ARCHITECTURAL STRUCTURE

Week 2: Historical points of view

Photo by Jorge Fernández Salas on Unsplash

Outline

1
INTRODUCTION

Aims

LOs

2
LECTURE:

- **PREHISTORIC ARCHITECTURE**
- **SEARCH OF STRUCTURAL UNDERSTANDING**
- **STRUCTURAL SYSTEM**

3
SEMINAR

4
SUMMARY REFLECTION

- UPLOADING STUDY MATERIALS TO DISQUS

Aims and objectives

- To expand **historical background** of the concept of understanding structure behaviour.
- To **contextualise** the need to look backward through the history to shape our understanding on building structure.
- To enumerate **milestones** and **related theories** in building construction with regards to structure behaviour.
- To elicit **key concepts,** which we can consider in future architecture practice.

Learning outcomes

Students will be able to..

01 Draw **lessons** from historical perspective of the development.

02 A better **conceptual understanding** when starting a new design project.

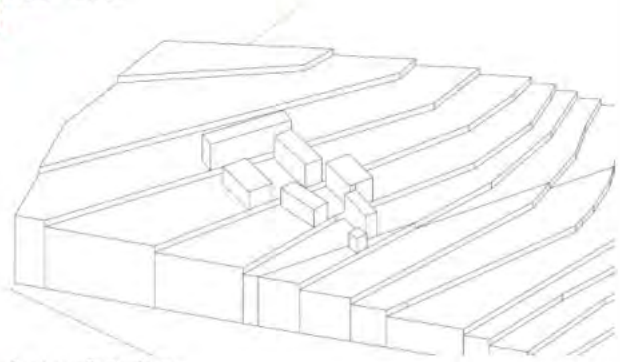
03 Become aware of the **important aspects** to think about during designing stage.

Previously in Week 1..

t it is... Then

2 · Reply · Share ›

Inas El · 7 days ago



1 · Reply · Share ›

Inas El · 7 days ago

First of all we should have an adequate geotechnical study of the soil and terrain carried out. Design the foundation according to the actual ground conditions and the relevant slope. here in Morocco rammed earth is the common way used to build hillsides homes as shown in the picture bellow but we can use some wood and glass for a better aesthetic besides making sure to set all foundations and pillar footings on competent soil or compacted fill.

inas

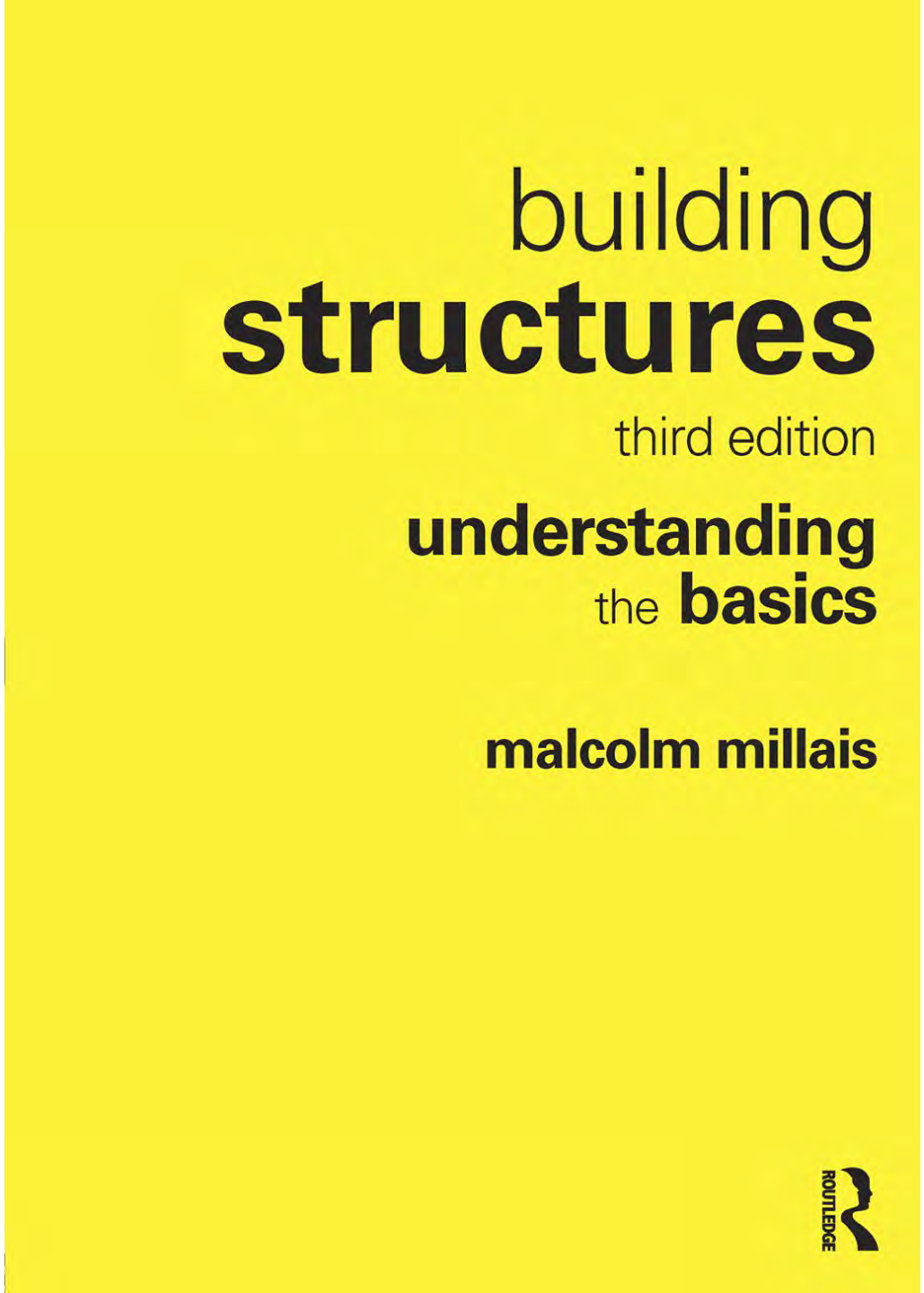
1. Why do we need to understand the **history** behind **understanding structural behaviour**?
2. Why do we want to know **historical perspective** of building structure?

Common problem in building practice:

The division between architectural design of a building and the structural design of the building.

The key is the conceptual understanding of structural behaviour.

Millais, M. (2017). *Building Structures: understanding the basics*, Routledge.



Any designed structure needs to meet these requirements:

- **Strong enough**
- **Stiff enough**
- **Affordable**
- **Sufficiently durable**

Millais, M. (2017). *Building Structures: understanding the basics*, Routledge.

Part 1:
Pre-structural understanding

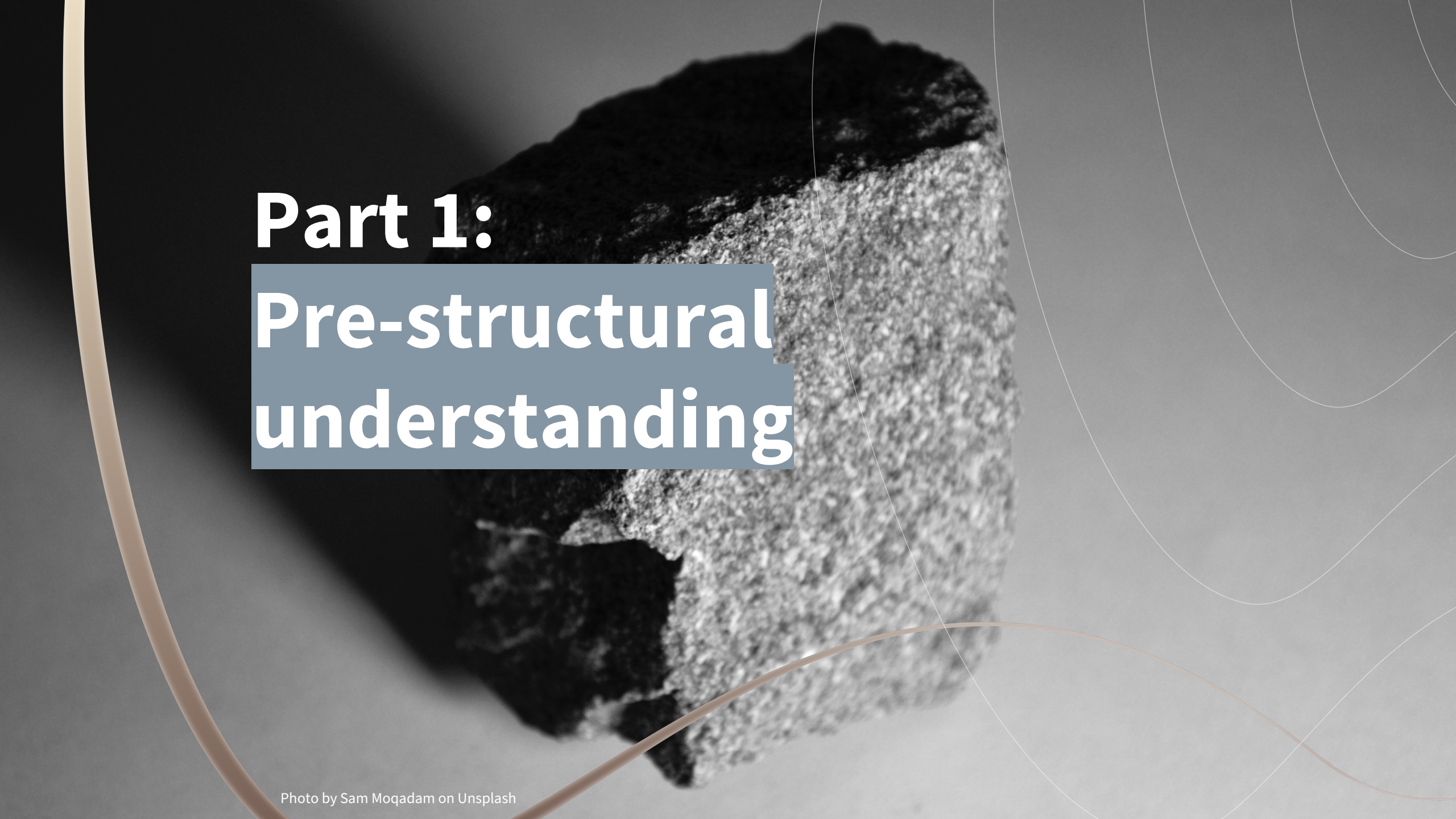


Photo by Sam Moqadam on Unsplash

1) Pre-historical time: Hunter-gatherers

As far back as 2 million years ago. Hunter-gatherer society is a human living in which all food is obtained by foraging.

Typical hunter-gatherer societies are egalitarian.

1) Pre-historical time: Hunter-gatherers

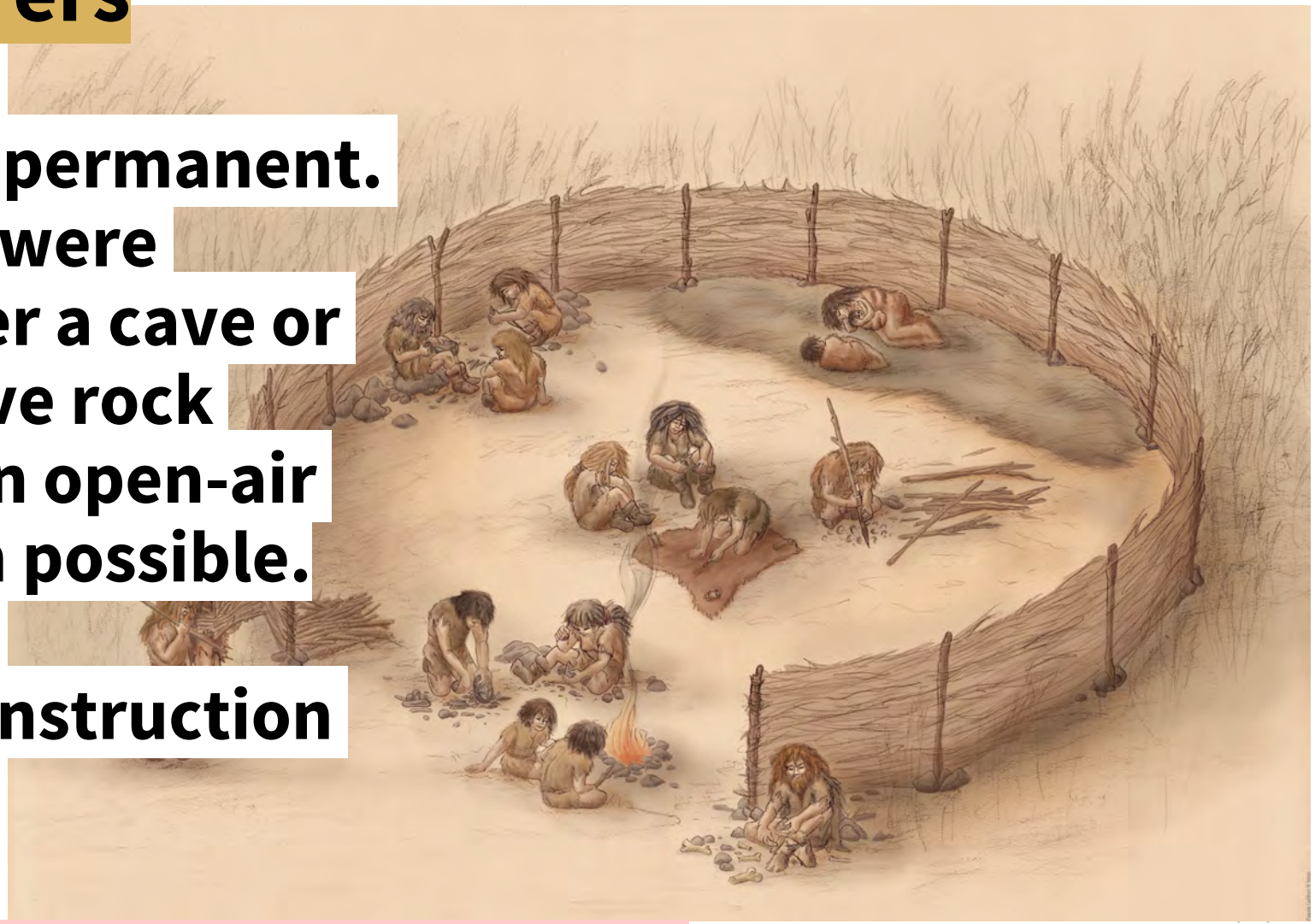
Early hunter-gatherers moves as nature dictated, adjusting to: proliferation of vegetation, presence of predators or deadly storms.

In search for sources of food and suitable shelter. In small self-contained groups.

Hunter-Gatherers - HISTORY

1) Pre-historical time: Hunter-gatherers

Shelters were impermanent. Sometimes they were established under a cave or under a protective rock formations. Or an open-air settlement when possible.



Speculative reconstruction of “La Folie”.

The daily lives of nomadic hunter-gatherers | Neanderthal: the Exhibit (museedelhomme.fr)

1) Pre-historical time: Hunter-gatherers

The use of natural materials for shelters. Often using materials derived from animals.

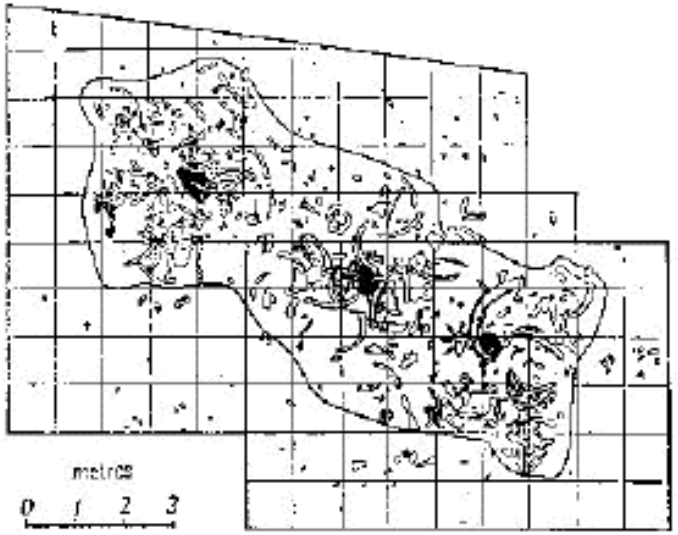
Origin of design was unknown. Handed down from older generation to the next generation.

1) Pre-historical time: Hunter-gatherers

The typical design (of each nomadic group) was repeated endlessly as they move around.

No need to make design changes or know how to make structure stronger or stiffer.

