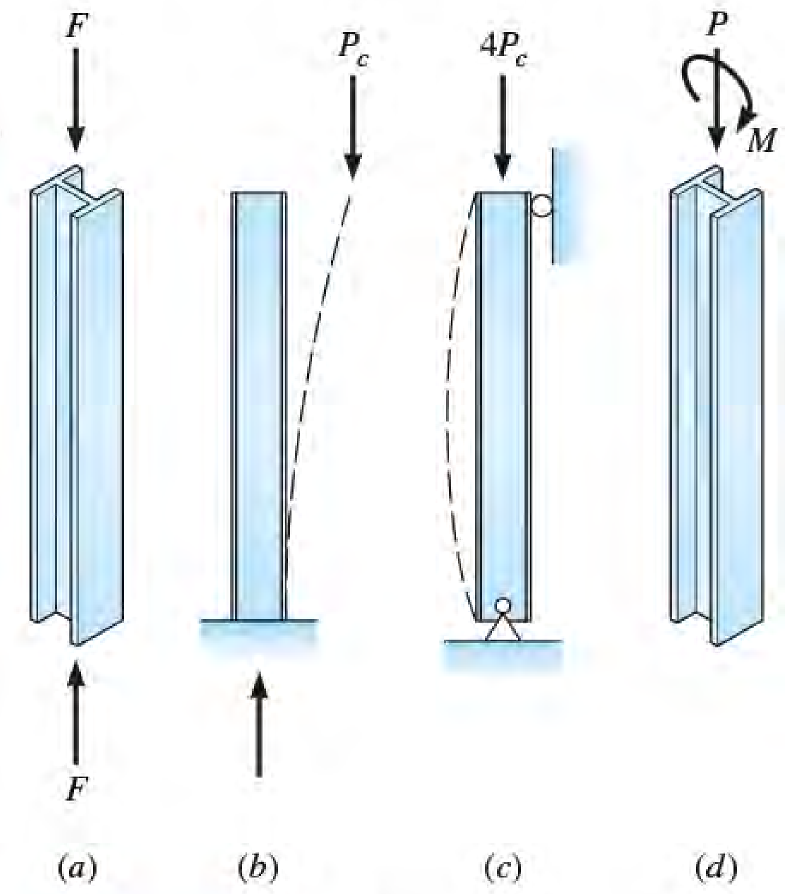


Figure 1.6: (*a*) Axially loaded column; (*b*) cantilever column with buckling load P_c; (*c*) pin-supported column with buckling load $4P_c$; (*d*) beam-column.

Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

Basic structural elements

Beams- members carrying bending moment and shear

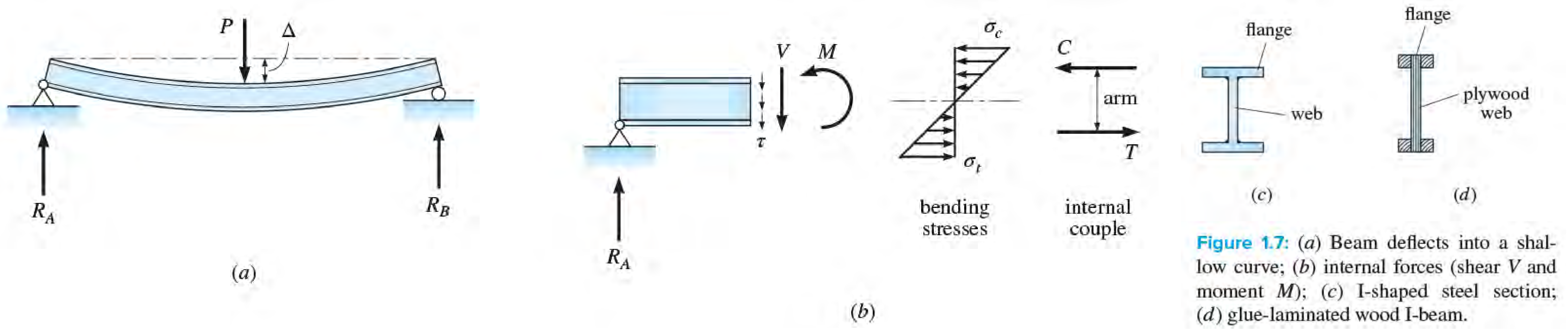
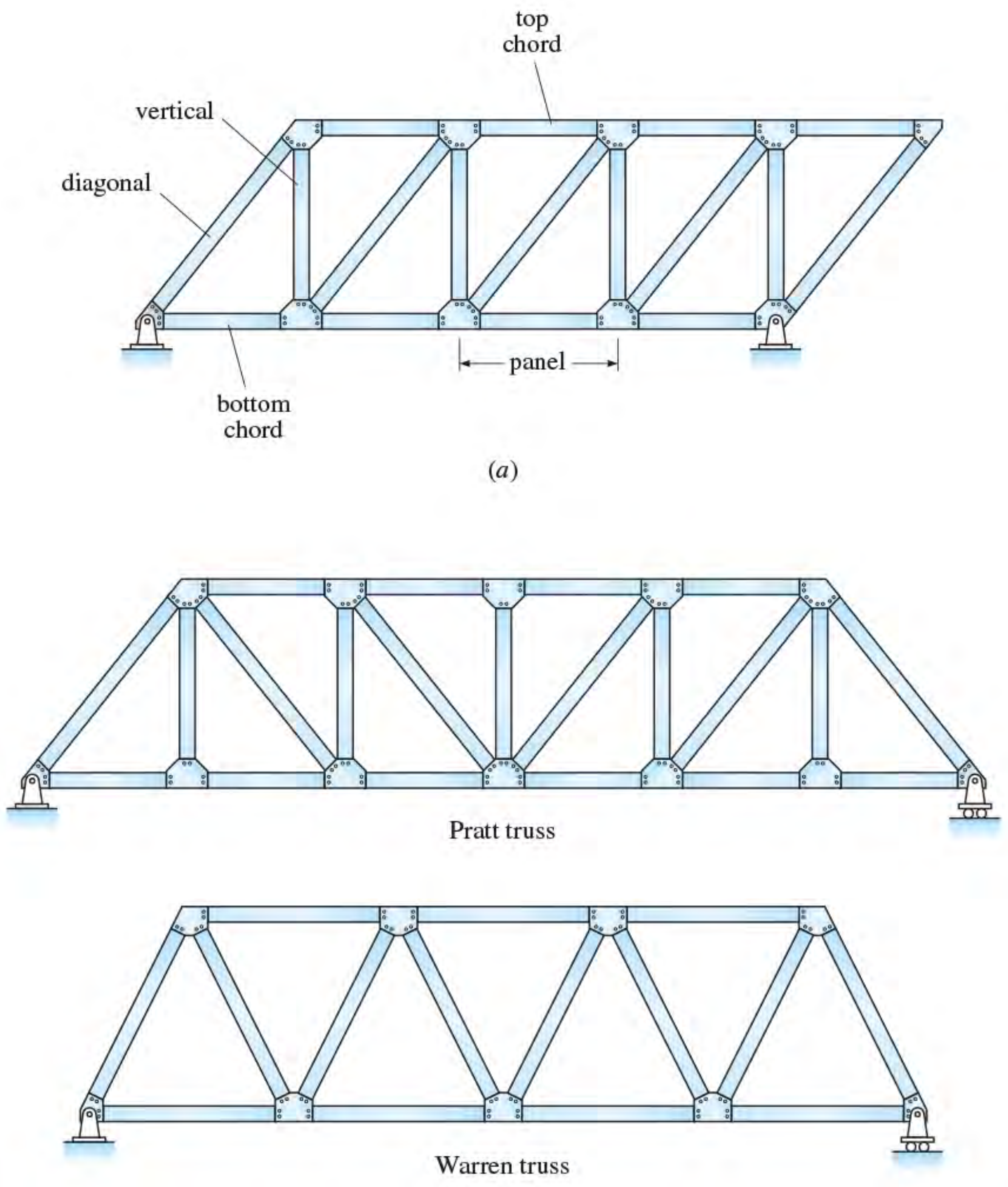


Figure 1.7: (*a*) Beam deflects into a shallow curve; (*b*) internal forces (shear *V* and moment *M*); (*c*) I-shaped steel section; (*d*) glue-laminated wood I-beam.

Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

Basic structural elements

Planar Trusses- all members axially loaded



(a)

Pratt truss

Warren truss

(b)

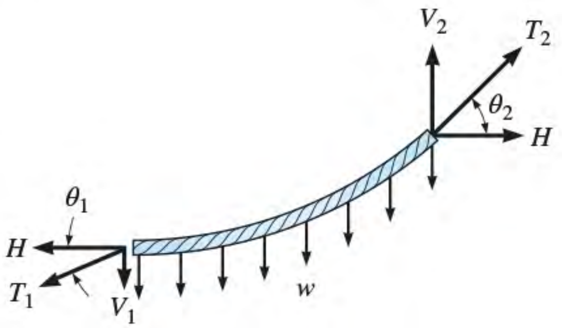
Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

(a)

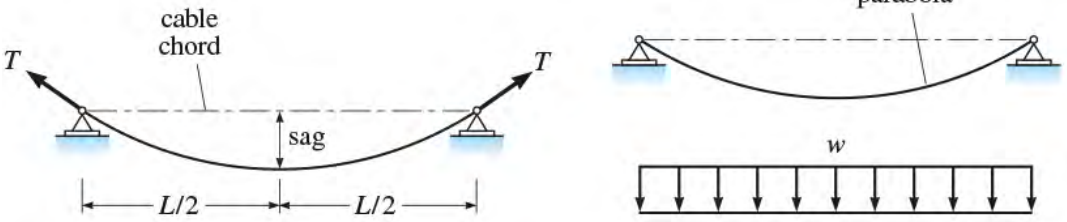
Basic structural elements

Cables- flexible members stressed in tension

(b)



(c)



(a) (b)

Figure 1.11: (*a*) Cable in the shape of a catenary under dead load; (*b*) parabolic cable produced by a uniform load; (*c*) free-body diagram of a section of cable carrying a uniform vertical load; equilibrium in horizontal direction shows that the horizontal component of cable tension H is constant.

Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

Basic structural elements

Plates or slabs- load carried by bending

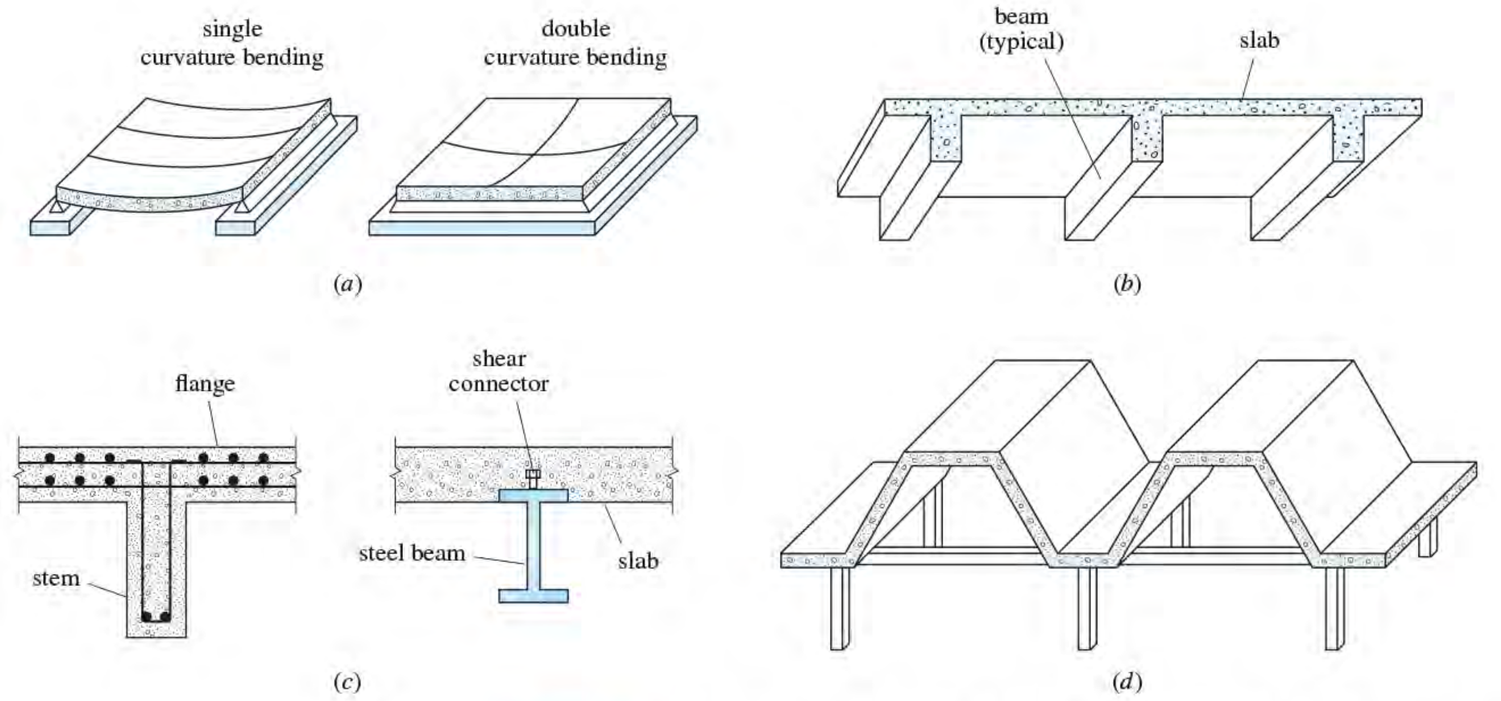
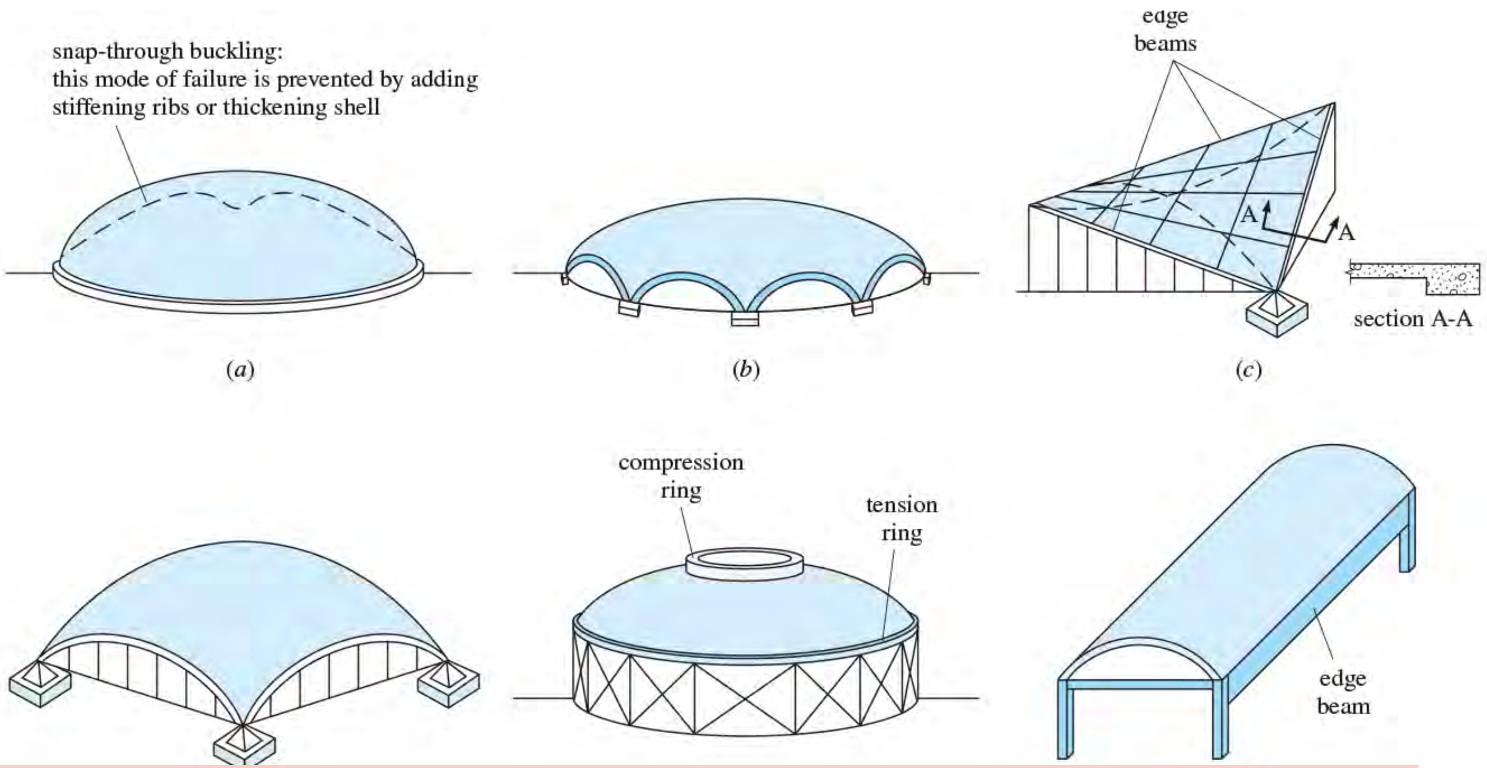


Figure 1.15: (*a*) Influence of boundaries on curvature; (*b*) beam and slab system; (*c*) slab and beams act as a unit: on left, concrete slab cast with stem to form a T-beam; right, shear connector joins concrete slab to steel beam, producing a composite beam; (*d*) a folded

Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

Basic structural elements

Thin shells (curved surface elements)- stresses acting primarily in plane of element



Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

Part 3:
Types of loads

Photo by Ricardo Gomez Angel on Unsplash

Types of loads

VERTICAL LOADS

DEAD LOADS
LIVE LOADS

LATERAL LOADS

WIND, SEISMIC AND LATERAL EARTH PRESSURES

Building's vertical loading

Building's vertical loading is based on:

1. Its intended use
2. Number of occupants
3. Type of construction

→ Dead and live loads.

Dead loads depend on material used to construct the building
Live loads are based on the anticipated occupants using the building
Loads are often applied in **combination** based on their likelihood of occurring simultaneously.

Pilla, D. R. (2017). *Elementary Structural Analysis and Design of Buildings: A Guide for Practicing Engineers and Students*, CRC Press.

Vertical load:
Warehouse vs residential project

Higher floor load (weights of contents)
→ higher dead loads.

More occupants → higher live loads

Vertical load:
Dead loads

Dead load is the self-weight of the building that is composed of all construction materials that form the building.

The **structural system** must be able to support:

its **self-weight** (dead loads) + **other possible loads** building might experience

Vertical load:
Live loads

Live loads are the maximum loads imposed by the occupants using the building.

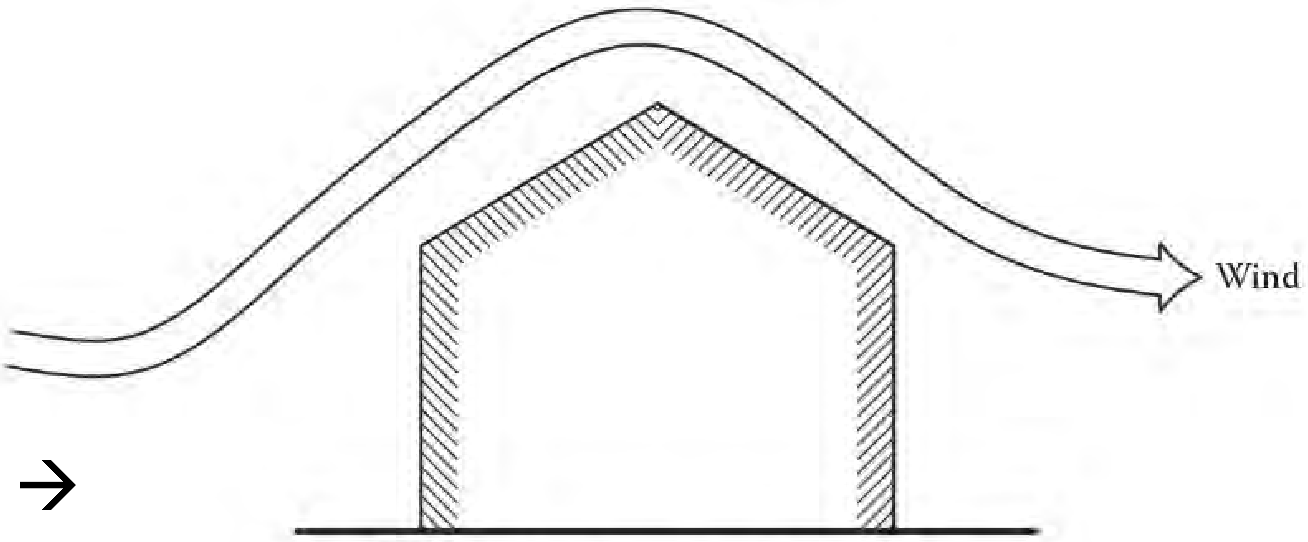
Components of buildings (roof, walls and floors) are to be designed to sustain:
Uniformly distributed live loads and **concentrated live loads**.

Building codes help building practitioners with the regulations.

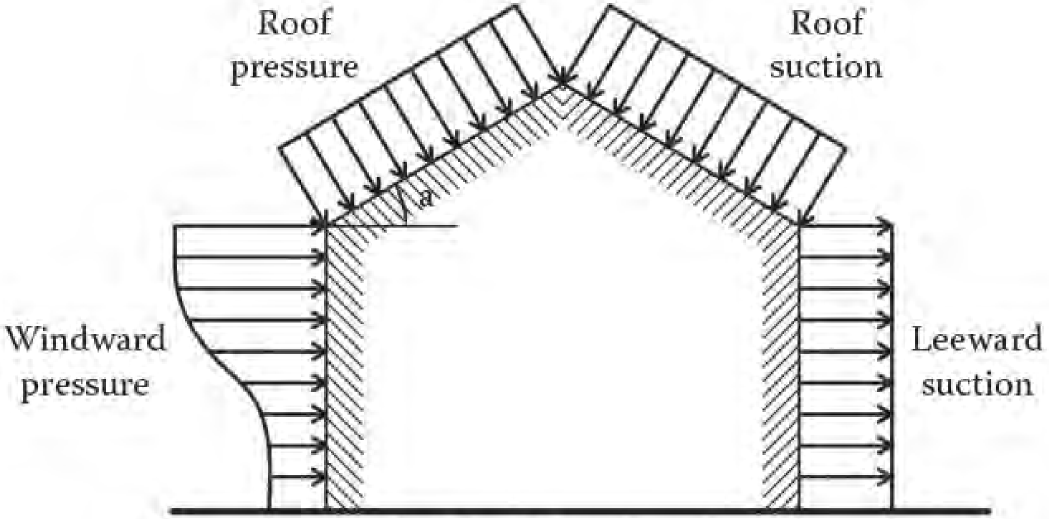
Lateral load

Building’s location will dramatically affect its loading → affect structural system.

<u>Seismic loading</u>
<u>Wind forces</u>
<u>Lateral soil pressures</u>



Wind rushing at and over the structure



Applied loads based on direction

Pilla, D. R. (2017). *Elementary Structural Analysis and Design of Buildings: A Guide for Practicing Engineers and Students*, CRC Press.

Lateral load

Buildings are design to respond lateral loads that are exerted on them, by generating resistance. A **building's lateral structural system** is specifically designed to **meet requirements of minimum design loads** as prescribed by the governing building code.

ACTIVITY 1

1. CHOOSE OF THE THREE AVAILABLE SECTIONAL PERSPECTIVE DRAWINGS. 5 MINS
2. INDIVIDUAL BRAINSTORMING SESSION: 30 MINS
   - IDENTITY MAIN STRUCTURAL COMPONENTS
   - IDENTIFY DIFFERENT TYPES OF LOADS ON BUILDING THE ARCHITECT NEED TO CONSIDER
   - HOW DO WE CONSIDER THEM? SKETCH ON THE DRAWING

