ARCHITECTURAL STRUCTURE

Week 5: Concrete structure

Photo by uve sanchez on Unsplash

Outline

1
INTRODUCTION

Aims

LOs

2
LECTURE:

- CONCRETE AS BUILDING MATERIAL
- ELEMENTS OF CONCRETE STRUCTURE
- FUTURE CHALLENGES

3

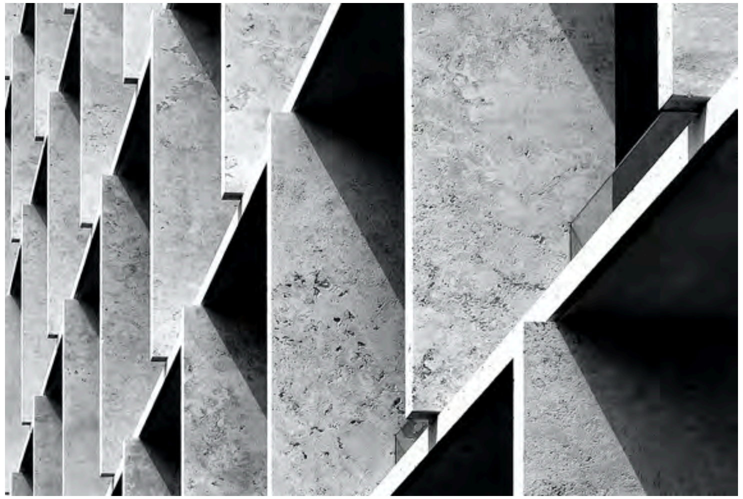
SEMINAR

- DESIGN PRECEDENTS SHARING SESSION

4

SUMMARY REFLECTION

- ~~UPLOADING STUDY MATERIALS TO DISQUS~~



LECTURE

The brief lecture to kickstart the discussion on concrete structure.

SEMINAR

Active learning through peer presentations, followed by Q&A session

A combination of

student –led

learning

experience

Photo by 준영 박 and Ricardo Gomez Angel on Unsplash

Aims and objectives

- To gain understanding on concrete as **building materials** and its characteristics
- To learn about concrete as main **structural materials**
- To expand on concrete within **construction system**

Learning outcomes

Students will be able to..

01 Understand strength and weaknesses of concrete as building materials

02 Potentially incorporate the use of concrete in future projects

03 Become aware of structural behaviour of the material

Part 1:
Concrete as building material

Photo by Maxim Hopman on Unsplash

Historical perspective

- Dated back around **7000BC**. Concrete floor was found in Yiftah El in southern Galilee, Israel → Stone Age man was technologically advanced.

BritishCementAssociation (1999). *Concrete through the ages,* Berkshire, British Cement Association.

Historical perspective

- Historically, concrete was used as early as the times of the ancient Mayans.
- Early **cement** (*meaning to glue, to bond*) was not used until the 1830s as concrete- cement was used as mortar, to cause building blocks such as bricks to adhere to one another. Cement was commonly made of lime in early times. Such mixes were used by the Romans as both plaster and concrete, then rediscovered in the 18th century.

Fried, A., Roberts, J. J. & Tovey, A. (2014). *Concrete masonry designer's handbook*, CRC Press.

Historical perspective

- The first entirely concrete-built house dates back to **1835** in Kent, UK. It was built for John Bazley White, a major manufacturer of Roman cement in Seacombe, Kent.

Fried, A., Roberts, J. J. & Tovey, A. (2014). *Concrete masonry designer's handbook*, CRC Press.

From Wikipedia

"**Portland cement** is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar, and many plasters. British masonry worker **Joseph Aspdin** patented Portland cement in **1824.** It was named because of the similarity of its color to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture.

It consists of a mixture of calcium silicates (alite, belite), aluminates and ferrites—compounds which combine calcium, silicon, aluminum and iron in forms which will react with water. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay or shale (a source of silicon, aluminum and iron) and grinding this product (called *clinker*) with a source of **sulfate** (most commonly gypsum)."

Gypsum

Gypsum is **a crucial component of concrete.** It is a finite resource, as are other materials used in concrete. It is found in the following places:

Estimated production of Gypsum in 2015(thousand metric tons)[19]		
Country	Production	Reserves
China	132,000	N/A
Iran	22,000	1,600
Thailand	12,500	N/A
United States	11,500	700,000
Turkey	10,000	N/A
Spain	6,400	N/A
Mexico	5,300	N/A
Japan	5,000	N/A
Russia	4,500	N/A
Italy	4,100	N/A
India	3,500	39,000
Australia	3,500	N/A
Oman	3,500	N/A
Brazil	3,300	290,000
France	3,300	N/A
Canada	2,700	450,000
Saudi Arabia	2,400	N/A
Algeria	2,200	N/A
Germany	1,800	450,000
Argentina	1,400	N/A
Pakistan	1,300	N/A
United Kingdom	1,200	55,000
Other countries	15,000	N/A
World total	258,000	N/A

The making of concrete

(in lieu of hands-on class due to pandemic)

Duration: 4mins

https://youtu.be/sbpHsedLxkM

Poll: What is in the mixture?

https://PollEv.com/free_text_polls/xAUjS9CI6vtIkmV6NuDP1/respond

Why concrete?

- It became more common after WW2 as steel was scarce (having been largely depleted by munitions manufacture)
- There was **massive rebuilding** in many parts of the world, and traditional brick and mortar structures are time consuming to produce.
- One of the urgent tasks in the post-war was the construction of schools to take influx of children following post-war baby boom.
- In 1960s: prefabricated wall, floor and roof units

Roman concrete

Is the Ancient Roman concrete better than modern concrete?

In the mixture: volcanic ash, lime and seawater.

[Why 2,000 Year-Old Roman Concrete Is So Much Better Than What We Produce Today (sciencealert.com)]

Photo by Evan Qu on Unsplash

Popularity of concrete

Due to many reasons:

- Widespread availability (typically produced within 100km of the building site)
- Low embodied carbon due to simplified logistics
- Economically attractive
- Good mechanical properties- strong in compression (though weak in tension and shear: see “reinforced concrete” later)
- Thermal and acoustic properties
- Speed of construction
- Fits to any desired shapes and forms

Fits to any desired shapes and forms




What is good concrete?

Criteria:

- Concrete has to be **satisfactory** in its **hardened state,** also in
- **Fresh state** while being transported from the mixer and placed in form work.

Consistency of the mix can be compacted by the means desired without excessive effort. The mix is also **cohesive** enough so as **not to produce segregation**.

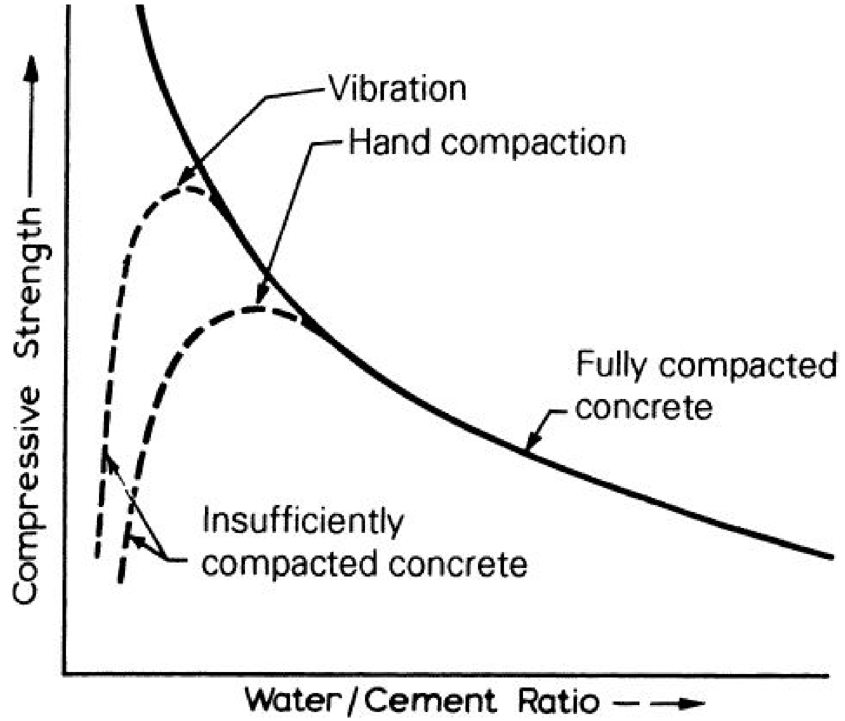
Neville, A. M. (1995). *Properties of concrete*, Longman London.

Strength of concrete?

Primarily depends on two factors:

- Water/cement ratio
- Degree of compaction

The influence of air voids.



Neville, A. M. (1995). *Properties of concrete*, Longman London.

Factors affecting concrete deterioration

Due to many reasons: external factors and internal factors.

Can be **physical, chemical or mechanical**.

