5 Slabs

In-depth study and additions to Stahlbeton II

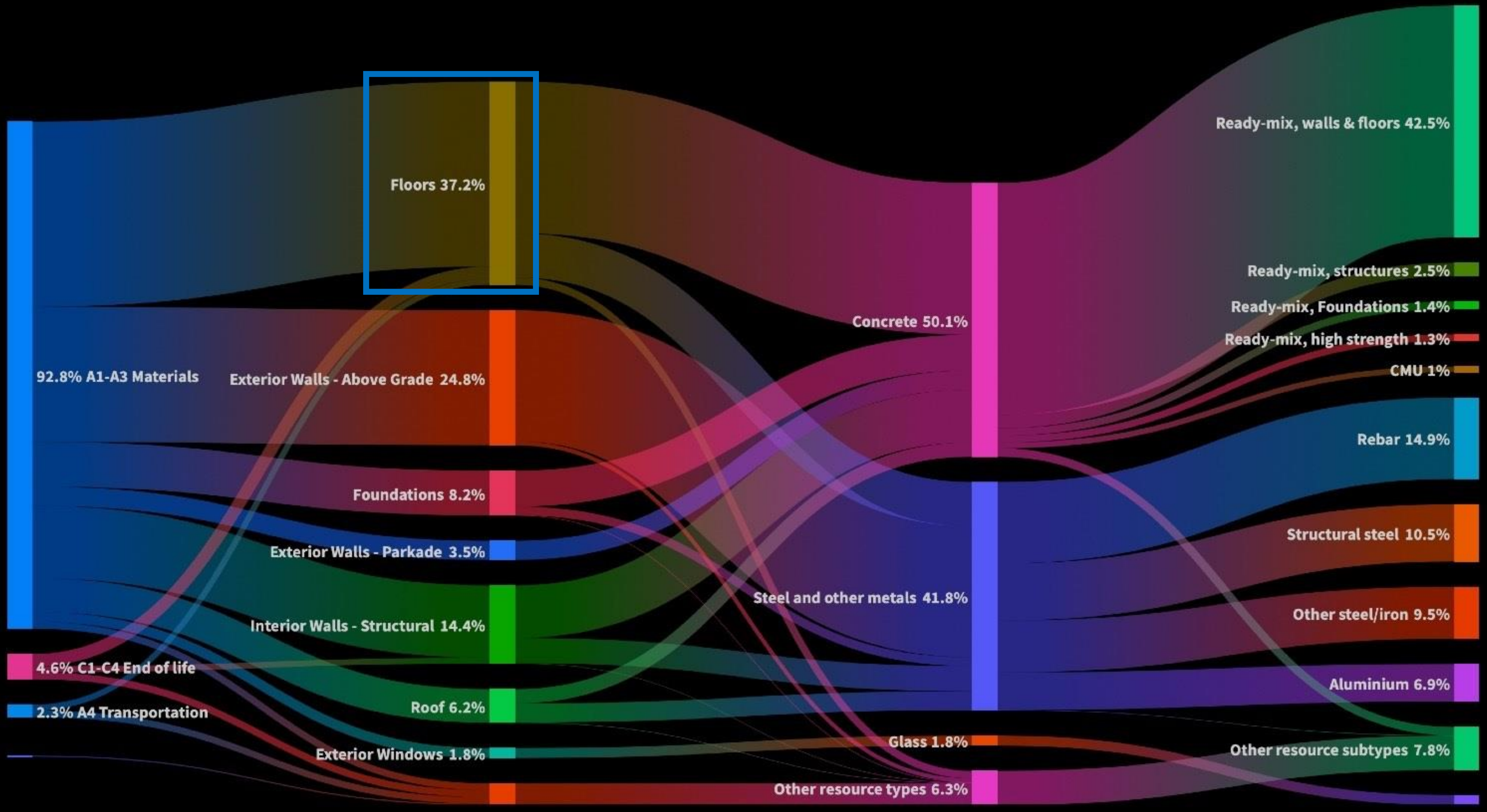
5.9 Sustainability

Learning objectives

Within this chapter, the students are able to:

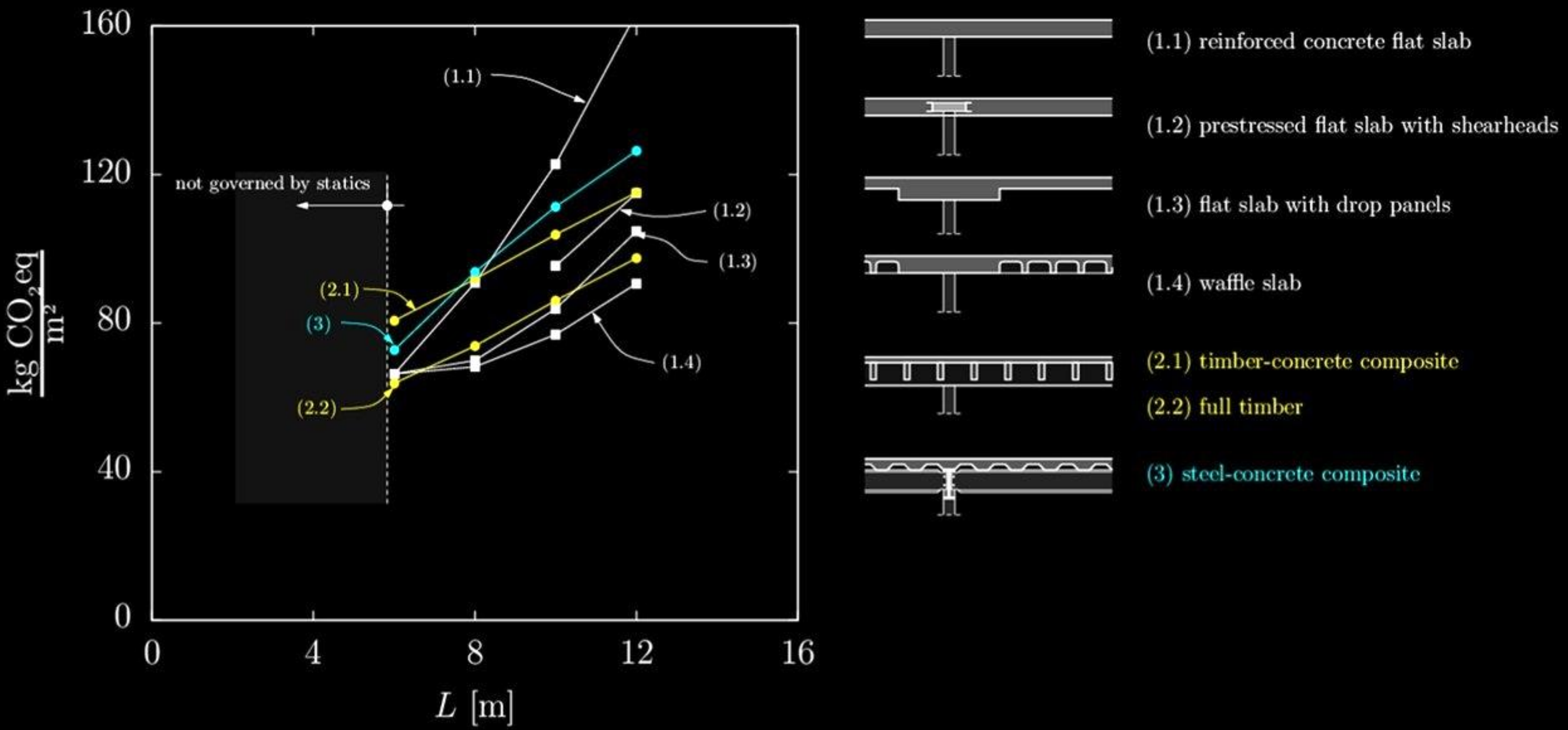
- select different types of concrete slabs and assess their environmental impact as well as structural efficiency:
  - recognise the importance of the engineer in the decision-making and minimising the environmental impact of a structure
  - identify the potential and limitations of various concrete slab types.

