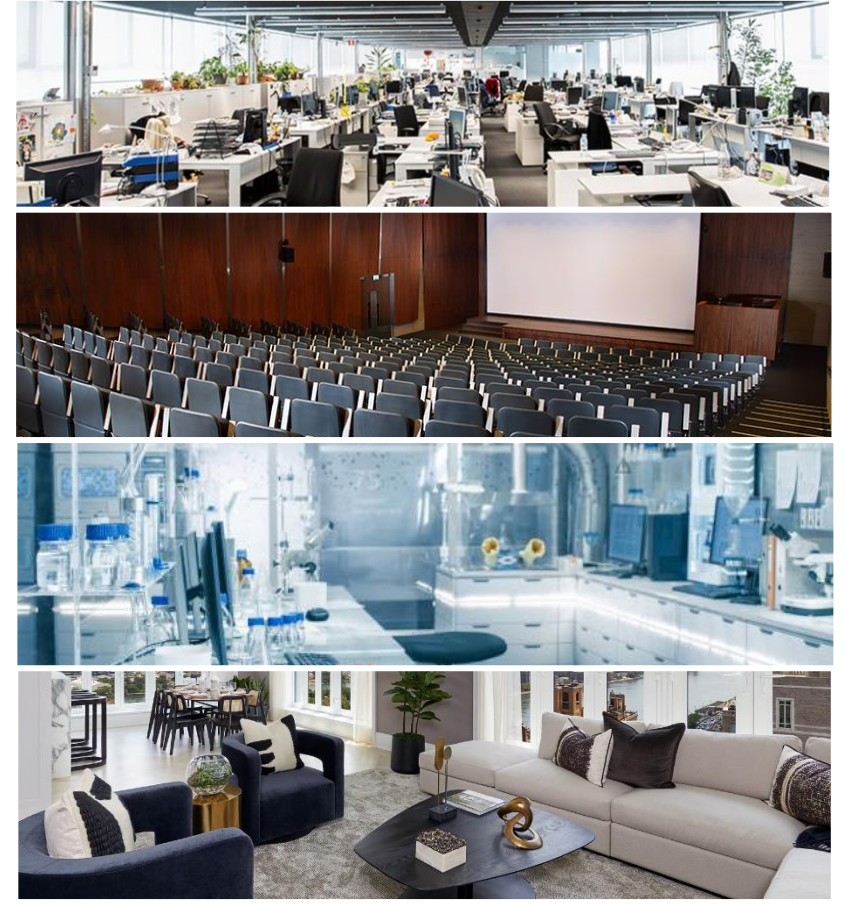
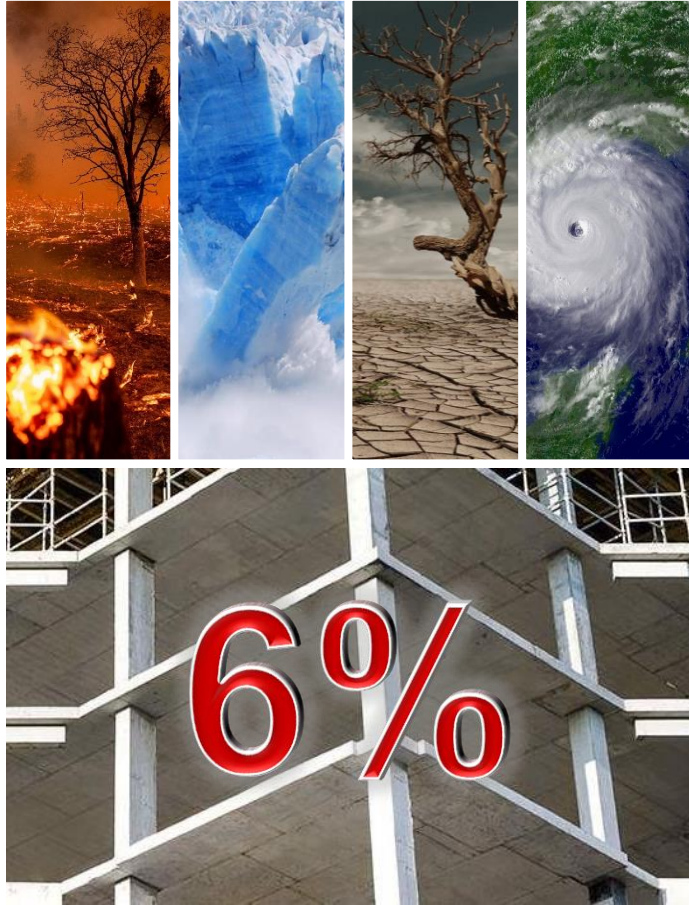


Comparing The Embodied Carbon and Cost of Concrete Floor Solutions

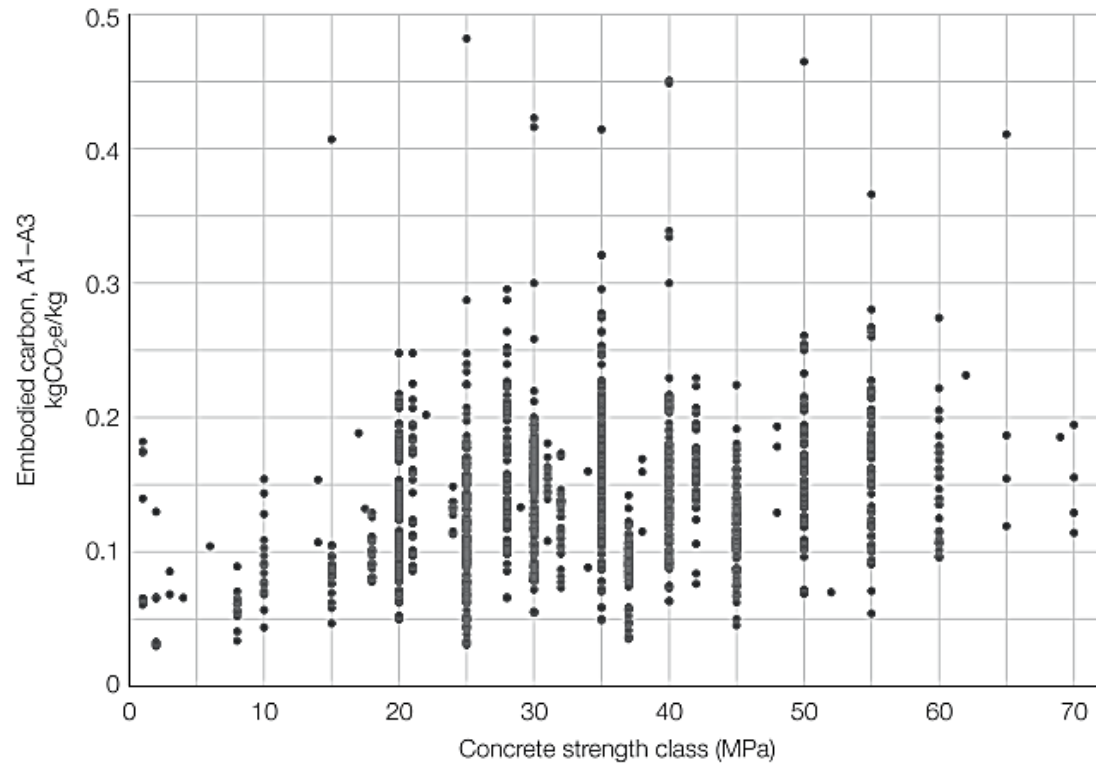
Amila Jayasinghe, John Orr, Tim Ibell, William P Boshoff