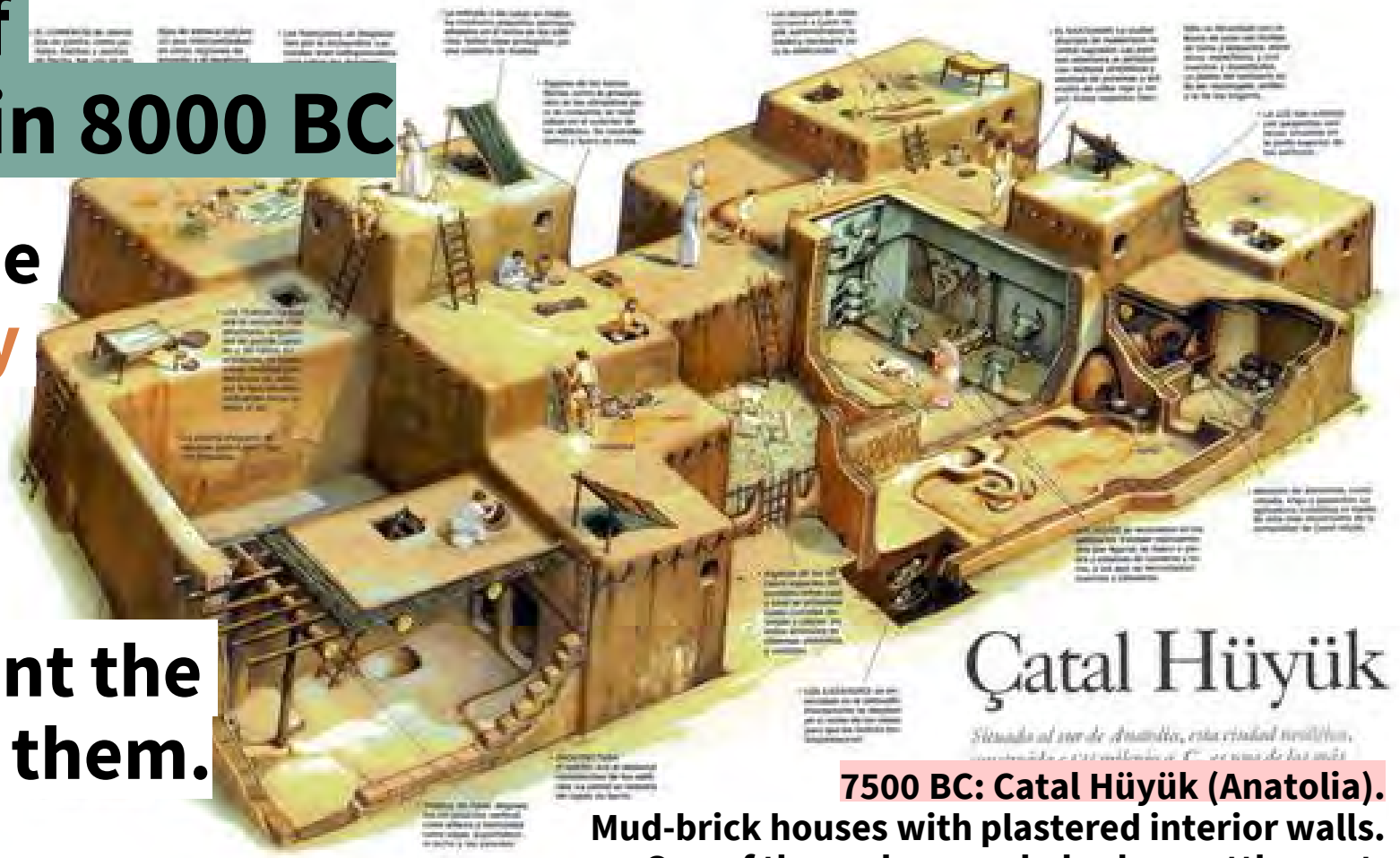
1) Pre-historical time: Hunter-gatherers



2) Traditional design: Discovery of agriculture in 8000 BC

Groups become geographically fixed.

Agriculture surpluses meant the needs to store them.



7500 BC: Catal Hüyük (Anatolia).
Mud-brick houses with plastered interior walls.
One of the early recorded urban settlement.

2) Traditional design: Discovery of agriculture in 8000 BC

The need to have more permanent structures.

The beginning of building technology.

Ching et al. (2013) on the brief historical survey from 5000BC to the year of 2000.

Ching, F. D., Onouye, B. S. & Zuberbuhler, D. (2013). *Building Structures Illustrated: Patterns, Systems, and Design*, John Wiley & Sons.

2) Traditional design: Discovery of agriculture in 8000 BC

Advances in building technology with the use of mud, mud dried bricks and timber.

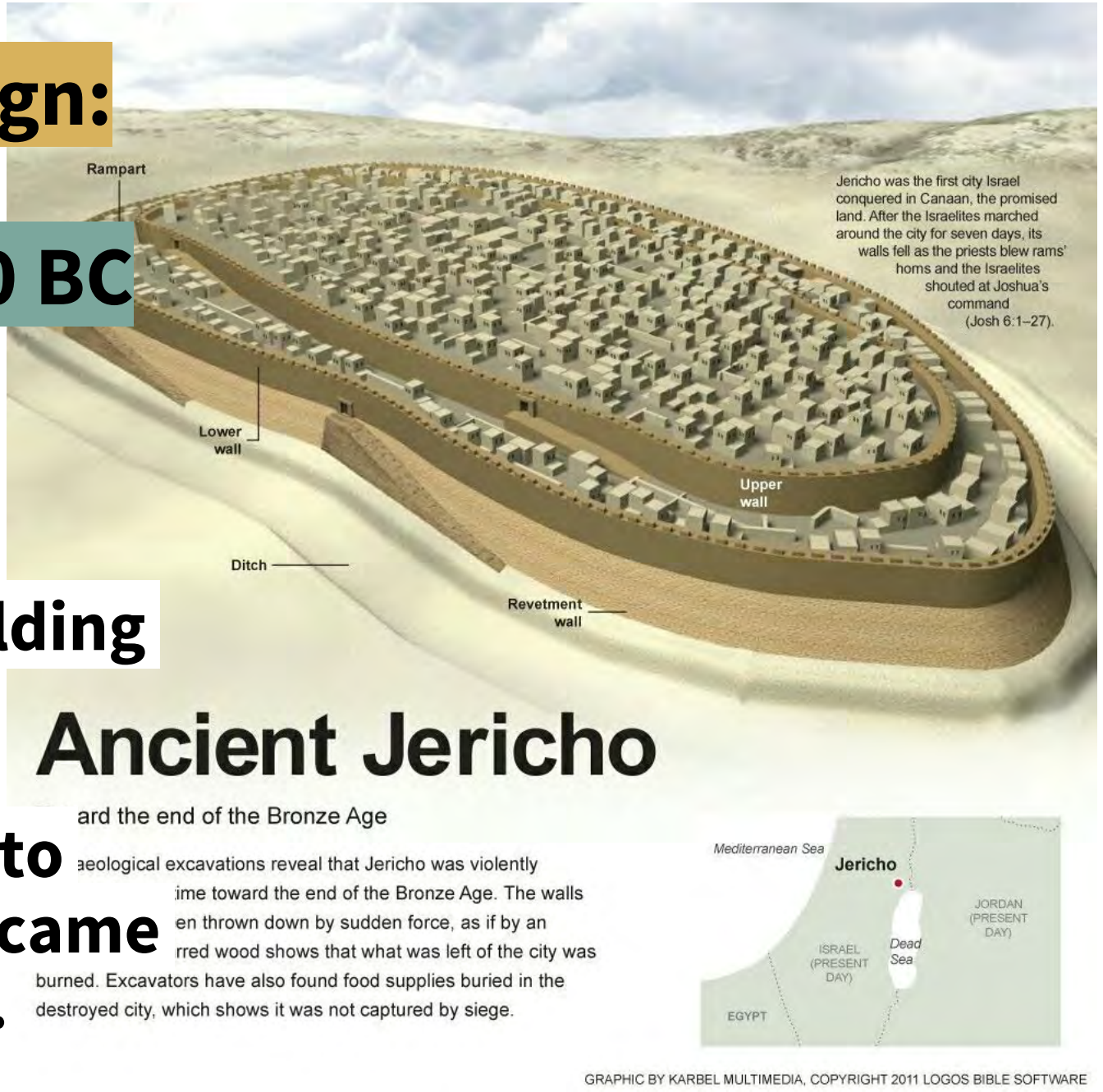
Traditional buildings, carried out by craftsmen without scientific knowledge.

8000 BC: Jericho, Israel
Fortified settlement consisted of circular mud huts that had conical roofs.

2) Traditional design: Discovery of agriculture in 8000 BC

The rise of cities and powerful elites → resulting in new and different forms of building and structures.

Some villages grew into bigger centres and became towns and then cities.



3) Civilisation: Dismissal of traditional methods

New specialised groups:
Ruling, religious elite or warlords.

New types of buildings:
Temples, storehouses, castles and so on.

Well known examples are the pyramids in Egypt, Parthenon in Greece and the Colosseum in Rome.

3) Civilisation: Dismissal of traditional methods

The development o metal tools circa 3500BC.

The use of caves for sheltering and dwelling continue.

However, no evidence that any sort of theory about behaviour of structures was used before 1742.

3) Civilisation:
The step pyramid, Saqqara, Egypt circa 2360 BC

Designed by Imhotep is credited with designing the first pyramid.
Egypt's first monumental construction in stone.

Imhotep is the first engineer in history known by name.

3) Civilisation: Materials

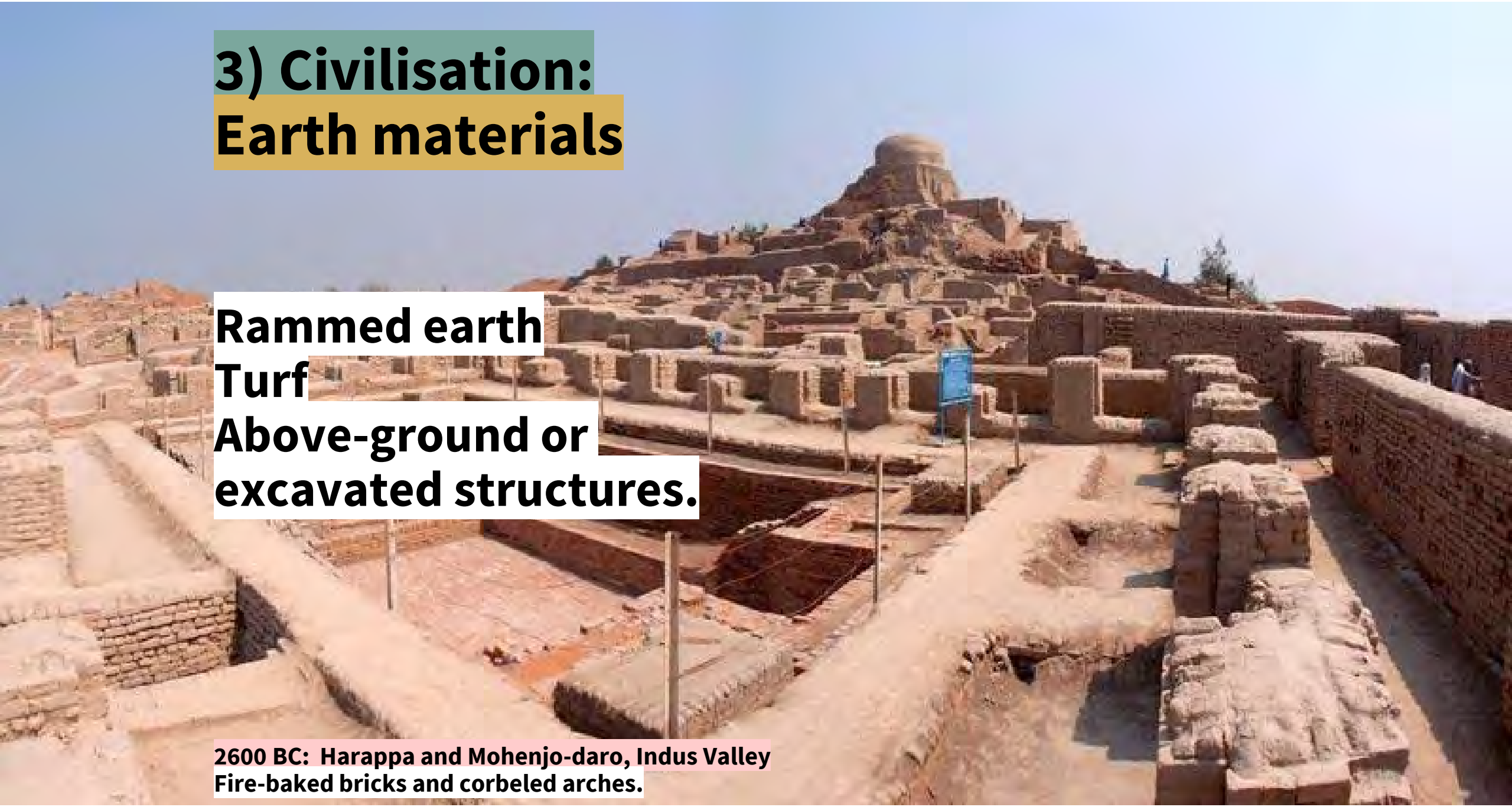
Easily available materials or cheaply manufactured ones.

Types of materials:

- **Earth materials**
- **Vegetation**
- **Animal hides or skins**

Allen, G. N. (2007). Traditional Buildings: A Global Survey of Structural Forms and Cultural Functions (International Library of Human Geography). IB Tauris.

3) Civilisation: Earth materials



Rammed earth
Turf
Above-ground or excavated structures.

2600 BC: Harappa and Mohenjo-daro, Indus Valley
Fire-baked bricks and corbeled arches.

3) Civilisation: Earth materials

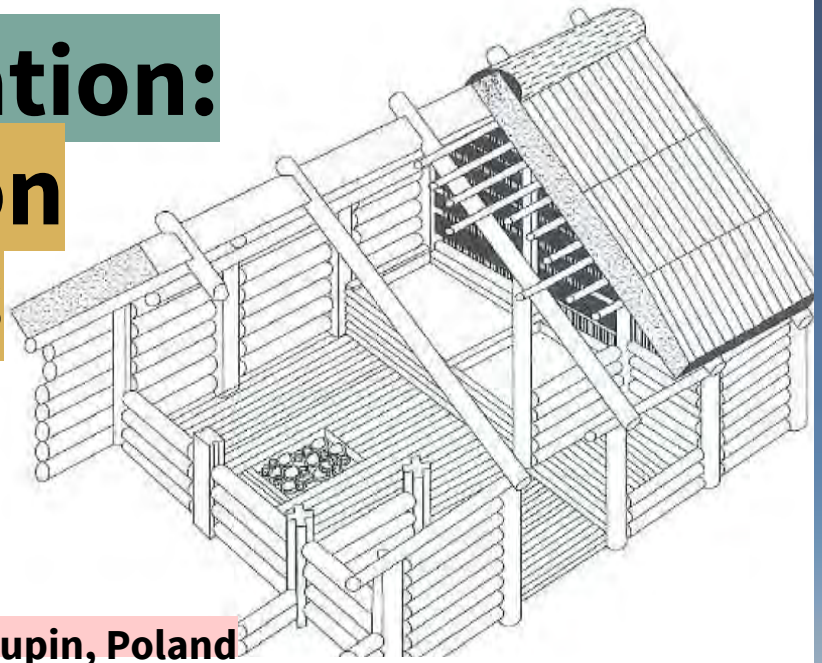
Rammed earth
Turf
Above-ground or excavated structures.

1000 BC: Cappadocia, Anatolia
Extensive excavations formed houses, churches and monastries

3) Civilisation:
Vegetation materials

Logs
***Light vegetative materials*,**
frames made of:
Small wooden,
Bamboo poles and
Thatched roof
Rafia palm
Wattle and daub as combination

3) Civilisation: Vegetation materials

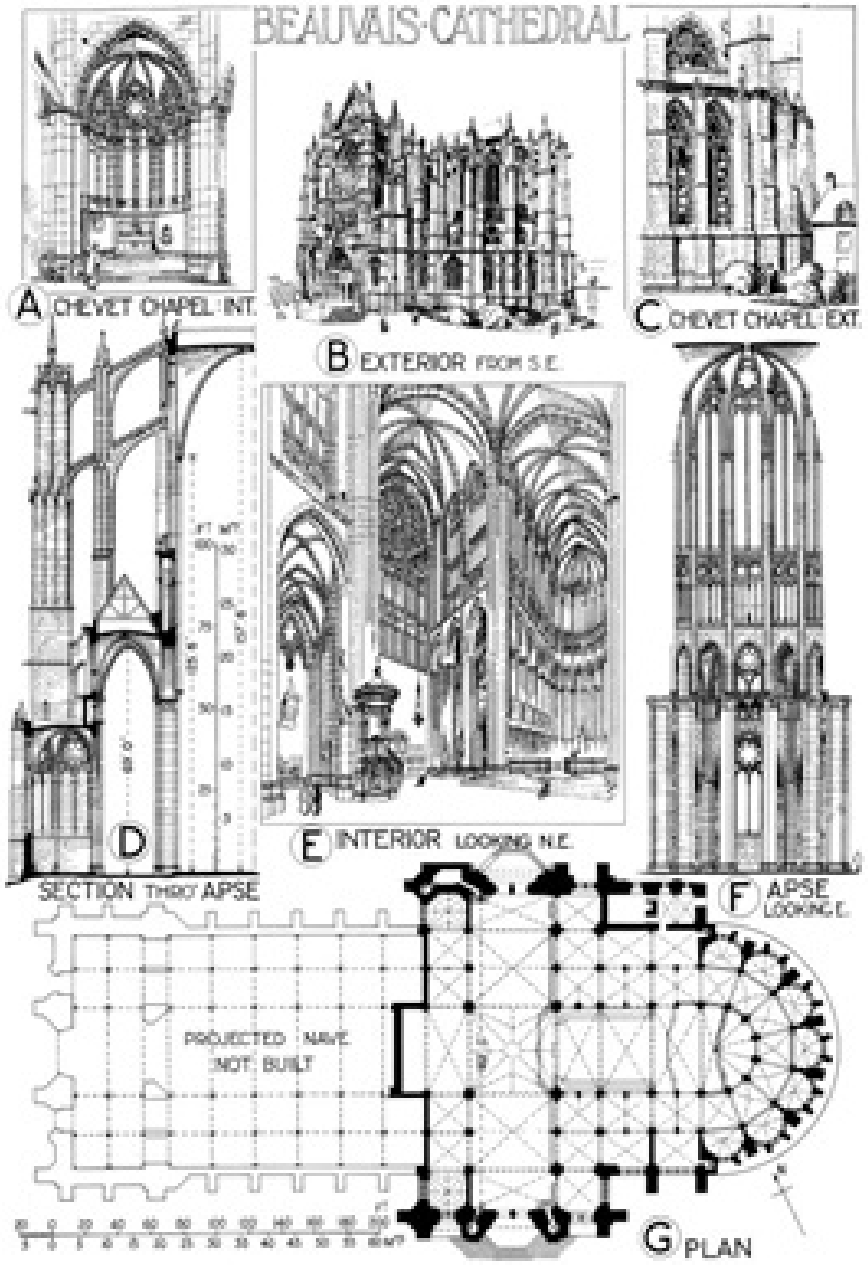


Circa 100-500 BC: Biskupin, Poland

Fortified settlement using logs as main materials.