Physical damage includes the effects of high temperature or of the differences in thermal expansion of aggregate and of the hardened cement paste. Alternating freezing and thawing and associated action of de-icing salts. Damage resulted by chlorides.

Mechanical damage caused by impact, abrasion, erosion and cavitation.

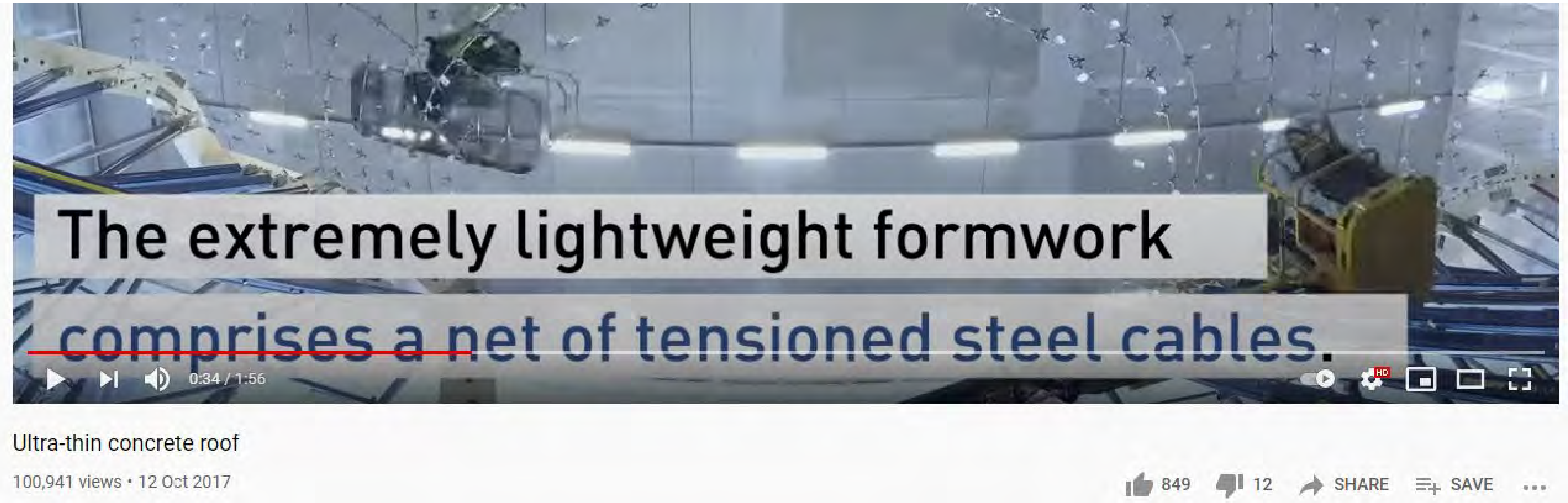
Chemical damage: The alkali-silica and alkali-carbonate reactions

ETH Zurich (BRG): Ultra-thin concrete roof

Duration: 2 mins

Block Research Group (ethz.ch)

