

The EPFL logo is displayed in a bold, red, sans-serif font in the top left corner of the slide. The background of the entire slide is a high-angle photograph of a construction site, showing concrete structures under development, two tall red tower cranes, and various construction materials and equipment. In the distance, a range of mountains is visible under a clear blue sky.

**EPFL**

Sustainability in Construction and Urban Futures

# The structural diet: Designing more material-efficient buildings

■ École  
polytechnique  
fédérale  
de Lausanne

VENUE & DATE

**EPFL Sustainability Days**  
6 March, 2026

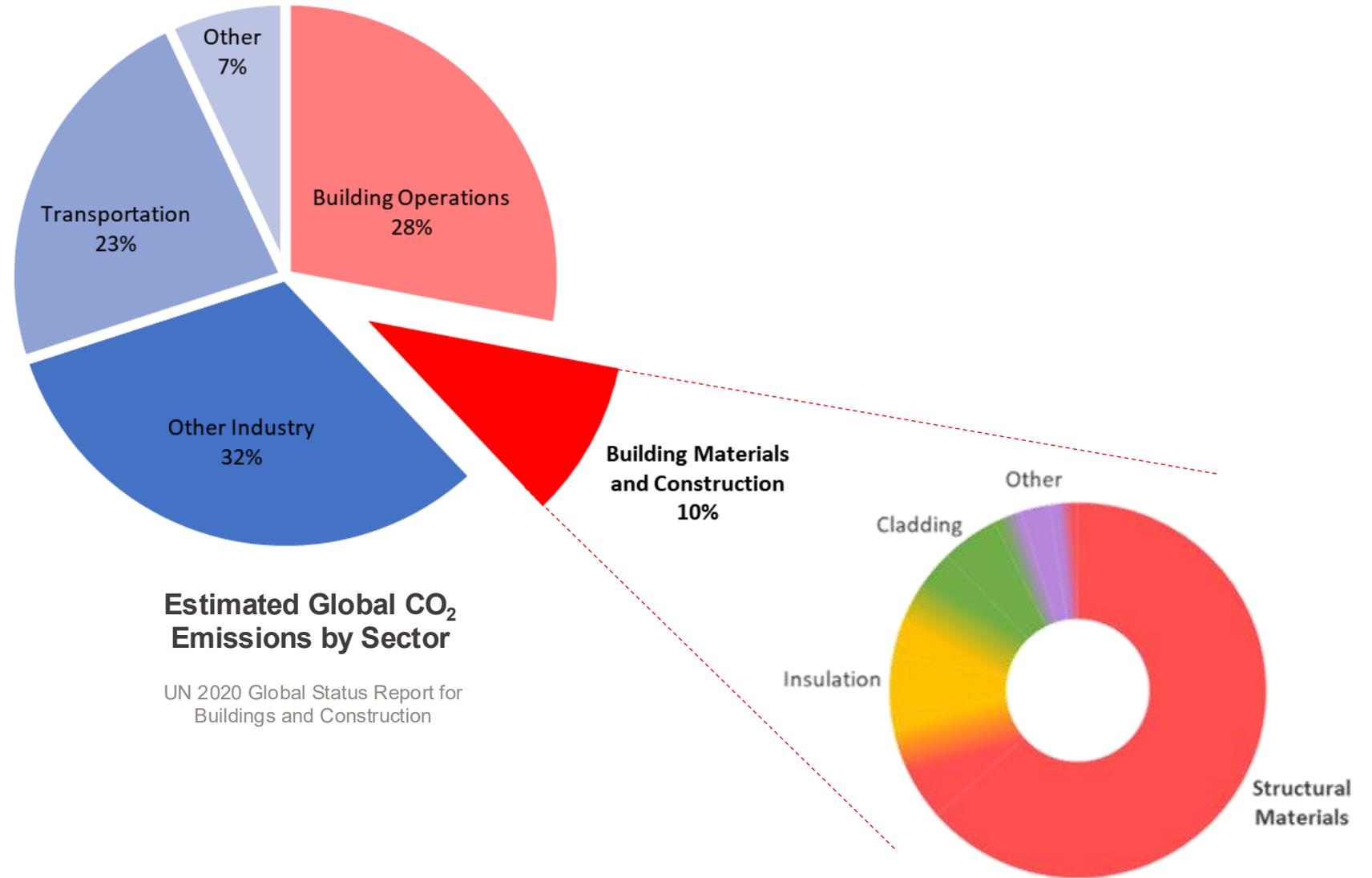
PRESENTED BY

**Prof. David Ruggiero**  
Concrete Behaviour and  
Structural Design Laboratory

”

By one estimate, the world will add 2 trillion square feet of buildings by 2060—the equivalent of putting up **another New York City every month** for the next 40 years.