8th RECBE (on-line) meeting, 25th February 2022

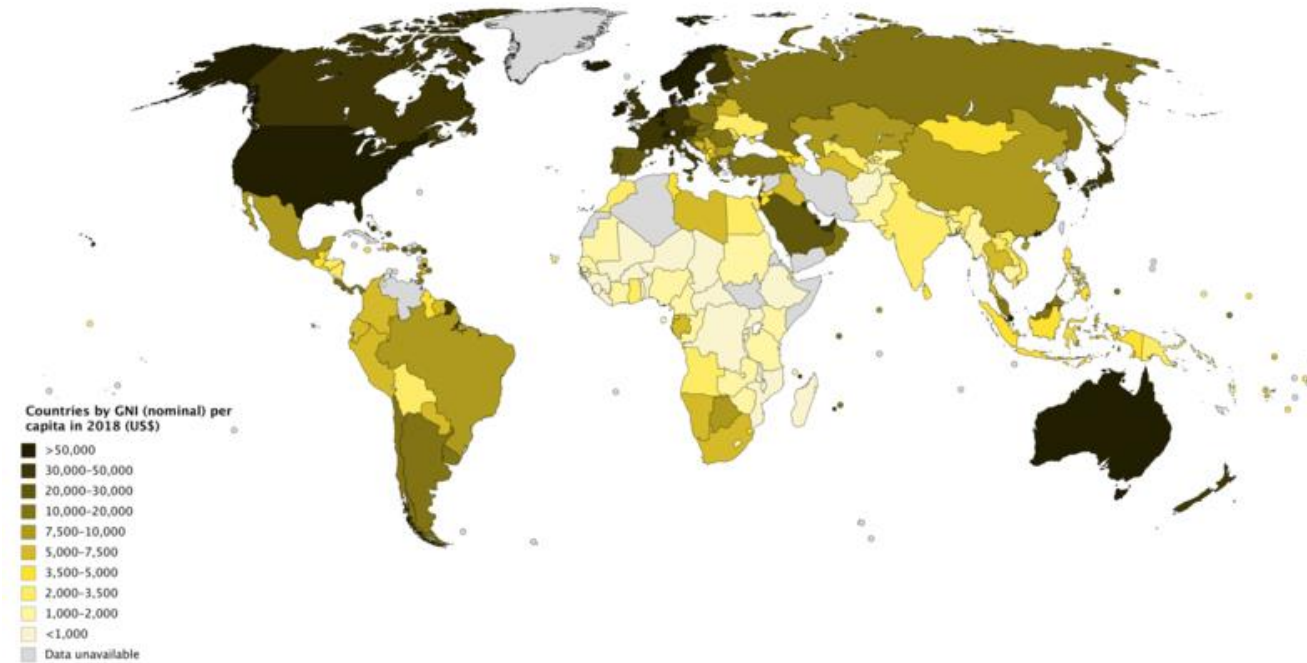
The Construction Industry, Carbon and ...



Embodied Carbon vs Cost

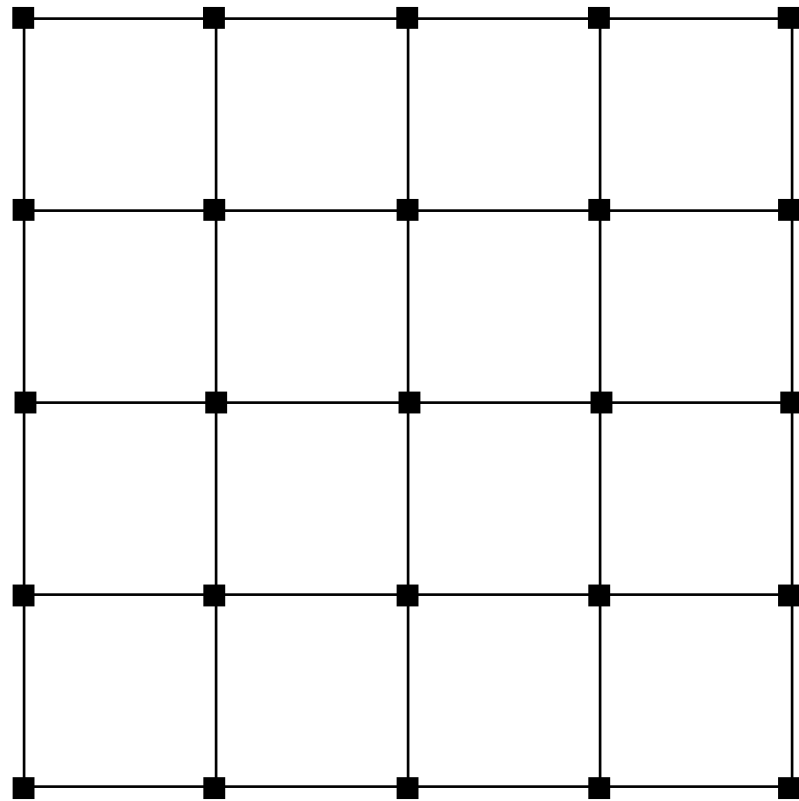


Possible Variation of Embodied Carbon for Different Concrete Mixes: *Gibbons and Orr (2020)*



Global Variation of Gross National Income (GNI) Per Capita: *The World Bank (2020)*

Cost and Embodied Carbon of Different Slab Types



Structural Materials for One-Storey Frame

$\text{kgCO}_2\text{e/m}^2$

vs

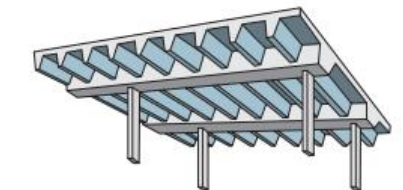
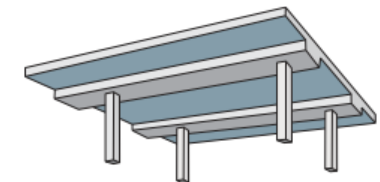
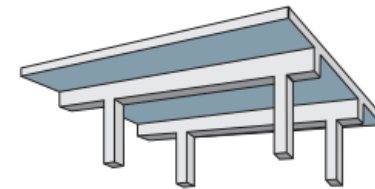
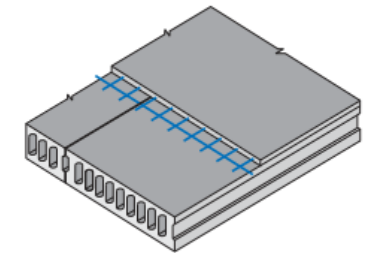
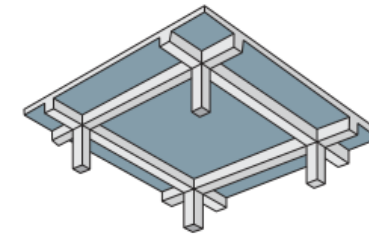
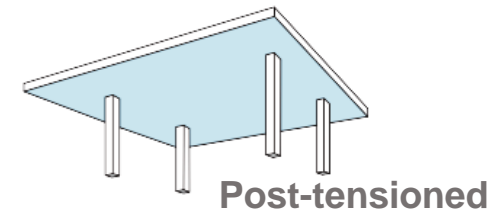
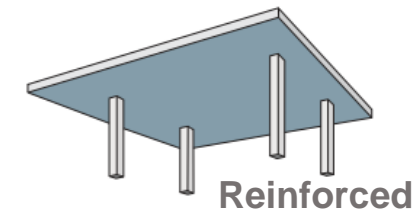
£/m^2



Pareto Optimality



*Dependability on Adopted
Cost Rates and Carbon
Coefficients*



Concept V4



CONCEPT Geometry

PROJECT: New
CLIENT: Client
DATE: 09/1
Project No.: 1000

Geometry	Loads	Rates	Results	Cost summary	Member sizes	View
----------	-------	-------	---------	--------------	--------------	------

SET NUMBER OF BAYS

Bays in X direction: 3 USE ARROWS max 16m X from left 8.000 8.000 8.000

Bays in Y direction: 3 max 16m Y from top 8.000 8.000 8.000

STOREY HEIGHTS

Storey heights are:

For Wide Beam solutions: Clear height is to

For Ribbed Slab solutions:

Wide beam & slab depths

SET STOREY HEIGHTS: 3.50 metres

Floor-floor height = 3.5 m plus slab & beam depth.