https://youtu.be/Ki1EcBCurqc



Why concrete needs reinforcement

Duration: 8 mins

https://youtu.be/cZINeaDjisY

Part 2:
Types of concrete structure

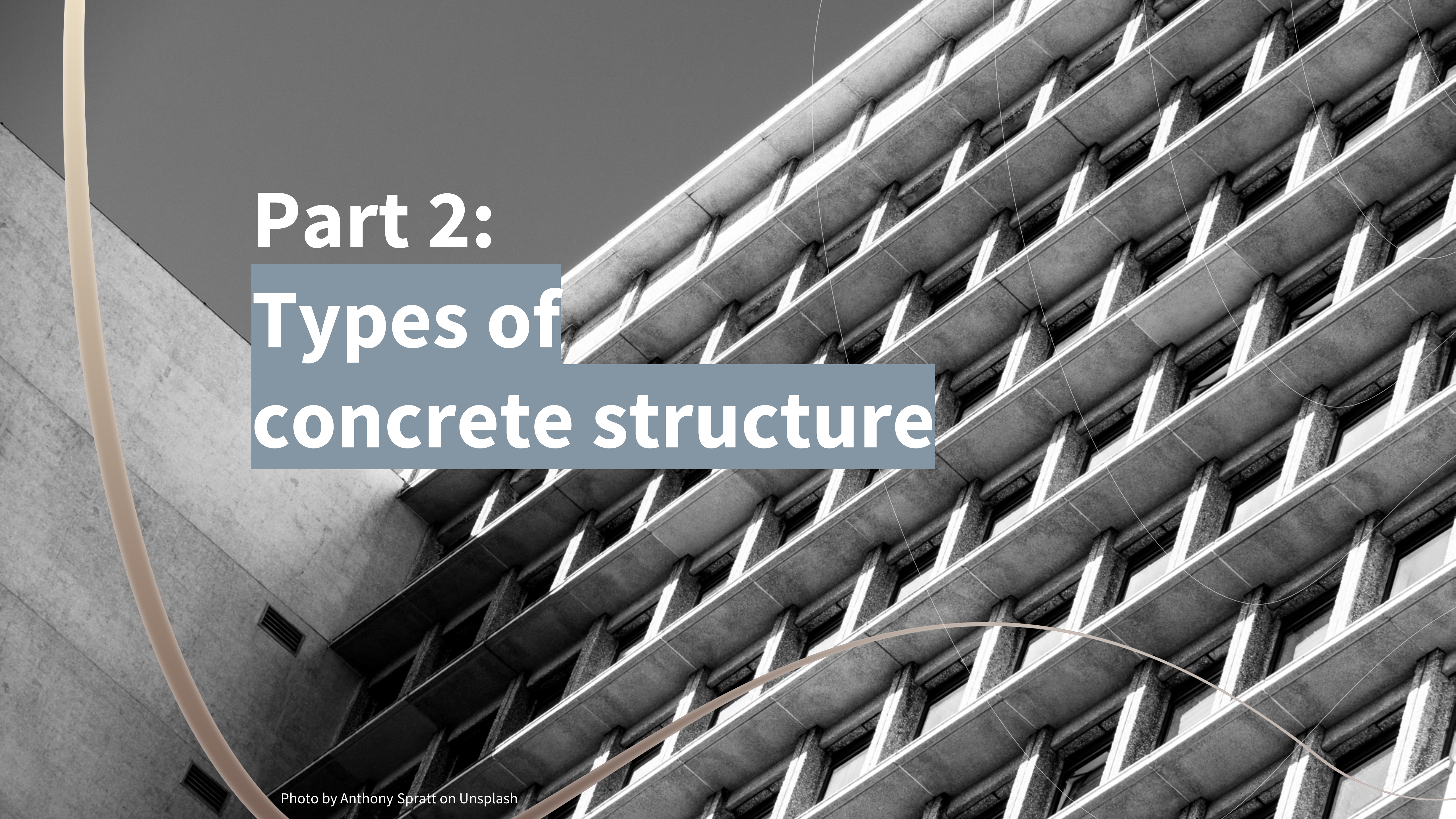


Photo by Anthony Spratt on Unsplash

1 | REINFORCED CONCRETE

2 | PRESTRESSED CONCRETE

3 | PRECAST CONCRETE

4 | CONCRETE MASONRY

1- REINFORCED CONCRETE

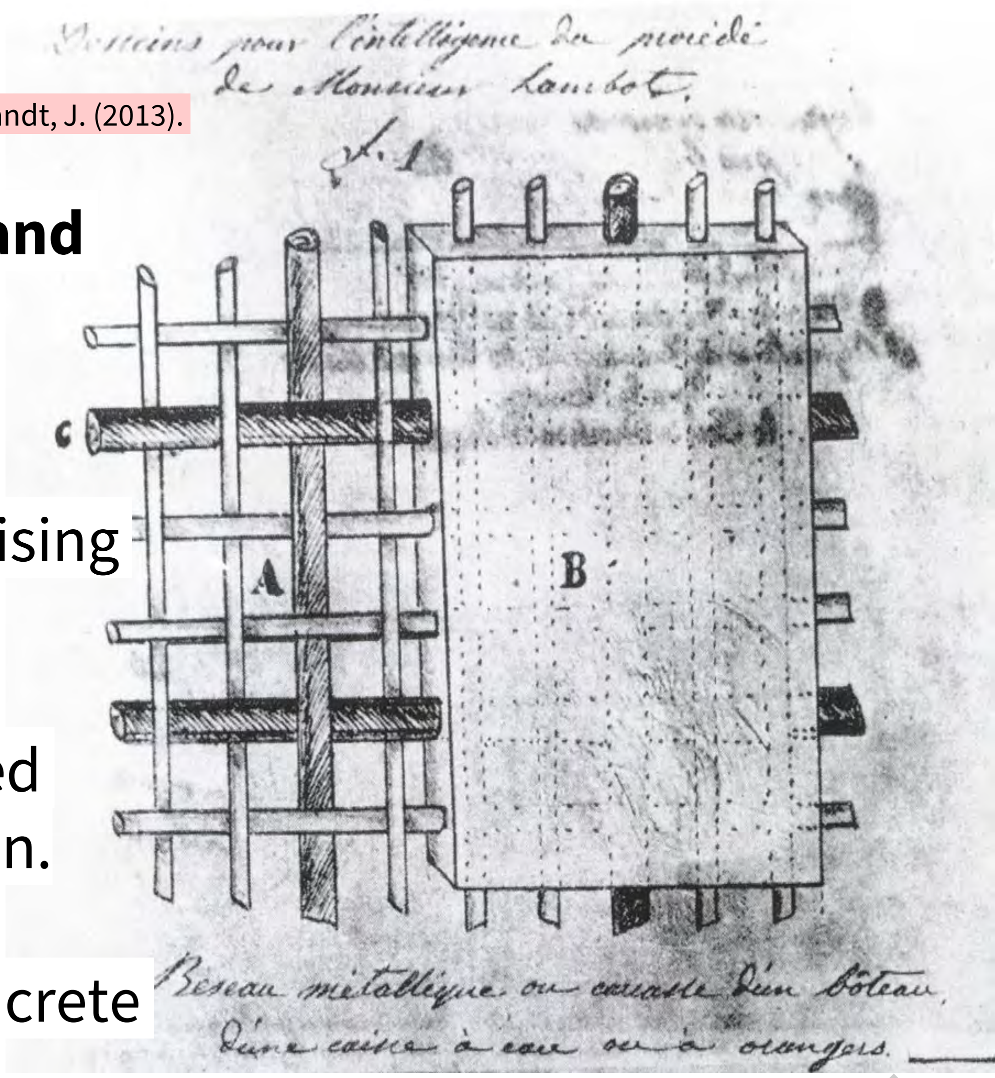
Kind-Barkauskas, F., Kauhsen, B., Polónyi, S. & Brandt, J. (2013). *Concrete construction manual*, Walter de Gruyter.

In 1854 English stucco master **William Boutland Wilkinson** applied for a patent for an iron-reinforced concrete composite floor slab.

T.E. Tyerman patented iron inserts for stabilising structures and components also in 1854.

Franyois Coignet in 1855 developed a tamped concrete method- imitating loam construction.

Josef Louis Lambot patented reinforced concrete as a substitute for timber in 1855 (see image).



1- REINFORCED CONCRETE

- Fundamentally, this means using **reinforcing material inside the concrete**, usually steel
- **Rebar**- Reinforcing bar- is most common
- This **can mitigate mechanical weaknesses** of concrete, e.g. tension, shear, span etc.

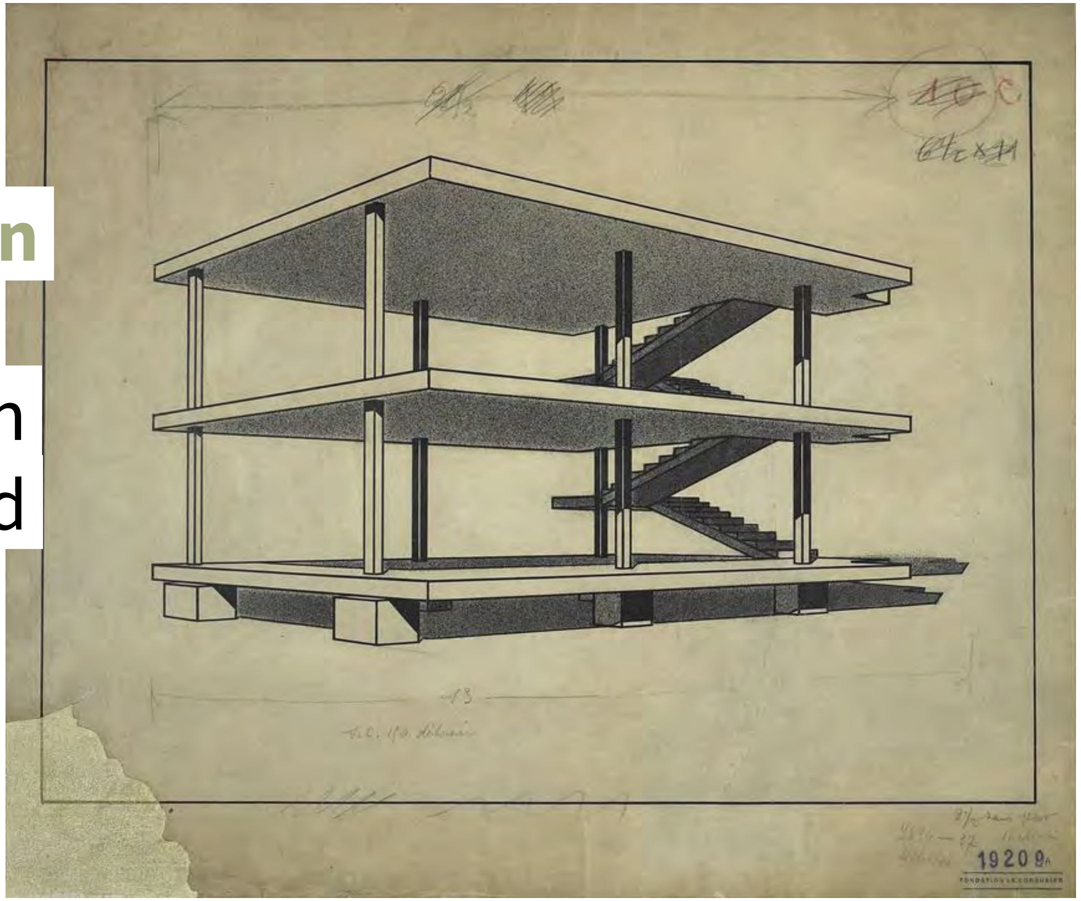
1- REINFORCED CONCRETE in Modern Movement

"After iron, reinforced concrete is probably the most important invention in the realm of materials, perhaps the most important of all because reinforced concrete possesses all the properties that are missing in iron - and because the properties of ***stone and iron are united*** *in this building material…"*

Dutch architect, Hendrik Petrus Berlage (1922)

1- REINFORCED CONCRETE in Modern Movement

Le Corbusier developed his **Maison Domino** units made from prefabricated standard elements in 1914. Only columns, floor slabs and stairs are reinforced concrete, the rest could be filled in according to user's ideas.



Fondation Le Corbusier - Projects - Maison Dom-Ino

1- REINFORCED CONCRETE Advantages as a structural material

1. Has considerable compressive strength
2. Great resistance to the actions of fire and water
3. Reinforced concrete structure is very rigid
4. Low-maintenance material
5. Compare to other materials, it has a very long service life
6. The only economical material available for footings, floor slabs, basements, and similar applications

1- REINFORCED CONCRETE

Advantages as a structural material

7. The ability to be cast into an extraordinary variety of shapes
8. In most areas, concrete takes advantages of inexpensive local materials
9. Lower grade of skilled labour is required

1- REINFORCED CONCRETE Disadvantages as a structural material

1. Low tensile strength, which requires tensile reinforcing
2. Forms are required to hold the concrete in place until it hardens
3. Low strength per unit of weight: Its large dead weight has a great effect on bending moments, especially in long-span. Members will be relatively large
4. Properties of concrete varies, depending on the mixing.

1- REINFORCED CONCRETE

Fibre-reinforced concrete

The **fibres** are made from steel, plastics, glass and other materials. Resulting concrete are substantially tougher and have great resistance to cracking and higher impact resistance.

Reinforced in small scale, in all directions.

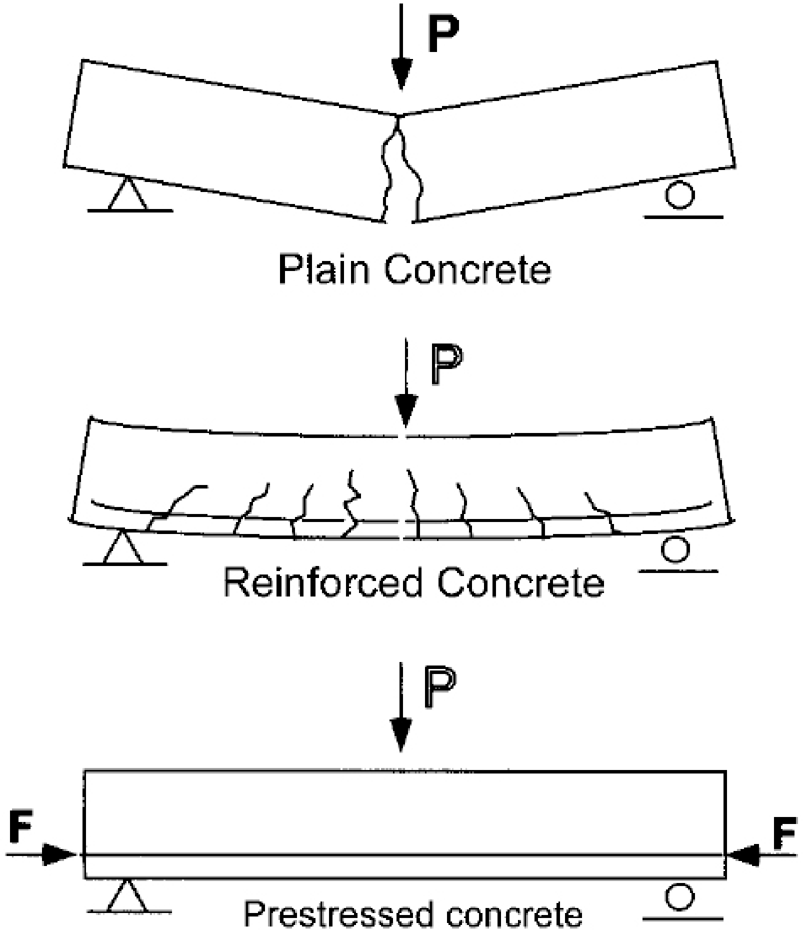
McCormac, J. C. & Brown, R. H. (2015). *Design of reinforced concrete*, John Wiley & Sons.