Environmental impact of slabs



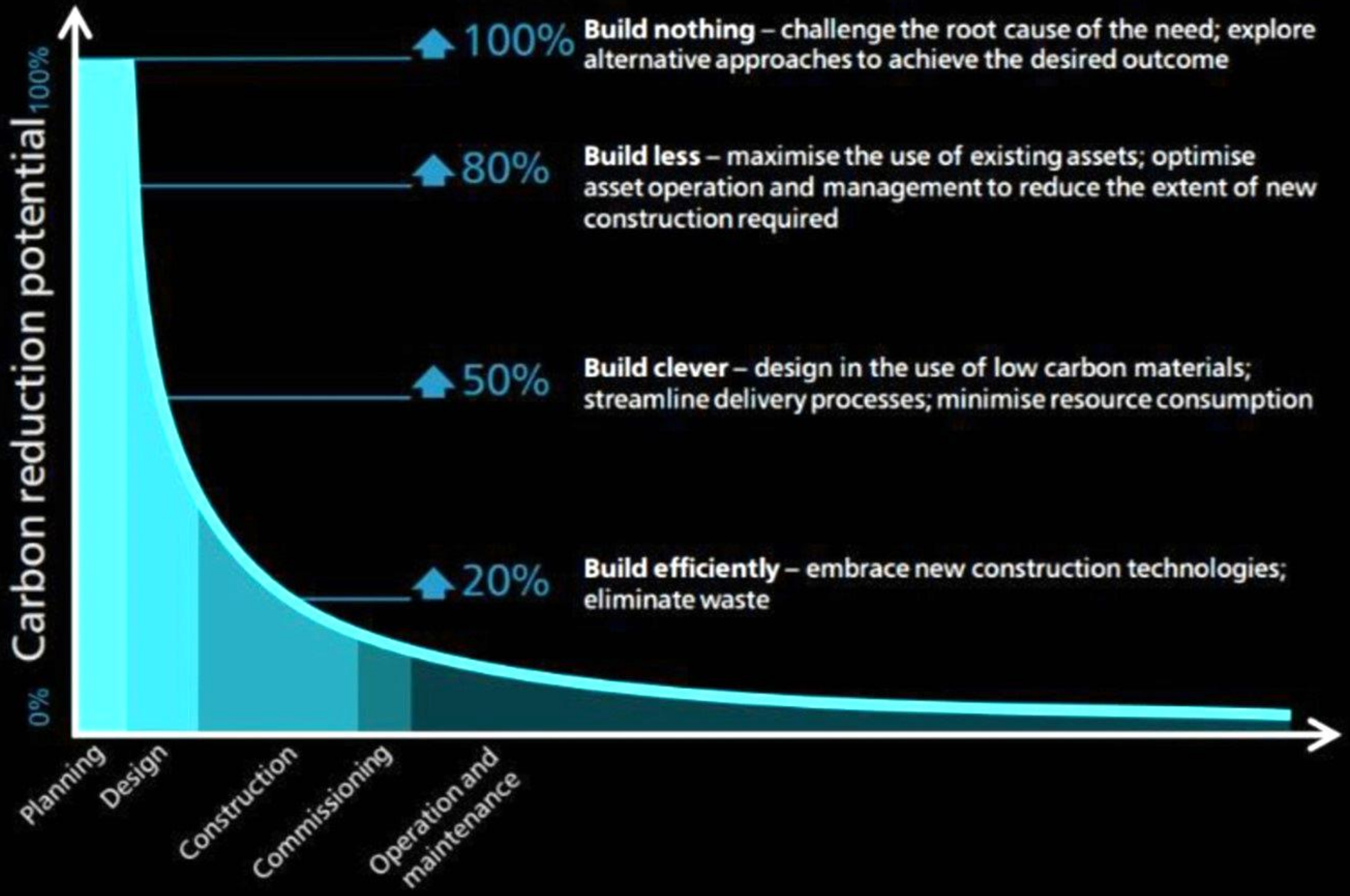
Anthony Pak - Embodied Carbon: Key Considerations for Key Materials, 2020

Environmental impact of slabs



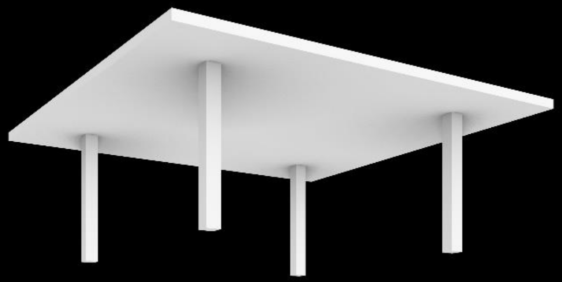
Regúlez et al. 2022

Environmental impact of slabs

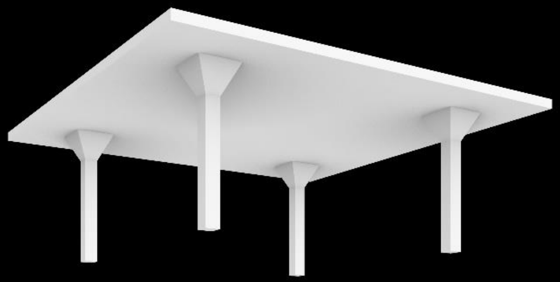


Negle et al. 2022

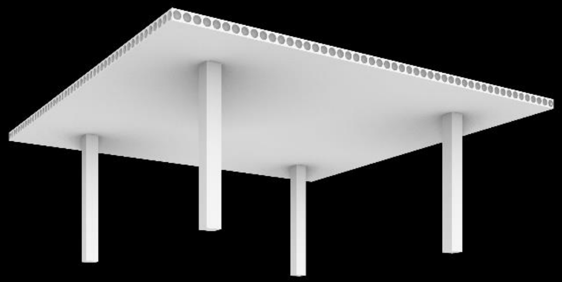
Concrete slab types



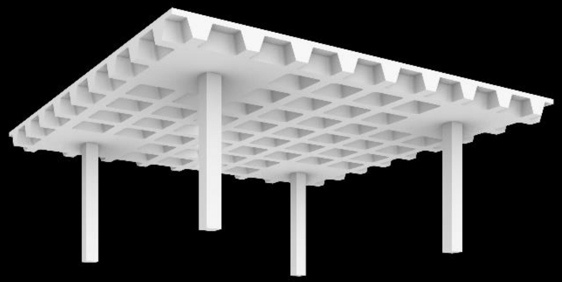
Flat slab
Post-tensioned flat slab



Mushroom slab



Voided flat slab

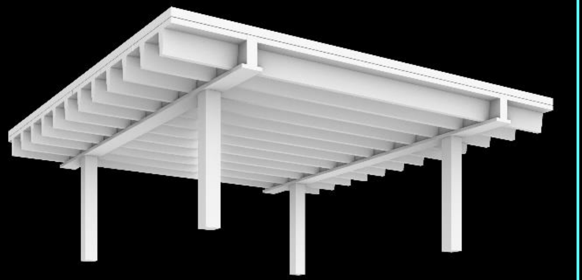


Waffle slab

Onsite

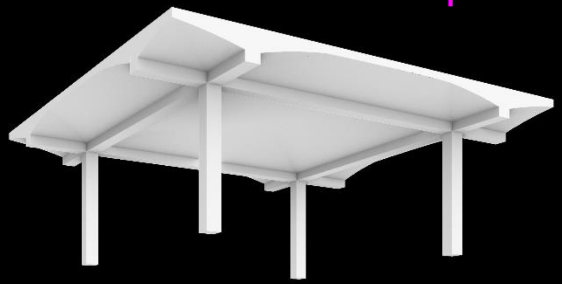
Pre-fabrication

Hollow core slab (with topping)



Ribbed slab (with topping)