THE NUMBER OF FLOORS WILL BE SET ON THE NEXT SHEET

CLICK Refresh Layout

TO REMOVE A PANEL delete 1 in the matrix on the right or enter 1 to reinstate

Do not paste or drag cells

BAY LAYOUT

MATRIX SHOW

1	1	1
1	1	1
1	1	1

To retrieve data, open data file in normal way and click LOAD button within the data file (DO NOT change this filename)



CONCEPT Results (summary)

PROJECT / No.: 1000 New Building
CLIENT: Client
DATE: 09/11/21

CONCEPT.xls
version 4.2

Geometry	Loads	Rates	Results	Cost summary	Member sizes	View plan	View sections	3D view
----------	-------	-------	---------	--------------	--------------	-----------	---------------	---------

Total Cost (selected solution) = £199,395 Time = 10.9 weeks (estimate for superstructure only) GIFA = 1,786 m²

SOLUTION	Solution	Construction cost £k	RANK	Cost per m ² GIFA £/m ²	Construction time Days	RANK	Total cost £k	RANK	Total cost m ² GIFA £/m ²	Structure Cost £k	RANK	Structure m ² GIFA £/m ²	Superstructure ISEC tCO ₂ e	RANK	Superstructure ISEC per GIFA kgCO ₂ /m ²
S2	Two-way Slab	£199k	£112	60	£199k	£112	£86k	£48	156	87.5					
S11	Ribbed Slab - Wide Beam, spanning in Y	£254k	£142	63	£254k	£142	£108k	£60	175	98.1					
S3	Post-tensioned flat slab	£226k	£126	48	£226k	£126	£122k	£68	178	99.4					
S13	Hollowcore, spanning in Y	£210k	£118	54	£210k	£118	£147k	£83	181	101.6					
S10	Ribbed Slab - Wide Beam, spanning in X	£254k	£142	63	£254k	£142	£107k	£60	182	102.0					
S12	Hollowcore, spanning in X	£211k	£118	54	£211k	£118	£148k	£83	183	102.5					
S1	Flat Slab	£211k	£118	51	£211k	£118	£134k	£75	197	110.4					
S8	Ribbed Slab, spanning in X	£284k	£159	63	£284k	£159	£116k	£65	198	110.9					
S9	Ribbed Slab, spanning in Y	£284k	£159	63	£284k	£159	£116k	£65	198	110.9					
S5	One-way Slab, spanning in Y	£224k	£126	57	£224k	£126	£112k	£63	204	114.0					
S4	One-way Slab, spanning in X	£225k	£126	57	£225k	£126	£112k	£63	204	114.4					
S6	One-way Slab - Wide Beam, spanning in X	£229k	£128	57	£229k	£128	£120k	£67	207	116.2					
S7	One-way Slab - Wide Beam, spanning in Y	£231k	£129	57	£231k	£129	£122k	£68	212	118.9					

Notes:
CONSTRUCTION COST includes ALL COST (material, construction, prelims & external works, mechanical & electrical, cladding, & allows for stairs, shear walls) - see Cost Summary.
TOTAL COST includes CONSTRUCTION COSTS + COST OF TIME DIFFERENCE
STRUCTURE COST includes SLAB, BEAMS, COLUMNS, GROUND FLOOR SLAB, FOUNDATIONS
ISEC - Initial Superstructure Embodied Carbon (A1-A3) - includes SLAB, BEAMS, COLUMNS, GROUND FLOOR SLAB

See if actions required:

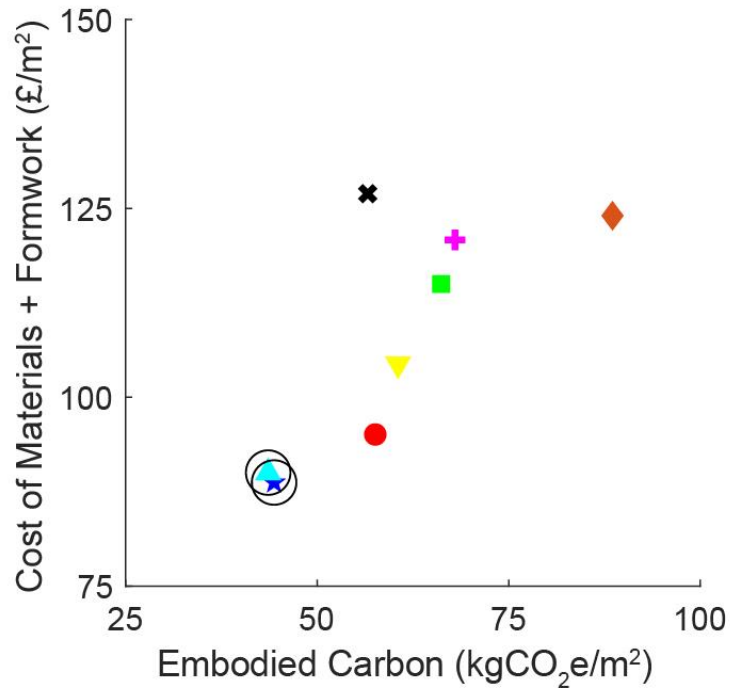
Office Floor Loading
 Superimposed dead load – 0.85 kN/m²
 Imposed load - 2.5 kN/m²



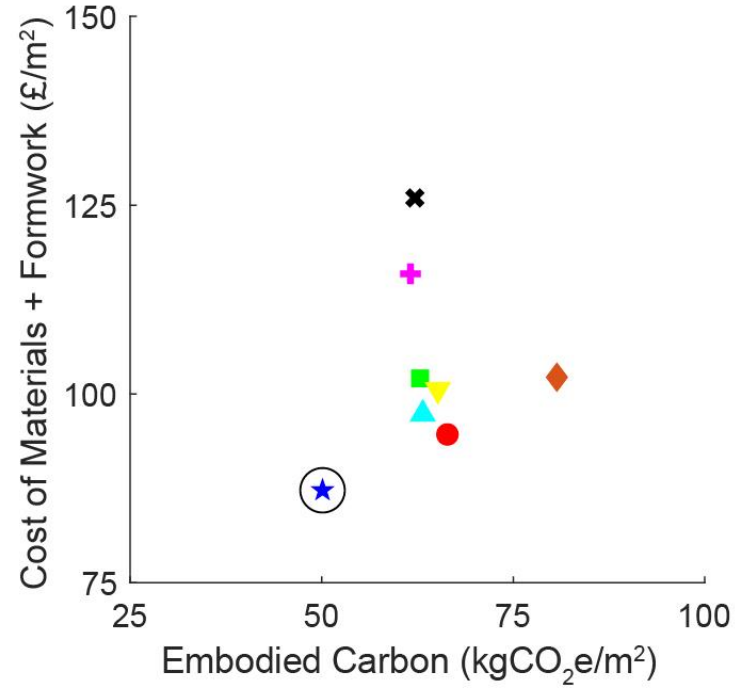
The Concrete Centre (2020) 'Cost and Carbon: Concept V4'. London: The Concrete Centre.