# Embodied emissions



**Estimated Global CO<sub>2</sub> Emissions by Sector**

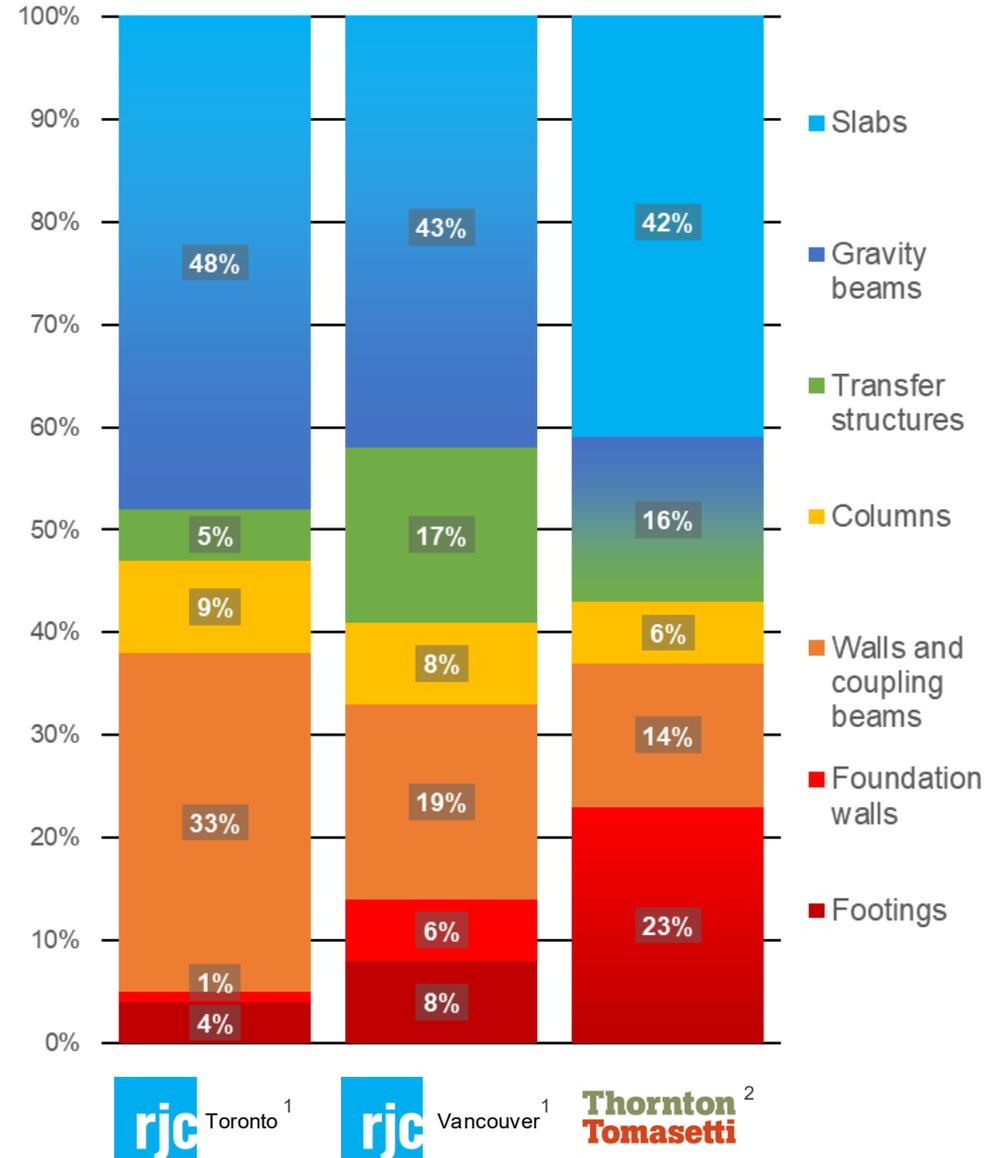
UN 2020 Global Status Report for Buildings and Construction

Sample breakdown for midrise residential building

# Structural materials



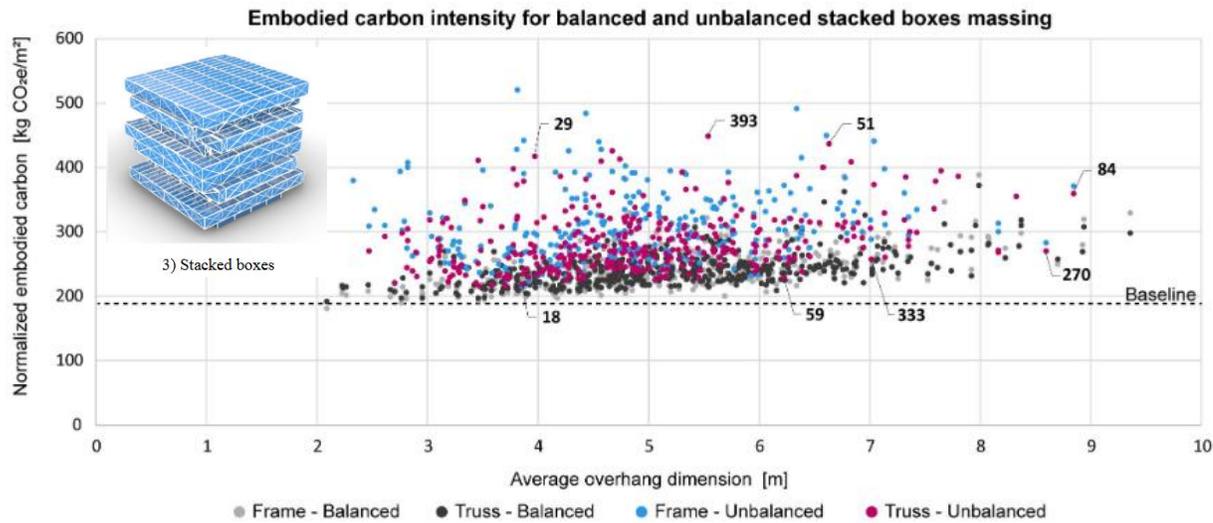
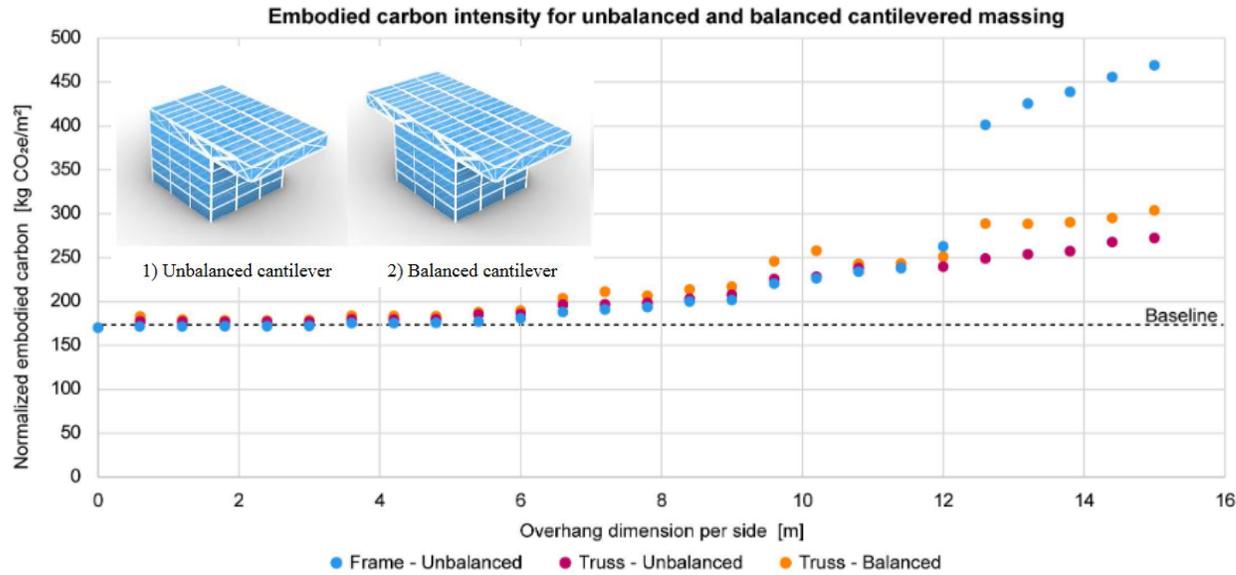
# Where is the carbon?