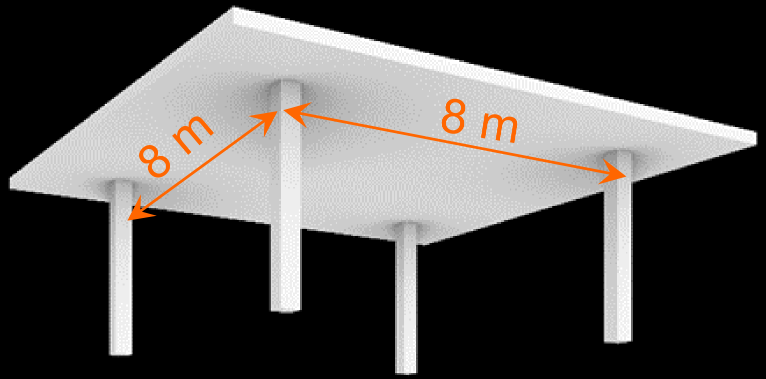
Special



Vaulted slab

… and many more

Case study: Concrete slab systems



Floor slab with 8 m inter-column span

Load combination: self-weight, additional load (2kN/m^2), live load (2kN/m^2)

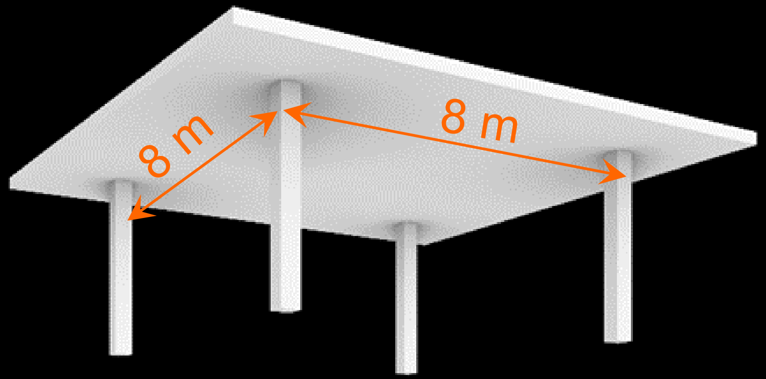
Impact of design on Global Warming Potential GWP (CO_2-eq.)?

Assumptions for CO_2-eq of used materials:

(*) including reinforcement in prefab element

KBOB – Ökobilanzdaten im Baubereich, V4.0, 2023

Case study: Concrete slab systems



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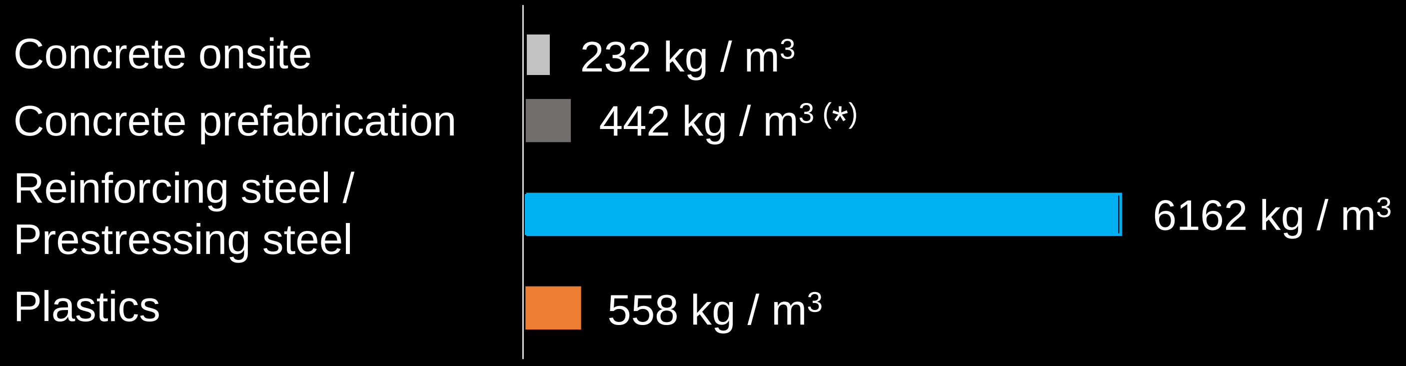
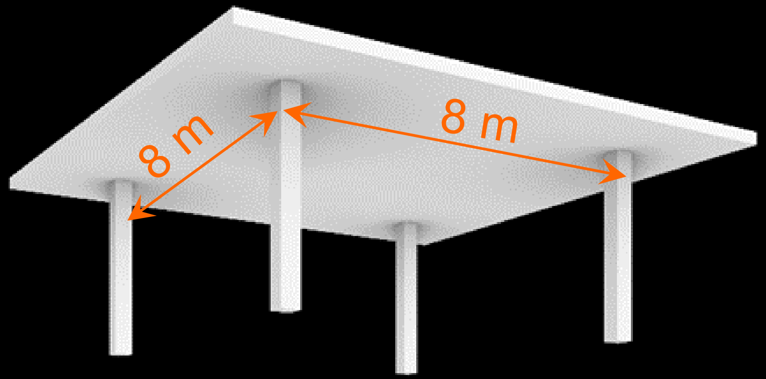


(*) including reinforcement in prefab element

KBOB – Ökobilanzdaten im Baubereich, V4.0, 2023

Case study: Concrete slab systems

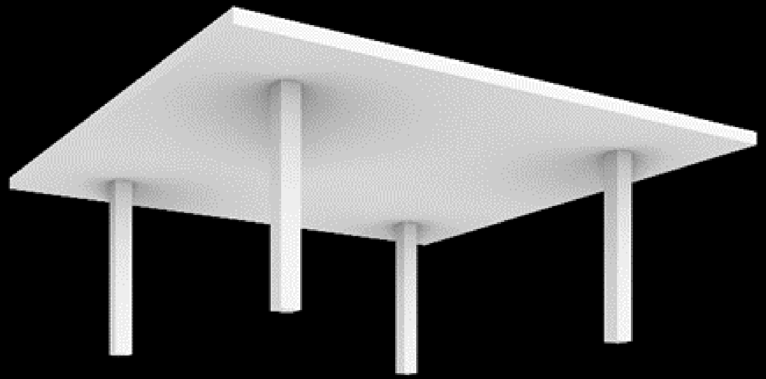


The following results are only valid for the assumptions made and cannot directly be generalised to other conditions. Results can change especially for

- different inter-column spans
- edge regions
- non-regular floor layouts
- in case of openings

Often requirements independent of the direct structural design case, such as of fire safety, sound insulation, thermal insulation, limit the optimisation of the dimensions. The GWP of the formwork (different for each case presented here) and costs are not considered.

Flat slabs



Classic way of constructing in-situ concrete slabs

Dimensions are often defined by building systems, sound insulation etc.

Advantages

- Easy and simple construction
- Easy to dimension
- Redundancy and high flexibility
- Integration of building systems

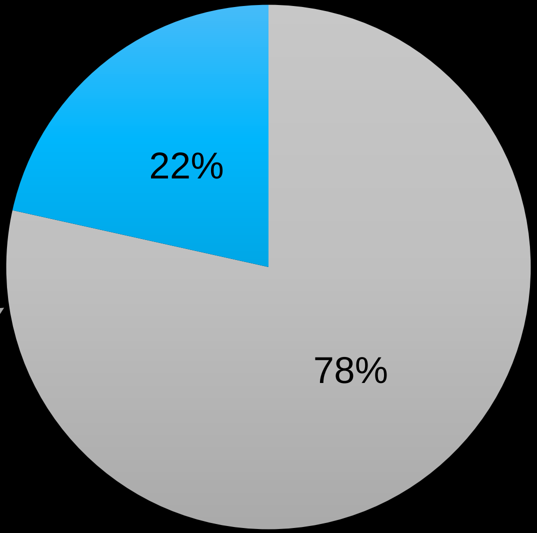
Limitations

- Very high material usage
- High self-weight
- Deflections and punching often governing

Not optimised flat slab

h = 26 cm

77 kg/m² CO_2-eq.