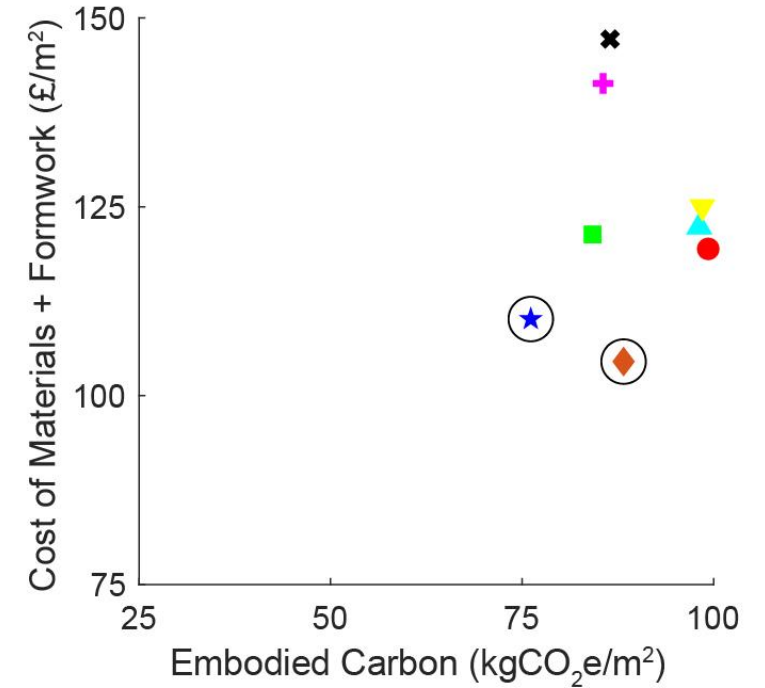
Variation of Cost and Embodied Carbon with Span



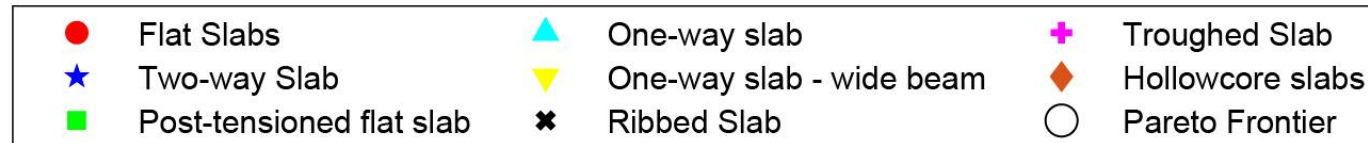
(a) Column Spacing of 4 m



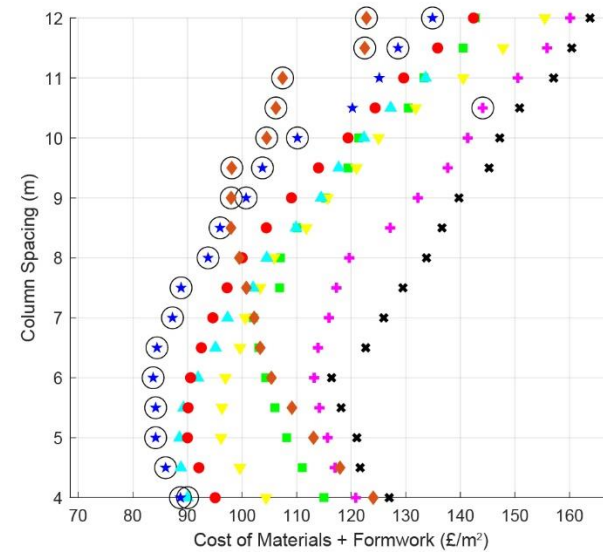
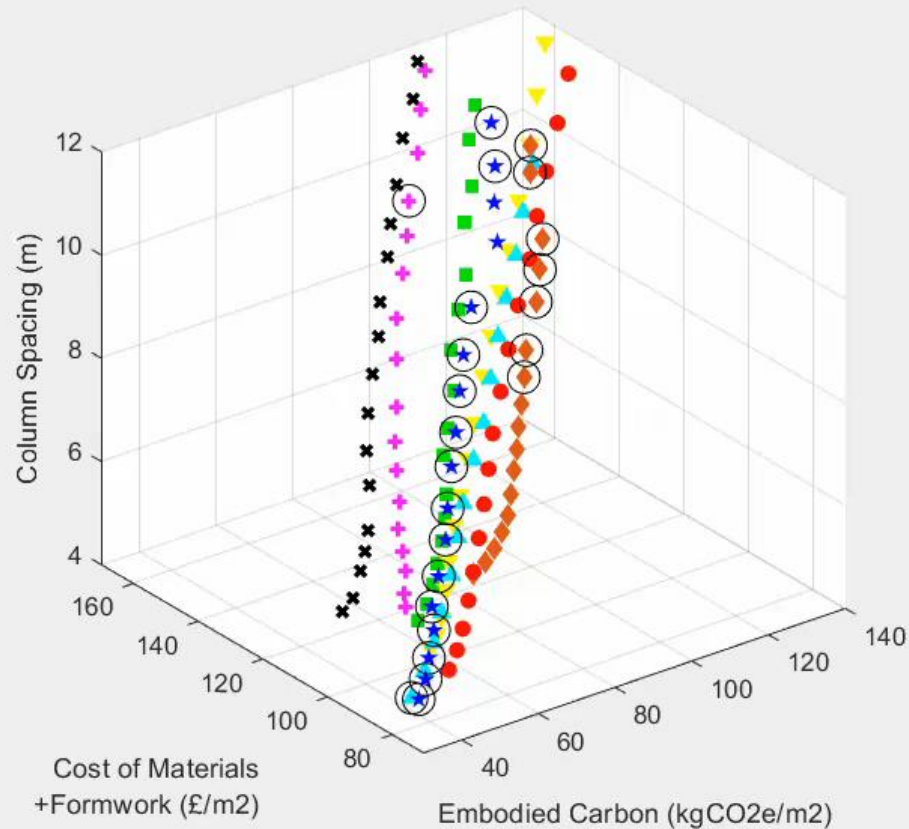
(b) Column Spacing of 7 m



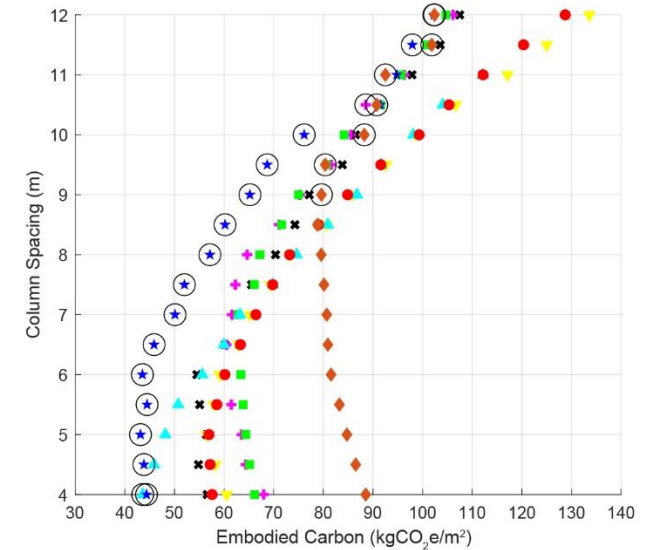
(c) Column Spacing of 10 m



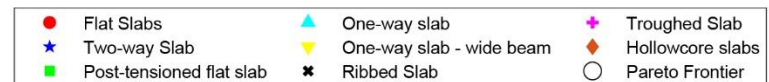
Variation of Cost and Embodied Carbon with Span