1. D. Arciaga and C. Plett, 'Comparative Study and Benchmarking of Embodied Carbon in the Structural Design of Concrete Residential Buildings in Vancouver, BC and Toronto, ON markets', NHICE 04 - 4th International Conference on New Horizons in Green Civil Engineering, Aug. 26, 2024.  
2. D. Fang, P. Kenny, and C. Mueller, 'Material Efficiency as a Key Opportunity to Reduce Embodied Carbon in Structural Systems: Data Insights from 226 Fully Designed Projects', Journal of Structural Engineering, vol. 152, no. 2, p. 04025275, Feb. 2026.

# Structural complexity





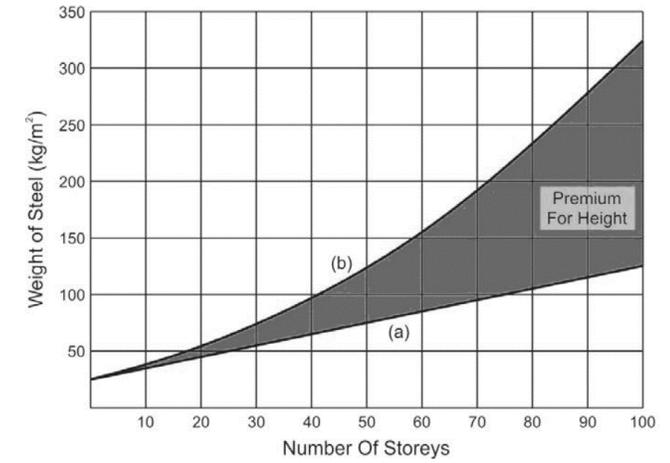
# Carbon premium: Cantilevers



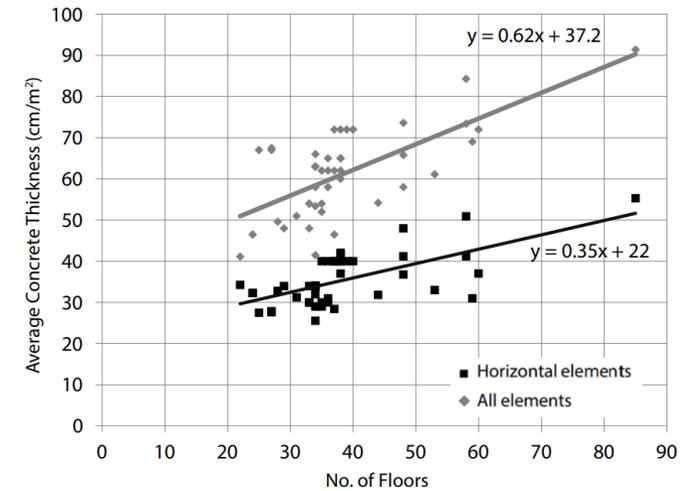




# Carbon premium: Height



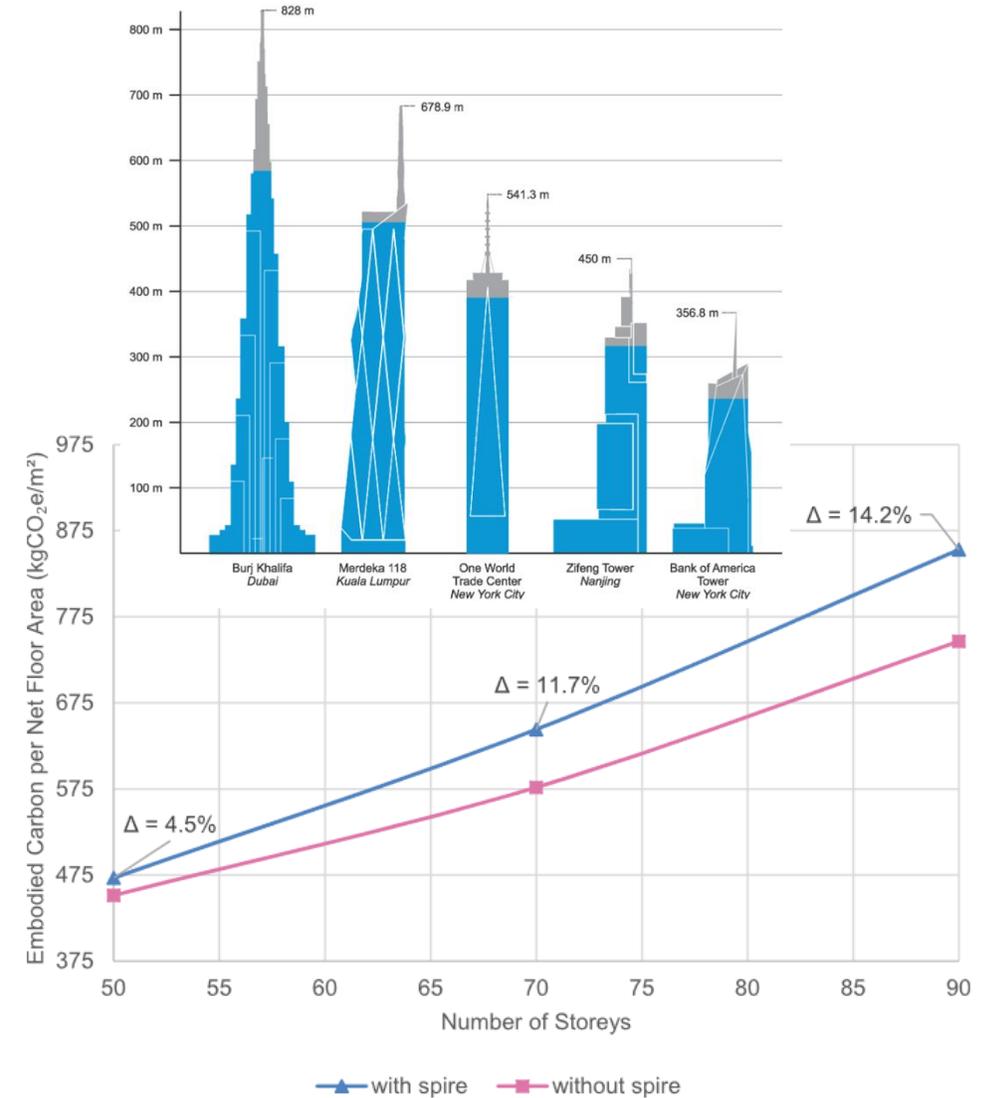
Steel buildings<sup>1</sup>



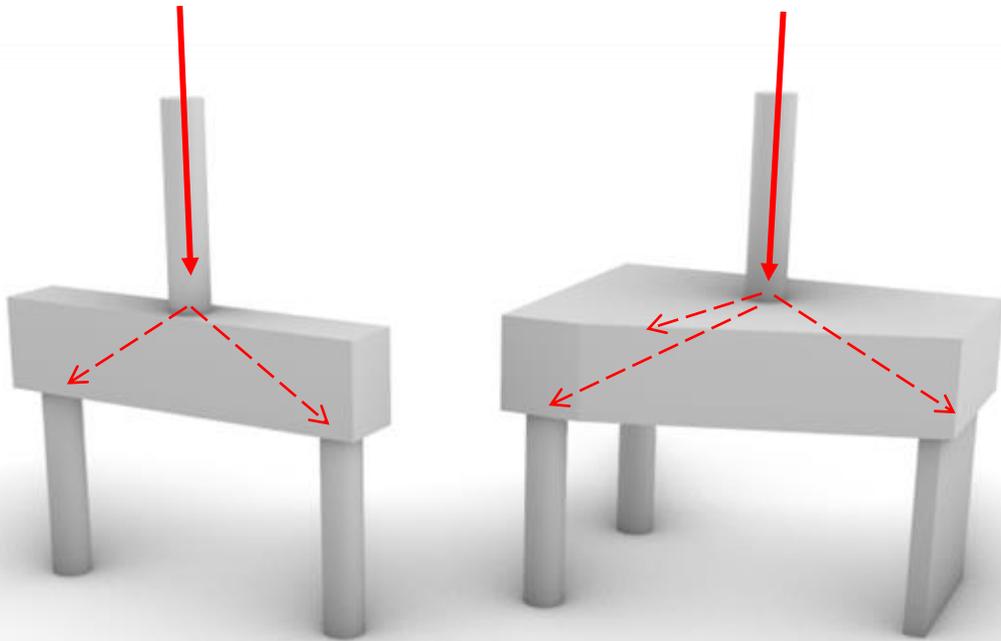
Concrete buildings<sup>2</sup>

1. J. Helal, A. Stephan, and R. Crawford, 'Beyond the "premium-for-height" framework for designing structural systems for tall buildings: considering embodied environmental flows', Dec. 2018, after Khan (1967).
2. A. S. S. Rizk, 'Structural Design of Reinforced Concrete Tall Buildings', CTBUH Journal, no. 1, 2010.

# Carbon premium: Height

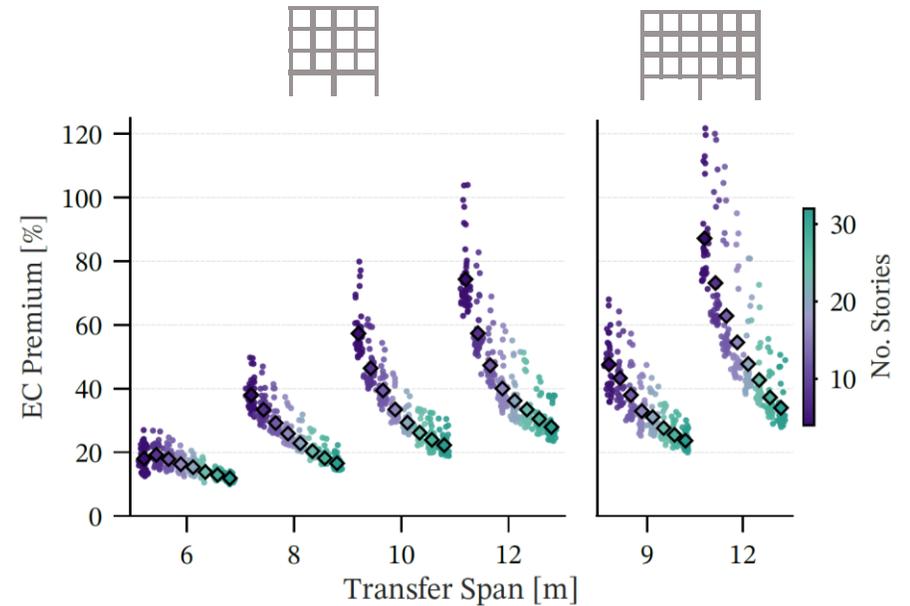
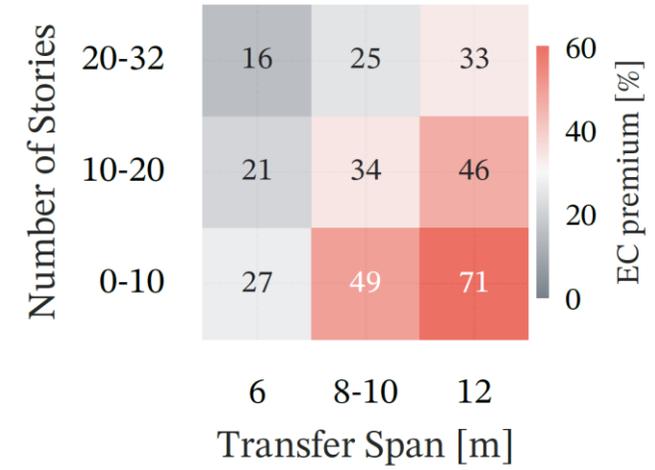