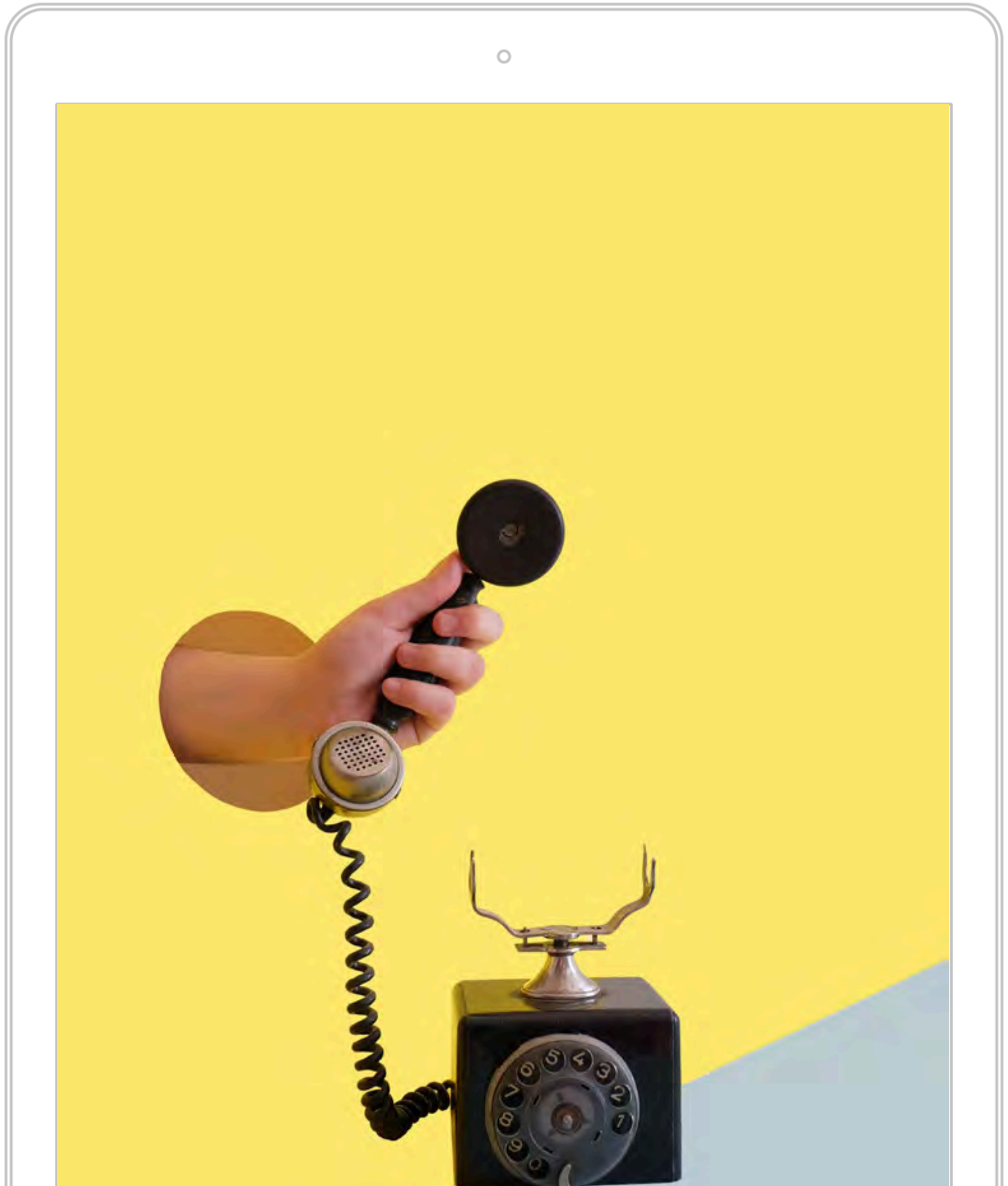
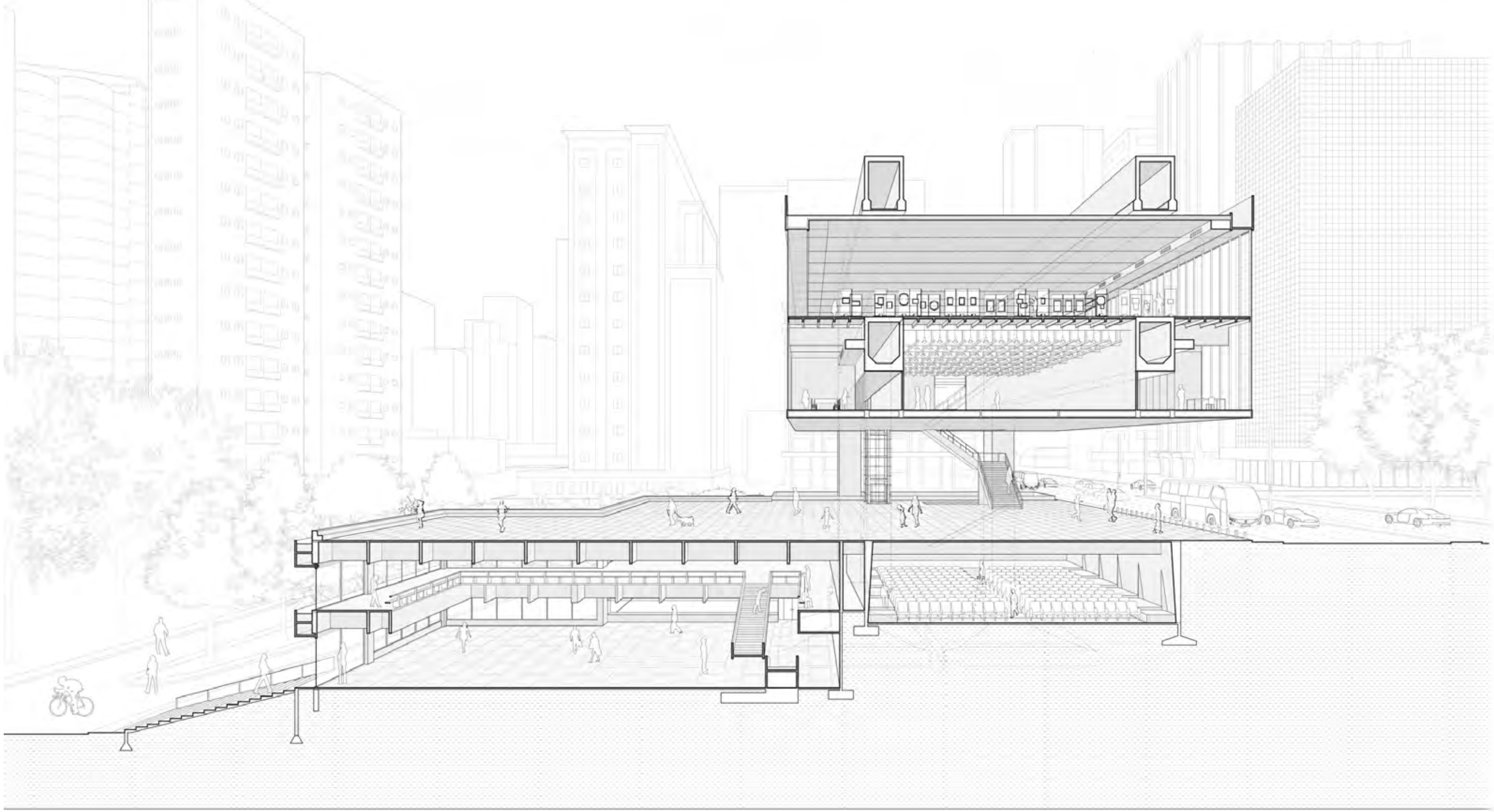


Photo by Elena Koycheva on Unsplash

Lewis, P., Tsutumaki, M. & Lewis, D. J. (2016). *Manual of section*, Chronicle Books.



São Paolo Museum of Art | São Paolo, Brazil

Lina Bo Bardi | 1968

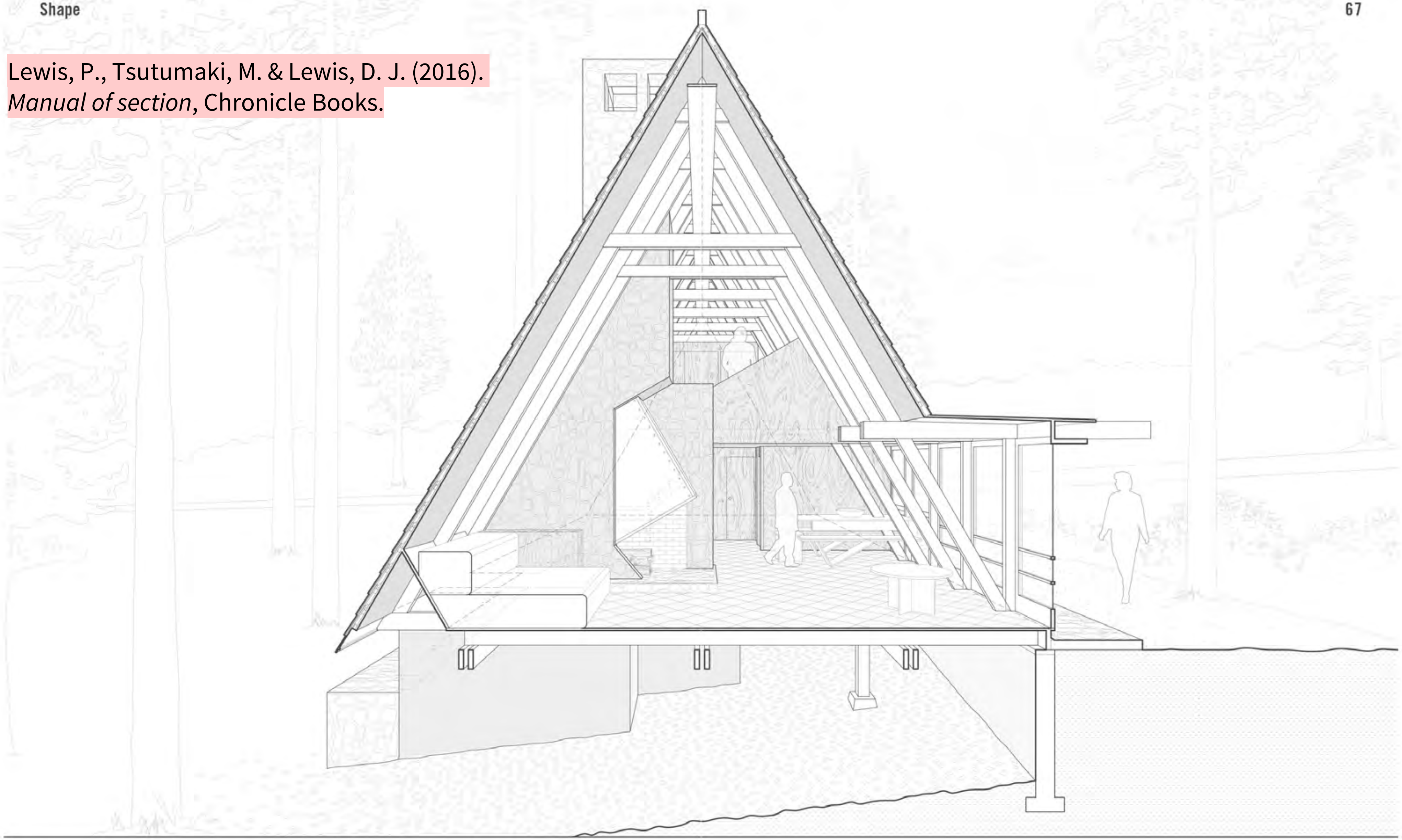
This cultural center comprises three stacked volumetric parts: the first suspended 26 ft 3 in (8 m) in the air, the second submerged below grade, and the third located in between—an exterior belvedere at street level. Two pairs of hollow prestressed 8-ft-2-in–by–11-ft-6-in (2.5 by 3.5 m) concrete frames span the 243-ft (74.1 m) length of the upper volume, suspending two floors. The lower floor contains offices, a library, and a central exhibition space, with circulation corridors located immediately below the concrete beam. On the upper level, the concrete beams are external, producing an unimpeded exhibition hall enclosed by a curtain wall on all four sides. An external stair and elevator link the suspended volume and the plaza with the below-grade civic hall, auditoriums, theater, library, restaurant, and service spaces. Exploiting the topography of its urban site, this stacked complex is paradoxically both subterranean and floating, camouflaged and monumental, compressed and expansive.

Lewis, P., Tsutumaki, M. & Lewis, D. J. (2016). *Manual of section*, Chronicle Books.

Palace of Labor | Turin, Italy — Pier Luigi Nervi | 1961

Covering 269,098 sq ft (25,000 sq m), this enormous exhibition hall and training center was designed in part as a response to the expedited construction sequence of a competition. Built in eleven months, the roof was conceived as sixteen individual 82-ft-tall (25 m) mushroomlike forms, each consisting of a 65-ft-7-in (20 m) cast-in-place reinforced-concrete column topped with a 131-ft-3-in (40 m) square steel roof assembly. The accumulation of these units, built one by one, allowed interiors and the glass enclosure to be constructed prior to the completion of the entire roof. The large concrete columns taper from a 16-ft-5-in-wide (5 m) cruciform, to a 8-ft-2-in-diameter (2.5 m) circle, to which are anchored twenty radiating steel-beam spokes that support the roof. Continuous glass strips run between the structures, allowing natural light into the space and registering the autonomy of each massive structural unit. A row of external steel ribs spans between a perimeter mezzanine and the roof to stiffen the enclosing glass curtain. The height and scale of this section exceeds conventions and transforms this extruded section into a grand civic space and spectacle.

Lewis, P., Tsutumaki, M. & Lewis, D. J. (2016). *Manual of section*, Chronicle Books.



Bennati Cabin | Lake Arrowhead, California, USA — Rudolph Schindler | 1937

An early example of the A-frame vacation home, this two-bedroom cabin is structured by fourteen equilateral, triangular wood frames, 24 ft (7.3 m) on each side, placed 4 ft (1.2 m) apart. Rather than being positioned above rectilinear walls as in a typical wood-framed house, here the roof reaches down to the bottom of the enclosure. The common spaces of the cabin are on the wider lower level, and two bedrooms with bunks are on the narrower upper level. Pairs of 2-by-8-in (5.1 by 20.3 cm) horizontal beams attached to each 3-by-6-in (7.6 by 15.2 cm) roof rafter support the floors and resist the outward thrust of the roof. Vertical windows, which extend the interior space horizontally, and custom furniture integrated with the acute triangular frame enable the lower corners to be inhabited. The wood building anchors to a stone base that negotiates the topography and extends vertically through the house as the fireplace chimney. A staircase clad in plywood aligns with the chimney. In addition to providing an efficient shape for a wood structure, the section defines the organization of the house and fulfills the mandates of local aesthetic building ordinances, which require Alpine themes.

Part 4:
Structural considerations

Photo by Ricardo Gomez Angel on Unsplash

1. Aims
2. The importance
3. Using rules of thumb
4. How do they impact out design process?

4.1- Aims and Rationale

When designing a structure, we must account for its safety, aesthetics and serviceability. Also we need to take into consideration economic and environmental constraints.

Preliminary design needs to be analysed to ensure that it has its required **stiffness** and **strength**.

Hibbeler, R. C. & Kiang, T. (2015). *Structural analysis*, Pearson Prentice Hall Upper Saddle River.

4.2- The importance as an architect to gain basic understanding

Relationship between structural analysis and design phases

1	CONCEPTUAL DESIGN	Designer begins by considering all possible layouts and structural system which might satisfy requirements of project. Architects and engineers consult as a team to establish layouts with **efficient structural system** and meeting architectural requirements of the project.
2	PRELIMINARY DESIGN	Engineers chose from the conceptual design and **sizes their main components.** The preliminary **proportioning of structural membe**r requires understanding of: structural behaviour and a loading condition knowledge.
3	ANALYSIS OF PRELIMINARY DESIGNS	Using estimated values of load, the engineer carries out an analysis of **several structural systems**.