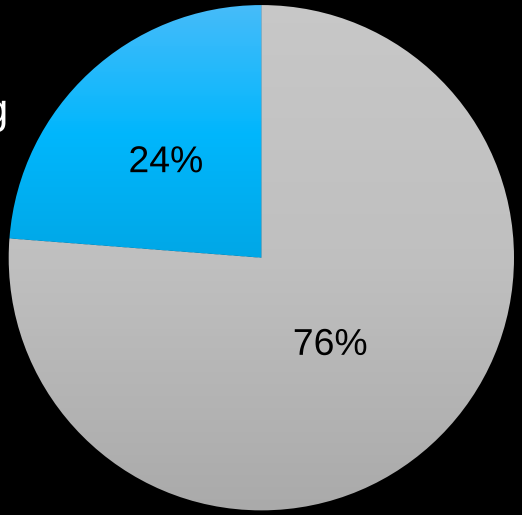


Optimised flat slab

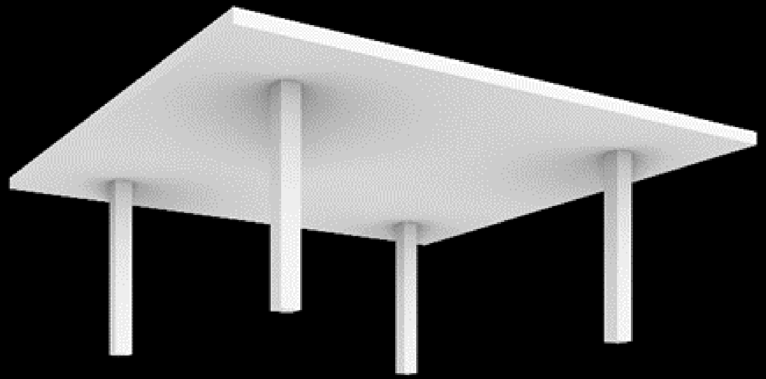
h = 23 cm, deflections governing

70 kg/m² CO_2-eq.
-10 %

Concrete
Reinforcement
Prefab concrete
Plastics



Prestressed flat slab



Classic way of constructing in-situ concrete slabs

Dimensions are often defined by fire safety & punching

Advantages

- Easy and simple construction
- Medium effort for dimensioning
- Redundancy and some flexibility
- Substantially less material usage

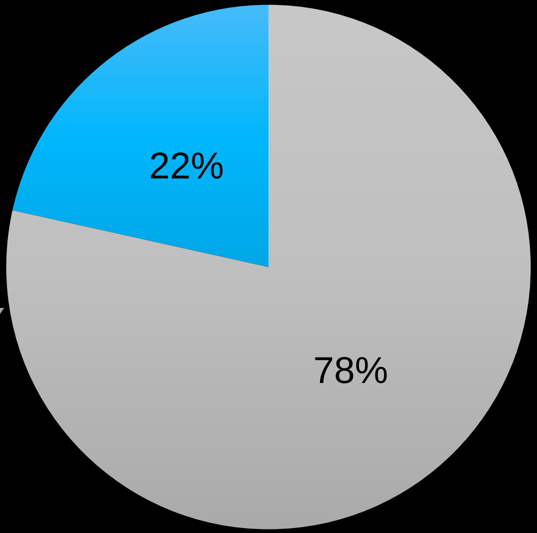
Limitations

- Fire safety & punching often governing
- Integration of building systems only partly possible

Not optimised flat slab

h = 26 cm

77 kg/m² CO_2-eq.

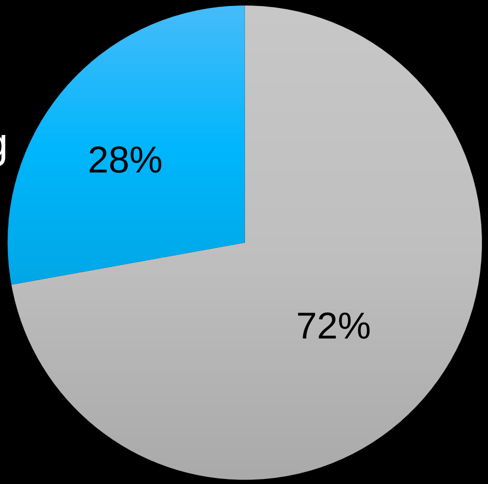


Prestressed flat slab

h = 20 cm, fire-safety & punching governing

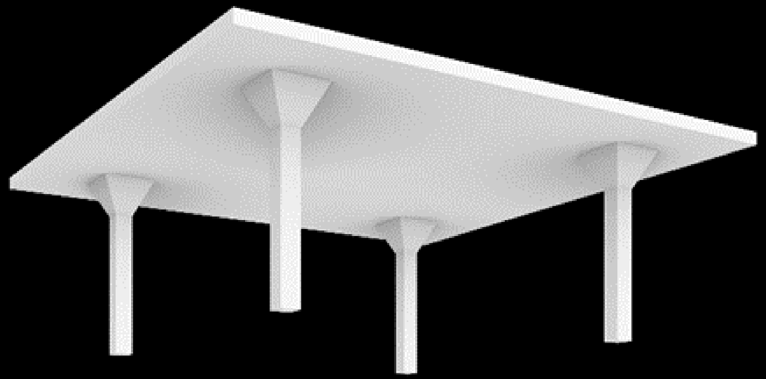
64 kg/m² CO_2-eq.

-17 %



Concrete | Reinforcement | Prefab concrete | Plastics

Mushroom slab



Particularly suitable for high punching loads

Reduced slab thickness in the fields but increased concrete volume at supports

Advantages

- Substantial material savings
- Much lighter structure (leaner foundation)
- Redundancy
- Very efficient regarding punching

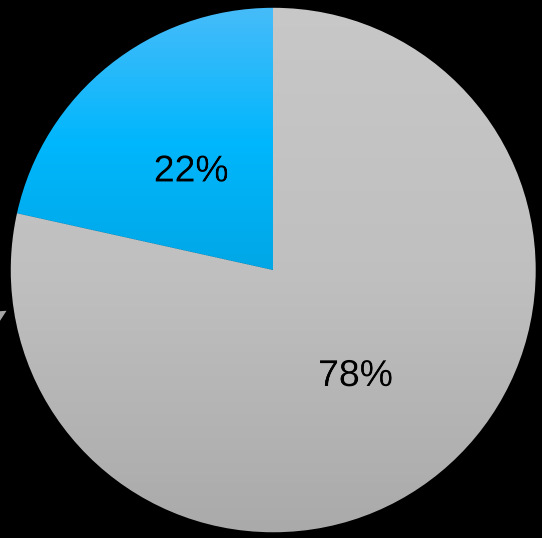
Limitations

- Formwork more tedious
- Discussible aesthetics
- Deflections often governing
- Integration of building systems only partly possible

Not optimised flat slab

h = 26 cm

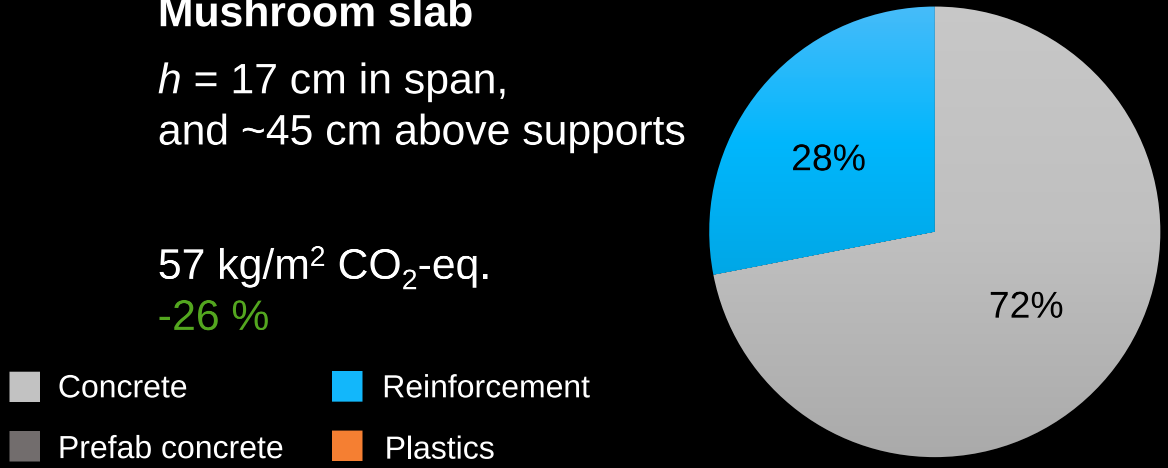
77 kg/m² CO_2-eq.