Video (5:30 mins) https://youtu.be/8gNXbYGmyCY

Structural failures were taken into account in building process.
Structural system was considered through experience.
For example: Beauvais Cathedral (1225-1573)



https://frenchmoments.eu/beauvais-cathedral/#A_very_fragile_monument

The essence remains:
Enduring presence of some form of structural system, from 8000BC to present days.

Strong enough and stiff enough.

Structural system is considered as:
a stable assembly of elements designed and constructed to function as a whole in supporting and transmitting applied loads to the ground safely without exceeding tolerable stress in each member (Ching et al., 2013).

Part 2: The search for structural understanding

Photo by Sam Moqadam on Unsplash

Rational scientific approach:

The need of predictive information for structural designers.

Logic and rationale explanations

Greek philosophers:
Plato (428-348 BC)
Aristotle (384-322 BC)

Archimedes (290/80 – 212/11 BC) as founder of theoretical mechanics
“Eureka”

Archimedes

One of the nine treatises

‘On the equilibrium of planes’, which deals with

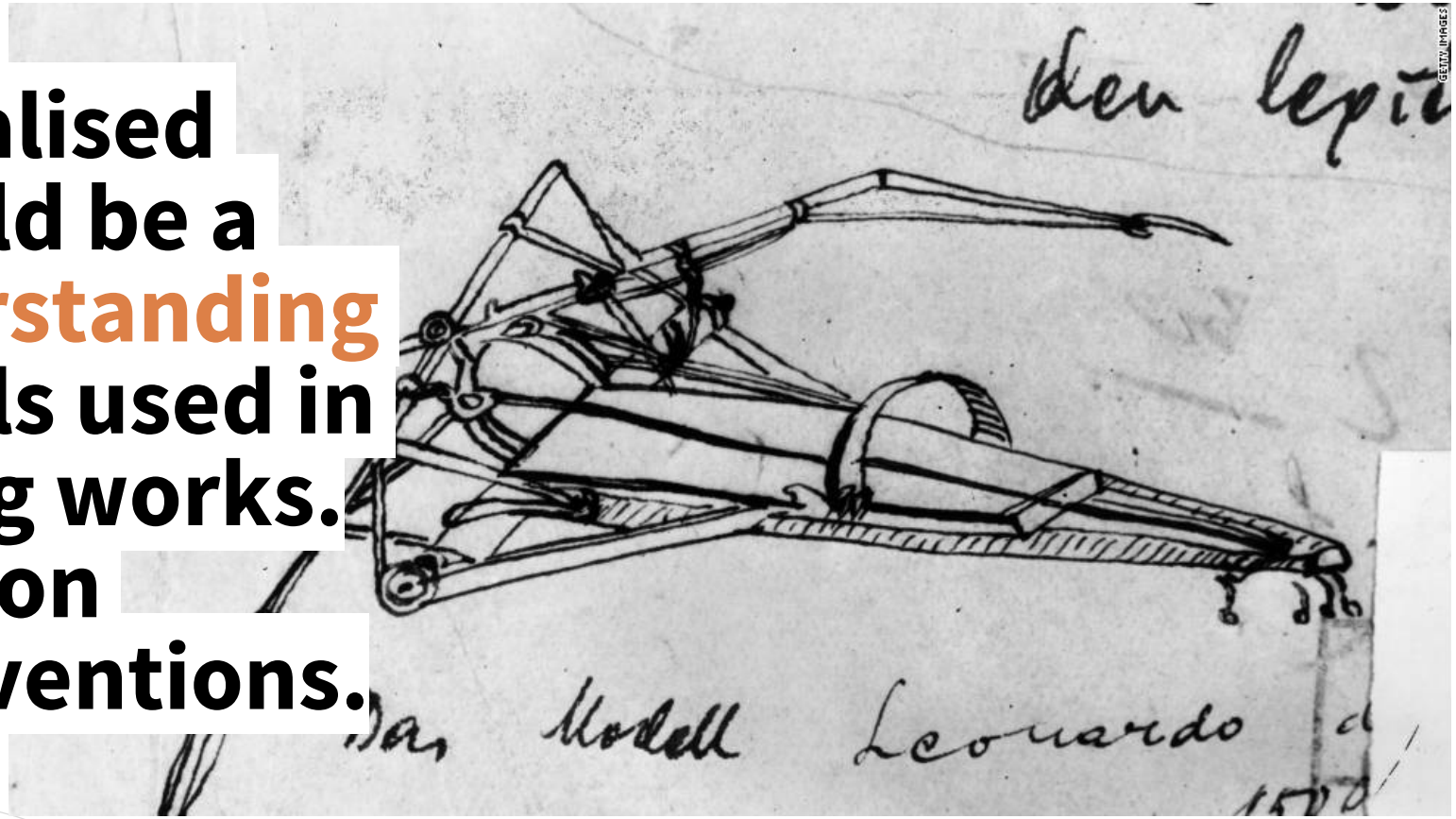
1) centre of gravity **and** ***2) law of the lever***

1) Concepts of stress and stress distribution

2) Reaction loads **(floor providing reaction force or reaction load so people don’t fall off)**

Leonardo da Vinci
(1452-1519)

In 1480s he realised that there could be a physical understanding of the materials used in his engineering works. Experimentation through his inventions.



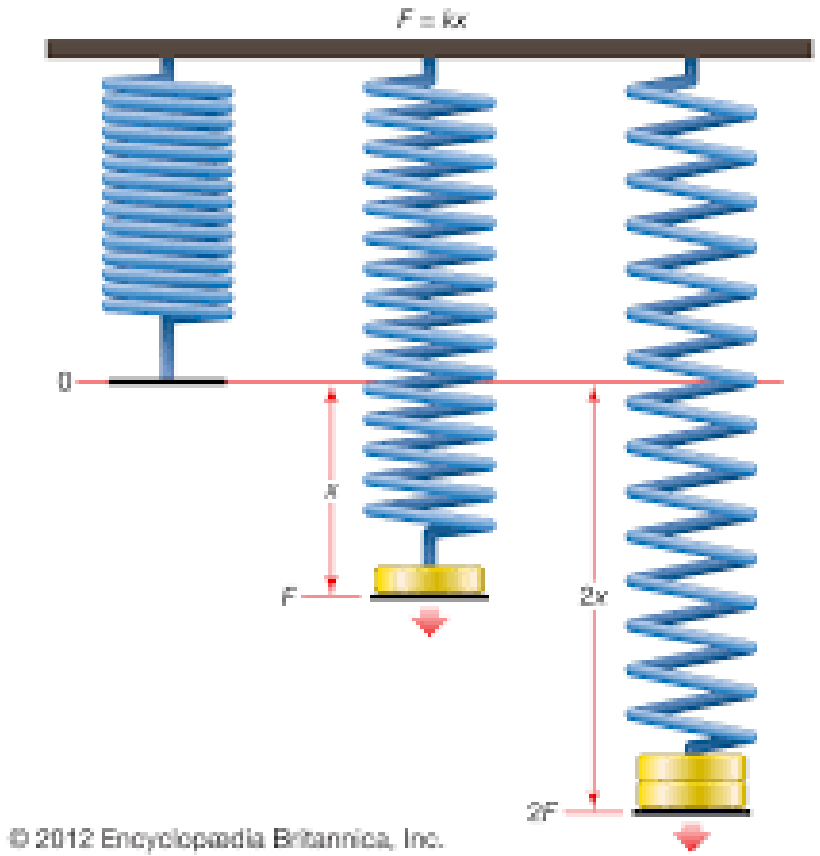
Simon Stevin
(1548-1620)
and
Galileo Galilei
(1564-1642)

They investigated the aspects of structural behaviour.

Galileo's bending beam
The study of strength of materials, on how size and shape of structural member affects the ability to carry and transmit loads.
Cantilever beam

Robert Hooke
(1635-1703)
and
Edme Mariotte
(1620-1684)

On elasticity and springiness of engineering materials to understand structural behaviour.



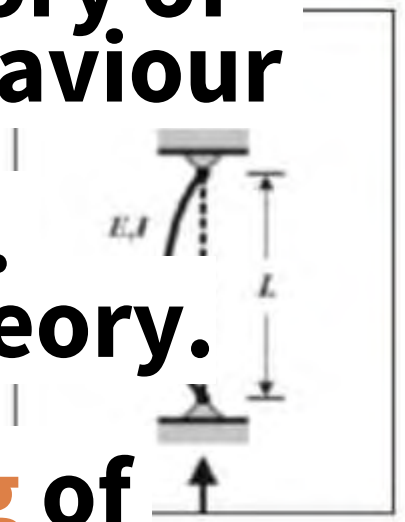
Hooke's Law

Leonhard Euler
(1707-1783)

Mathematical theory of the beam, the behaviour of 'elastic curve'. Bending of beams. Euler-Bernoulli theory.

Theory of buckling of columns.

7 bridges of Konigsberg.



"---" : Original Shape

Shape

Buckled Steel Column

Buckled R.C.C. Column

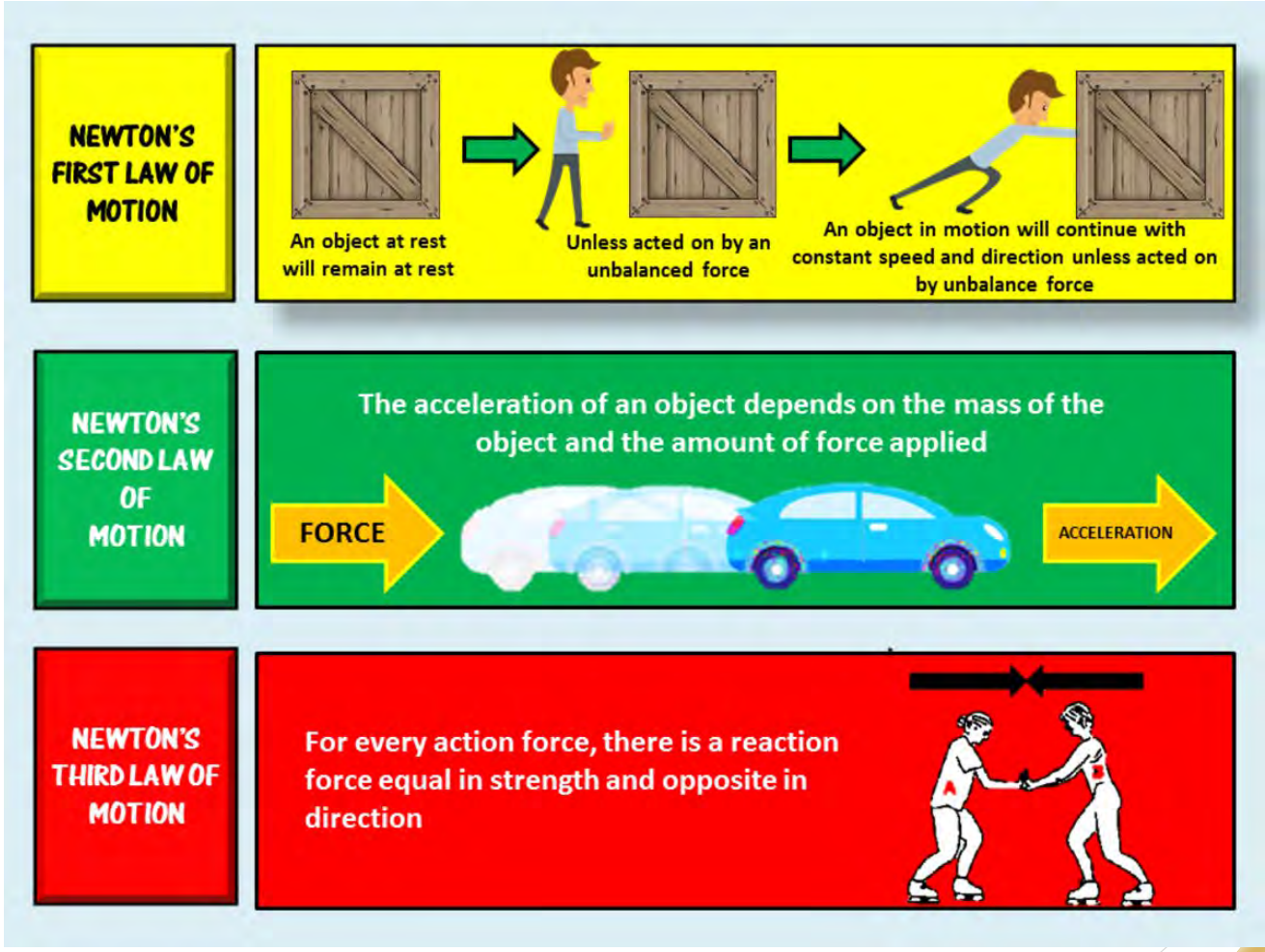
https://theconstructor.org/structural-engg/euler-theory-column-buckling/37341/

Isaac Newton (1643-1727)

Newton's laws of motion.

With these laws it is possible to understand the forces on a structure and how the structure will resist them.

And the sum of internal and external forces must be in equilibrium.



Towards the end of 18th century, these mathematical theories could be used to predict structural behaviour.

Architecture as union of space, form and structure.

Part 3: Conceptual understanding of structural behaviour

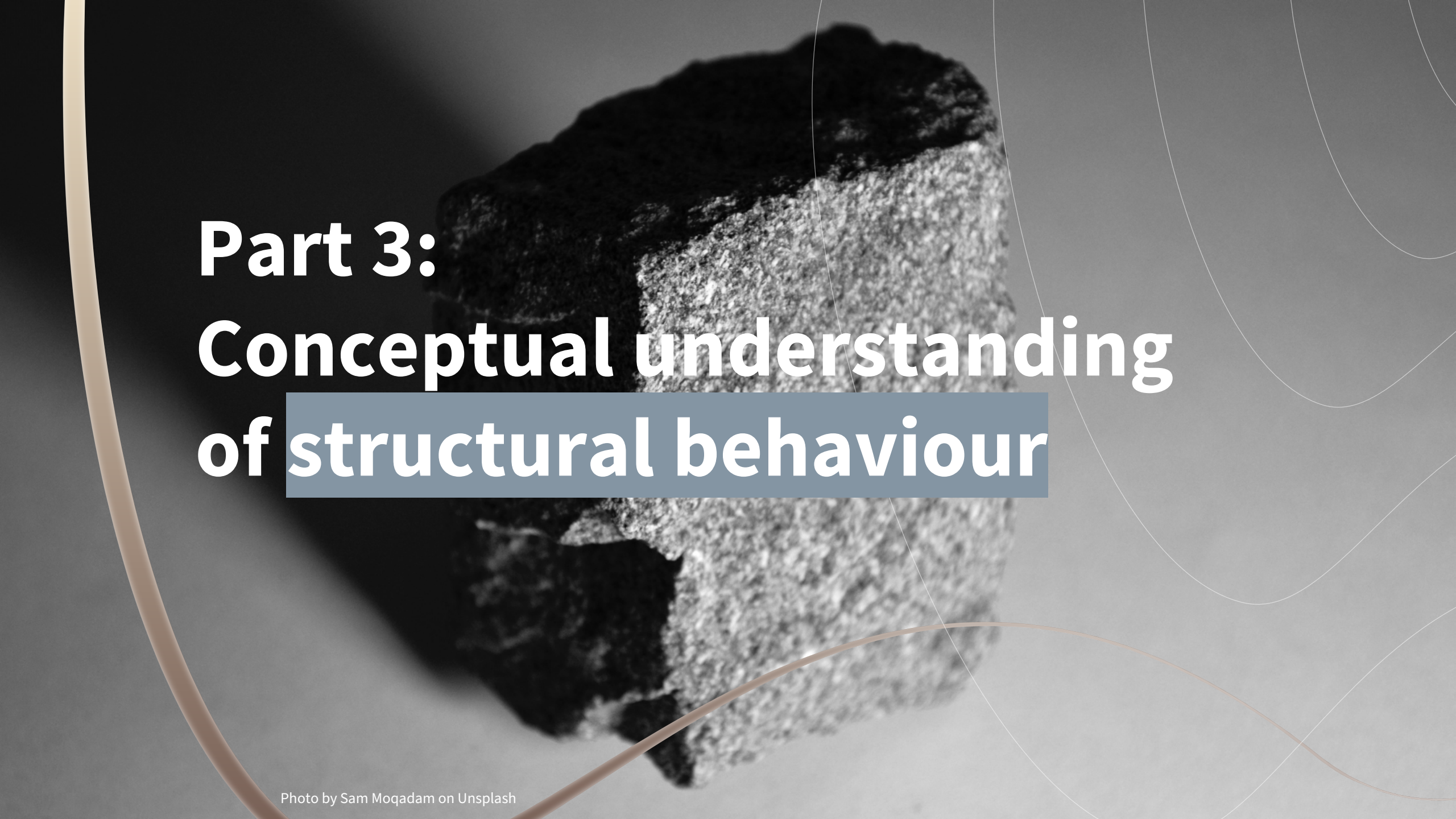


Photo by Sam Moqadam on Unsplash

The modern approach

Checking and confirming design of structure by making calculations.