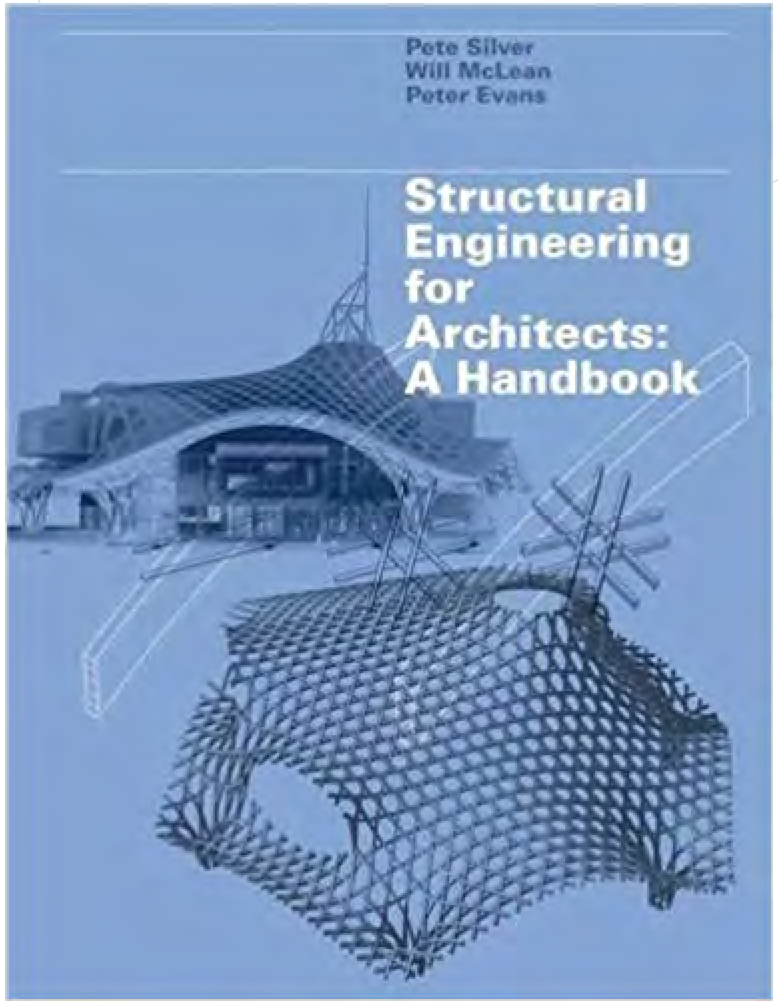
Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

4.2- The importance as an architect to gain basic understanding

4	REDESIGN OF THE STRUCTURES	From the result of preliminary designs, (structural) designers **recomputes the proportions** of the main elements of all structures.
5	EVALUATION OF PRELIMINARY DESIGNS	The design is compared with regard to **cost, availability of materials, appearance, maintenance, time for construction** and other important considerations. The structure best satisfying **client's criteria** is selected for further refinement in the final design phase.
6	FINAL DESIGN AND ANALYSIS PHASES	The engineer makes minor adjustments to the selected structure to improve: **economy** and **appearance**. **Strength** and **stiffness** of the structure are evaluated for all significant loads and combination of loads. Final design will also reveal certain deficiencies, the designer will have to adjust. Members are sized with regards to design codes, and also taking into account each material's special properties.

Leet, K., Uang, C.-M. & Gilbert, A. M. (2008). *Fundamentals of structural analysis*, McGraw-Hill.

4.3- Rules of thumbs



McLean, W., Silver, P. & Evans, P. (2013). *Structural engineering for architects: a handbook*, Laurence King.

Allen, E. & Iano, J. (2017). *The architect's studio companion: Rules of thumb for preliminary design*, John Wiley & Sons.

CONTENTS

- COVER
- THE ARCHITECT'S STUDIO COMPANION
- COPYRIGHT
- ACKNOWLEDGMENTS
- HOW TO USE THIS BOOK
- SECTION 1 DESIGNING WITH BUILDING CODES
  - 1 DESIGNING WITH BUILDING CODES
    - BUILDING CODES AND ZONING ORDINANCES
    - OCCUPANCIES: INTERNATIONAL BUILDING CODE
    - OCCUPANCIES: NATIONAL BUILDING CODE OF CANADA
- SECTION 2 DESIGNING THE STRUCTURE
  - 1 SELECTING THE STRUCTURAL SYSTEM
    - BUILDING CODE CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS
    - DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS
    - DESIGN CRITERIA: SUMMARY CHART
    - PRACTICAL SPAN RANGES FOR STRUCTURAL SYSTEMS
    - LIVE LOAD RANGES FOR BUILDING OCCUPANCIES
    - LIVE LOAD RANGES FOR STRUCTURAL SYSTEMS
    - SOME TYPICAL CHOICES OF STRUCTURAL SYSTEMS FOR DIFFERENT BUILDING TYPES
  - 2 CONFIGURING THE STRUCTURAL SYSTEM
    - LATERAL STABILITY AND STRUCTURAL SYSTEMS
    - WALL AND SLAB SYSTEMS
    - COLUMN AND BEAM SYSTEMS
    - TALL BUILDING STRUCTURES
    - TALL BUILDING STRUCTURES
  - 3 SIZING THE STRUCTURAL SYSTEM
    - WOOD STRUCTURAL SYSTEMS
    - WOOD STUD WALLS
    - WOOD FLOOR JOISTS
    - WOOD ROOF RAFTERS
    - WOOD FLOOR AND ROOF TRUSSES—LIGHT
    - WOOD COLUMNS
    - WOOD DECKING
    - WOOD BEAMS
    - GLUE-LAMINATED WOOD BEAMS
    - CROSS-LAMINATED TIMBER
    - WOOD TRUSSES—HEAVY
    - GLUE-LAMINATED WOOD ARCHES
    - MASONRY STRUCTURAL SYSTEMS
    - BRICK MASONRY COLUMNS
    - BRICK MASONRY WALLS
    - BRICK MASONRY LINTELS
    - BRICK MASONRY ARCHES
    - CONCRETE MASONRY COLUMNS
    - CONCRETE MASONRY WALLS
    - CONCRETE MASONRY LINTELS
    - STEEL STRUCTURAL SYSTEMS
    - LIGHTWEIGHT STEEL WALL STUDS
    - LIGHTWEIGHT STEEL FLOOR JOISTS
    - STRUCTURAL STEEL COLUMNS
    - STRUCTURAL HOLLOW STEEL COLUMNS
    - STEEL FLOOR AND ROOF DECKING
    - STRUCTURAL STEEL BEAMS AND GIRDERS
    - OPEN-WEB STEEL JOISTS
    - SINGLE-STORY RIGID STEEL FRAMES
    - STRUCTURAL STEEL TRUSSES
    - SITECAST CONCRETE STRUCTURAL SYSTEMS
    - SITECAST CONCRETE COLUMNS
    - SITECAST CONCRETE WALLS
    - SITECAST CONCRETE BEAMS AND GIRDERS
    - SITECAST CONCRETE ONE-WAY SOLID SLAB
    - SITECAST CONCRETE ONE-WAY JOISTS
    - SITECAST CONCRETE TWO-WAY FLAT PLATE
    - SITECAST CONCRETE TWO-WAY FLAT SLAB
    - SITECAST CONCRETE WAFFLE SLAB
    - PRECAST CONCRETE STRUCTURAL SYSTEMS
    - PRECAST CONCRETE COLUMNS
    - PRECAST CONCRETE WALL PANELS
    - PRECAST CONCRETE BEAMS AND GIRDERS
    - PRECAST CONCRETE SLABS
    - PRECAST CONCRETE SINGLE AND DOUBLE TEES

Allen, E. & Iano, J. (2017). *The architect's studio companion: Rules of thumb for preliminary design*, John Wiley & Sons.

4.3- Rules of thumbs

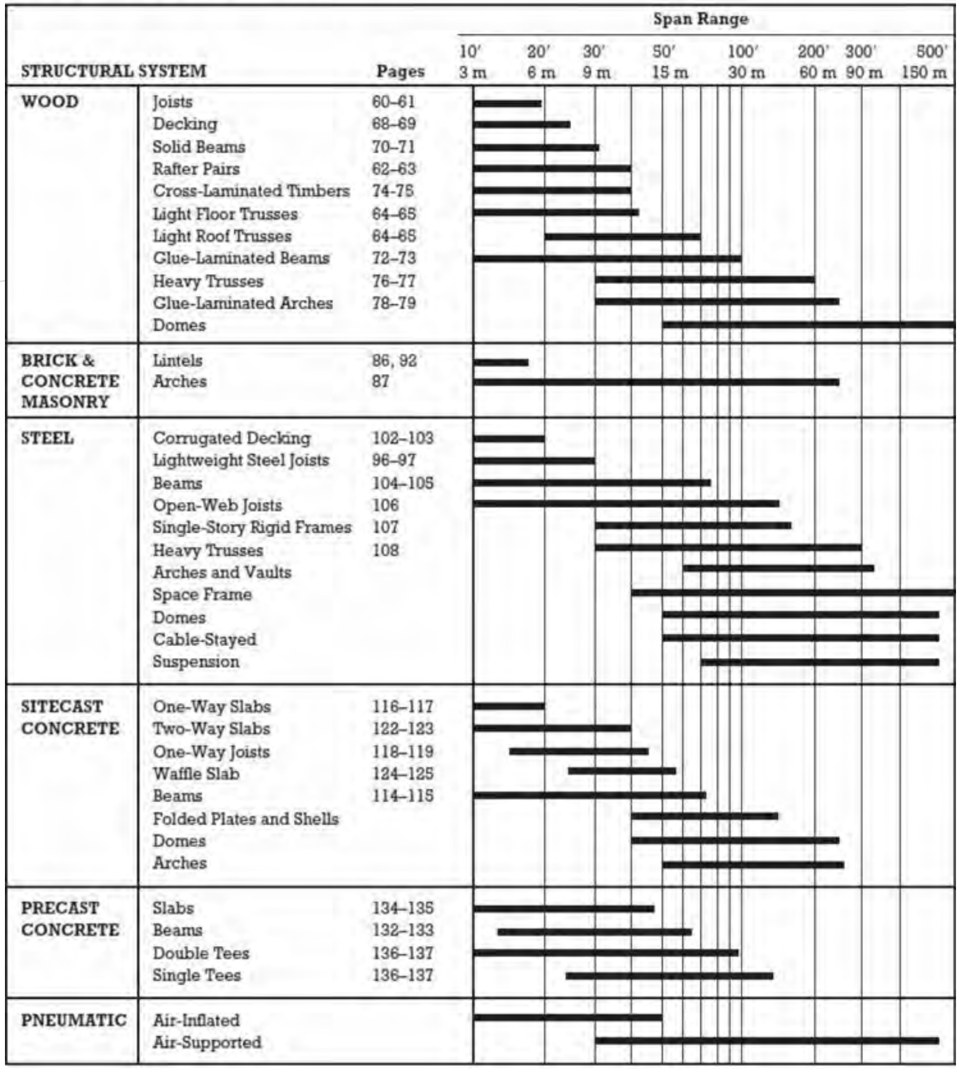
GIVE SPECIAL CONSIDERATION TO THE SYSTEM INDICATED IF YOU WISH TO:	WOOD AND MASONRY					STEEL				SITECAST CONCRETE										PRECAST CONCRETE			
	Pages 58–65	Pages 66–73	Pages 74–75	Pages 76–79	Pages 81–93	Pages 94–97	Pages 98–106	Page 107	Page 108	Pages 116–117	Pages 116–117	Pages 118–119	Pages 118–119	Pages 120–121	Pages 120–121	Pages 122–123	Pages 122–123	Pages 124–125	Pages 124–125	Pages 134–135	Pages 134–135	Pages 136–137	Pages 136–137
	Light Wood Frame	Heavy Timber Frame	Cross-Laminated Timber	Long-Span Wood Systems	Masonry Systems	Lightweight Steel Framing	Steel Frame	Single-Story Rigid Steel Frame	Trusses	One-Way Solid Slab	Posttensioned One-Way Solid Slab	One-Way Joist	Posttensioned One-Way Joist	Two-Way Flat Plate	Posttensioned Two-Way Flat Plate	Two-Way Flat Slab	Posttensioned Two-Way Flat Slab	Waffle Slab	Posttensioned Waffle Slab	Solid Slab	Hollow-Core Slab	Double Tee	Single Tee
Create highly irregular build form	●				●	●				●	●			●	●	●	●						
Expose the structure while retaining a high fire-resistance rating		●	●		●					●	●	●	●	●	●	●	●	●	●	●	●	●	●
Allow column placements that deviate from a regular grid							●							●	●	●	●						
Minimize floor thickness			●								●			●	●	●	●			●	●		
Minimize the area occupied by columns or bearing walls			●	●			●	●	●			●	●				●	●				●	●
Allow for changes in the building over time	●	●		●	●	●	●		●	●		●								●	●		
Permit construction under adverse weather conditions	●	●	●			●	●	●												●	●	●	●
Minimize site disturbance		●		●			●	●	●											●	●	●	●
Minimize off-site fabrication time	●				●	●				●	●	●	●	●	●	●	●	●	●				
Minimize on-site erection time		●	●				●	●	●											●	●	●	●
Minimize construction time for a one- or two-story building	●	●	●			●	●	●															
Minimize construction time for a 5- to 20-story building			●				●			●	●	●	●	●	●	●	●	●	●	●	●	●	●
Minimize construction time for a building 30 stories or more in height							●			●	●			●	●	●	●			●	●		
Avoid the need for diagonal bracing or shear walls							●	●		●	●	●	●	●	●	●	●	●	●				
Minimize the dead load on a foundation	●	●	●			●	●	●															
Minimize structural distress due to unstable foundation conditions	●	●	●				●													●	●	●	●
Minimize the number of separate trades needed to complete a building			●		●																		
Provide concealed spaces for ducts, pipes, etc.	●					●																	

Allen, E. & Iano, J. (2017). *The architect's studio companion: Rules of thumb for preliminary design*, John Wiley & Sons.