# Carbon premium: Transfers



Transfer beam

Transfer slab





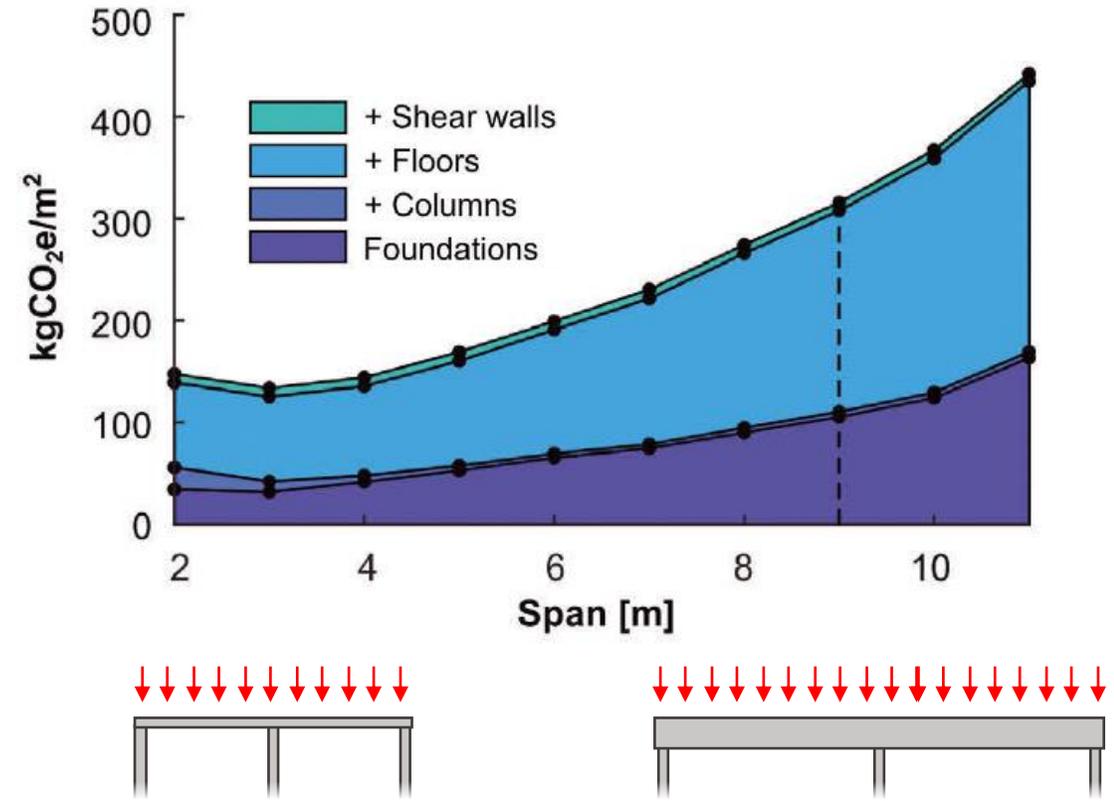


UrbanToronto contributor Rascacielo





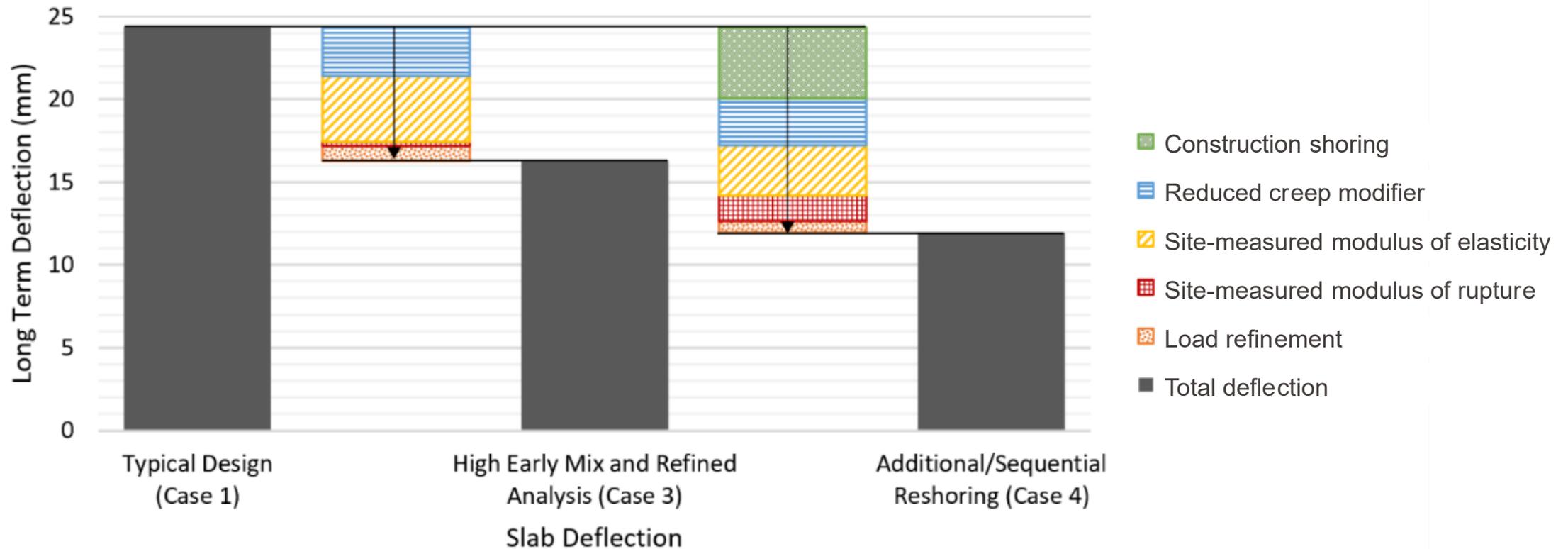
# Flat slabs

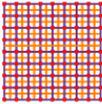
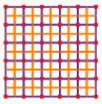
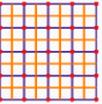
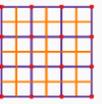
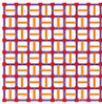
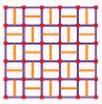
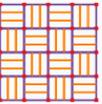
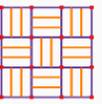
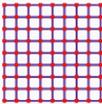
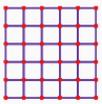
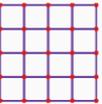
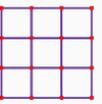
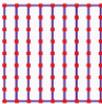
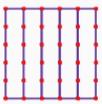
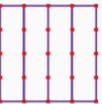
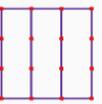
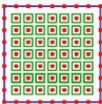
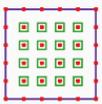
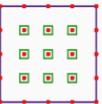
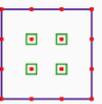
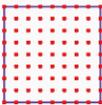
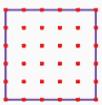
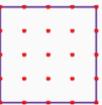
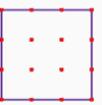
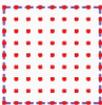
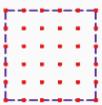
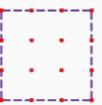