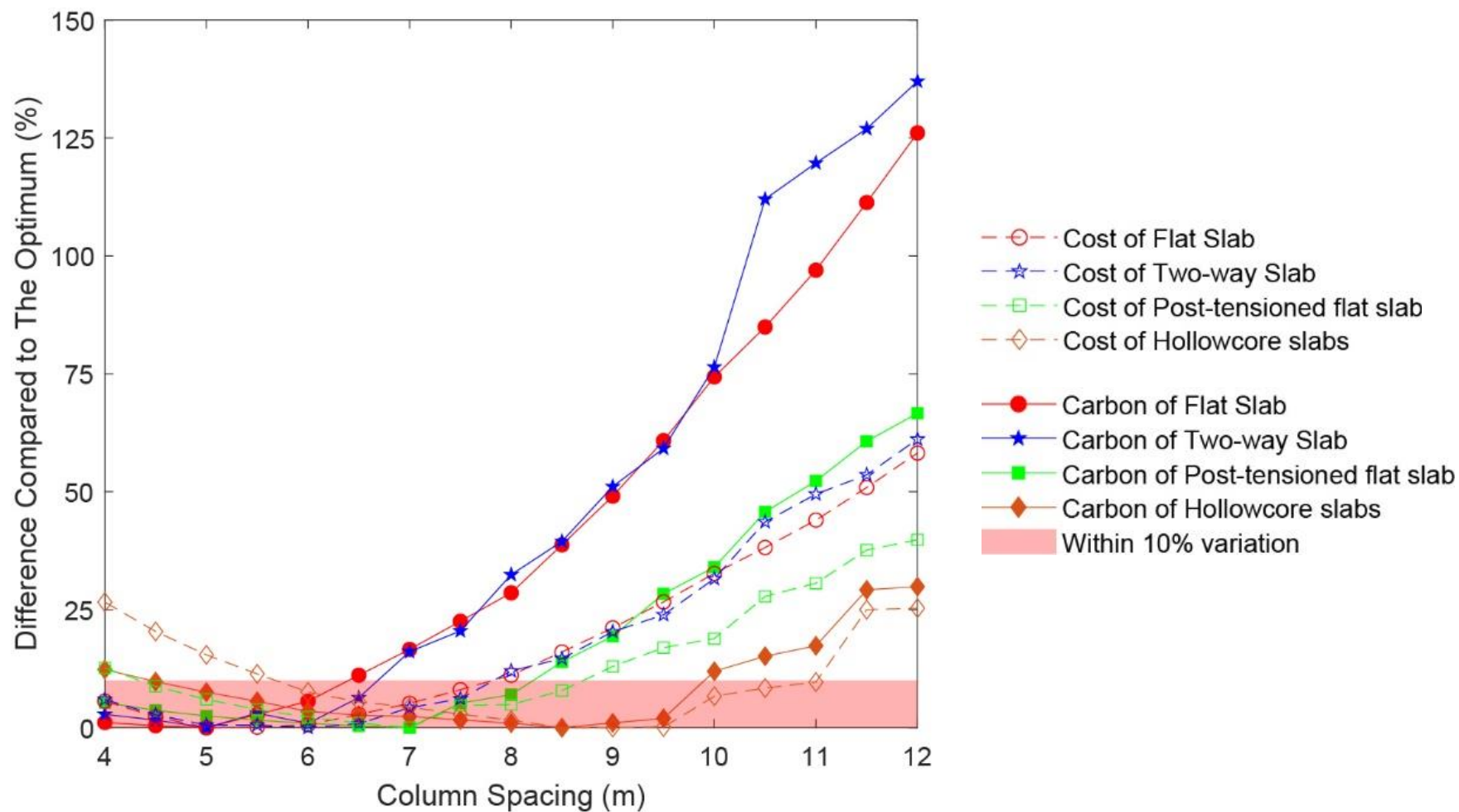
(c) Variation of cost with column spacing



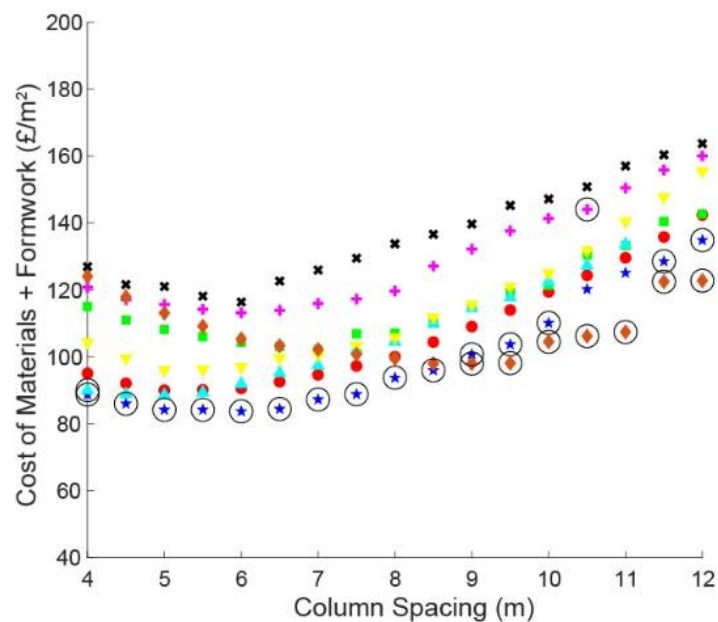
(d) Variation of embodied carbon with column spacing