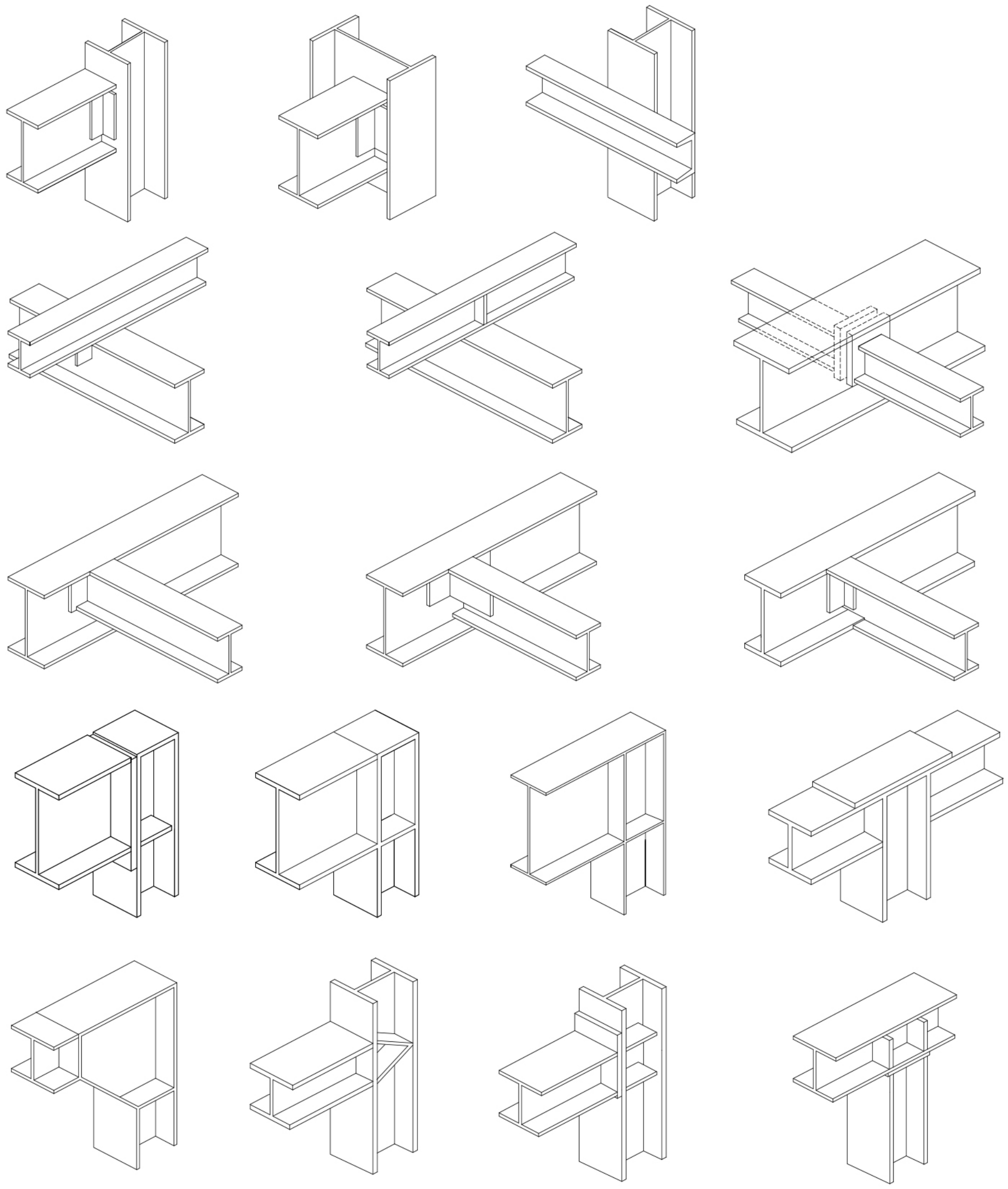
4.3- Rules of thumbs

PRACTICAL SPAN RANGES FOR STRUCTURAL SYSTEMS

This chart gives typical practical span ranges for various structural systems. Spans beyond the ranges indicated may be possible in unique circumstances. Page references are included where a system indicated is covered in greater detail elsewhere in this book.



Allen, E. & Iano, J. (2017). *The architect's studio companion: Rules of thumb for preliminary design*, John Wiley & Sons.



Previously in Week 4 (Steel Structure)..

Assembling and connecting steel loadbearing components

MEANS OF CONNECTIONS
COLUMNS
BEAMS
COLUMN BASE
BRACING
VIERENDEEL GIRDERS
LATTICE BEAMS

Reichel, A., Ackermann, P., Hentschel, A. & Hochberg, A. (2012). Building with steel. *Building with Steel.* Birkhäuser.

Rule of thumb: steel frame

- Span (centre-to-centre):
  - Floor beam- 12m max
  - Roof trusses- 17m max
  - Space frames- 60m max
- Governing factor → deflection limit, vibration limit
- Grouping and repetition
- Connection detail and design are important (bolted or welded, limit welding connection)
- Limited length to be transported
- Mixing metal materials (usually steel and aluminium) might lead to potential corrosion
- Determining beam depth: a reasonable estimate is 'span divided by 24 (L/24)'
- Maximum cantilever length equals to 1/3 length of the back-span

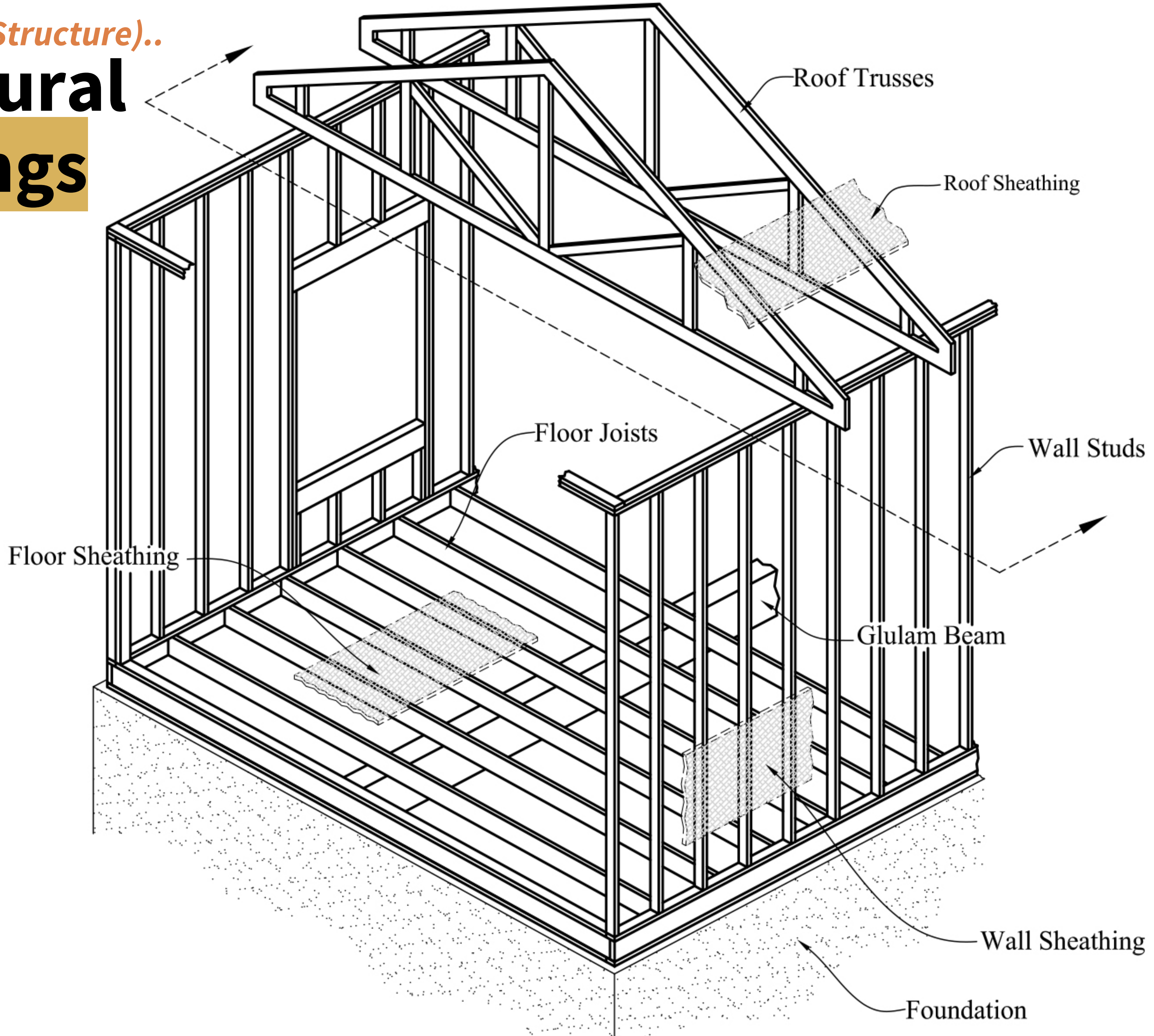
2000v02_rules_of_thumb.pdf (aisc.org) https://youtu.be/KWnBNf1INfs Craigs-article.pdf (mbjeng.com) catena consulting engineers | blog (catenaengineers.com)

Previously in Week 3 (Timber Structure)..

Typical structural timber buildings

Structural systems:

- Roof framing
- Floor framing
- Wall framing



Platform framing

Rule of thumb: timber construction

Properties of engineered timber products

Engineered timber products include Glue-laminated beams (glulam), Laminated Veneer Lumber (LVL), and Laminated Strand Lumber (LSL).

Each of these products is fabricated from layers of sawn timber, which are glued together to form the beam. This process increases the homogeneity of the final product as all the imperfections within sawn timber, such as knots, are distributed along the beam rather than being concentrated at particular positions. This in turn increases the strength of the element.

The fabrication process also reduces the tendency of the members to warp, twist, or bow.

Engineered timber products can be fabricated to a range of section sizes and lengths.

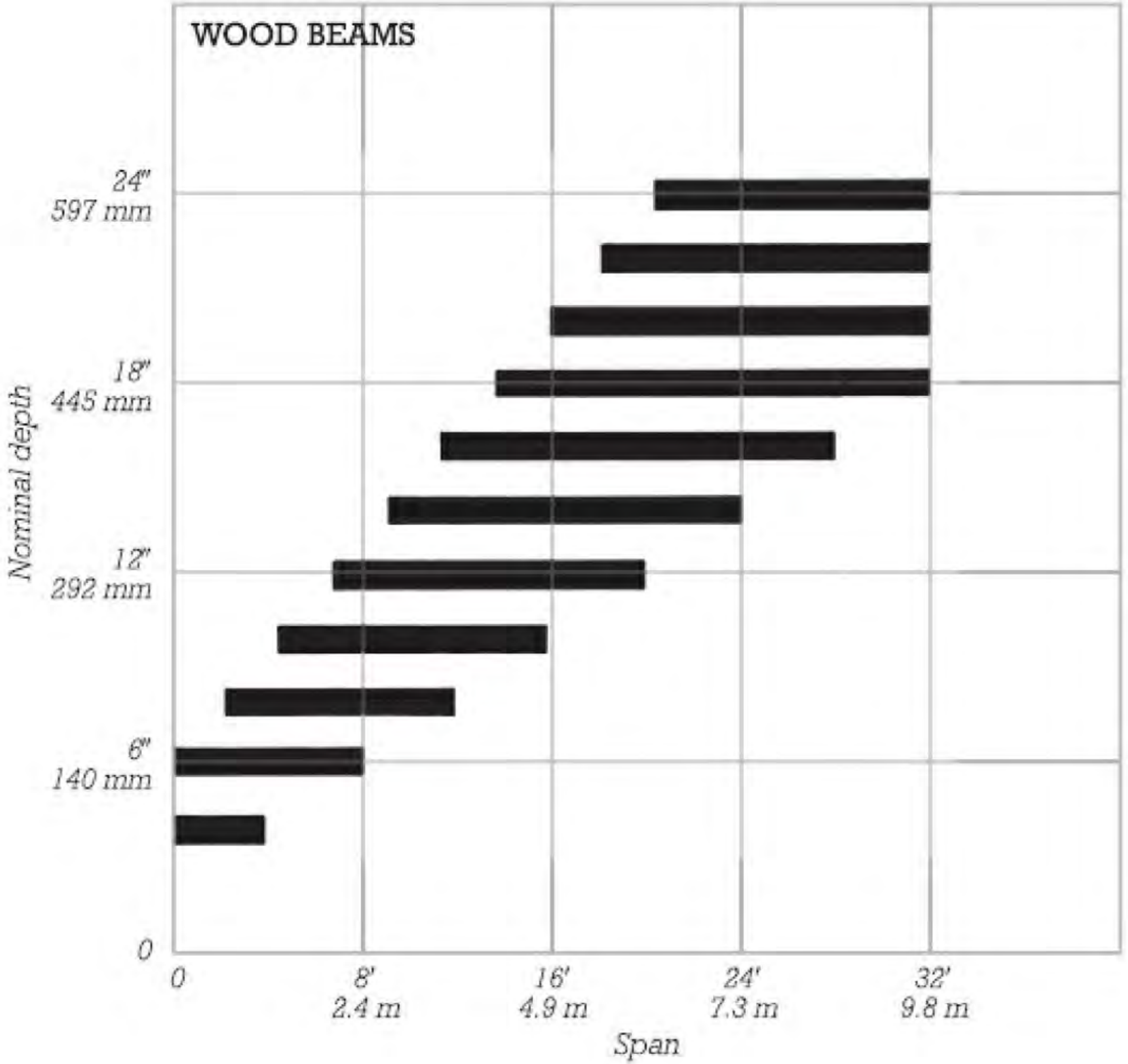
	Beam type	Comments	Typical span range	Typical span/depth ratio
	**Glulam beams**	**1** Typically used in lightweight timber roofs (often exposed) or light commercial structures **2** Can be fabricated to significantly longer lengths than standard sawn-timber joists **3** Strength subject to grade of timber used and number of laminations, and is advised by specific manufacturer	Roof beams 20–65ft for standard section sizes Can increase to 165ft with nonstandard sizes Floor beams 15–45ft for standard section sizes	20:1
	**Laminated Veneer Lumber (LVL) and Laminated Strand Lumber (LSL)**	**1** Can be used as simple beams similar to glulam **2** Typically used in residential, educational, or light commercial structures **3** Can be fabricated to significantly longer lengths than standard sawn-timber joist **4** Strength subject to grade of timber used and number of laminations, and is advised by specific manufacturer **5** Ranges and span-to-depth ratios similar to glulam.	Similar to glulam	20:1
	**Timber I-sections**	**1** Manufactured with either sawn-timber or LVL flanges and a plywood or Oriented Strand Board (OSB) web **2** Typically used in residential or light commercial structures **3** Can be fabricated to significantly longer lengths than standard sawn-timber joists **4** Strength subject to grade of timber used and number of laminations, and is advised by specific manufacturer **5** Ranges and span-to-depth ratios similar to sawn-timber beams	10–20ft	20:1 Subject to grade of timber, width, and spacing of joists

McLean, W., Silver, P. & Evans, P. (2013). *Structural engineering for architects: a handbook*, Laurence King.