2- PRESTRESSED CONCRETE

- This is a process to ensure the concrete is in its final, stable form before building
- It can mean that it has been stretched to its limit for example, so that structural elements in tension will not stretch and compromise the integrity of the structure over time

2- PRESTRESSED CONCRETE

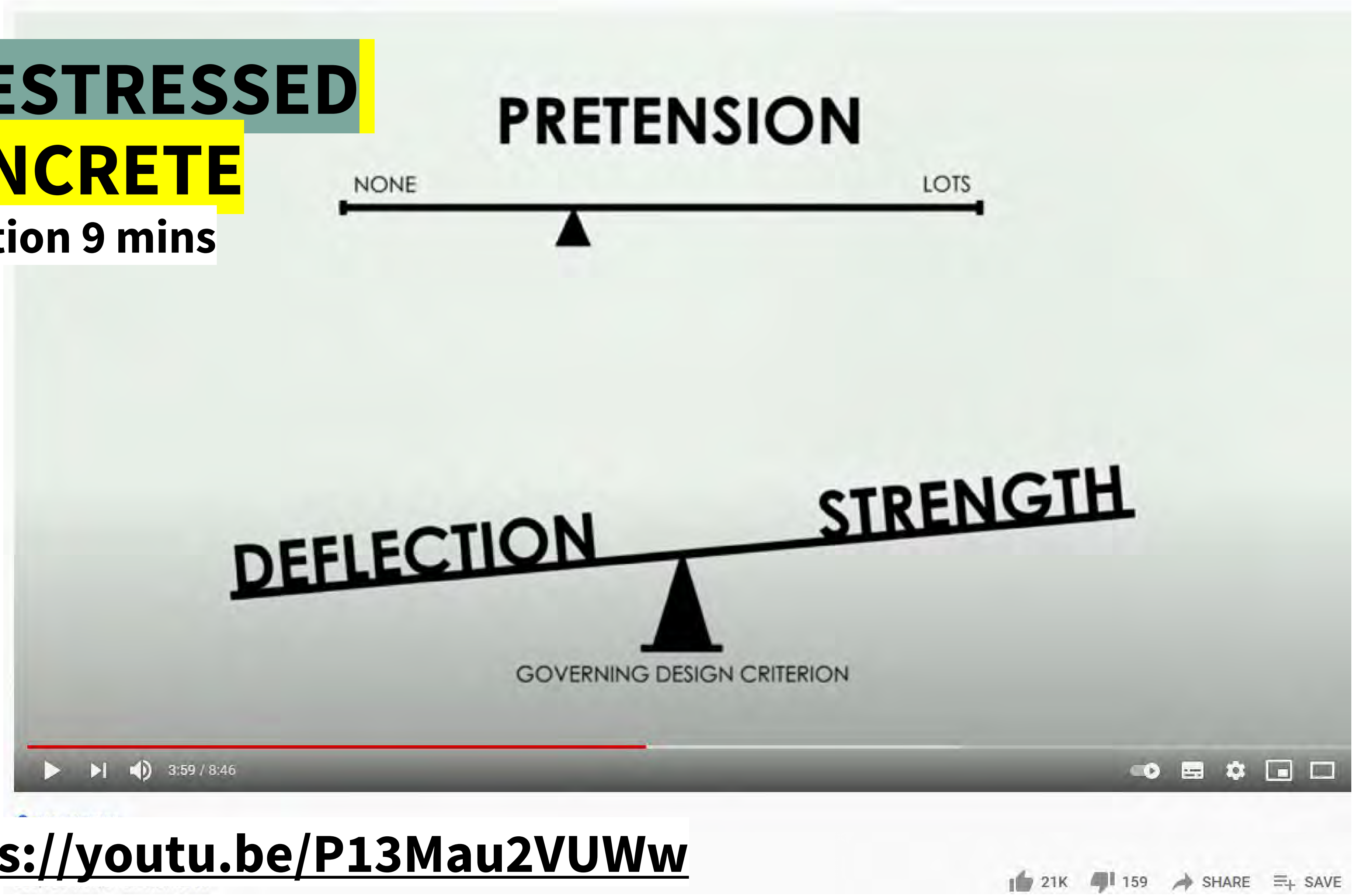
- A deliberate creation of permanent internal stresses in a structure to improve performance.



Kind-Barkauskas, F., Kauhsen, B., Polónyi, S. & Brandt, J. (2013). *Concrete construction manual*, Walter de Gruyter.

2- PRESTRESSED CONCRETE

Duration 9 mins



https://youtu.be/P13Mau2VUWw

2- PRESTRESSED CONCRETE

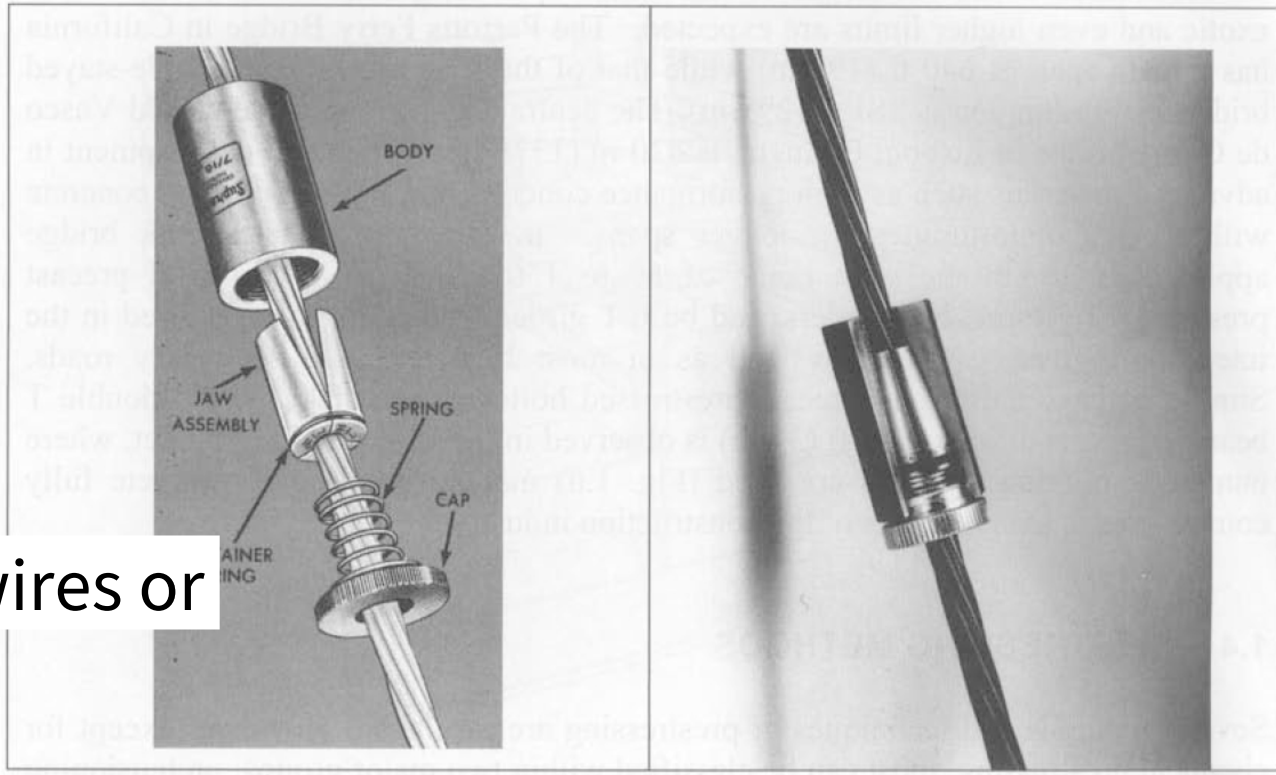
- The first application was by P.H. Jackson, an engineer from California in **1886**. The performance was hindered by quality of steel at the time.
- Common use: bridges, building components such as beams, slabs and columns, pipes and piles, etc.
- **Methods:** **Pretensioning** and **posttensioning**

Naaman, A. E. (1982). *Prestressed concrete analysis and design: Fundamentals*, McGraw-Hill New York.