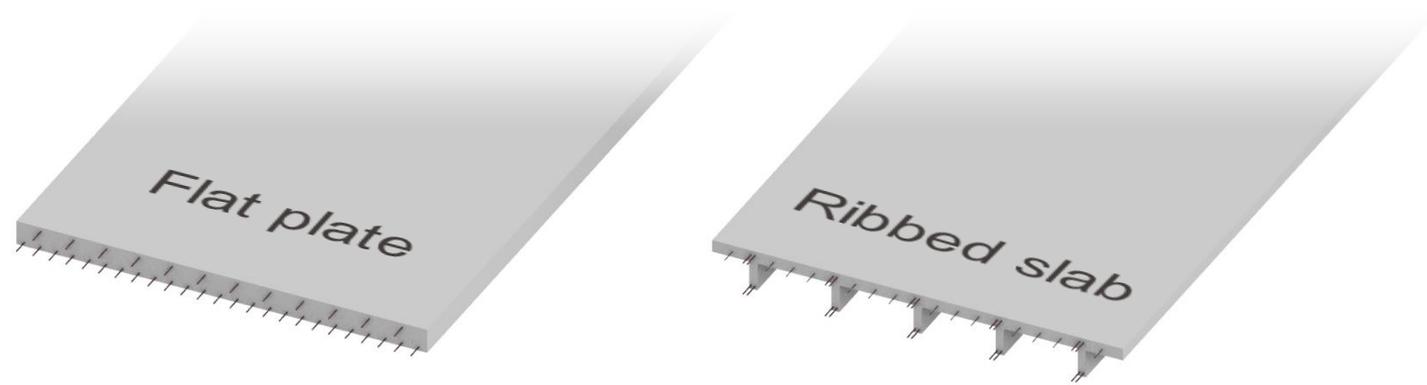


# Deflection mitigation

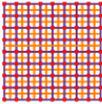
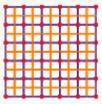
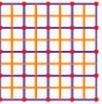
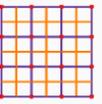
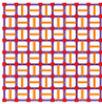
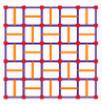
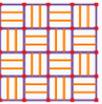
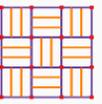
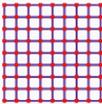
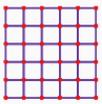
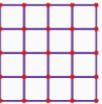
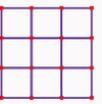
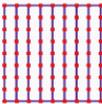
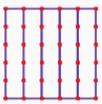
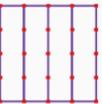
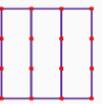
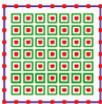
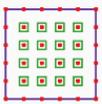
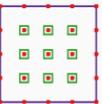
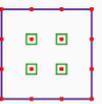
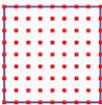
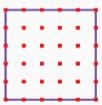
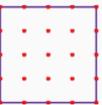
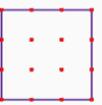
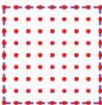
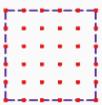
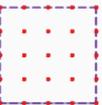
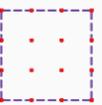


Typology	Embodied carbon intensity (kg CO <sub>2</sub> /m <sup>2</sup> )			
	span = 5.0 m	span = 7.5 m	span = 10.0 m	span = 12.5 m
A	 53	 58	 71	 83
B	 51	 55	 69	 87
C	 49	 64	 90	 115
D	 48	 71	 98	 119
E	 63	 76	 102	 125
F	 74	 82	 116	 153
G	 73	 99	 131	 167
Legend				