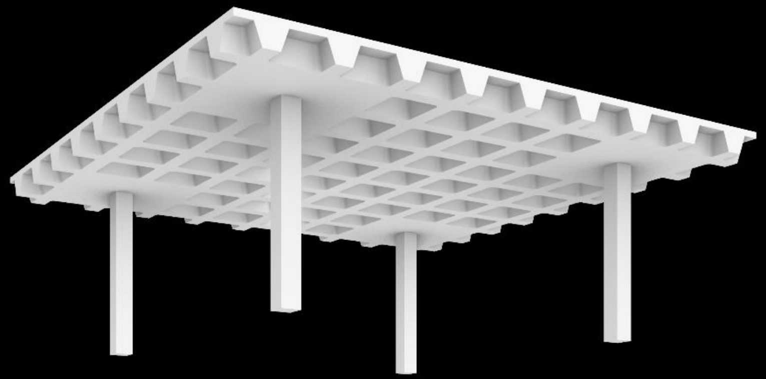
Mushroom slab

h = 17 cm in span,
and ~45 cm above supports

57 kg/m² CO_2-eq.
-26 %



Waffle slab



Very efficient floor system

Increases storey height (decreases number of stories for given total height)

Advantages

- Substantial material savings
- Much lighter structure (leaner foundation)
- Redundancy and high flexibility

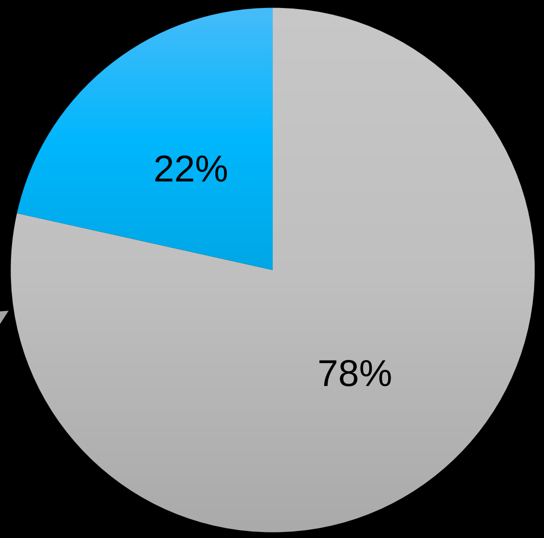
Limitations

- Increased storey height (especially with intermediate ceiling)
- No flat soffit
- No integration of building systems
- Very tedious formwork

Not optimised flat slab

h = 26 cm

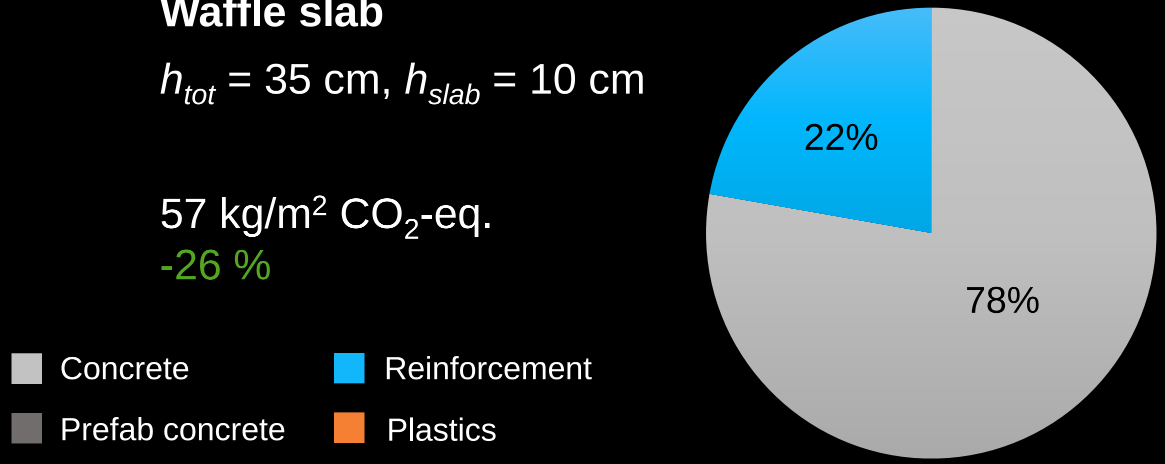
77 kg/m² CO_2-eq.



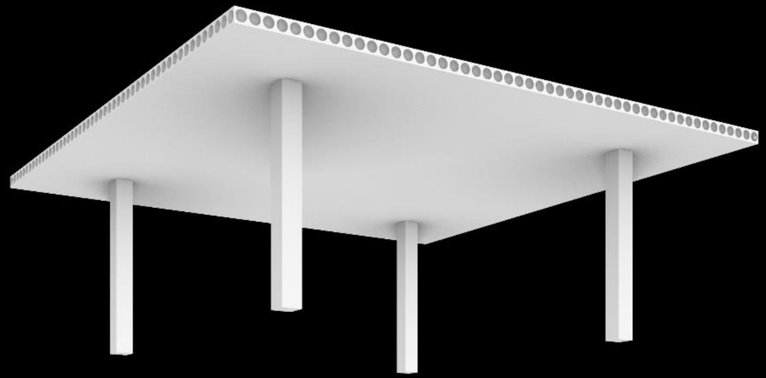
Waffle slab

h_{tot} = 35 cm, h_{slab} = 10 cm

57 kg/m² CO_2-eq.
-26 %



Voided slab



No influence on bending resistance but significant influence on shear resistance
→ do not place voids in areas of high shear forces

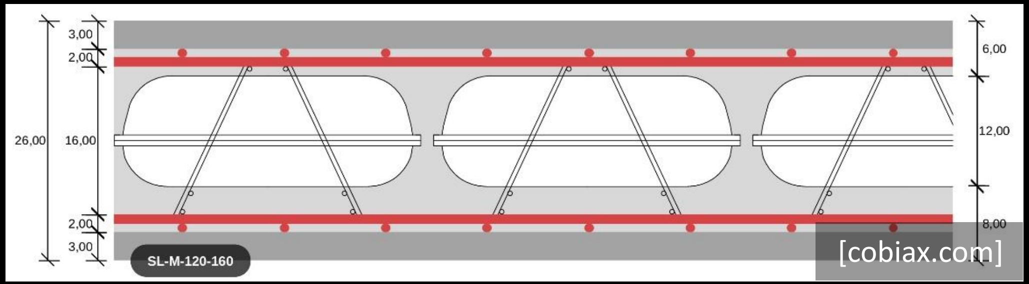
online dimensioning tools of the producers available

Advantages

- Substantial material savings
- Flat surfaces
- Much lighter structure (leaner foundation)

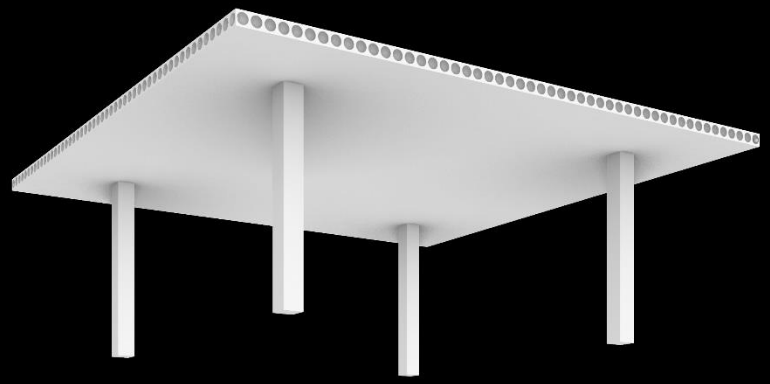
Limitations

- Less flexibility
- Challenging construction (e.g. buoyancy)
- Issues regarding recycling
- No integration of building systems