First known civil engineering practice in history was in 1742, in St Peter's Basilica in Rome.

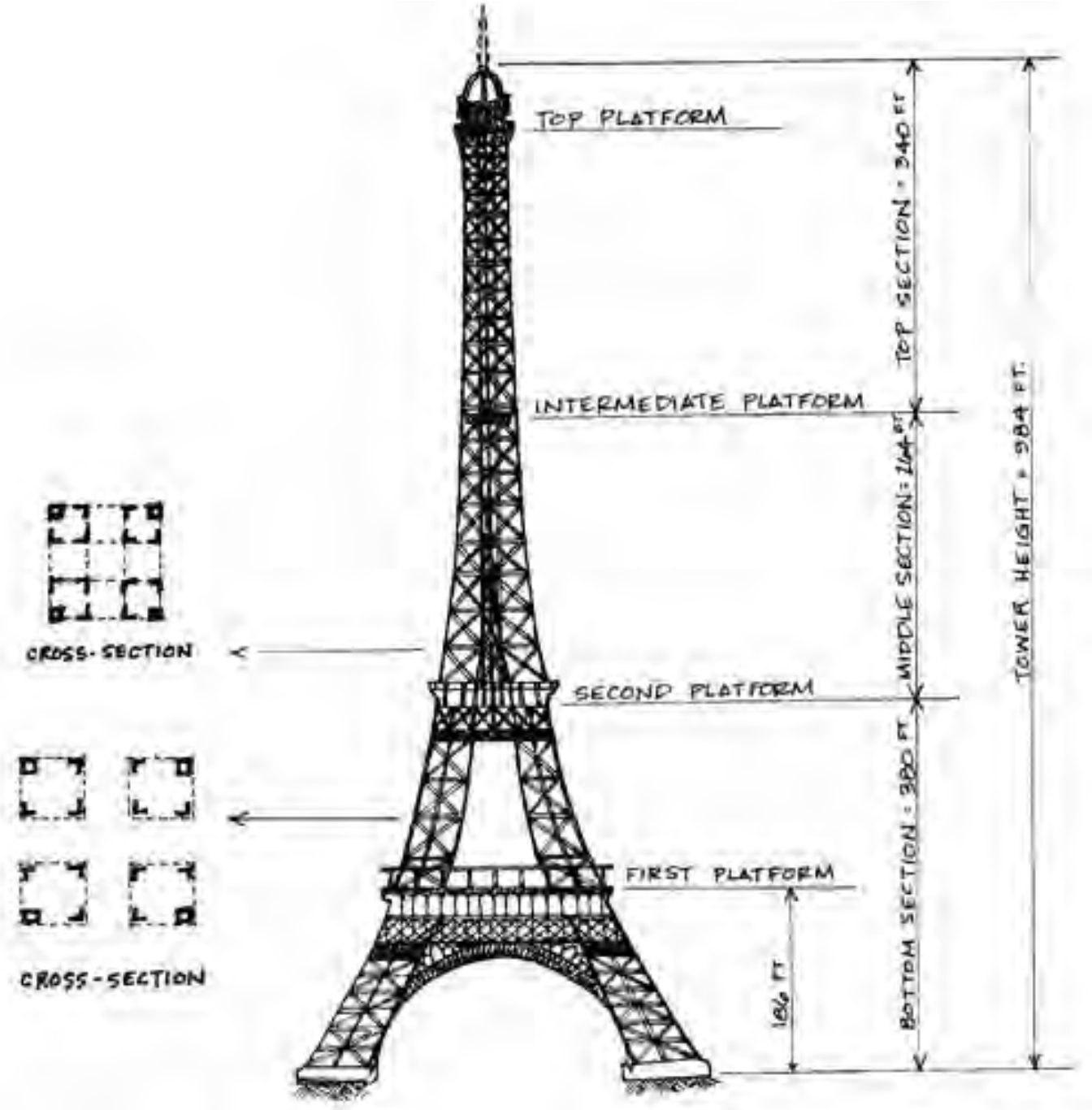
Trained engineers began in France in 1671, of the Academie Royale d'Architecture, where engineering was taught as much as architecture.

19th century: The famous engineers who calculates their structures.

One example is Gustave Eiffel (1832-1923)

Crossbow and trusses

Calculation of the strength of the Eiffel Tower (wonders-of-the-world.net)
Eiffel Tower: Geometry (jhu.edu)

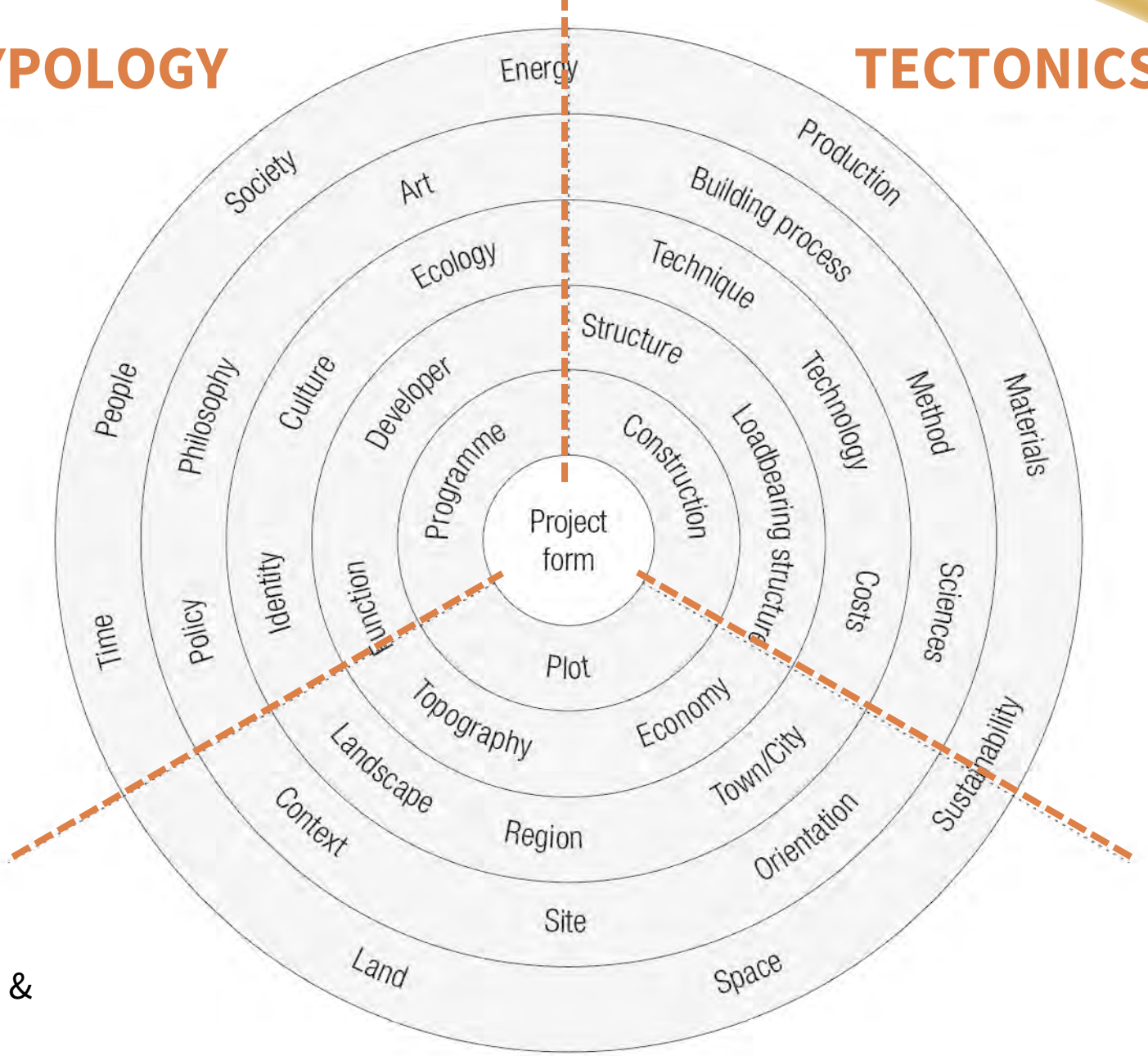


Common questions:

- What is the **function** of the structure?
- What are **the loads** and the **load paths**?
- How does the structure **transfer the loads**?
- What are the **forces** in the structural elements?
- Does the structure have **overall stability**?
- Is any element **too slender**?

Form-developing process:

TYPOLOGY
TECTONICS
TOPOLOGY

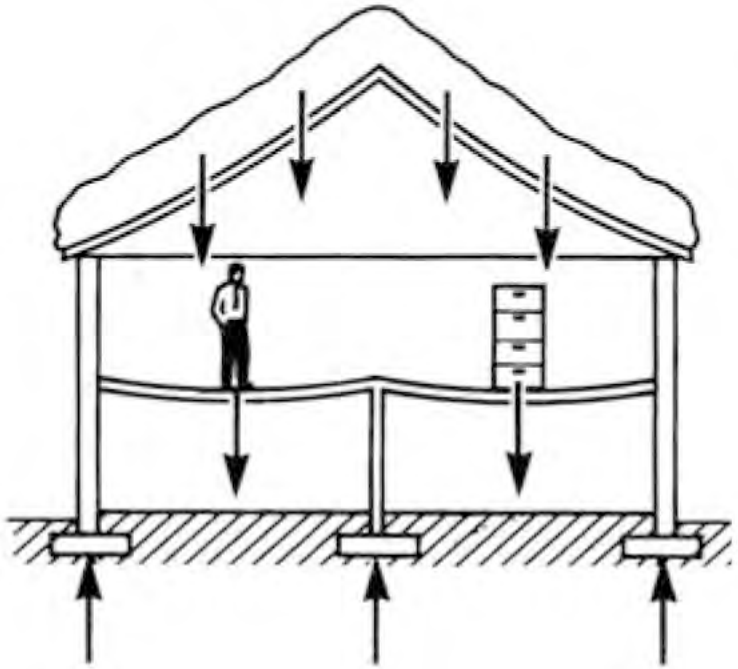


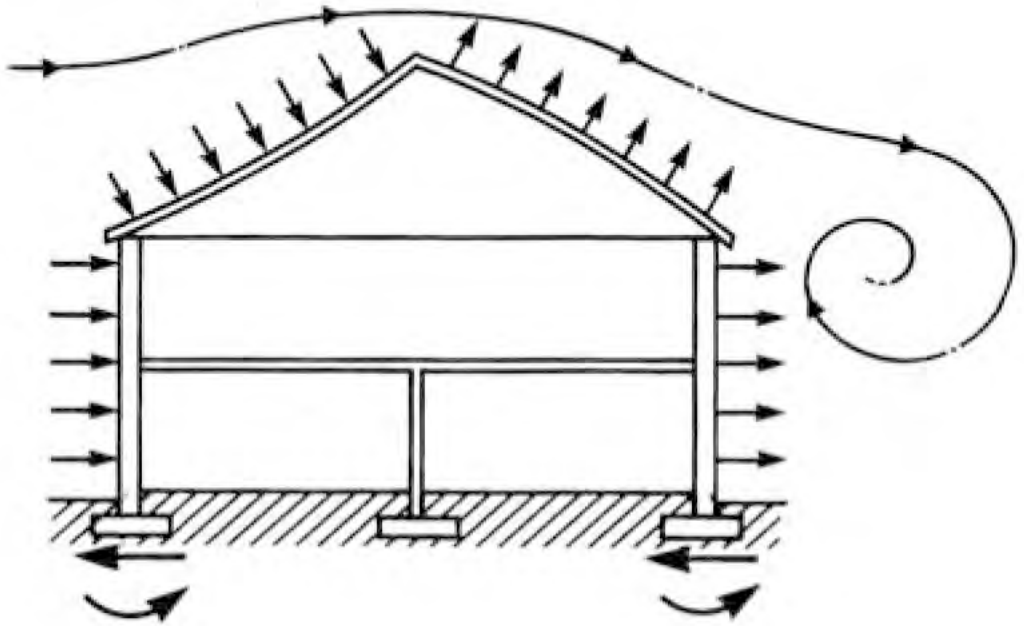
Form-finding or form-developing processes

Söffker, G. H. & Deplazes, A. (2005). *Constructing architecture: materials, processes, structures*, Springer Science & Business Media.

Relationship of structure to building

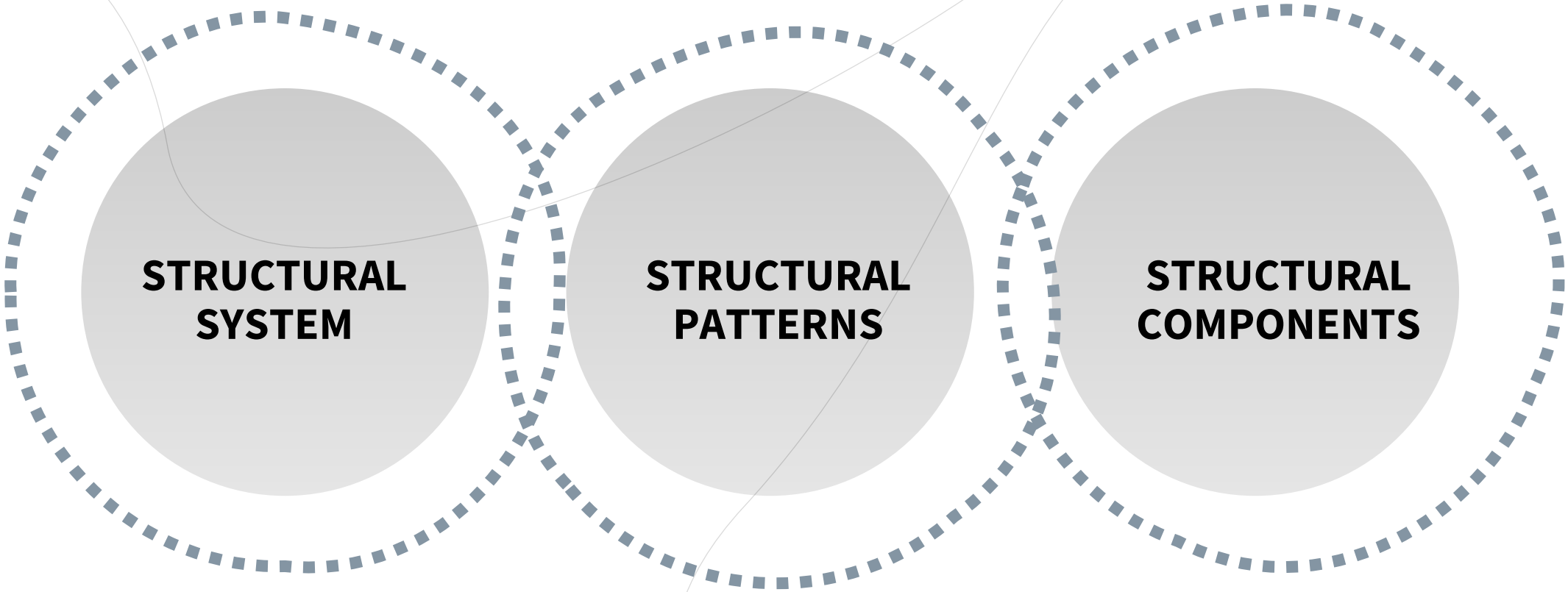
A building can be regarded as an envelope hosting subdivided spaces. The envelope is subjected to different loads, ditto the floor. These loads will distort the building envelope and it might collapse. The role of structure is to provide strength and rigidity to avoid collapsing.