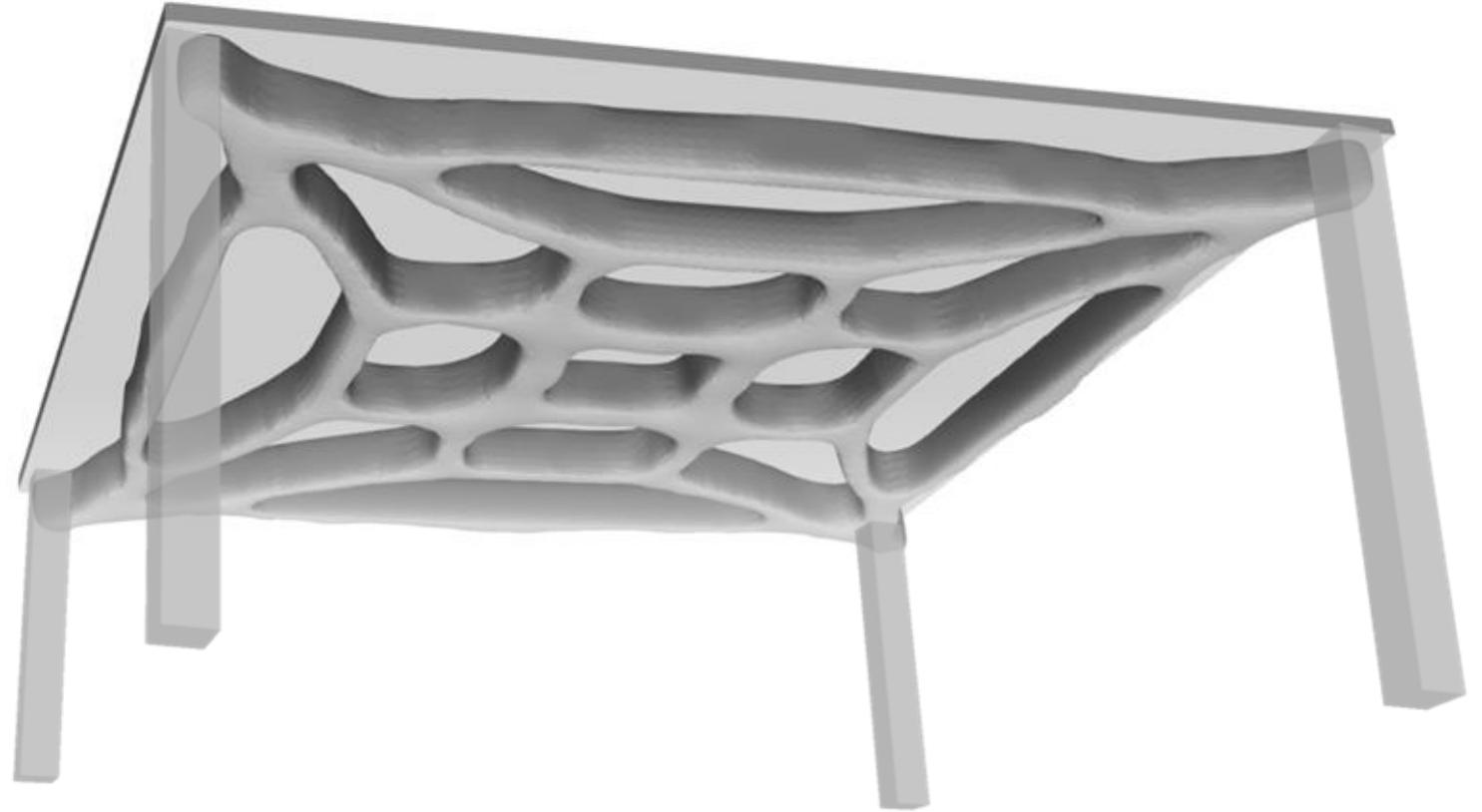
# Ribs and beams



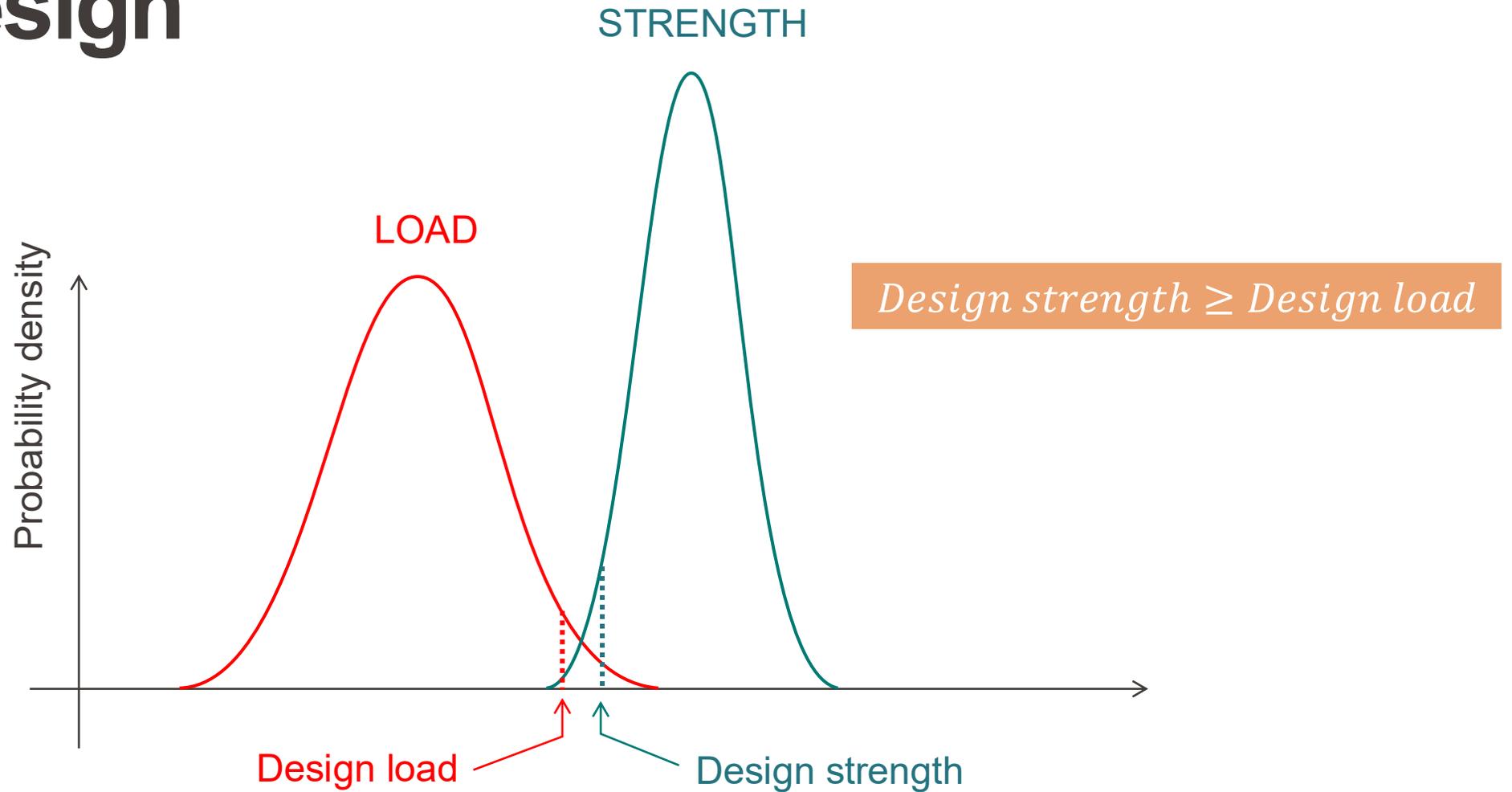
- ✗ More material, more embodied carbon
- ✓ Simpler formwork
- ✓ Cheaper
- ✓ Lower profile
- ✓ Less material, less embodied carbon
- ✗ Complex formwork
- ✗ More expensive