2- PRESTRESSED CONCRETE

Pretensioning

- The prestressing tendons (wires or strands) are stretched to a predetermined tension and anchored to fixed bulkheads or molds.
- The concrete is poured around the stressed tendons.
- The concrete is **compressed.**



1.7 Typical chuck anchor for a single tendon. *(Courtesy Supreme Products Corporation.)*

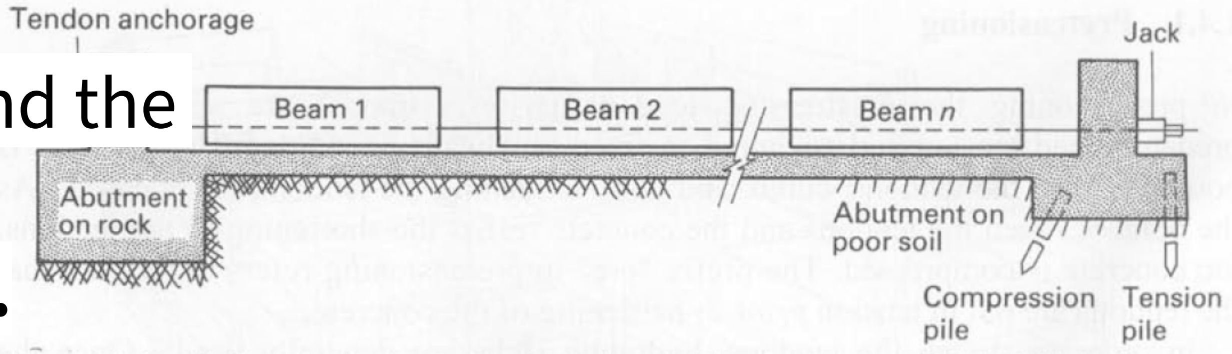


Figure 1.8 Typical pretensioning bed and abutments showing beams with straight tendons.

2- PRESTRESSED CONCRETE

Pretensioning

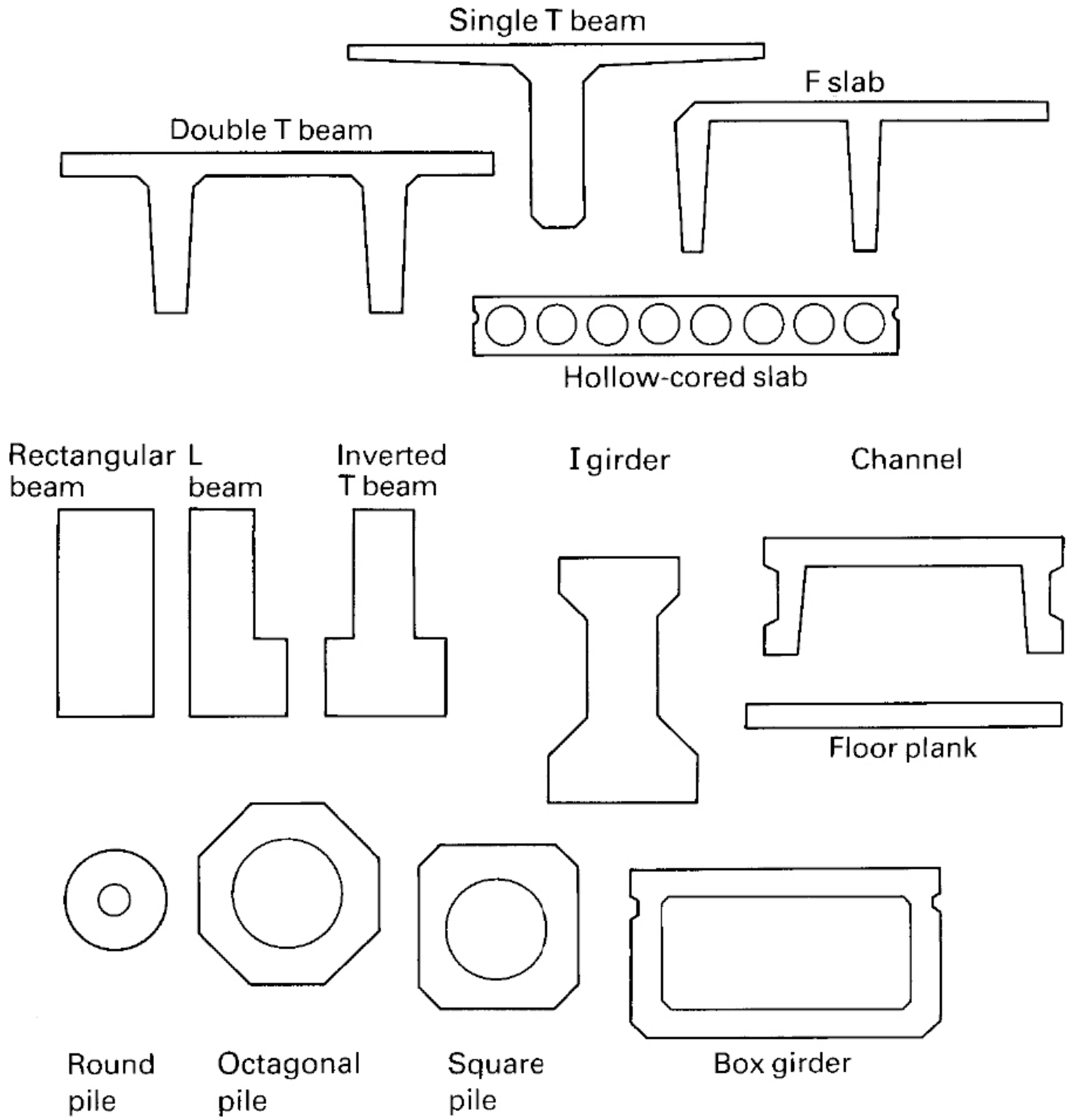


Figure 1.11 Typical standard sections of precast prestressed concrete products in the United States.

2- PRESTRESSED CONCRETE

Posttensioning

- The tendons are stressed and anchored at the ends of the concrete **after** the member has been cast and attain sufficient strength.
- Commonly used in large scale projects or customised structures which need tensioning on the job site.

2- PRESTRESSED CONCRETE

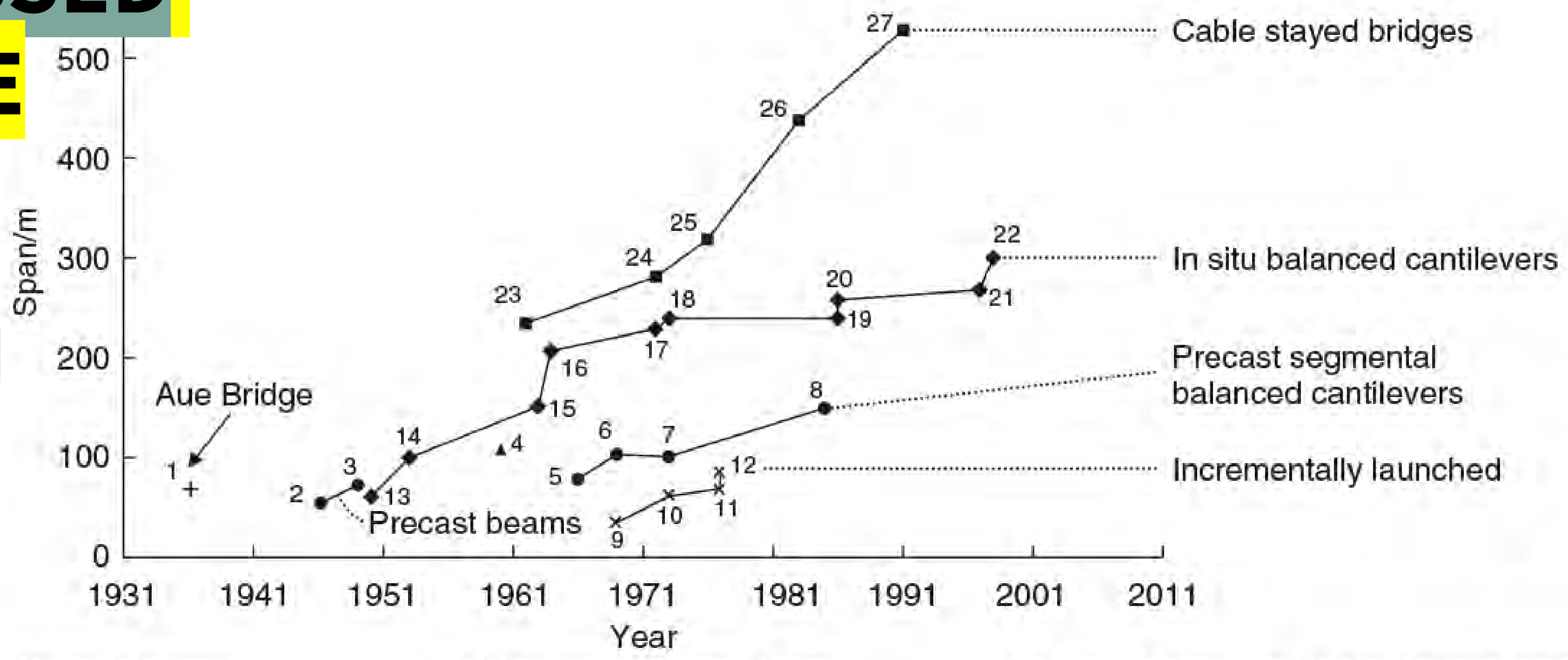
Prestressed concrete deck

Byker Viaduct, Newcastle, England

2- PRESTRESSED CONCRETE

Hewson, N. R. (2003). *Prestressed concrete bridges: design and construction*, Thomas Telford.