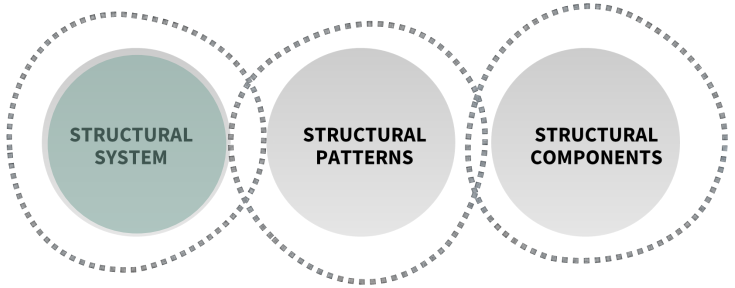


Macdonald, A. J. (2018). *Structure and architecture*, Routledge.

An overall view



Structural system



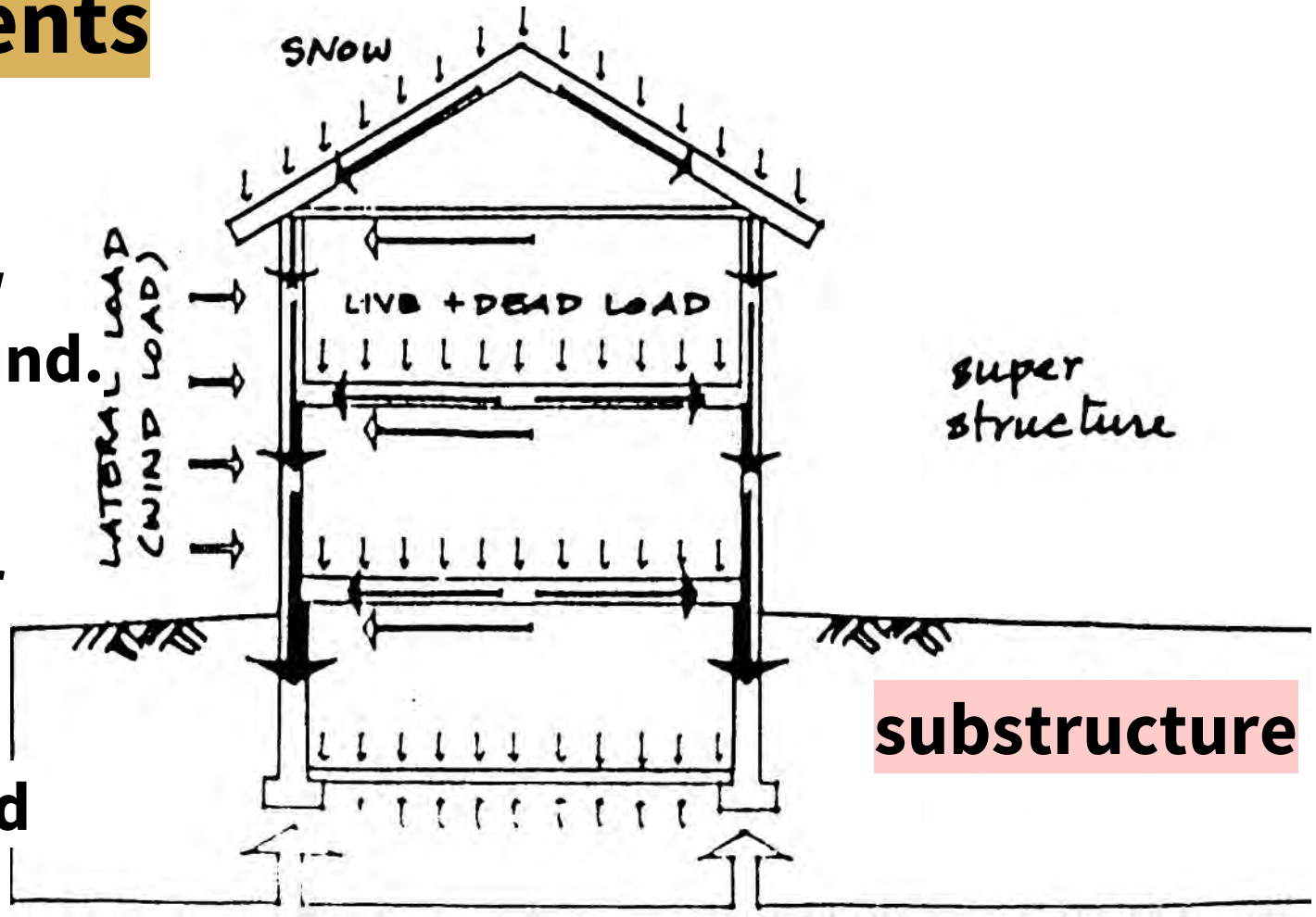
A system is:
An assembly or interrelated or interdependent parts of forming a more complex and unified whole.
Serving a common purpose.

Recap:
A structural system consists of a stable assembly of structural elements. They are designed to support and distribute the loads to the ground.

Structural system: Structural elements

Substructure:
Partly or wholly below the surface of the ground.

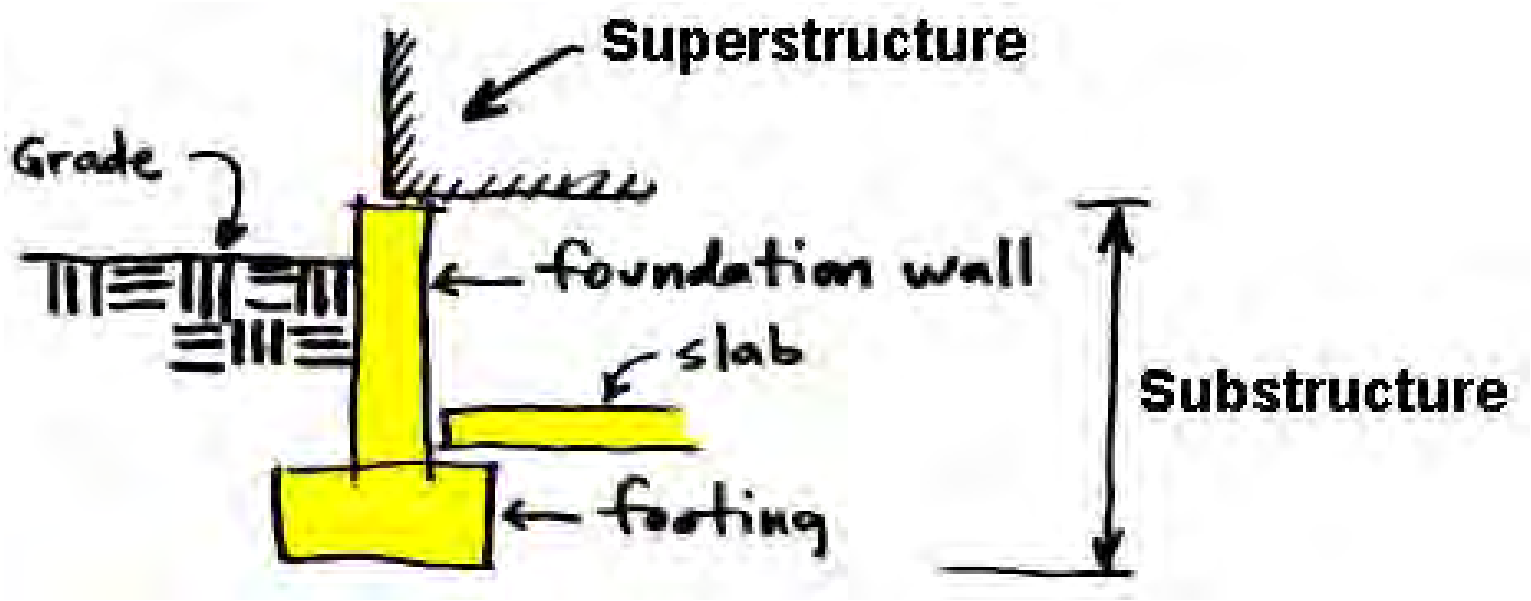
Primary function:
To support and anchor the super structure above.
And to transmit its load safely to earth.



Structural system: Structural elements

Substructure:
Consists of foundation, pier (column) and abutment.

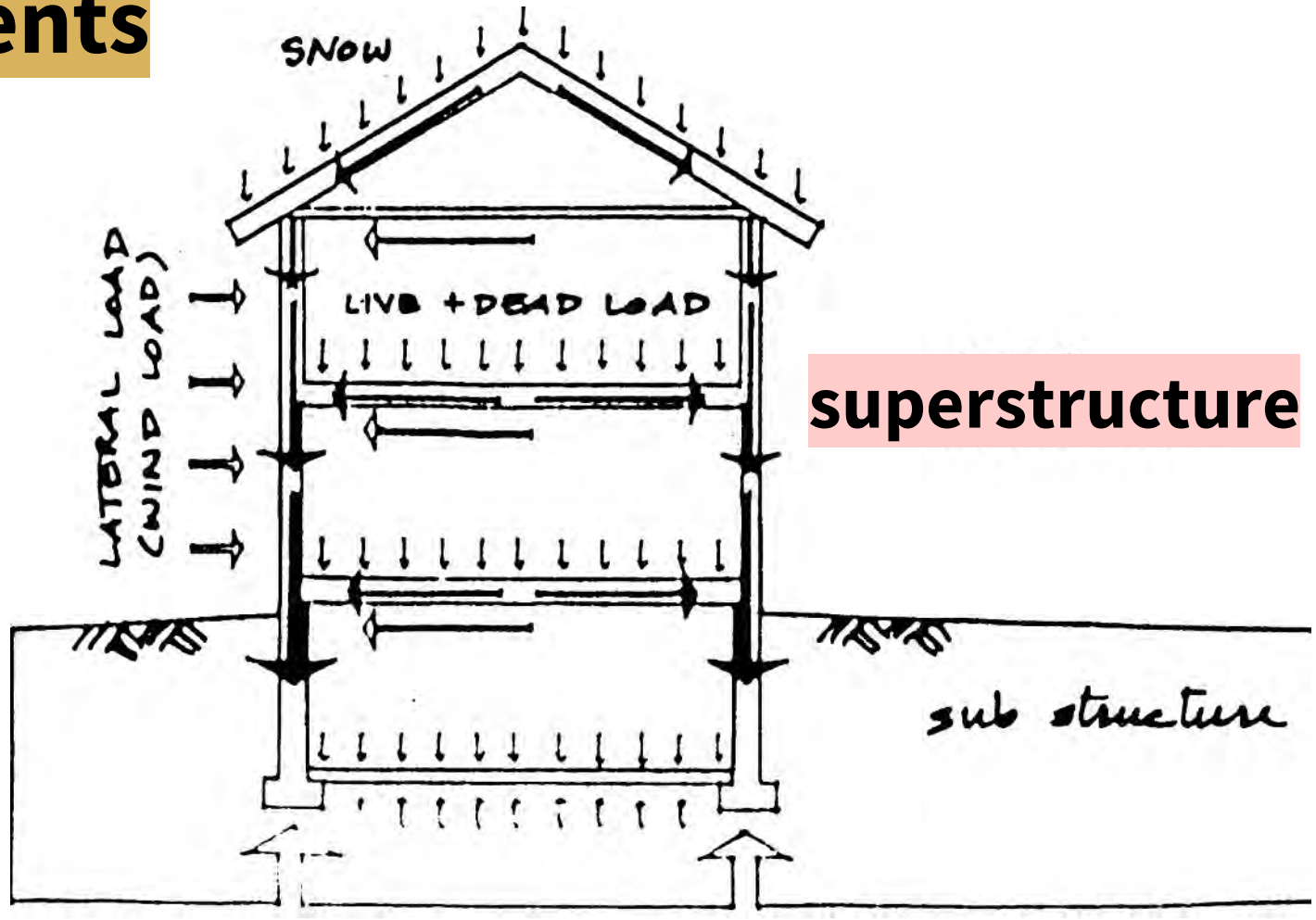
Example: footing

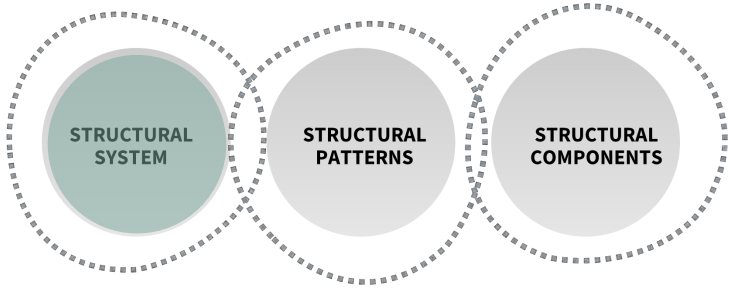


https://www.polytechnichub.com/difference-substructure-superstructure-building/

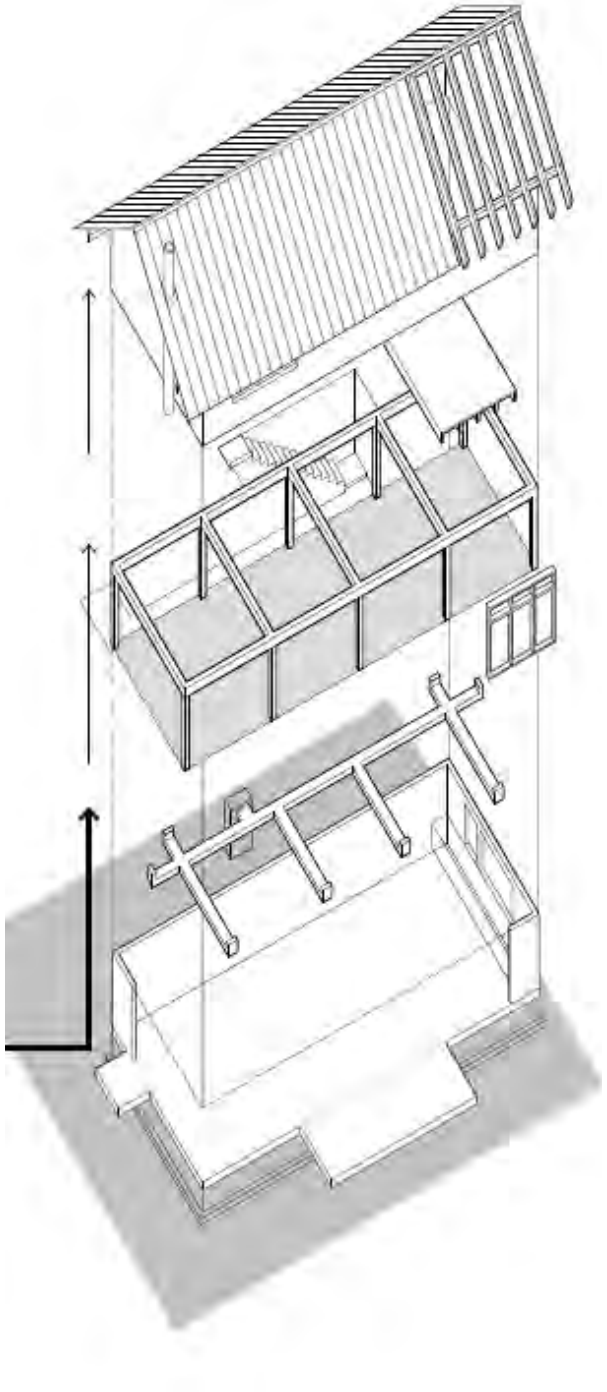
Structural system: Structural elements

Superstructure:
Vertical extension of a building above the foundation.





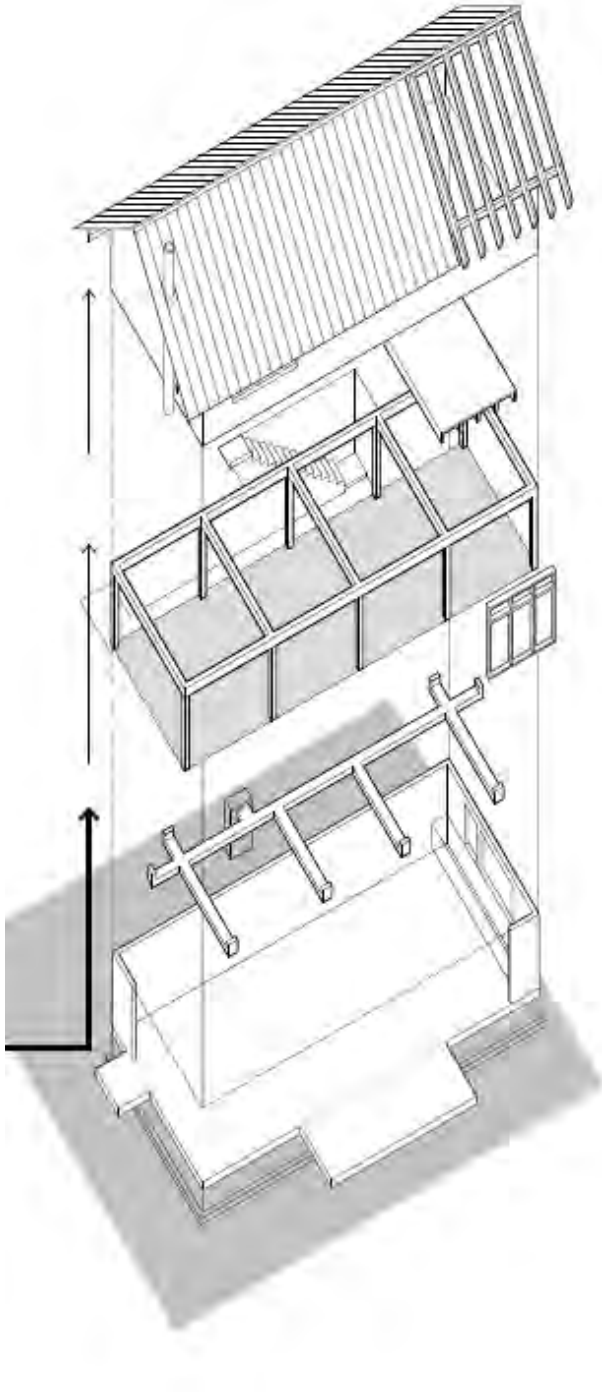
Structural system: Structural elements



In construction process, the super structure rises from the sub structure.