25% concrete volume reduction in voided areas compared to full slab

Voided slab



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Not optimised flat slab

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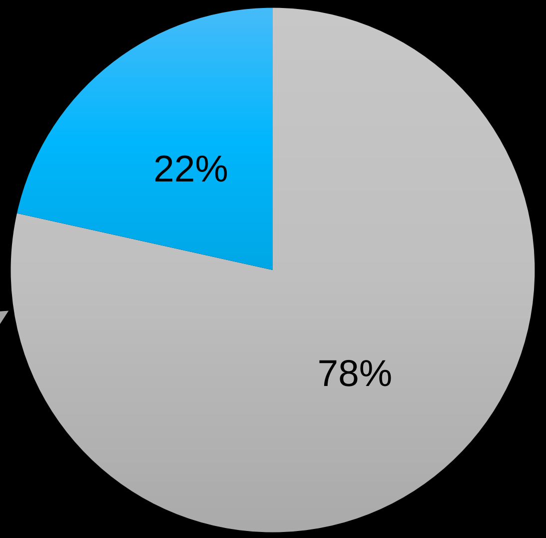
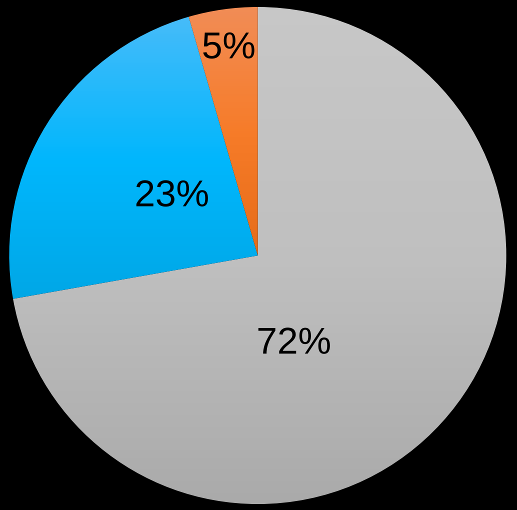
77 kg/m² CO_2-eq.



Voided slab

h = 26 cm

68 kg/m² CO_2-eq.
-12 %



Concrete
Reinforcement
Prefab concrete
Plastics

Hollow core slab

Prestressed beams

According to fabricator documentation

Advantages

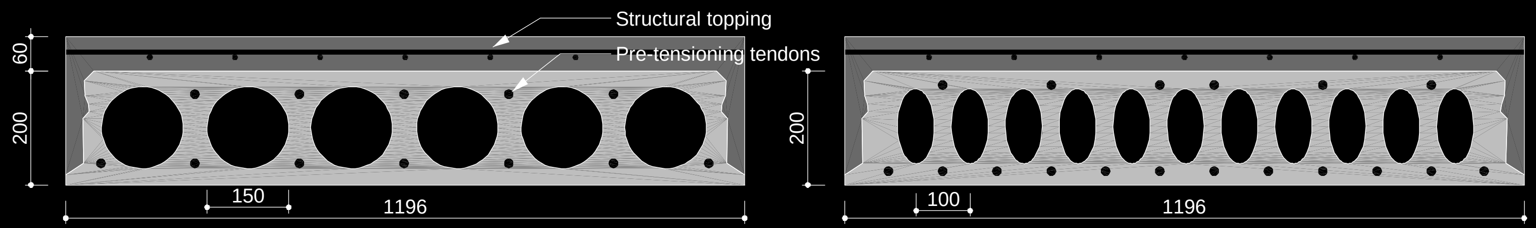
- Efficient production, i.e. extrusion
- Large material savings
- Scaffold-free construction
- Building systems partly integrable

Limitations

- Uni-directional load-bearing
- Topping required (in most cases)
- Limited customisation
- Typically higher cement contents in prefabricated elements

Reduction of self-weight compared to 26 cm full slab with 8 x 8 m span:

- ~ 50% (no topping)
- ~ 30% (60 mm structural topping)



Hollow core slab

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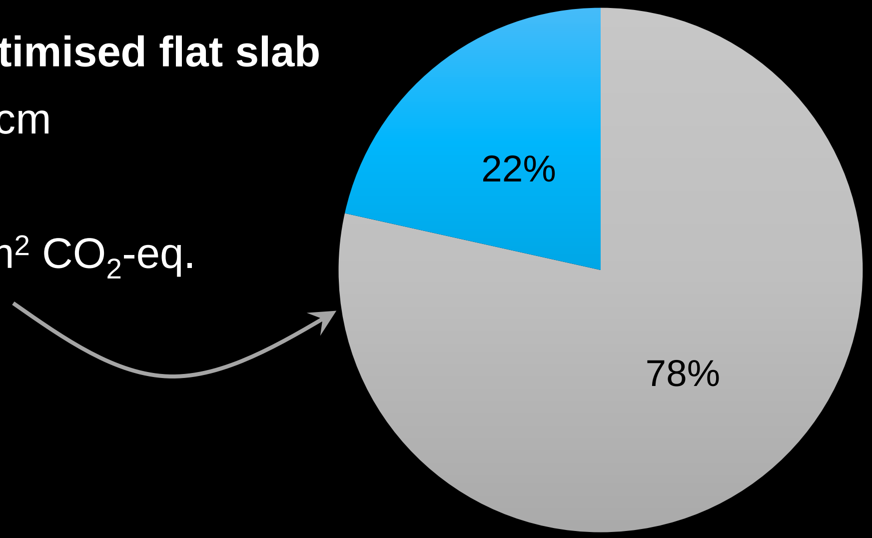
Not optimised flat slab

h = 26 cm

77 kg/m² CO_2-eq.

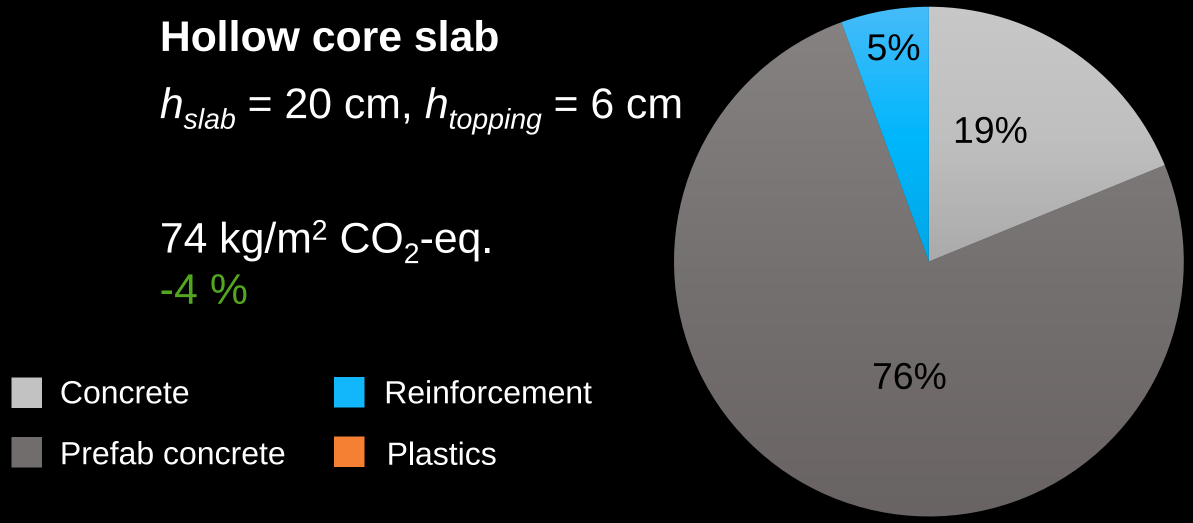


Hollow core slab

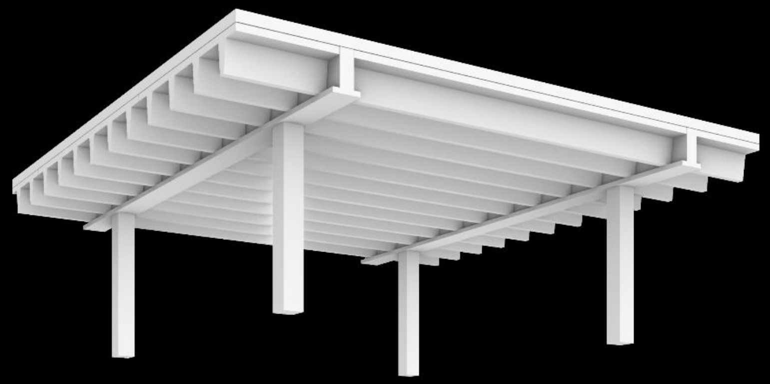
h_{slab} = 20 cm, $h_{topping}$ = 6 cm

74 kg/m² CO_2-eq.