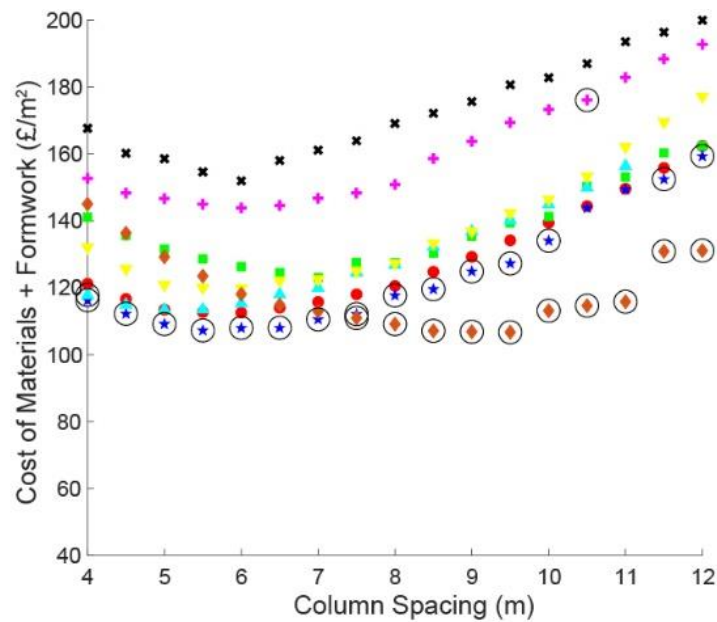
Column Layout Optimisation



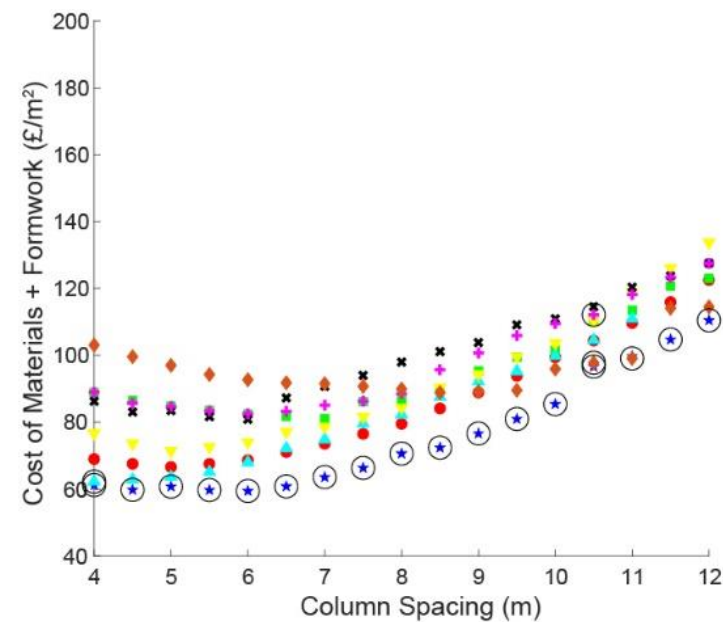
Effect of Adopted Cost Rates



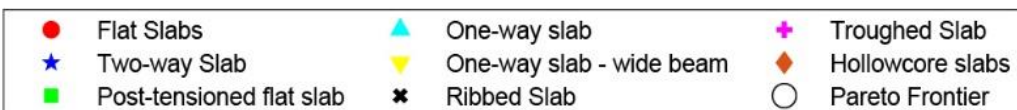
(a) With original cost rates



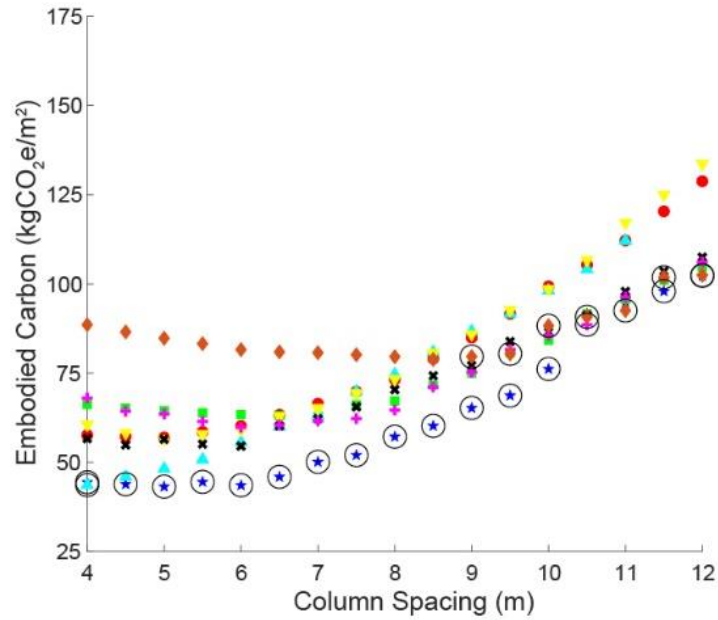
(b) If cost of formwork increased by 50%