Superstructure:
Consists of shell and interior structure that defines form of a building and its spatial layout and composition.

Structural system: Structural elements

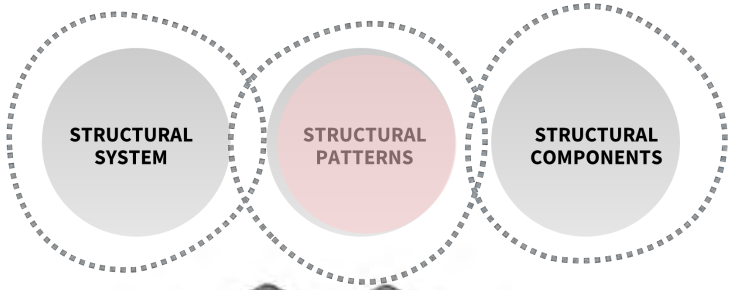


In construction process, the super structure rises from the sub structure.

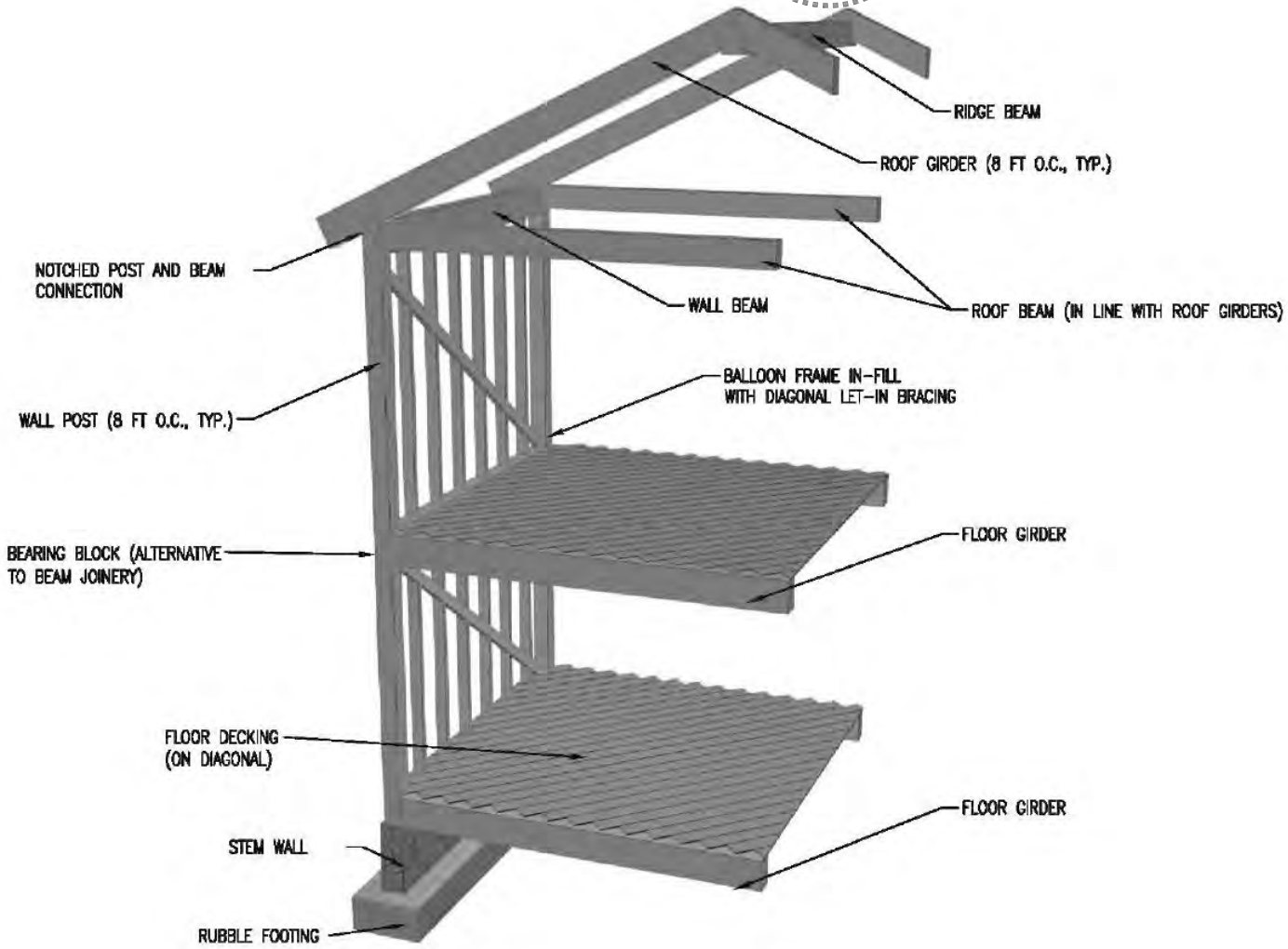
The shell includes: roof, exterior walls, windows, doors etc.

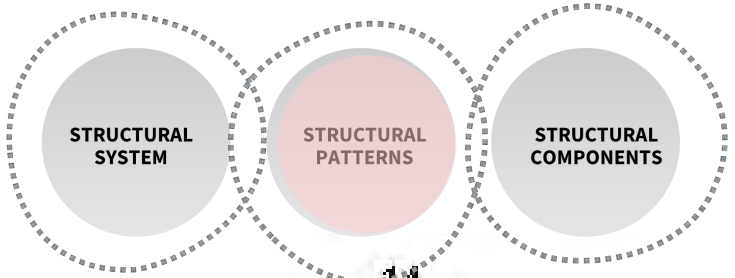
The structure includes: columns, beams, load bearing walls, floor structures, lateral-force-resisting elements for lateral stability.

Structural patterns



Structural patterns are: two dimensional or three-dimensional compositions consisting vertical supports, horizontal spanning system and lateral-force-resisting elements.

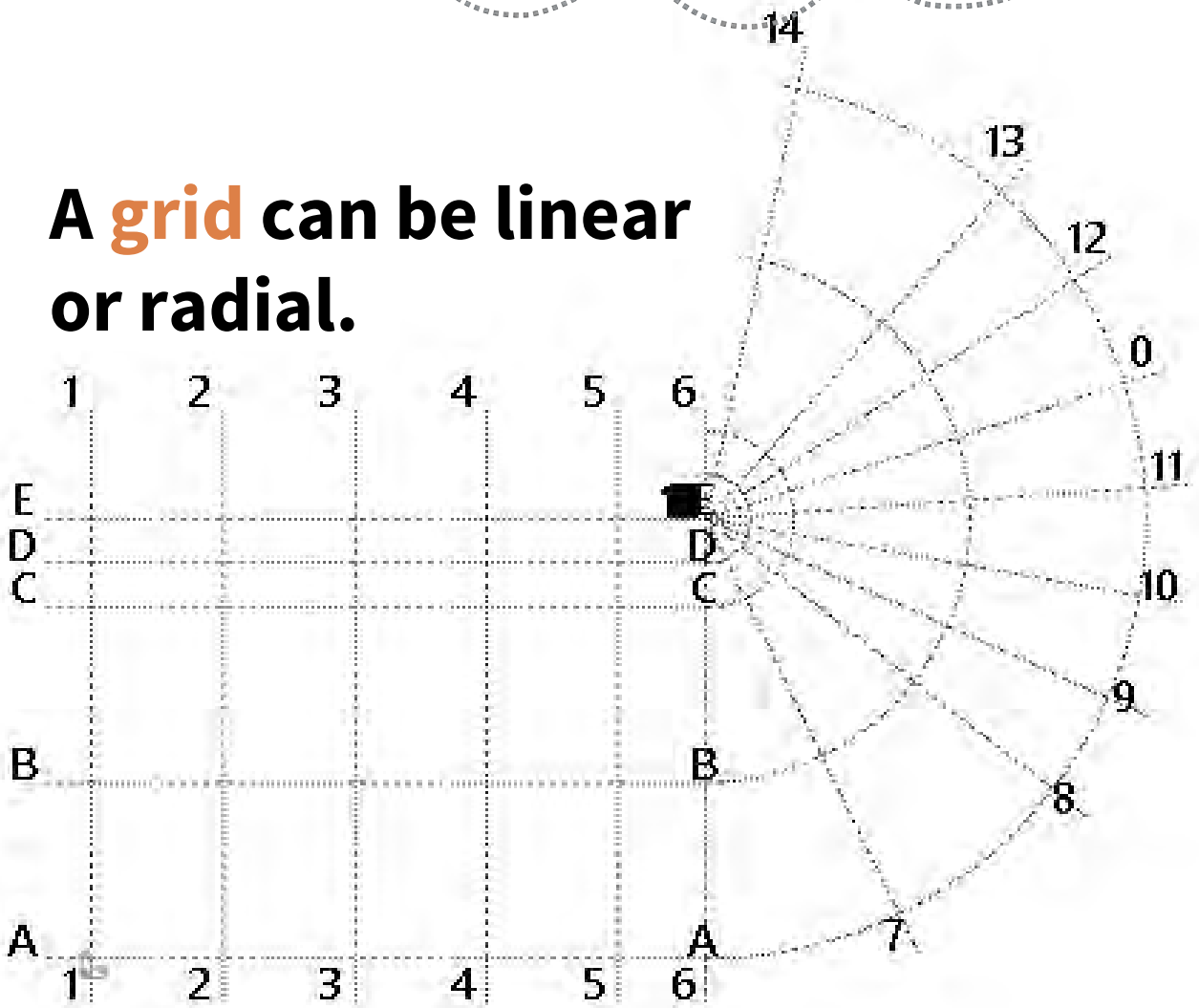




Structural patterns: Grid

A grid is a pattern of straight lines, usually equally spaces and intersecting at right angles, that serves as a reference for locating points.

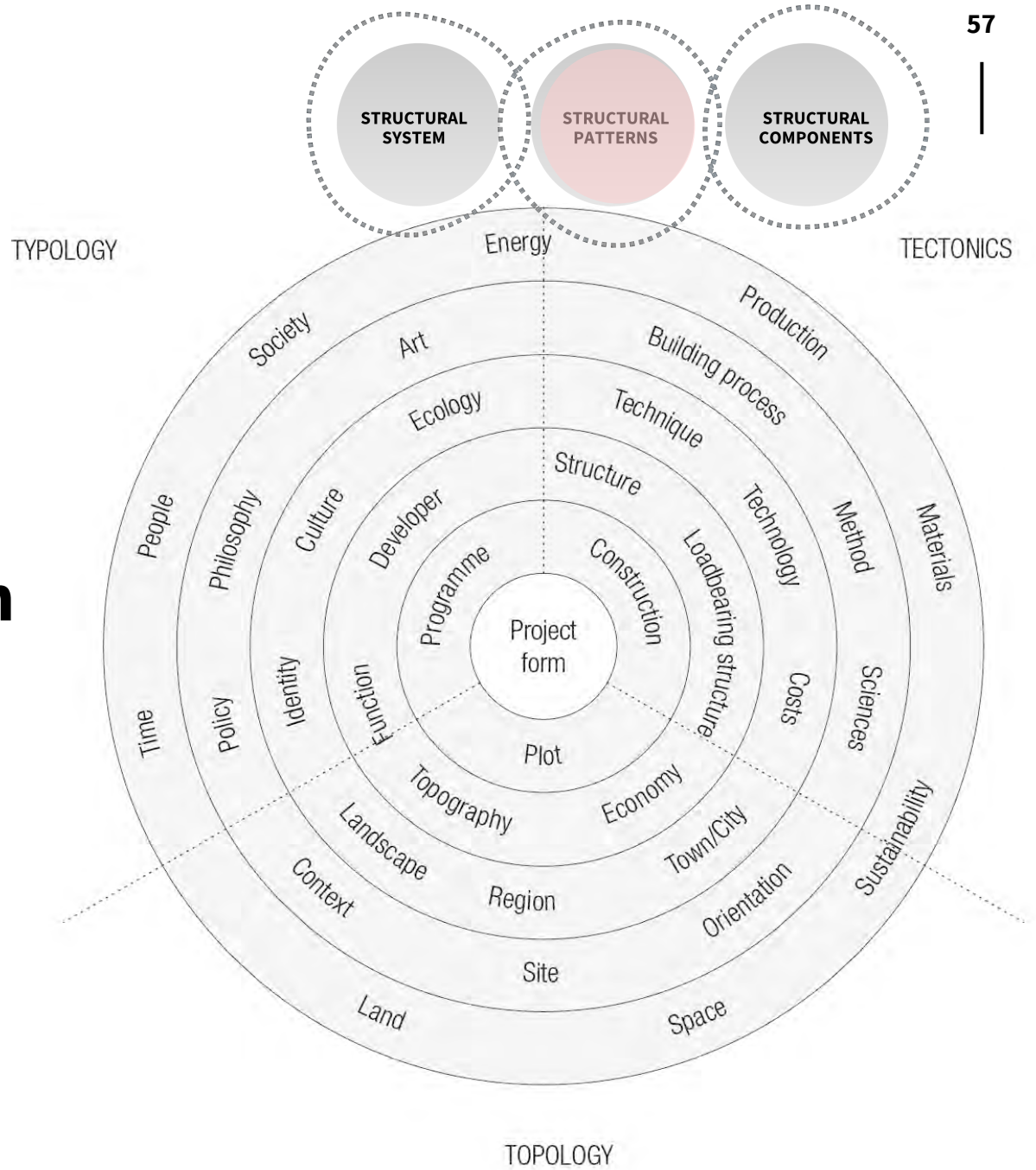
A grid can be linear or radial.



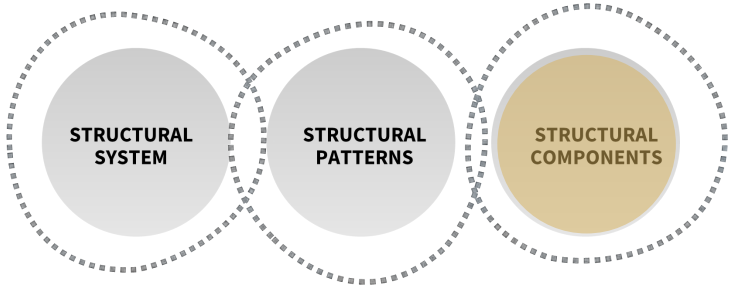
Structural patterns: Grid

The scale of grid is contributed by:

- **Types of activities within the space**
- **Efficient spanning system, which is highly related to**
- **Type of material system**



Structural components

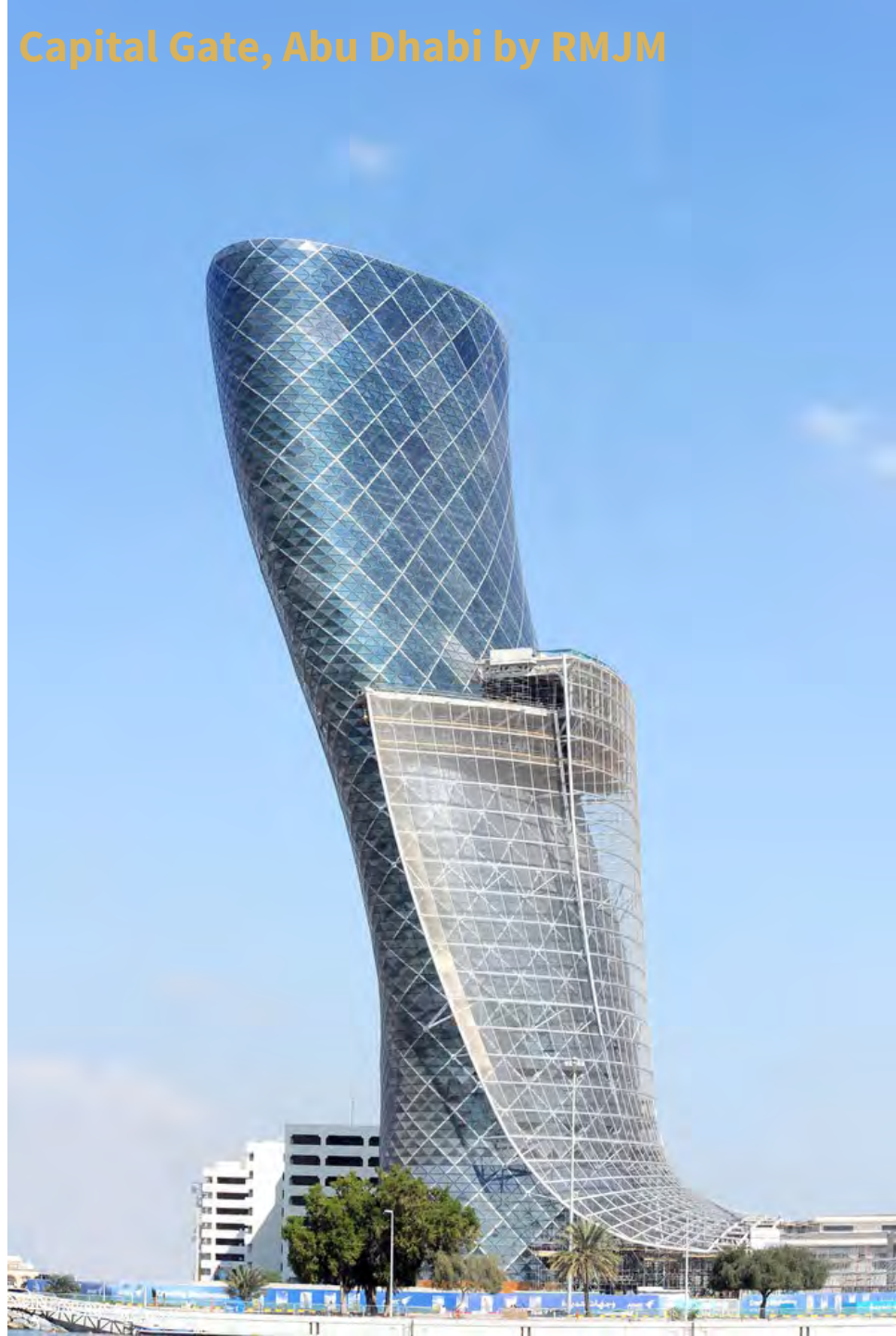


1. **Vertical dimension**
2. Horizontal spanning system
3. Lateral-force-resisting elements.