Figure 1.22 Longest prestressed concrete bridge span length plotted against year



1 Aue Bridge, Saxony
2 Luzancy Bridge, France
3 Esbly Bridge, France
4 Mangfall Truss Bridge, Germany
5 Oleron Viaduct, France
6 Chillon Viaducts, Switzerland
7 St Cloud Bridge, France
8 Bahrain Causeway, Saudi Arabia
9 Pipeline Bridge, Italy
10 Horomoi Bridge, Japan
11 Necker Bridge, Germany
12 Leck Bridge, Germany
13 Lahn Bridge, Germany
14 Nibelungen Bridge, Germany
15 Medway Bridge, UK
16 Bendorf Bridge, Germany
17 Urato Bridge, Japan
18 Hamana Bridge, Japan
19 Koror-Babelthaup Bridge, Pacific Islands
20 Brisbane Gateway, Australia
21 Humen Bridge, China
22 Stolmasundet Bridge, Norway
23 Rafael Urdaneta Bridge, Venezuela
24 Wadi Kuf, Libya
25 Brotonne Bridge, France
26 Barrios de Luna, Spain
27 Skarnsundet Bridge, Norway

3- PRECAST CONCRETE

- This is a process to **mould the concrete** into certain shapes before construction
- Shapes can be **complex** and tessellating, or simple- e.g. slabs, sheets etc. (commonly used in walls/ floors)

3- PRECAST CONCRETE

Advantages of factory production

- Improved quality: better working conditions, skilled workers, dimensional accuracy, possibility on having architectural textures and colours and efficient quality management.
- Lower production costs: Reducing the cost of formwork, total elimination of scaffolding costs, material saving, better for prestressing.
- Faster construction: Shorter construction time as elements can be produced simultaneously, no extensive on-site facilities are required, financial savings.

Bachmann, H. & Steinle, A. (2011). *Precast concrete structures*, Wiley Online Library.

3- PRECAST CONCRETE Disadvantages

- Require careful supervision
- Difficult to achieve uniform spacing
- Broken parts in transit

3- PRECAST CONCRETE Structures

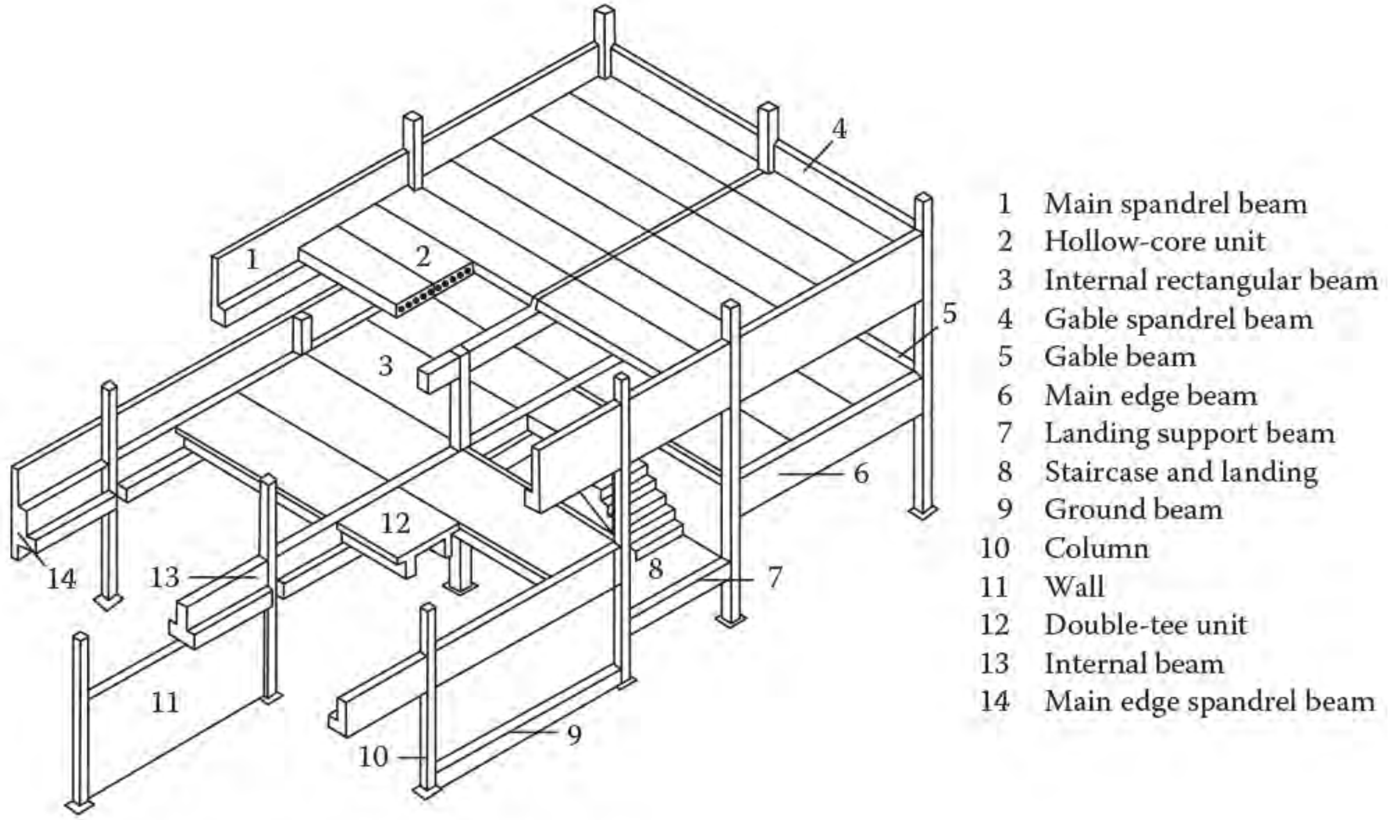


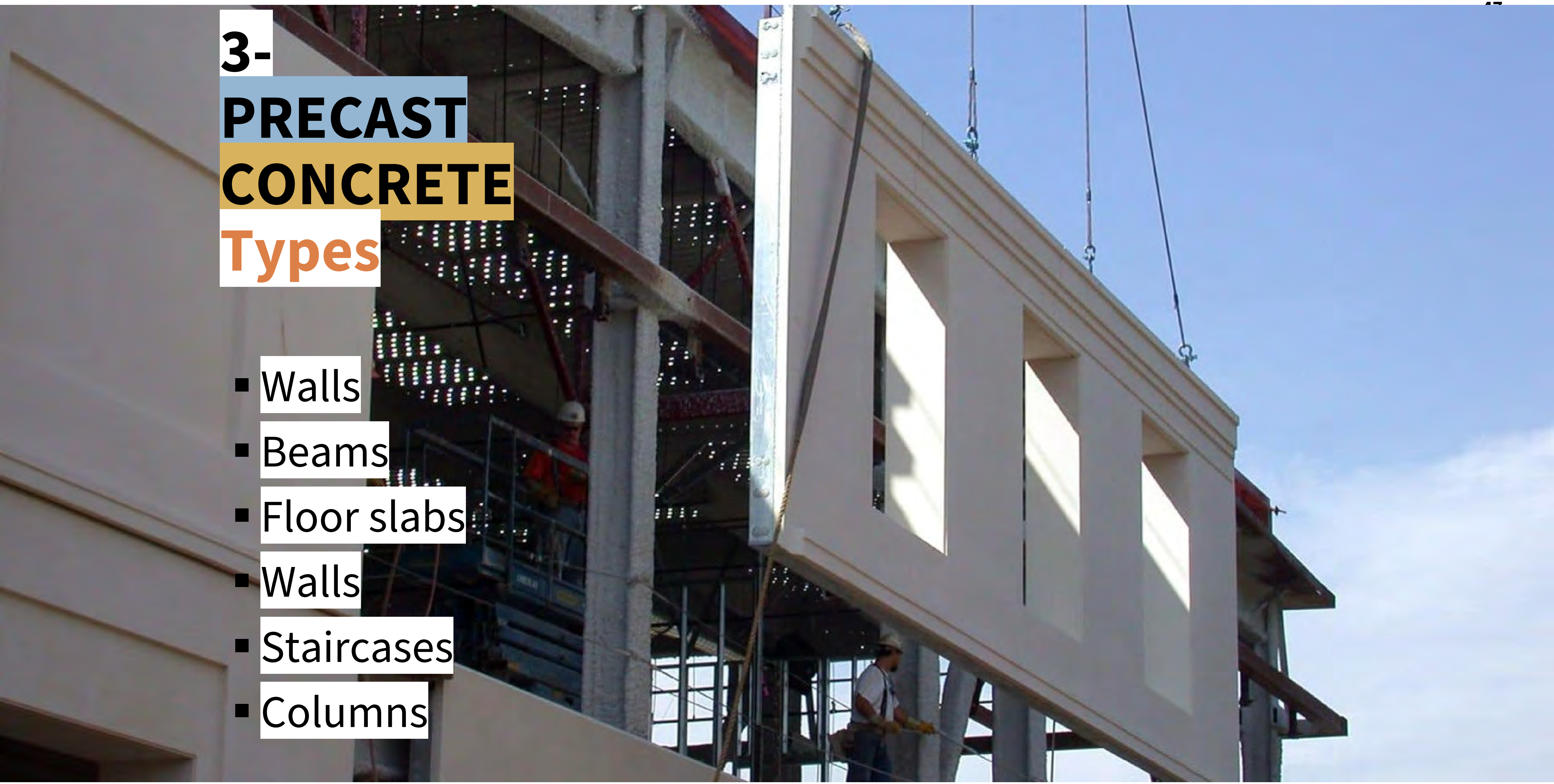
Figure 3.2 Definitions in a precast skeletal structure.