Rule of thumb: timber construction

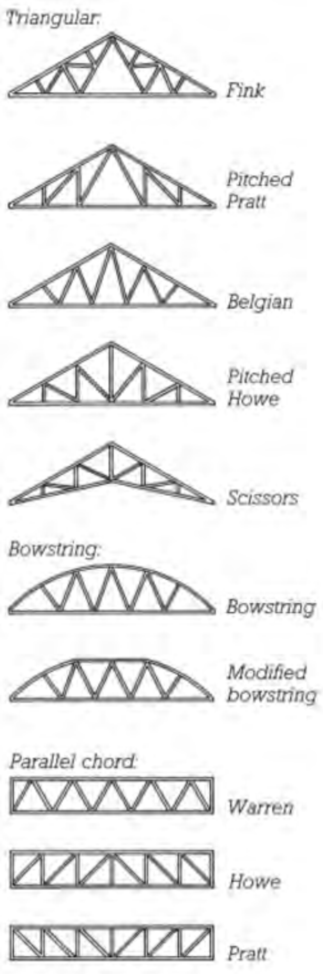
- 2 or 4 feet modular plan dimension will reduce waste (600 or 1200mm)
- Roof trusses space no greater than 1.2-2.4m without additional support
- Wall studs are commonly put spaced at 400-600mm on centre
- Decking 150-200mm
- Commonly available length of wood: 2.4m

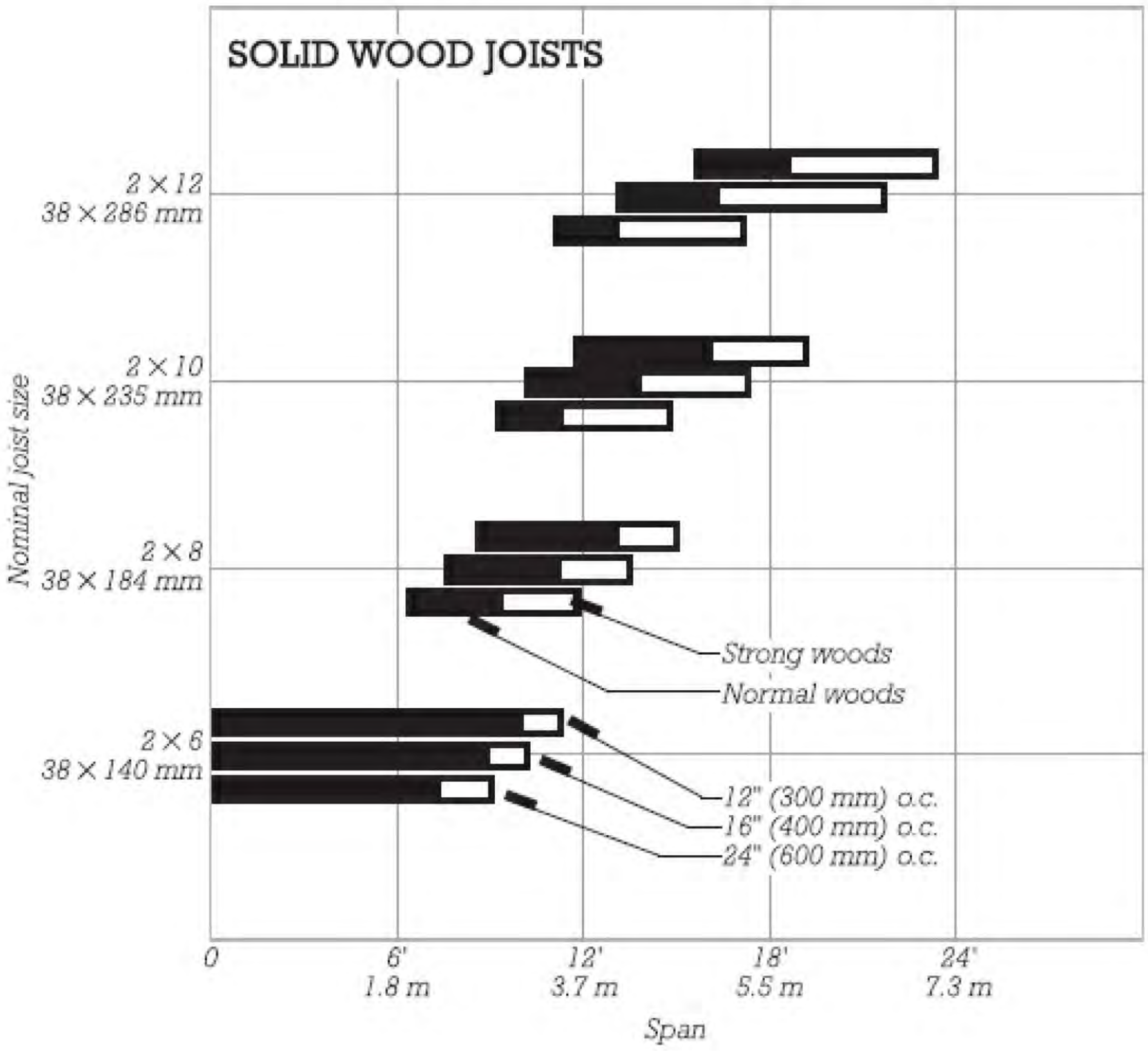
https://youtu.be/gAFS0A3xDJk



Allen, E. & Iano, J. (2017). *The architect's studio companion: Rules of thumb for preliminary design*, John Wiley & Sons.

Rule of thumb: timber construction

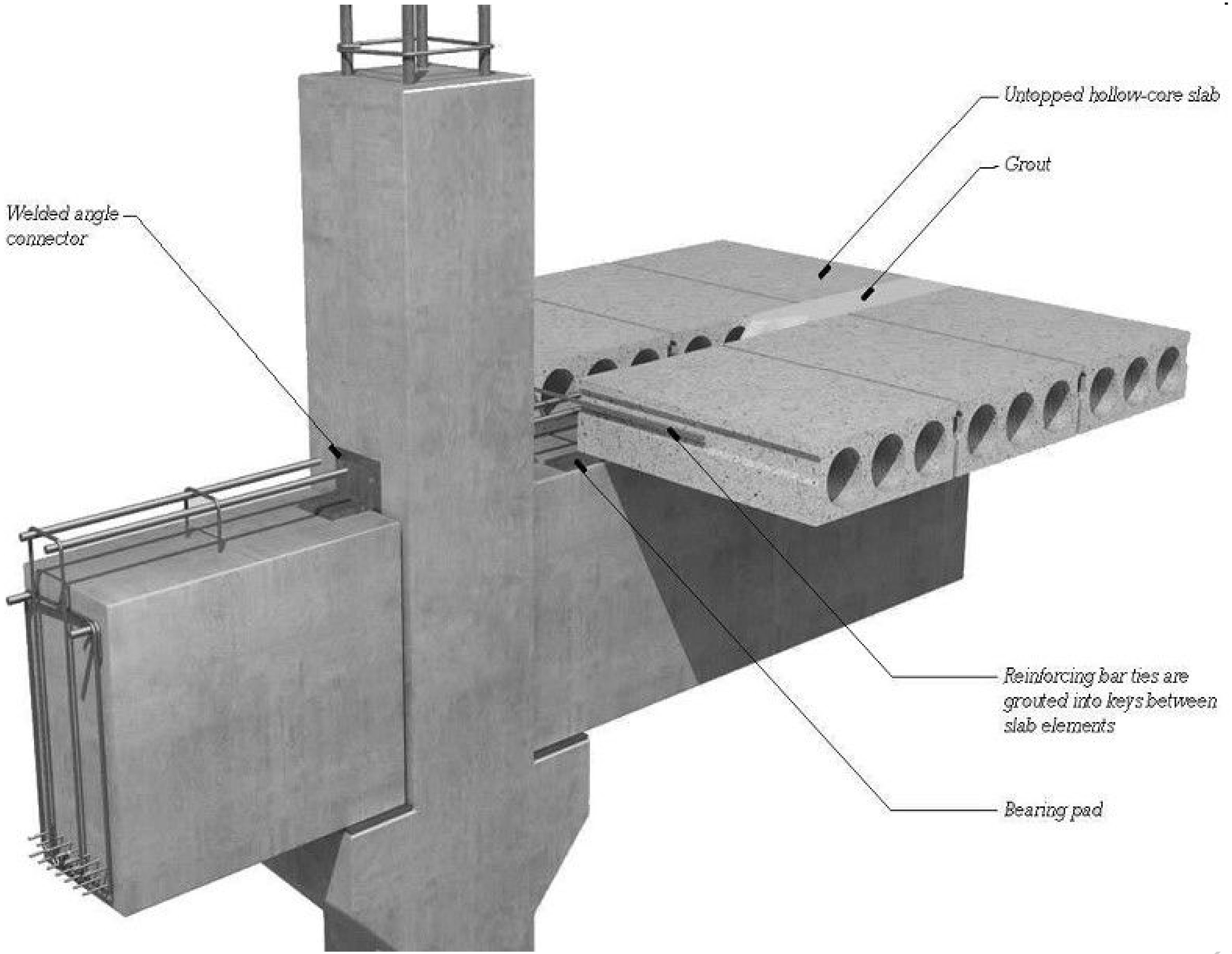




Allen, E. & Iano, J. (2017). *The architect's studio companion: Rules of thumb for preliminary design*, John Wiley & Sons.

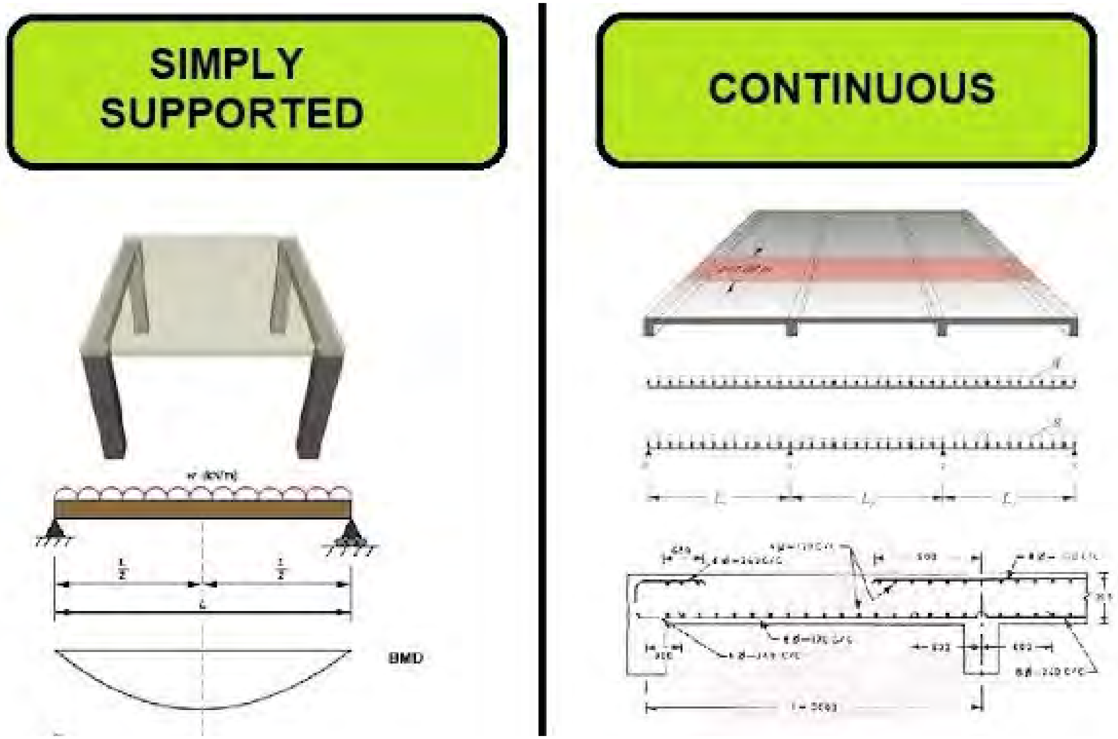
3- PRECAST CONCRETE Connection

- Bolting
- Welding
- Grouting



Rule of thumb: concrete structure

- Up to 10m span or less: **Beam depth** (effective span divide by 12)
- Up to 10m span or less: **Slab depth** (span divide by 30), only applicable for simply supported slab and continuous slab. But not for cantilevered slab.
- **Column size** (no rule of thumb, will be based on actual loading), but for small structure and normal loading we can use the concept of short column (effective length divide by 12). That is the minimum size.