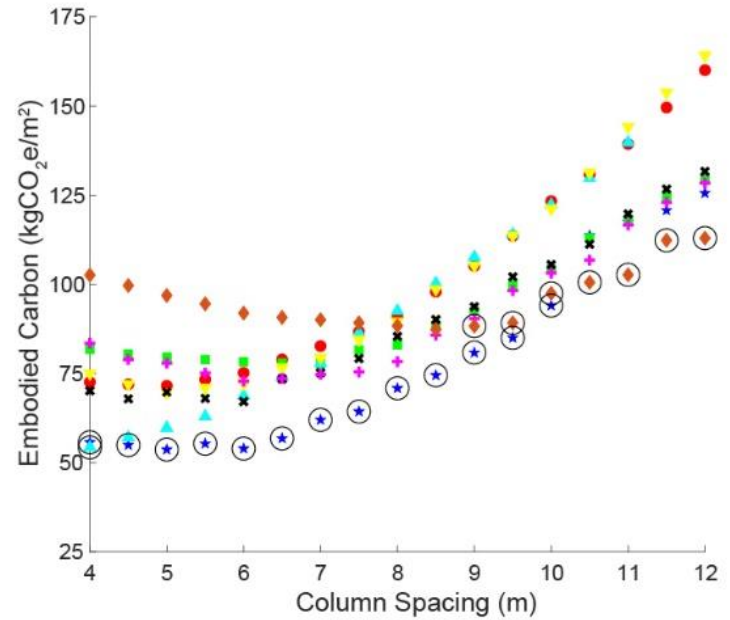
(c) If cost of formwork reduced by 50%



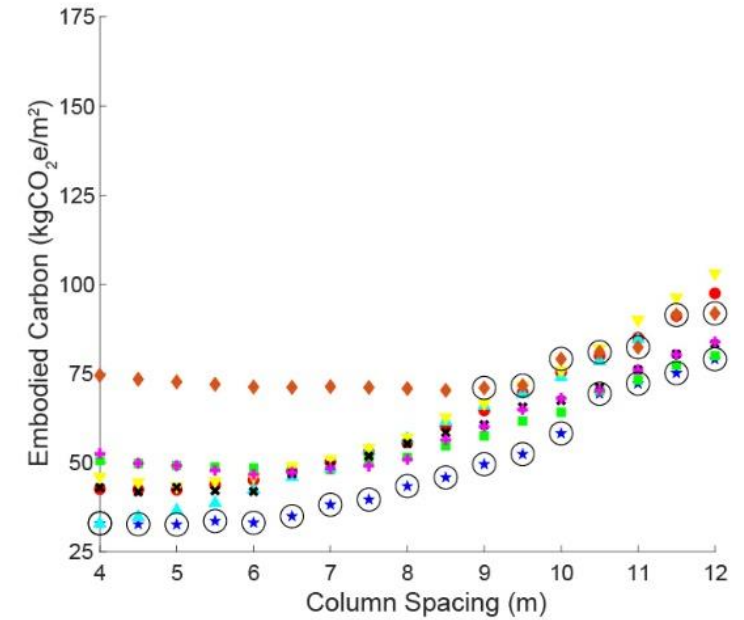
Effect of Adopted Carbon Coefficients



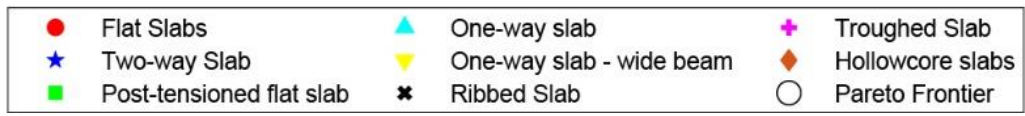
(d) With original carbon coefficients



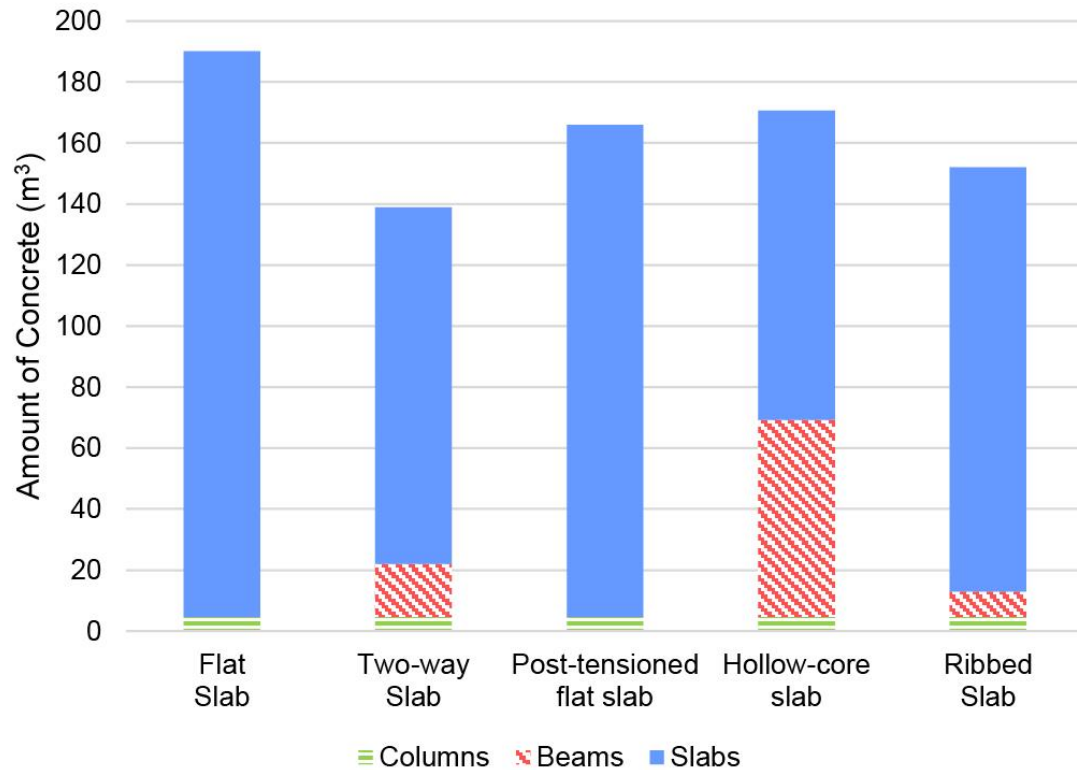
(e) If carbon of concrete increased by 30%



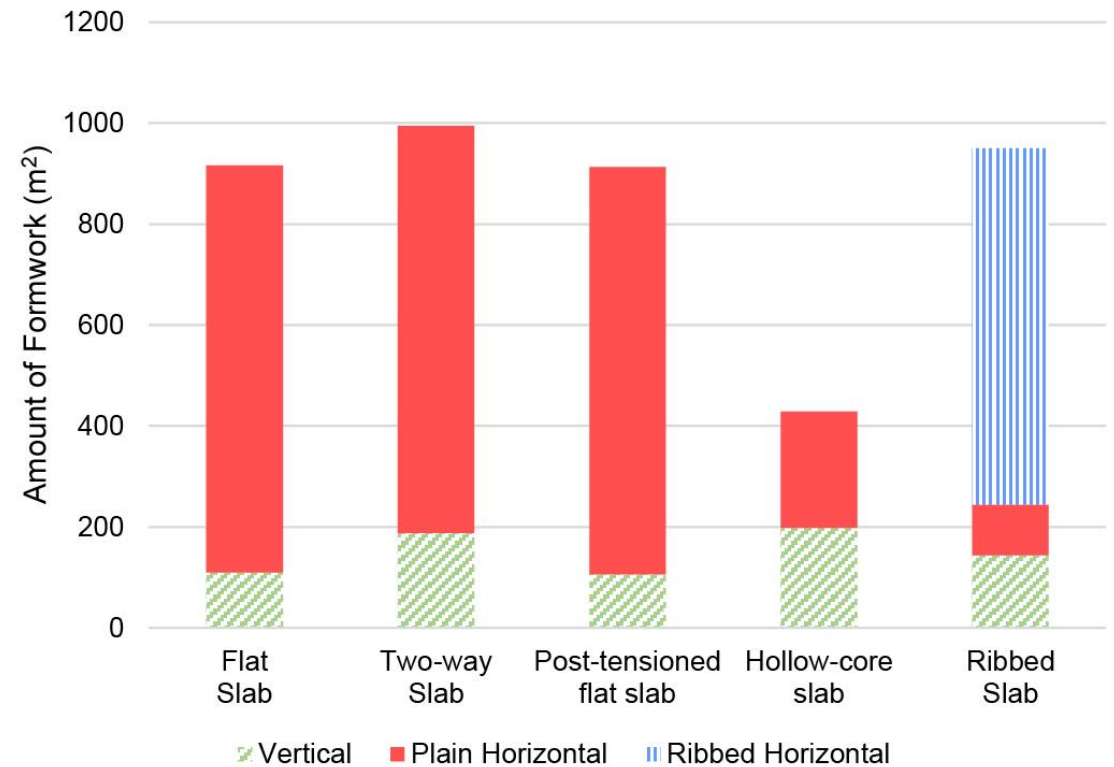
(f) If carbon of concrete reduced by 30%



Why Pareto Optimal Solutions Didn't Change



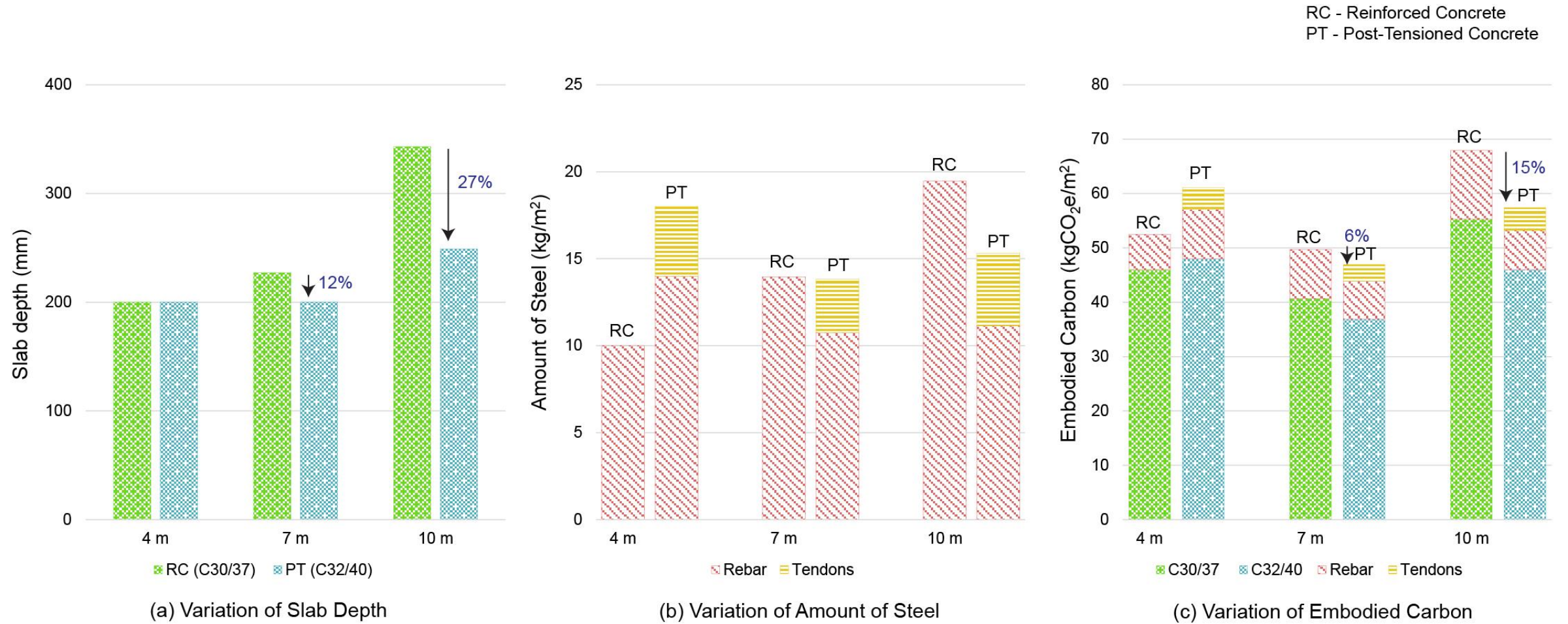
(a) Amount of concrete required for different forms of slabs