- ‘Skeletal’ resembles a skeleton of rather small but very strong components of columns, beams and floors, staircases and sometimes structural walls.
- Commonly used in buildings which require minimal obstructions.

Elliott, K. S. (2016). *Precast Concrete Structures*, CRC Press.

3- PRECAST CONCRETE Types

- Walls
- Beams
- Floor slabs
- Walls
- Staircases
- Columns

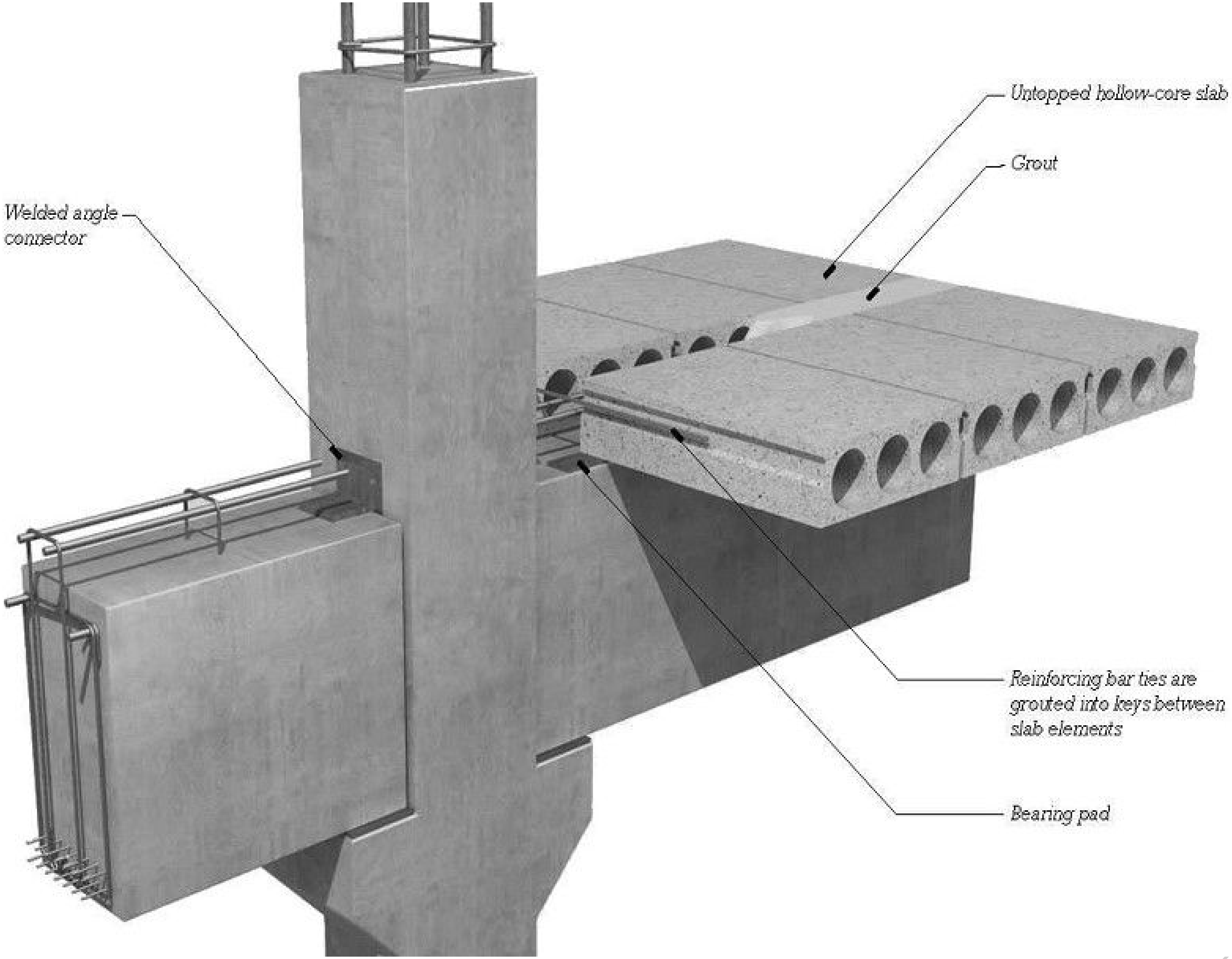


3- PRECAST CONCRETE Types

- Walls
- Beams
- Floor slabs
- Walls
- Staircases
- Columns

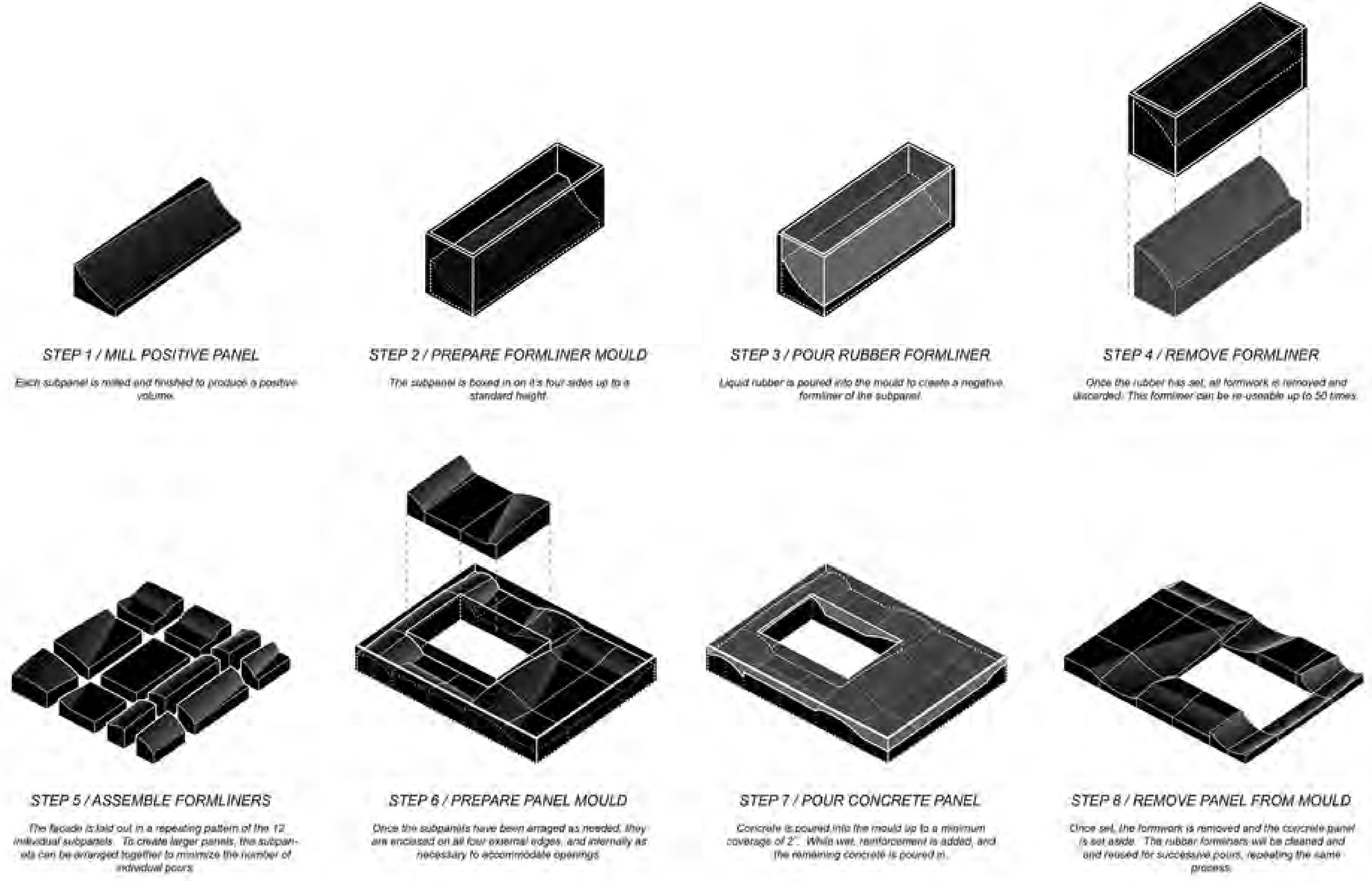
3- PRECAST CONCRETE Connection

- Bolting
- Welding
- Grouting



3- PRECAST CONCRETE Prefabrication (nonstructural/ façade)