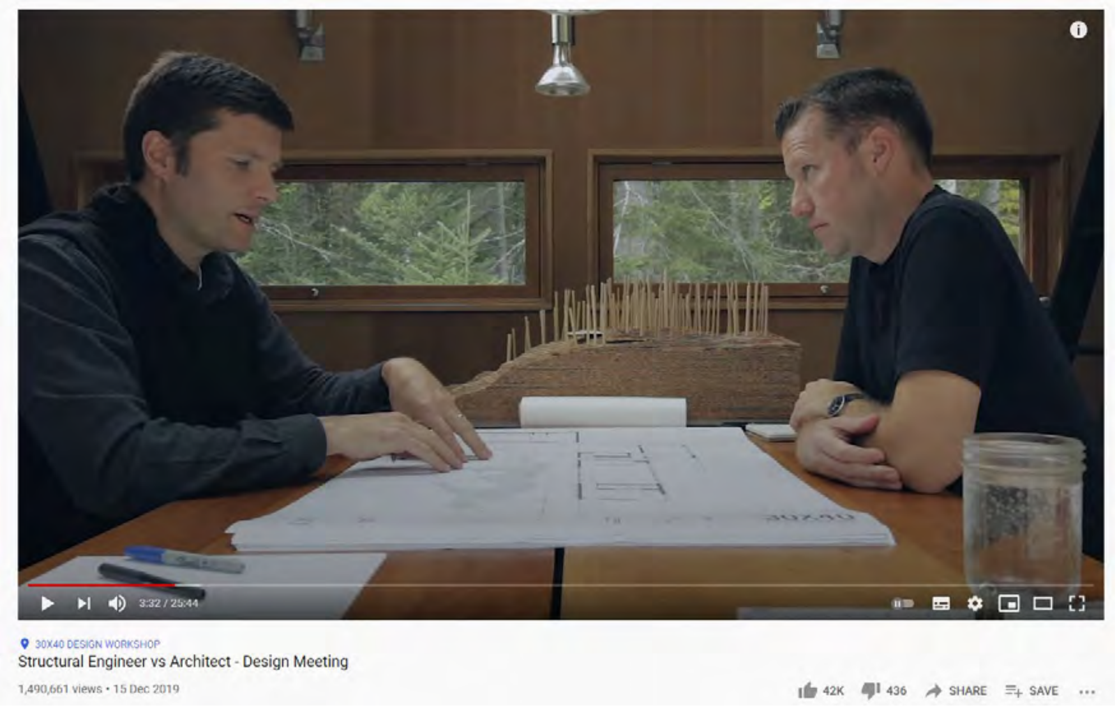


4.4. How do these impact our design process?

1	**CONCEPTUAL DESIGN**	Designer begins by considering all possible layouts and structural system which might satisfy requirements of project. Architects and engineers consult as a team to establish layouts with **efficient structural system** and meeting architectural requirements of the project.
2	**PRELIMINARY DESIGN**	Engineers chose from the conceptual design and **sizes their main components.** The preliminary **proportioning of structural membe**r requires understanding of: structural behaviour and a loading condition knowledge.
3	**ANALYSIS OF PRELIMINARY DESIGNS**	Using estimated values of load, the engineer carries out an analysis of **several structural systems**.

Previously in Week 1..

Practitioners dialogue



A DESIGN MEETING

https://youtu.be/29-xtjX8rAk

ACTIVITY 2

1. WORK IN GROUPS (FIRST PRESENTATION GROUPS): 45MINS
2. HYPOTHETICALLY YOU ARE TO DESIGN MULTIPLE PRE-FABRICATED VILLAS ON CONTOURED LAND
3. YOU CAN DEFINE YOUR OWN CLIMATE CONTEXT AND LOCATION
4. SIZES ARE- SEE NEXT SLIDE
   7.2 X 14.4M (8 VILLAS)
   7.2 X 7.2M (4 VILLAS)
6. CHOOSE THE MAIN STRUCTURE SYSTEM (STEEL/TIMBER/CONCRETE)
7. APPLY THE RULE OF THUMB
8. SUBMIT GROUP WORK VIA EMAIL

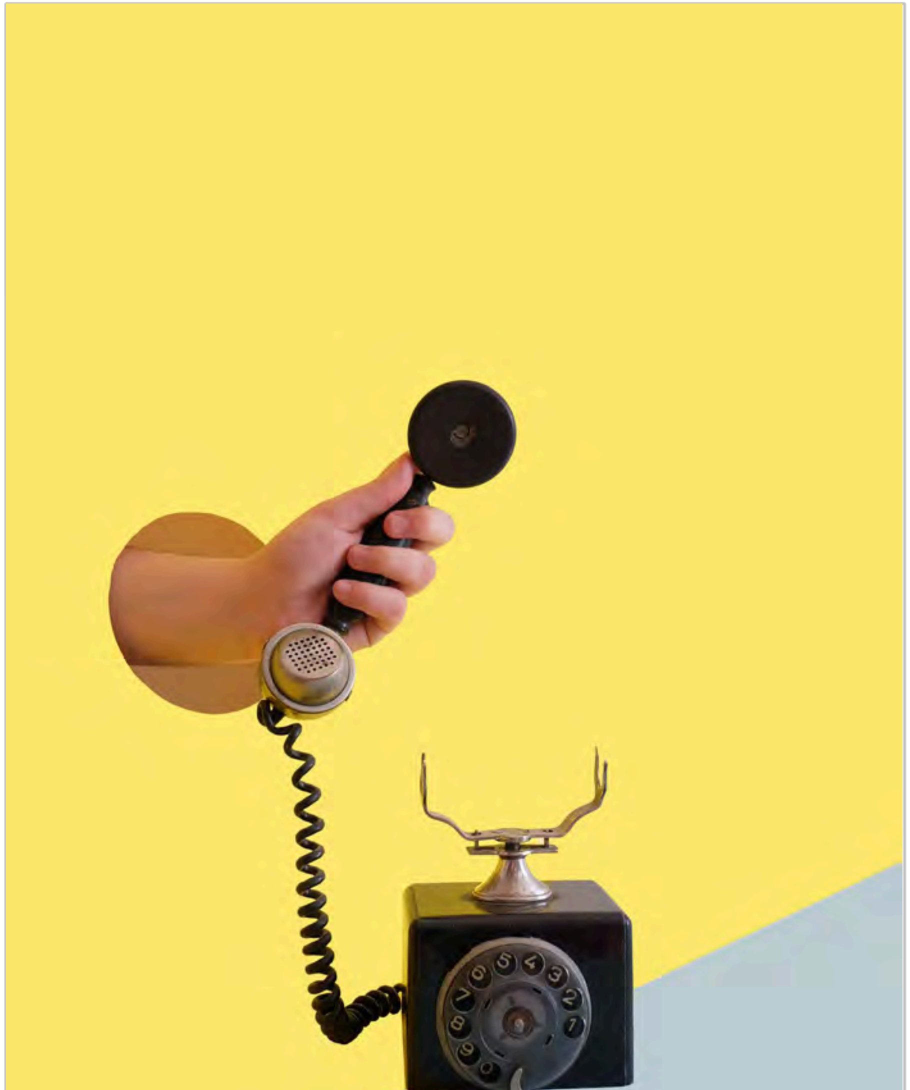


Photo by Elena Koycheva on Unsplash

ACTIVITY 2

EXPECTED OUTCOME:

- SKETCHES AND EXPLANATION ABOUT THE CHOSEN STRUCTURAL MATERIAL
- MAIN STRUCTURAL ELEMENTS

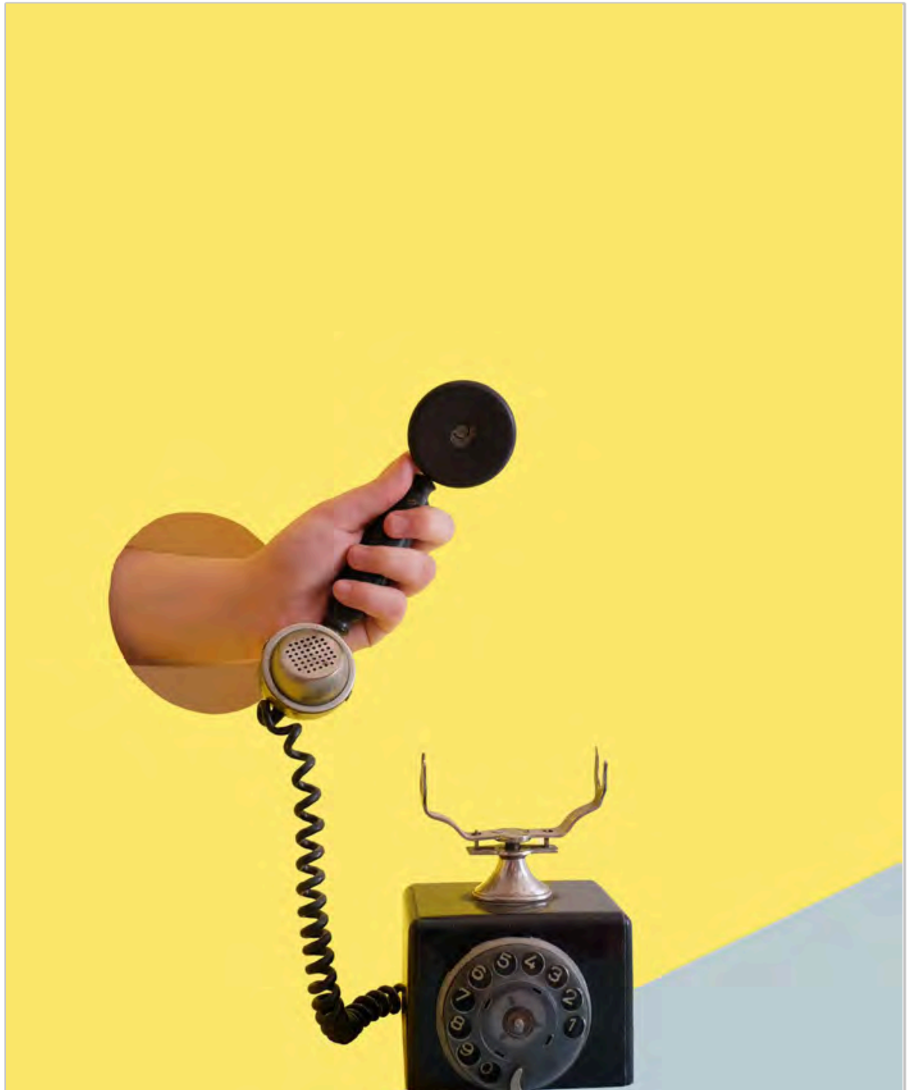


Photo by Elena Koycheva on Unsplash


7.2m x 14.4m
7.2m x 7.2m
alternative 2.2

Part 5:
Structural analysis

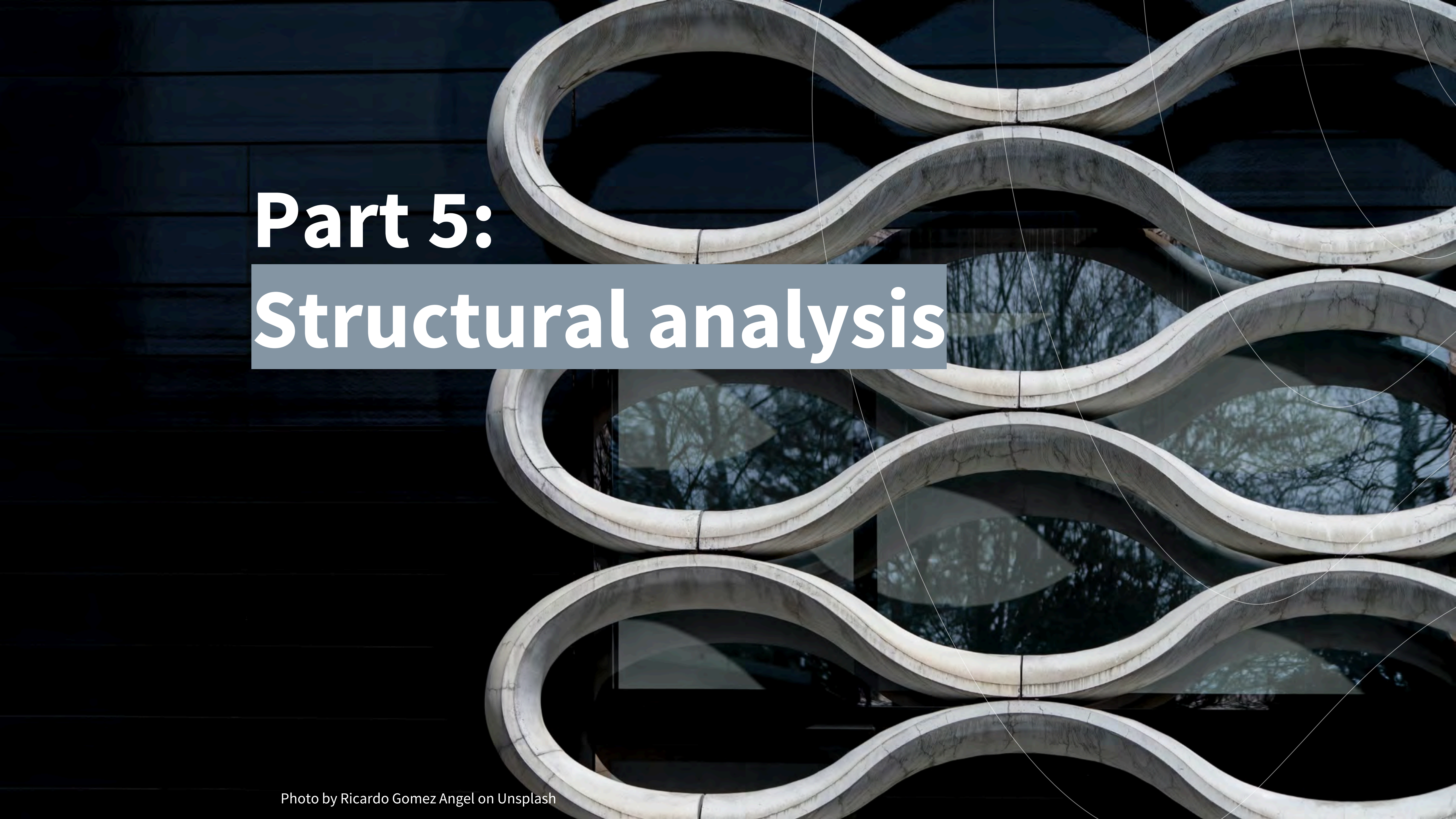
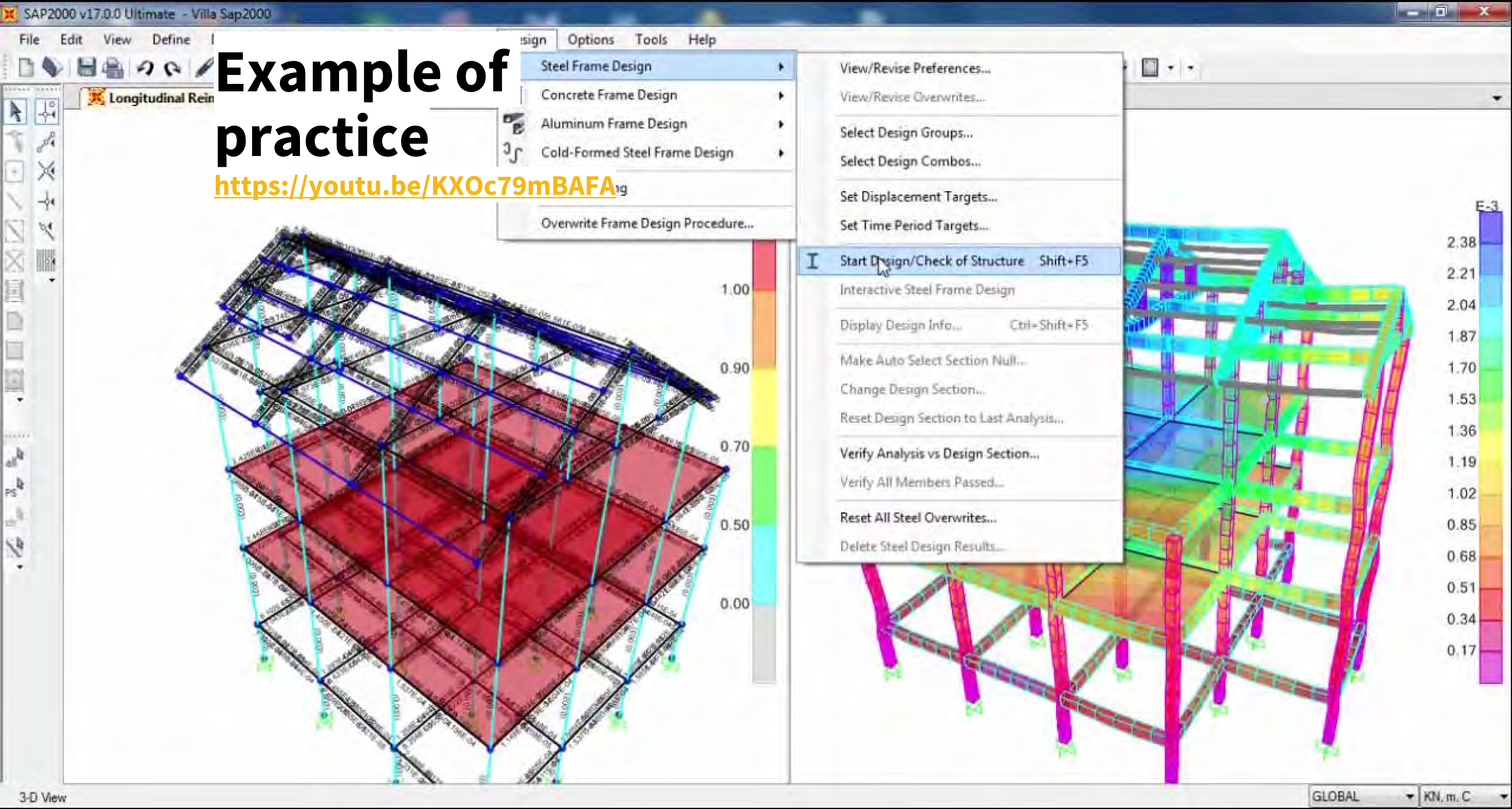


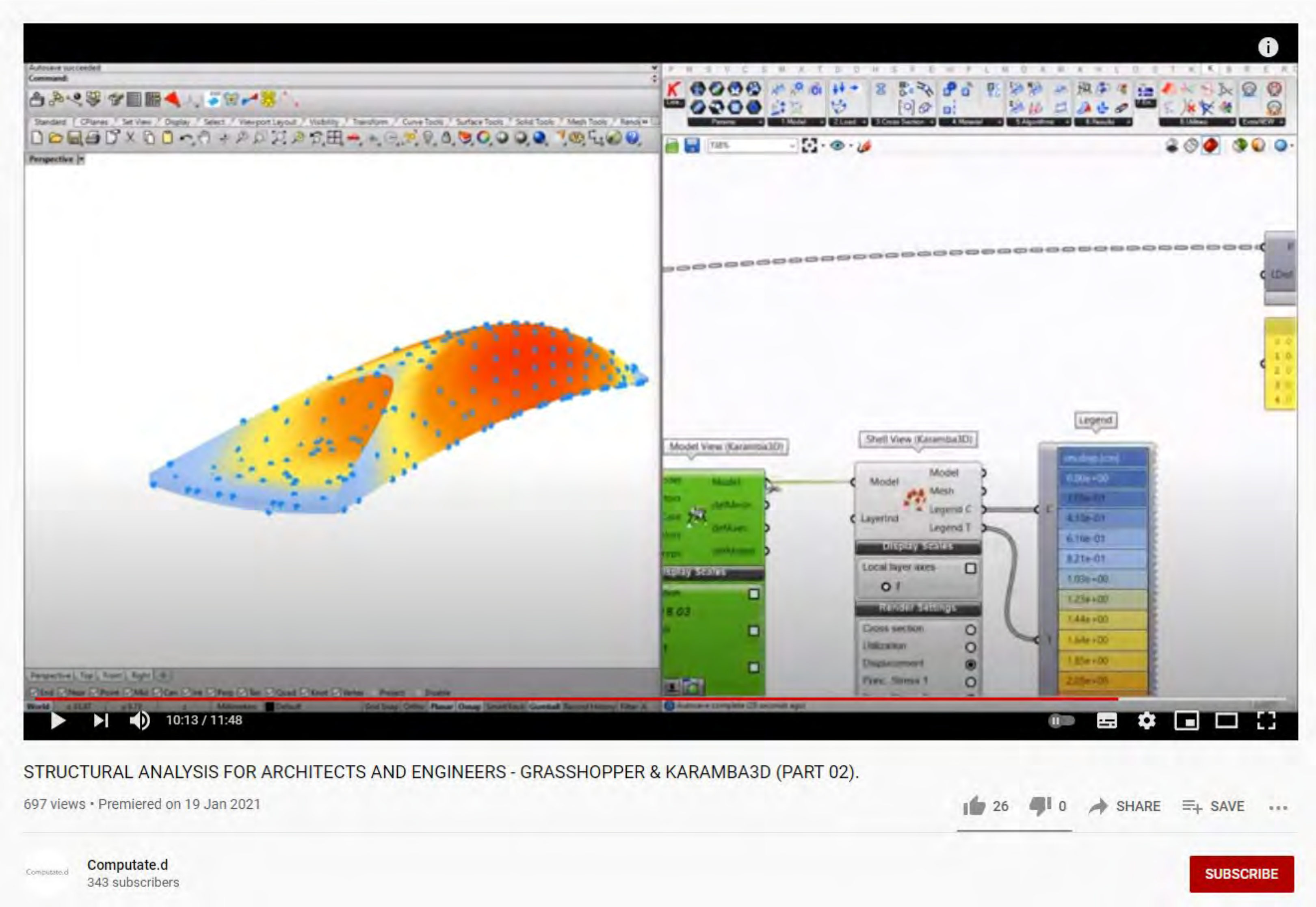
Photo by Ricardo Gomez Angel on Unsplash

Example of practice

https://youtu.be/KXOc79mBAFA

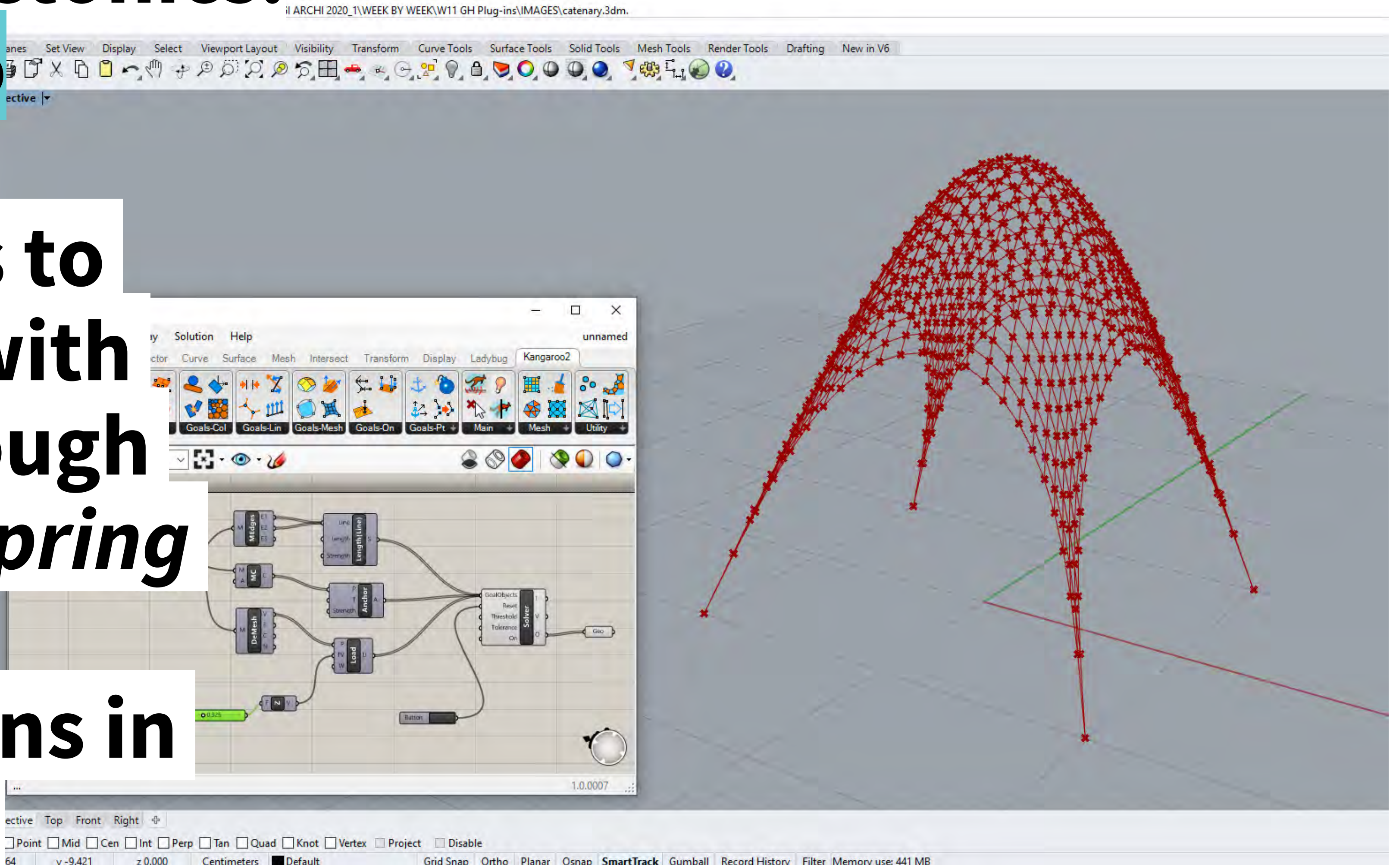


Digital tectonics



https://youtu.be/Wp604hqj7eg

Digital tectonics: Kangaroo enables designers to interact with form through *particle-spring system* simulations in real time.



Re-iterating aims and objectives

- To do a recap on **Assignment 1** submission
- To reiterate **Assignment 2's** submission requirements
- To look at **compositions of structure**
- To expand on **structural considerations** (rule of thumbs)
- To provide **examples** on classical tectonics and digital tectonics