Structural components

1. **Vertical dimension**
2. Horizontal spanning system
3. Lateral-force-resisting elements.

- **Vertical continuity**
- **Low-rise, mid-rise and high-rise buildings**
- **Elements of vertical supports: columns, wall and roof structure.**


Capital Gate, Abu Dhabi by RMJM

Structural components

1. **Vertical dimension**
2. Horizontal spanning system
3. Lateral-force-resisting elements.

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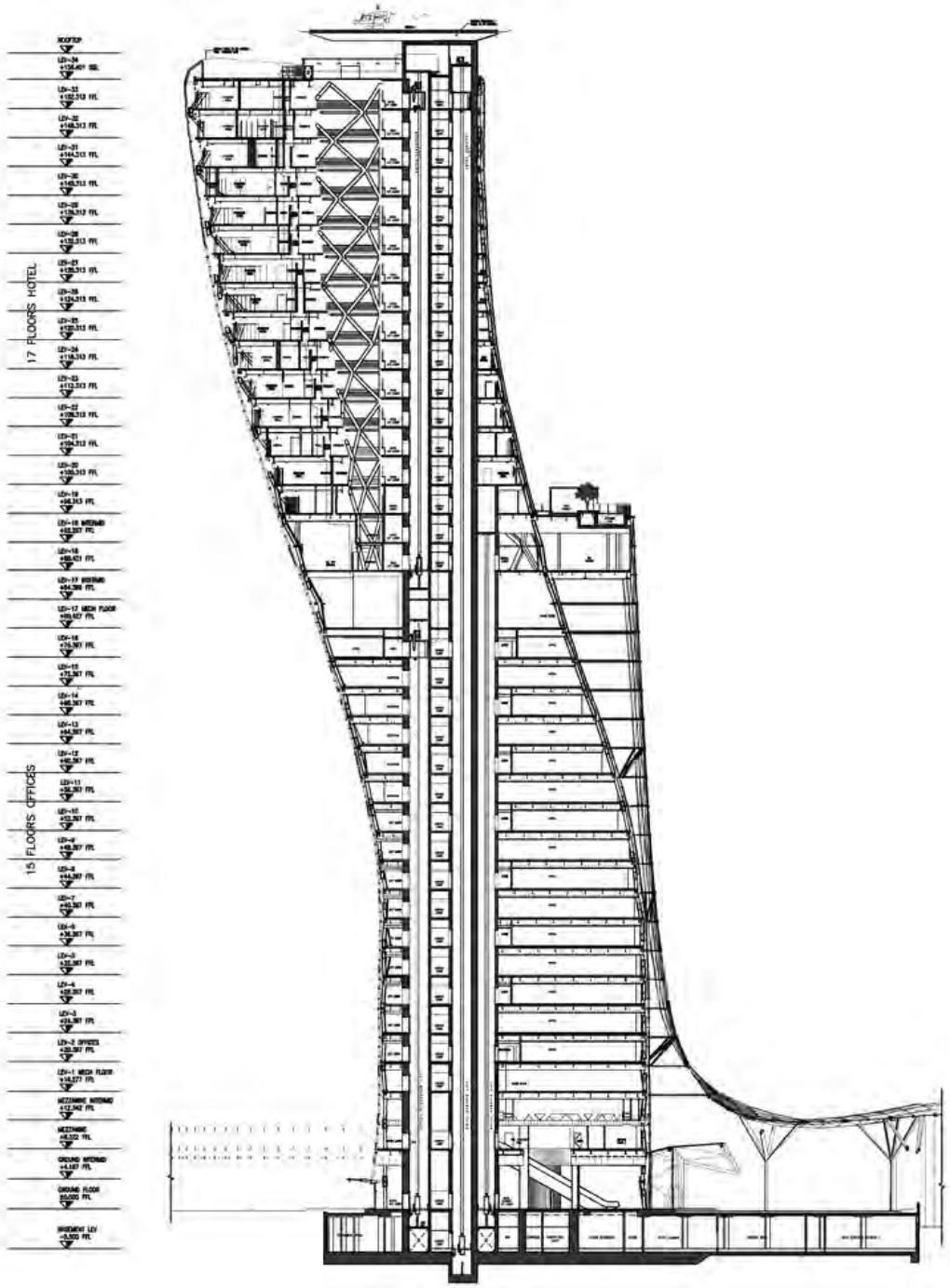
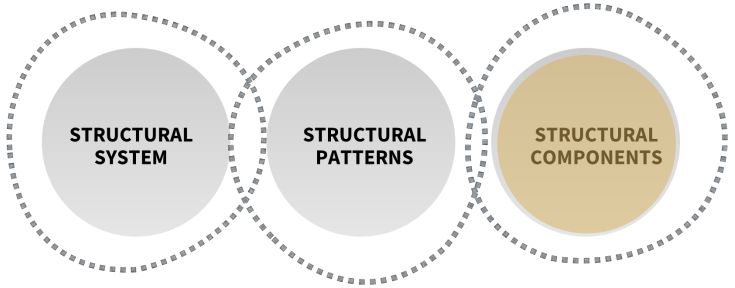
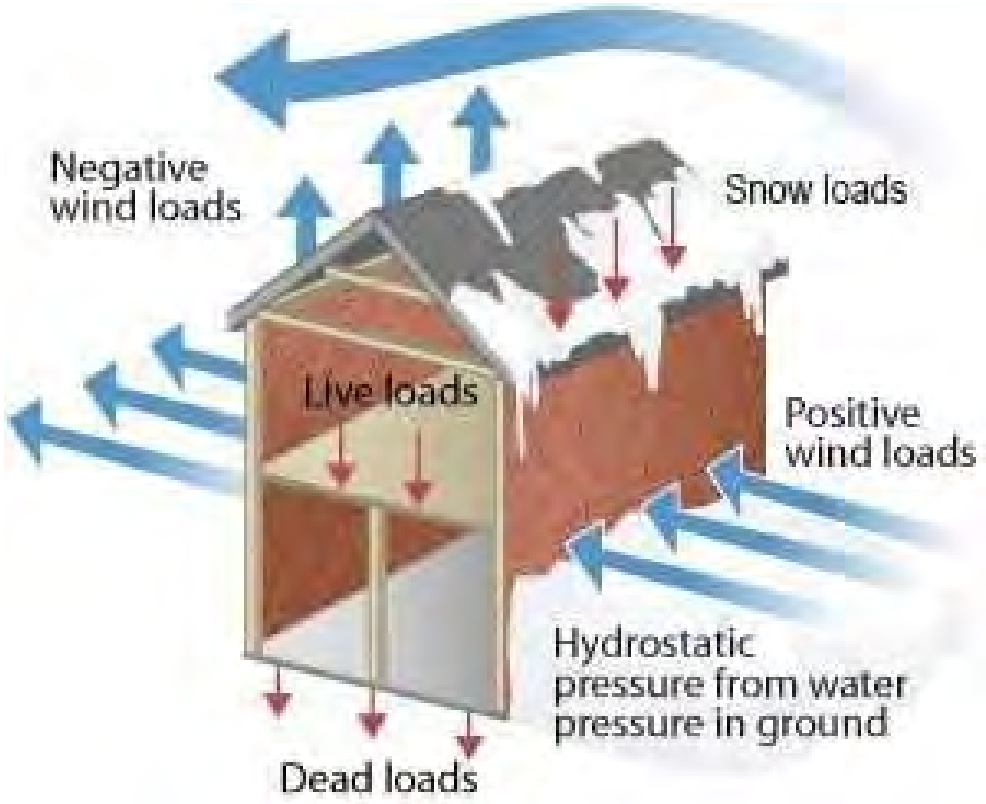


Structural components



1. **Vertical dimension**
2. Horizontal spanning system
3. Lateral-force-resisting elements.

- **Vertical continuity**
- **Low-rise, mid-rise and high-rise buildings**
- **Elements of vertical supports: columns, wall and roof structure.**



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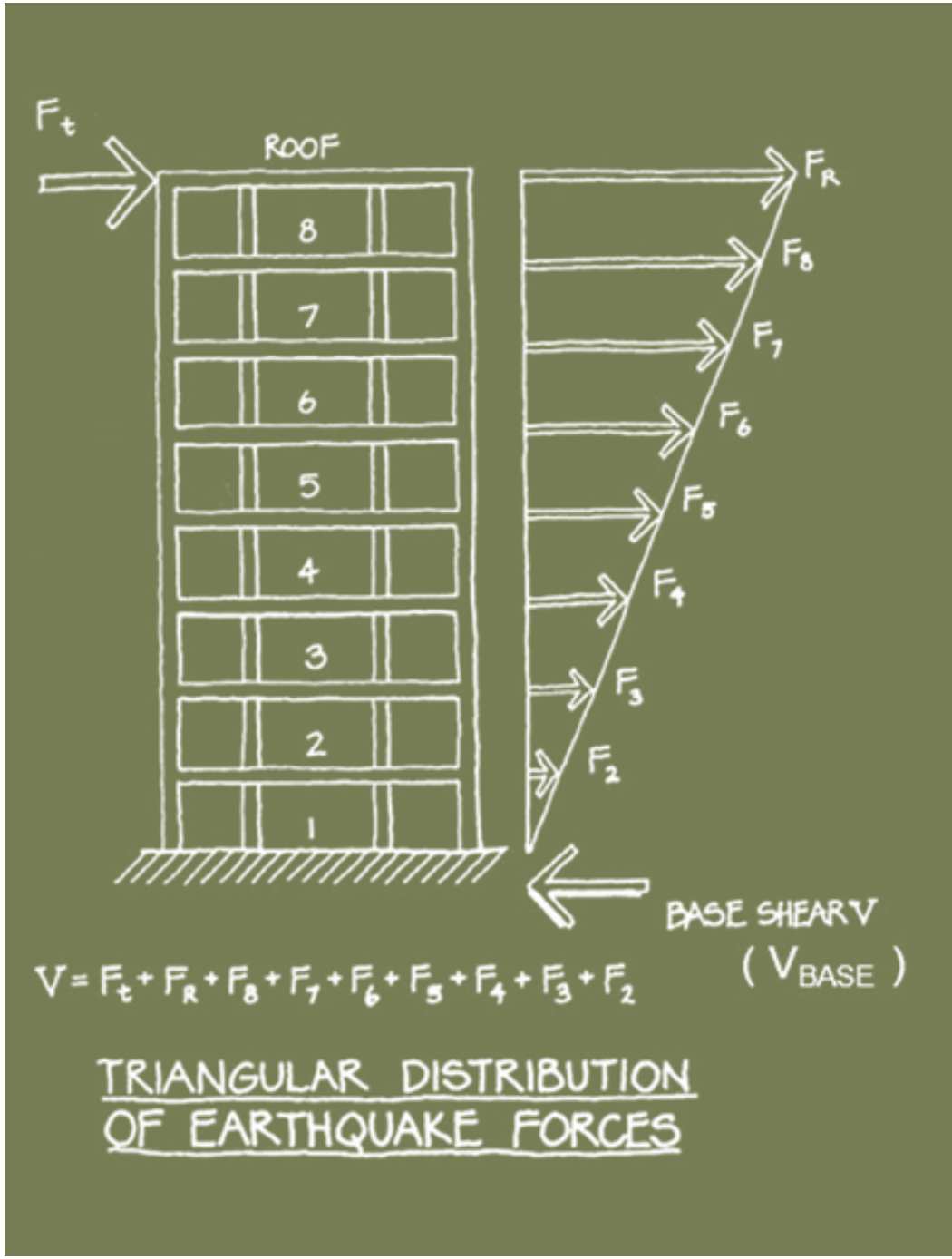

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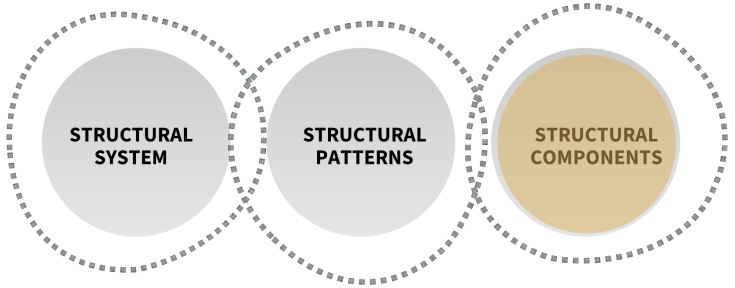

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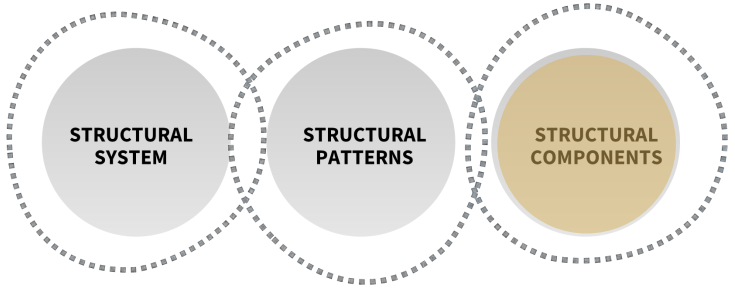
TYPES OF LOADS:

1. **Dead loads**
2. **Imposed loads/ live loads**
3. **Wind loads**
4. **Seismic loads**
5. **Snow loads**
6. **Other loads and effects acting on structures (foundation movement, fatigue, etc)**



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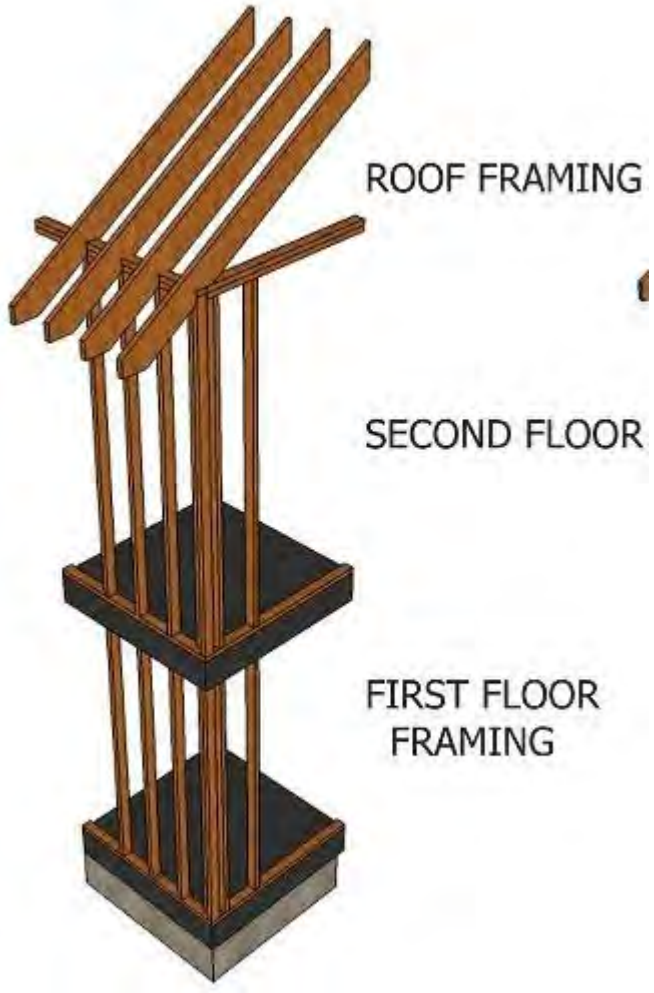