- ✗ Deeper profile

Typology	Embodied carbon intensity (kg CO <sub>2</sub> /m <sup>2</sup> )			
	span = 5.0 m	span = 7.5 m	span = 10.0 m	span = 12.5 m
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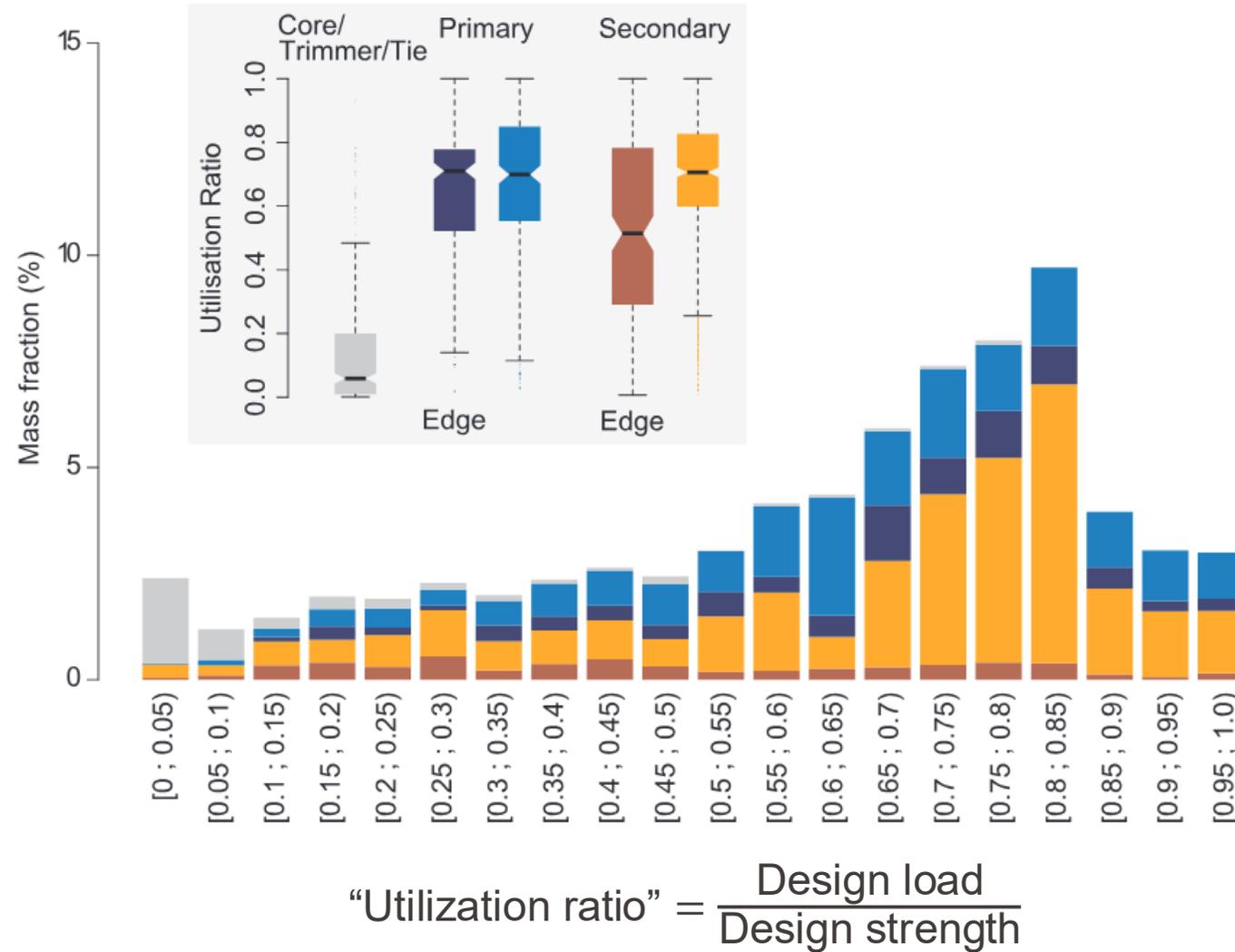
# Ribs and beams