-4 %



Ribbed slab with TT-beams



(Prestressed) beams

According to fabricator documentation

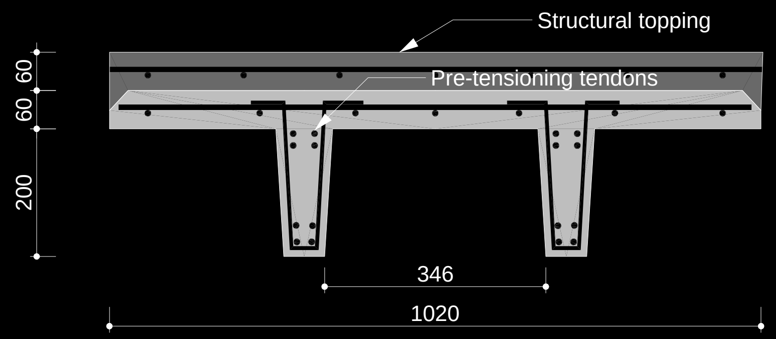
Advantages

- Efficient production
- Large material savings, especially for large spans
- Scaffold-free construction

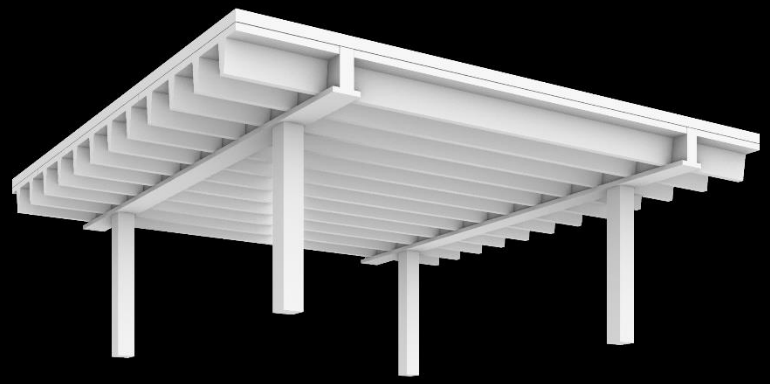
Limitations

- Uni-directional load transfer
- Limited customisation
- No flat soffit
- Increased storey height
- No integration of building systems

Reduction of self-weight compared to 26 cm full slab with 8 x 8 m span:
~ 40% (60 mm structural topping)



Ribbed slab with TT-beams



(Prestressed) beams

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- Large material savings, especially for large spans
- Scaffold-free construction

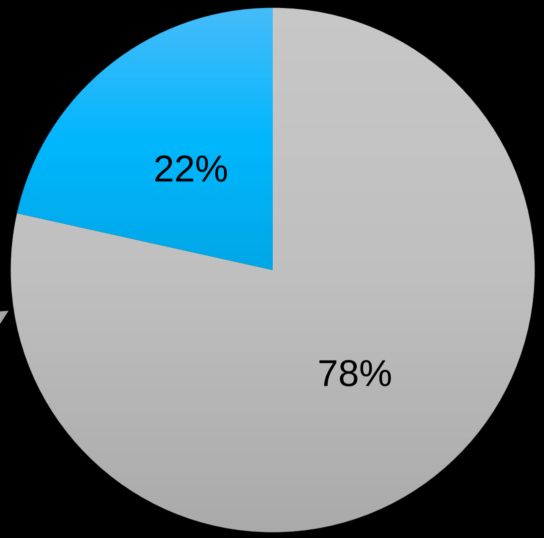
Limitations

- Uni-directional load transfer
- Limited customisation
- No flat soffit
- Increased storey height
- No integration of building systems

Not optimised flat slab

h = 26 cm

77 kg/m² CO_2-eq.

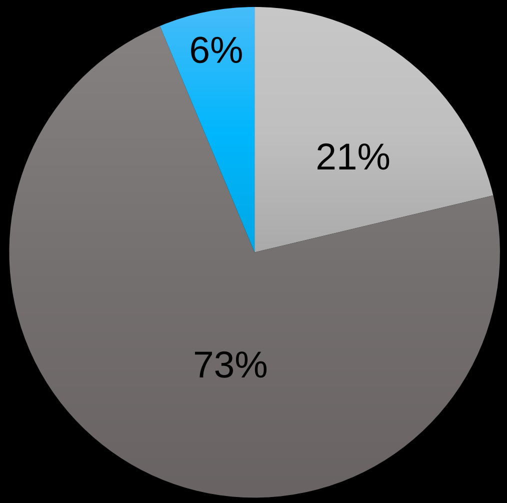


Ribbed slab

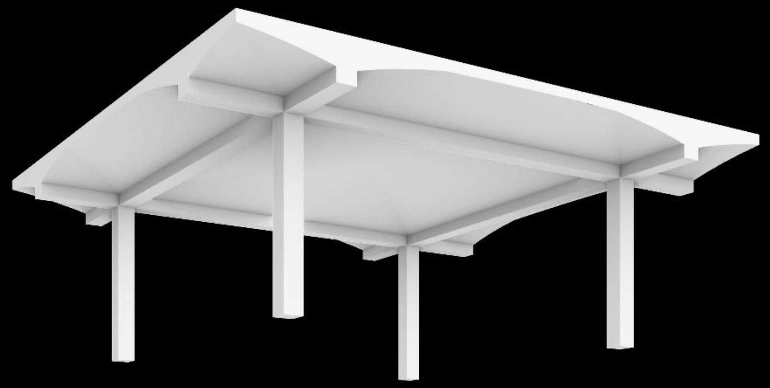
h_{tot} = 32 cm, h_{slab} = 12 cm

65 kg/m² CO_2-eq.
-16 %

Concrete
Reinforcement
Prefab concrete
Plastics



Vaulted slab



Shell design

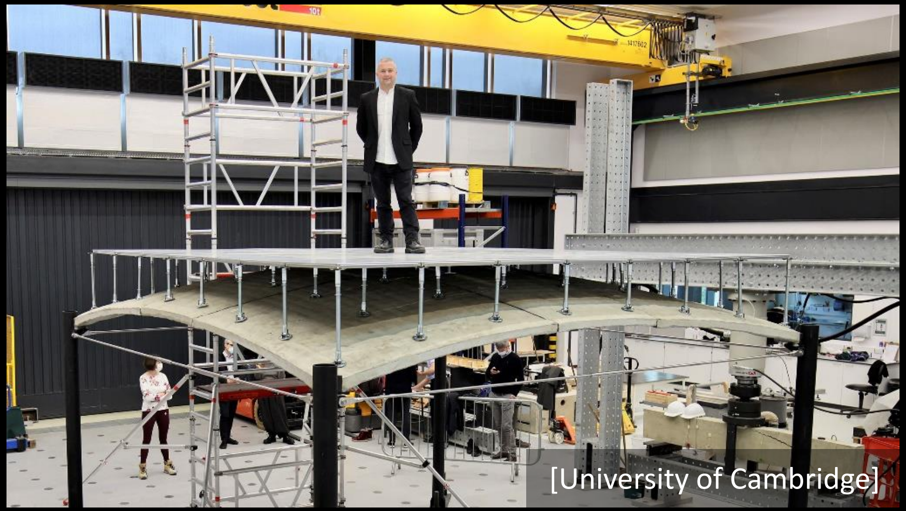
Large thrust forces need to be considered