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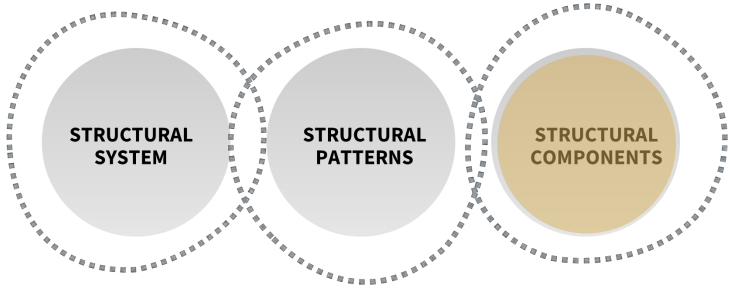


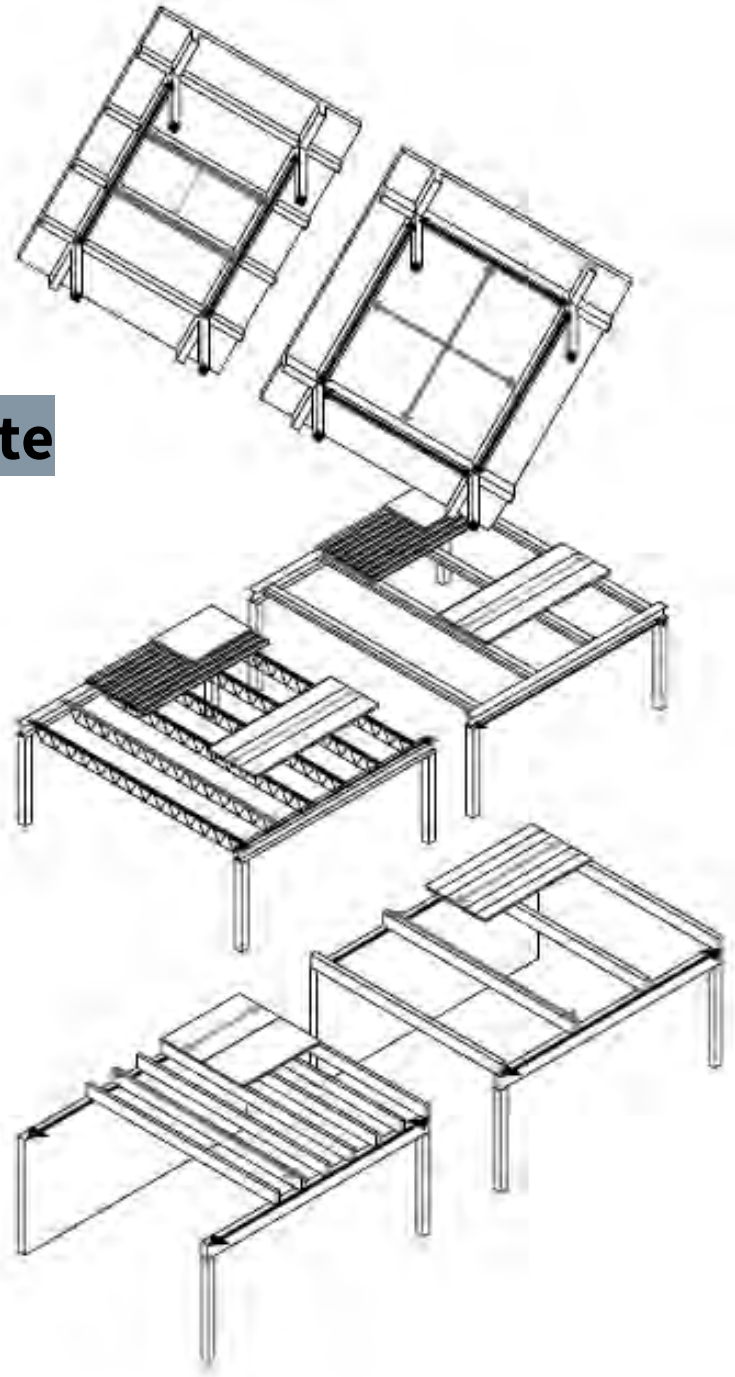
1. Vertical dimension
2. **Horizontal spanning system**
3. Lateral-force-resisting elements.

Consists of:
Floor and roof structures, such as joists, beams and slabs.

Function:
To transfer transverse loads across space to supporting elements.

Structural components

1. Vertical dimension
2. **Horizontal spanning system**
3. Lateral-force-resisting elements.



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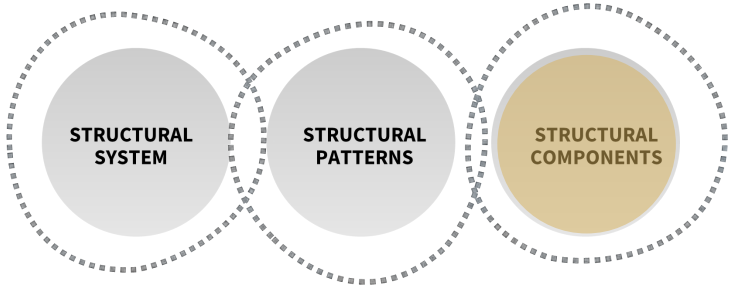

1. Vertical dimension
2. Horizontal spanning system
3. **Lateral-force-resisting elements.**

Primary concern: earthquake and wind

Common technique:
Braced frame
Shear wall
Moment-resisting frame

Structural components

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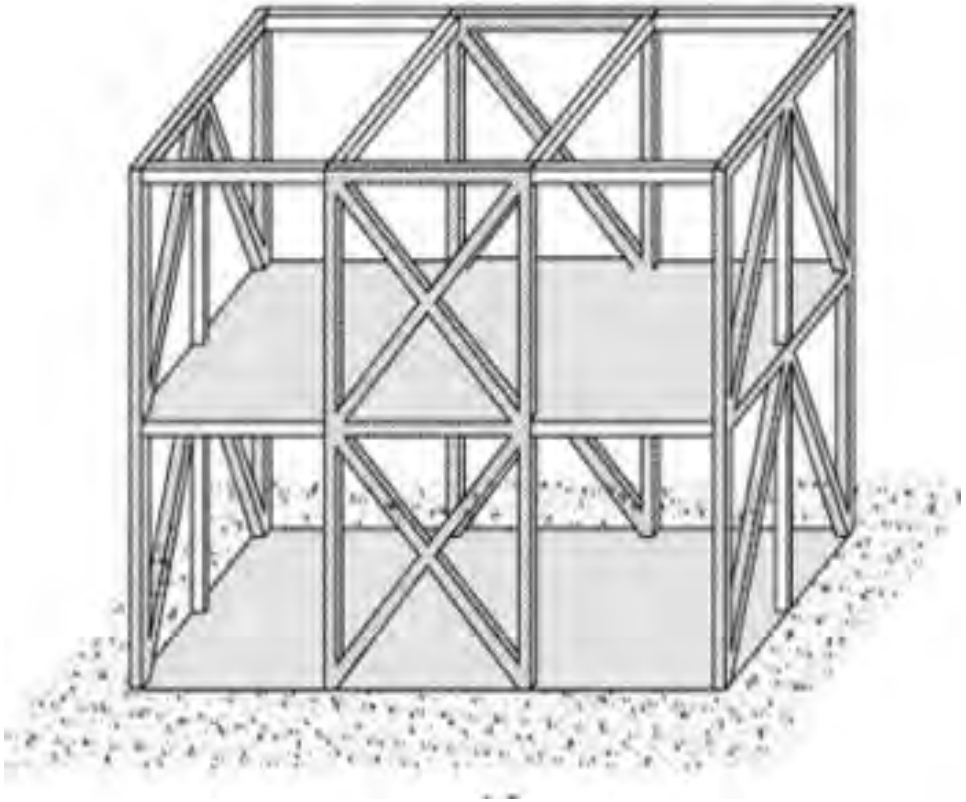

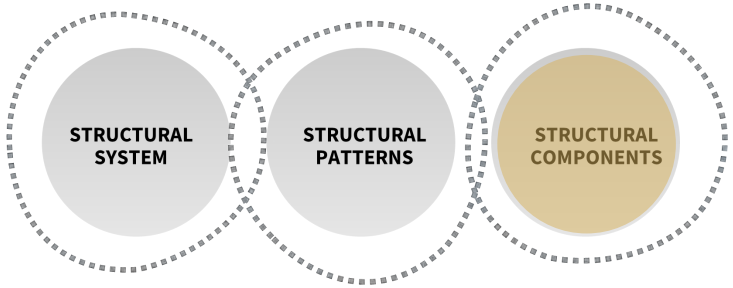

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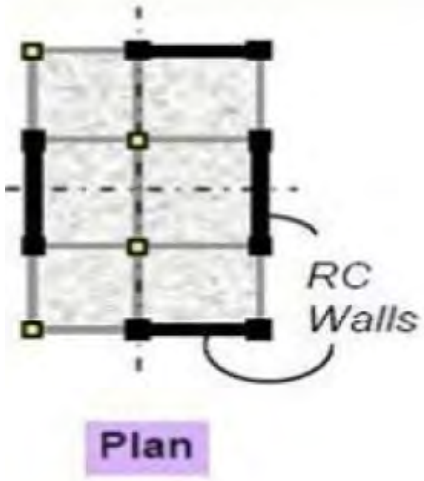

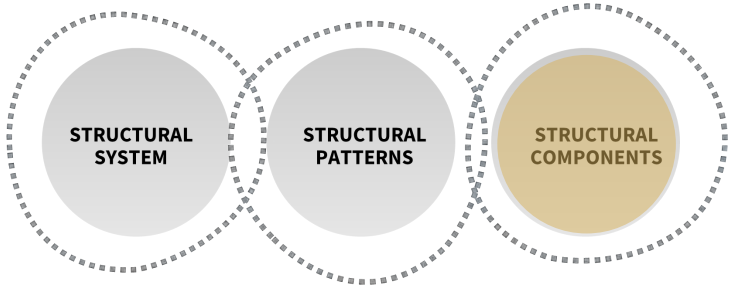

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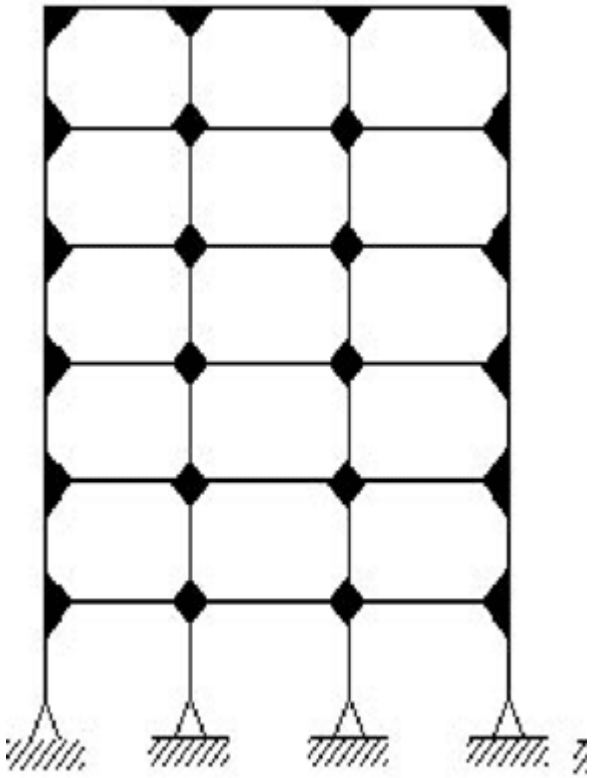

(a) Moment resisting frames

History changes our understanding of building structures

From stone structure, vaults & arches, to the invention of steel, when buildings become lighter, taller, span longer.

Glass as translucent structural material.

ACTIVITIES

1. GROUP ONLINE RESEARCH AND DISCUSSION: 40MINS
2. GROUP PRESENTATION (10MINS EACH GROUP), INCLUDING Q&A
3. ONLINE SUBMISSION: 10MINS

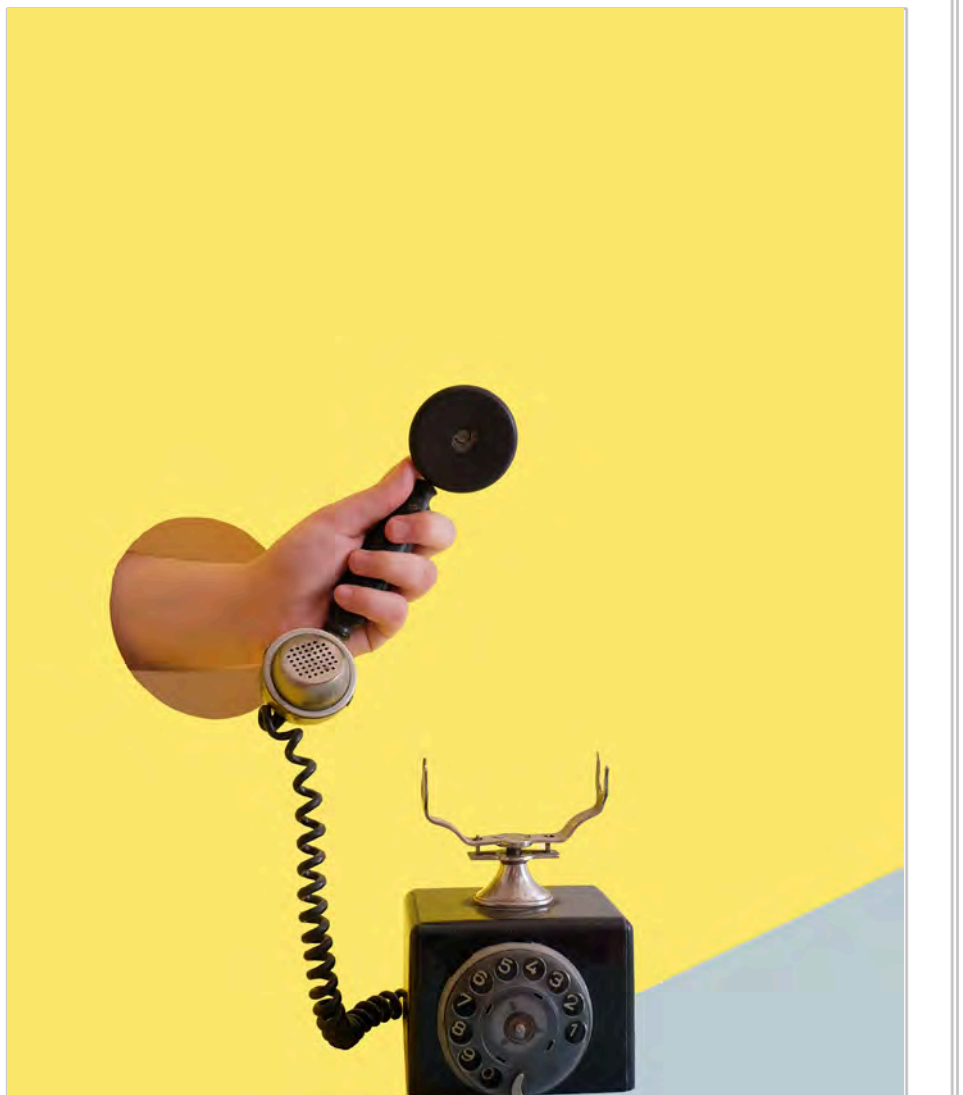

Photo by Elena Koycheva on Unsplash

1- Group
online research

40 minutes

Go online and find one example of the implementation of:

- Centre of gravity/ law of the lever (hint: consider also cantilevered structures)
- The elasticity of materials (hint- suspension bridge?)
- Columns
- Structural calculation (not the Eifel tower please!)
- Interrelationship of parts (where combinations of above elements have been used. E.g. column and cantilever)

2- Group presentation

10 minutes per group, followed by Q&A by other groups

Now, present your findings to the group

You should be prepared to say:

- Which building you've selected (for each example- there may be several buildings to cover all of the criteria)
- How the implementation is demonstrated
- Why you think the designers arrived at this solution
- How you think the design might be improved

3- Online submission

https://miatedjosaputro.com/2022/02/27/as3-week-2/

Individual submission

Brief summary of what your group presented and your own (individual) reflection.

Please include project data (location, sources, etc)

Learning materials

https://miatedjosaputro.com/2022/02/27/as3-week-2/
password: nbu-as

PDF of ppt slides

Re-treating aims and objectives

- To expand **historical background** of the concept of understanding structure behaviour.
- To **contextualise** the need to look backward through the history to shape our understanding on building structure.
- To enumerate **milestones** and **related theories** in building construction with regards to structure behaviour.
- To elicit **key concepts,** which we can consider in future architecture practice.