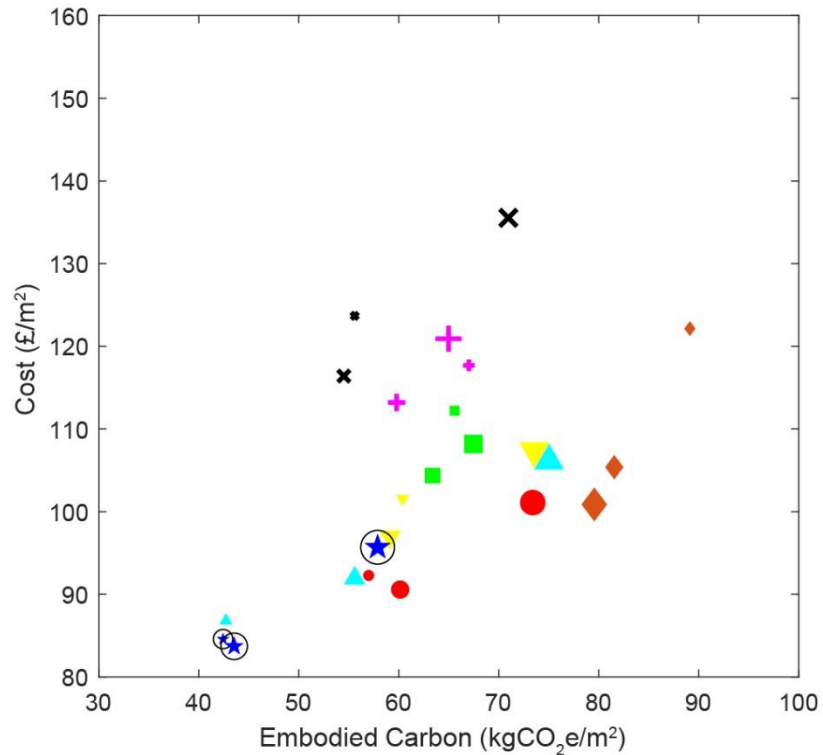
(b) Amount of formwork required for different forms of slabs

For 7 m x 7 m column grid

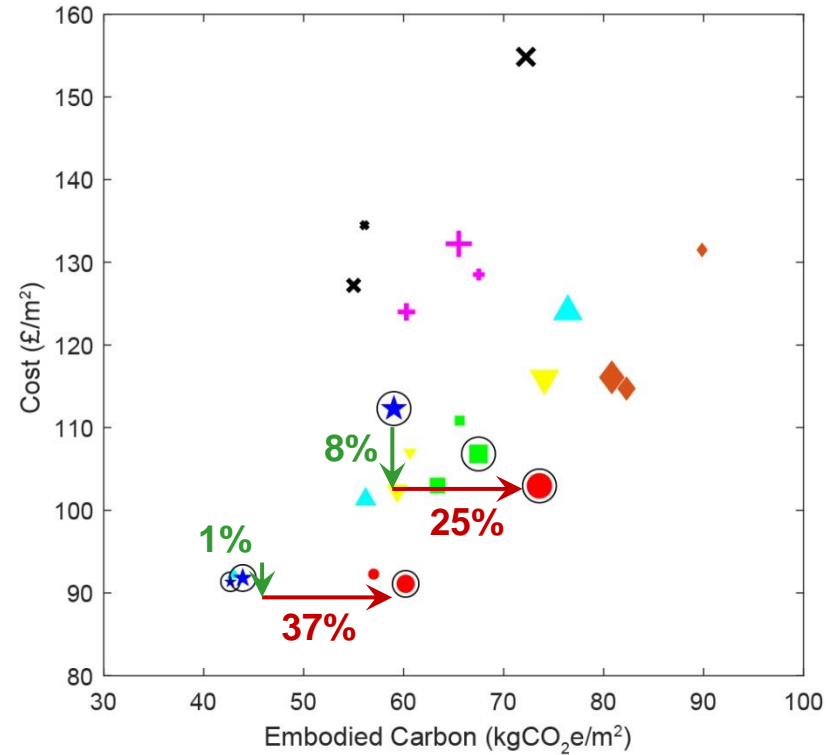
Passive vs Active Reinforcement



Effect of Construction Time and Storey Height



(a) Considering only the materials and formwork for slabs, beams and columns



(b) Including the differences in cladding and construction time

- Flat Slabs for 4 m column spacing
- ★ Two-way Slab for 4 m column spacing
- Post-tensioned flat slab for 4 m column spacing
- ▲ One-way slab for 4 m column spacing
- ▼ One-way slab - wide beam for 4 m column spacing
- Ribbed Slab for 4 m column spacing
- ✦ Troughed Slab for 4 m column spacing
- ◆ Hollowcore slabs for 4 m column spacing
- Pareto Frontier for 4 m column spacing
- Flat Slabs for 6 m column spacing
- ★ Two-way Slab for 6 m column spacing
- Post-tensioned flat slab for 6 m column spacing
- ▲ One-way slab for 6 m column spacing
- ▼ One-way slab - wide beam for 6 m column spacing
- Ribbed Slab for 6 m column spacing
- ✦ Troughed Slab for 6 m column spacing
- ◆ Hollowcore slabs for 6 m column spacing
- Pareto Frontier for 6 m column spacing
- Flat Slabs for 8 m column spacing
- ★ Two-way Slab for 8 m column spacing
- Post-tensioned flat slab for 8 m column spacing
- ▲ One-way slab for 8 m column spacing
- ▼ One-way slab - wide beam for 8 m column spacing
- Ribbed Slab for 8 m column spacing
- ✦ Troughed Slab for 8 m column spacing
- ◆ Hollowcore slabs for 8 m column spacing
- Pareto Frontier for 8 m column spacing

Conclusions

- Different slab types → Different cost and carbon for different spans
- Optimum column layout depends on slab type
- Cost or Carbon vs column spacing - Nonlinear
- Decisions from Pareto optimal solutions ↔ Compare relative gains and losses
- Two-way slabs on beams and Hollow-core slabs mostly Pareto Optimal
- Dependability of adopted cost or carbon coefficients ↔ Patterns in Optimisation

Special Thanks to

- *Dr John Orr*
- *Prof Tim Ibell*
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- *Dr Michal Drewniok*
- *Dr Will Hawkins*
- *Dr Robin Oval*



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