Advantages

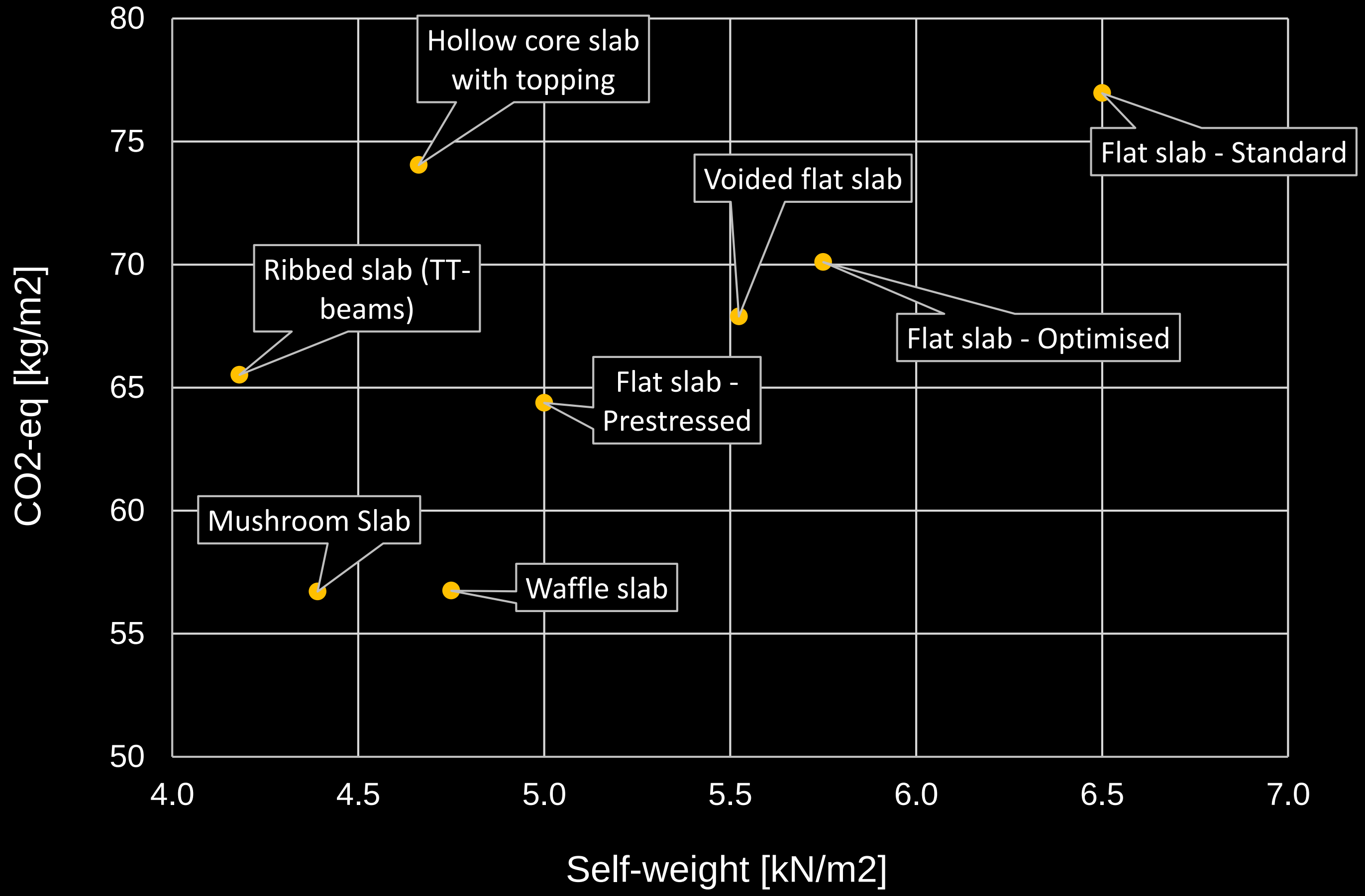
- Efficient load transfer
- Substantial material savings

Limitations

- Restricted floor plan
- Complex formwork required
- No flat soffit
- Typically requires large structural height

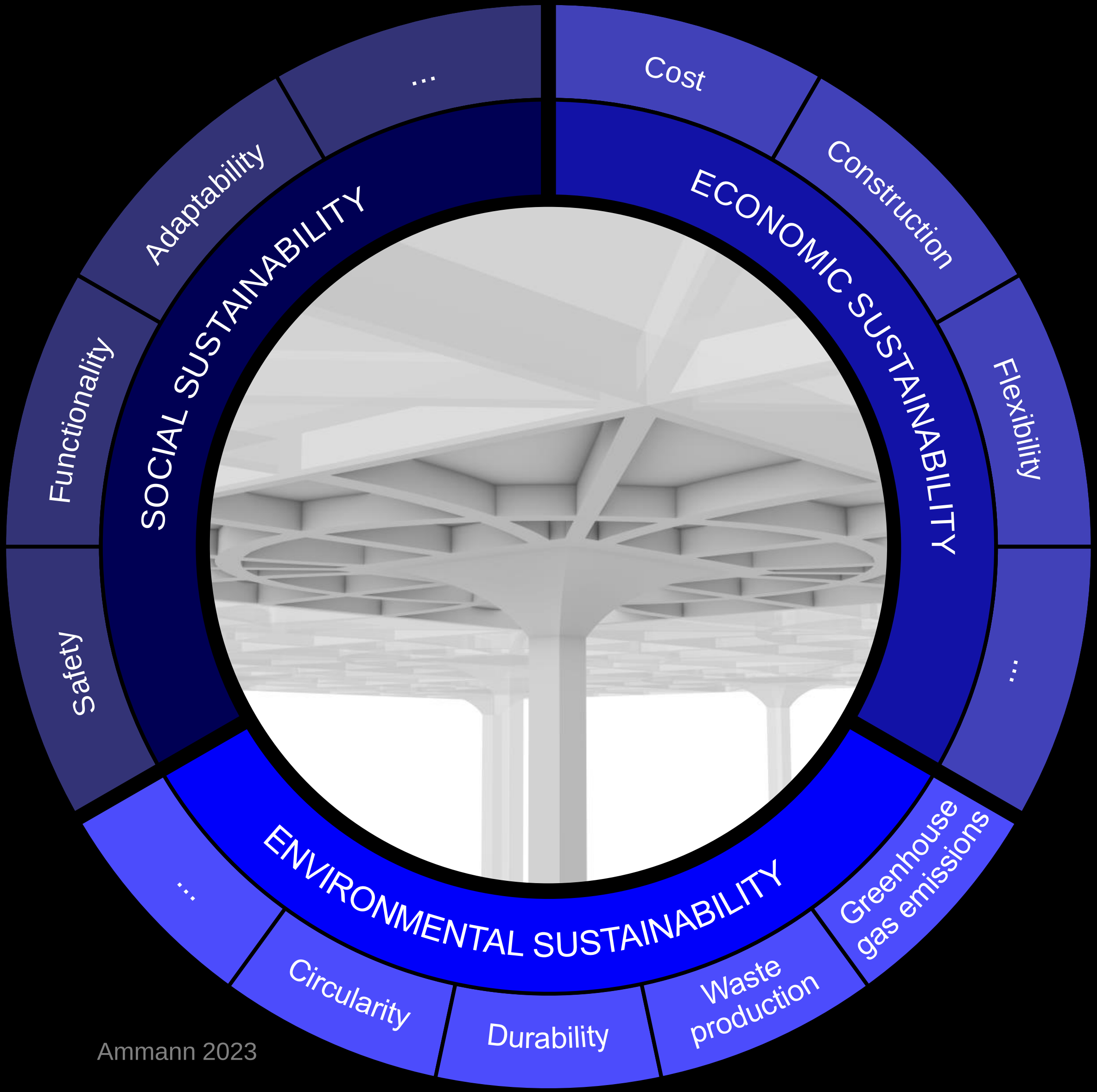


Overview slab systems



Only valid for the given boundary conditions, cannot be directly generalised.

Holistic approach



Ammann 2023