The Precast Concrete Building in Toronto | Batay-Csorba Architects | Archello



The Precast Concrete Building in Toronto | Batay-Csorba Architects | Archello

4- CONCRETE MASONRY

- Essentially means bricks or blocks made of precast concrete.
- Allows more flexibility than larger precast elements (e.g. bricks can be used in the same way as traditional clay bricks).

4- CONCRETE MASONRY

- Solid block
- Cellular block
- Hollow block

Structural concrete elements

- Slabs: horizontal plate elements in building floors and roofs. They may carry gravity and lateral loads
- Beams, main function is to support loads from slabs
- Columns, critical members that support loads from beams or slabs. May be subjected to axial loads or axial loads and moments.
- Frames, structural members that consists of combination of beams , columns and slabs.
- Footings, pads or strips that support columns
- Walls
- Stairs

Part 3: Future challenges

Photo by Malik Skydsgaard on Unsplash

Environmental considerations

dezeen

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Concrete must be abandoned by architects in fight against climate change (dezeen.com)

Architects should give up concrete say experts at Architecture of Emergency climate summit

India Block | 20 September 2019 | 154 comments

Environmental considerations

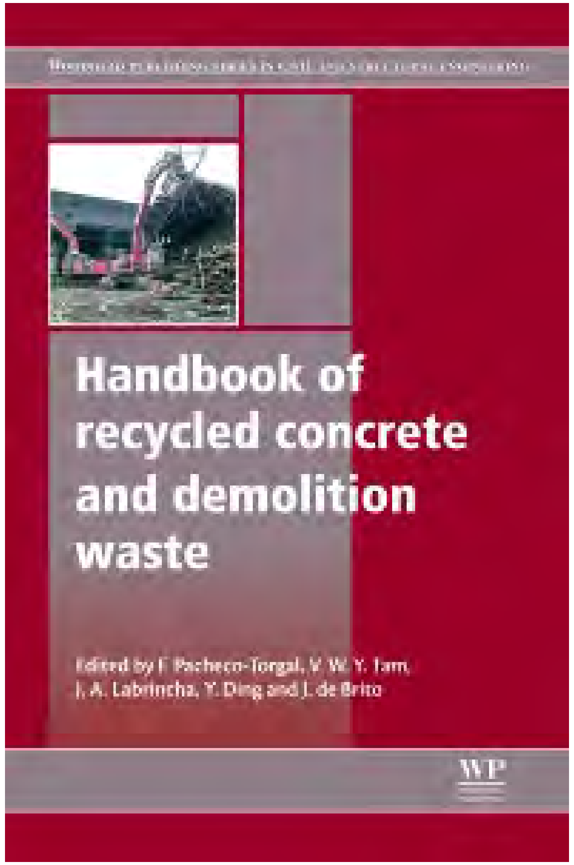
Portland-cement concrete is perceived as a green material relative to other building materials. However, it is not only energy-intensive but also responsible for a large emissions of CO2.

Mehta, P. K. & Monteiro, P. J. (2014). *Concrete: microstructure, properties, and materials*, McGraw-Hill Education.

Concrete recycling

- When we consider concrete “recycling”, it is not strictly speaking recycling- it is reusing
- Concrete setting is a chemical process that cannot be reversed
- Waste concrete used to be buried in landfill, now it is crushed and used as aggregate/ filler (mainly)
- Larger chunks can be cut into new slabs or blocks

Concrete recycling



Pacheco-Torgal, F. & Ding, Y. (2013). *Handbook of recycled concrete and demolition waste*, Elsevier.

ACTIVITIES

1. PRESENTATION BY CONCRETE PEEPS: 2 X 30MINS.
2. Q&A (OTHER GROUPS SHOULD AT LEAST POSIT ONE QUESTION).
3. NO ONLINE SUBMISSION

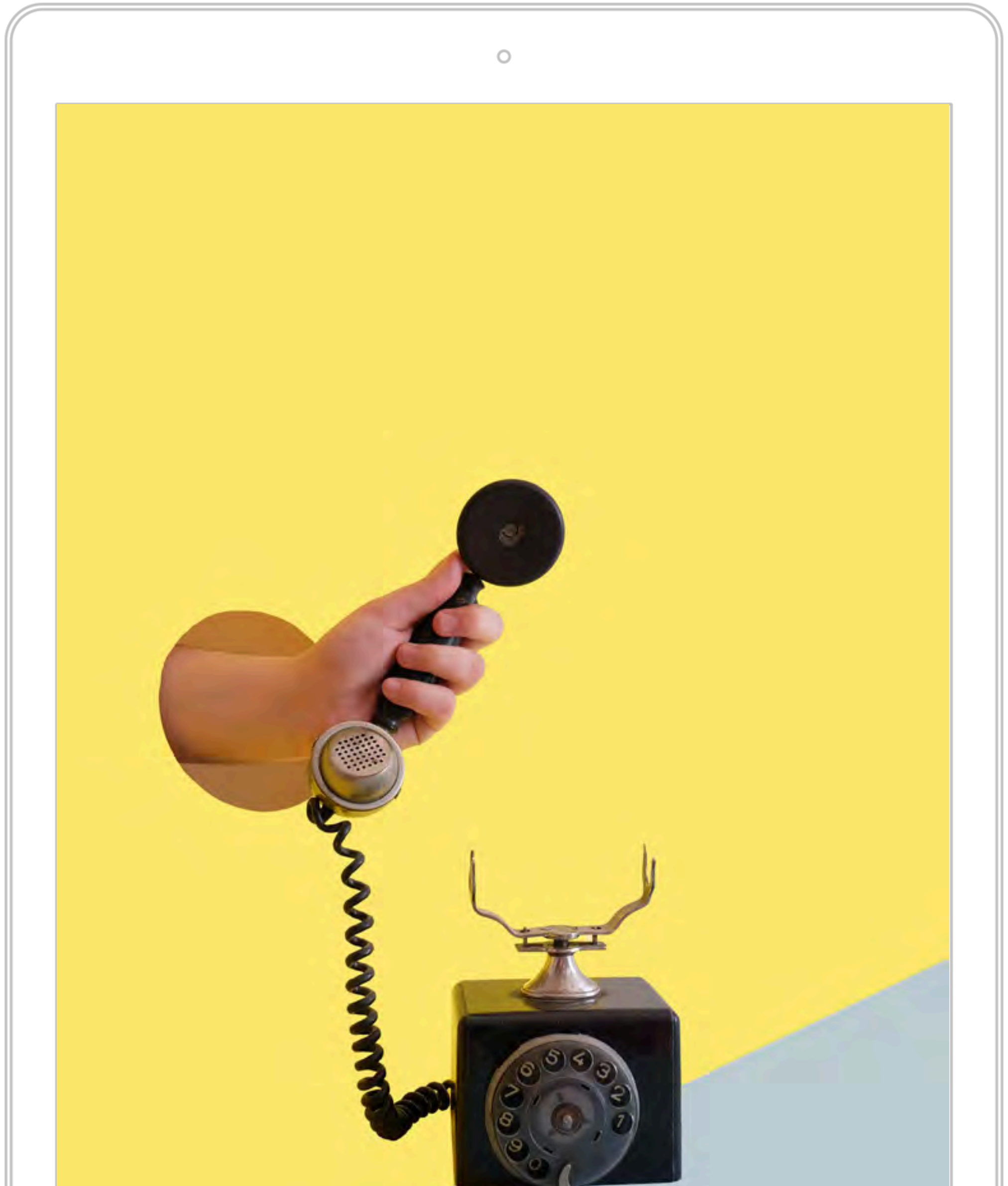


Photo by Elena Koycheva on Unsplash

What do we need to consider before designing concrete structure?

Re-iterating aims and objectives

- To gain understanding on concrete as **building materials** and its characteristics
- To learn about concrete as main **structural materials**
- To expand on concrete within **construction system**