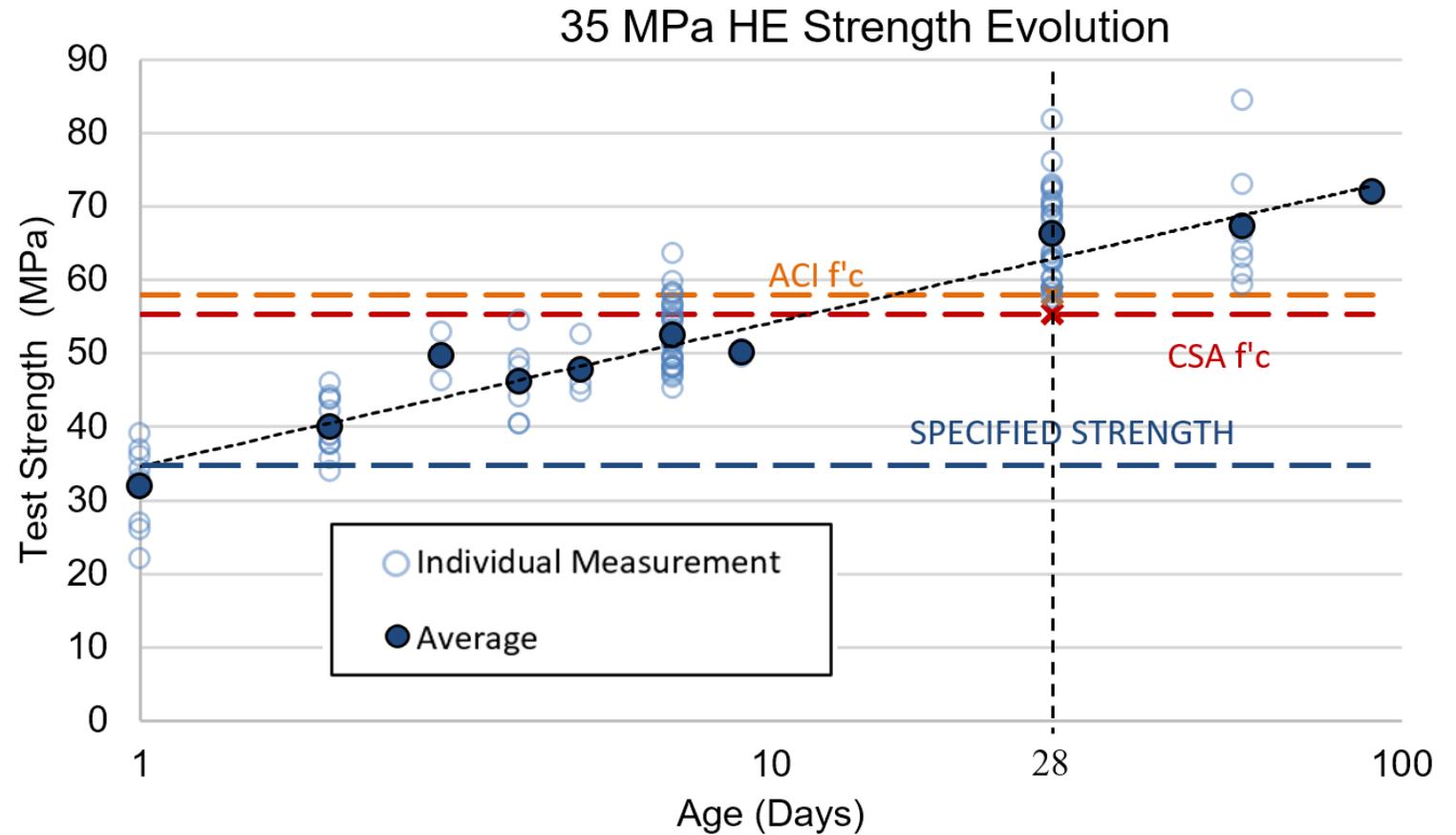
# Systemic over-design



# Systemic over-design



# Systemic over-design



D. Snodgrass and D. Ruggiero, 'Finding carbon and cost efficiencies in the design of RC slabs made from high early strength concrete', in *Concrete structures: extend lifetime, limit impacts Proceedings of the 2025 fib International Symposium, held in Antibes, France*, Antibes, France: Fédération internationale du béton - International Federation for Structural Concrete (fib), Jun. 2025, pp. 2379-2390.

# The structural diet

Weight-loss tips for our buildings

## Geometry and layout:

Right-size spans; shorter is better  
Align elements vertically to minimize transfers and cantilevers  
Accept structural depth where possible

## Design practice and culture:

Prioritize early coordination between disciplines  
Avoid stacking additional factors of safety  
Challenge the design brief

## Technical optimization:

Design floors for realistic deflection and serviceability targets  
Use higher strength materials strategically  
Make embodied carbon an explicit design variable

An aerial photograph of a dense urban area, likely a city center, with numerous skyscrapers and buildings. In the center of the image, there is a large, rectangular construction site with a red perimeter fence and some construction equipment visible. The overall color palette is dominated by blues and greys, with the red of the EPFL logo and the construction site fence providing contrast.

**EPFL**

Sustainability in Construction and Urban Futures

# Thank you for your attention!

■ École  
polytechnique  
fédérale  
de Lausanne

PRESENTED BY

**Prof. David Ruggiero**  
Concrete Behaviour and  
Structural Design Laboratory