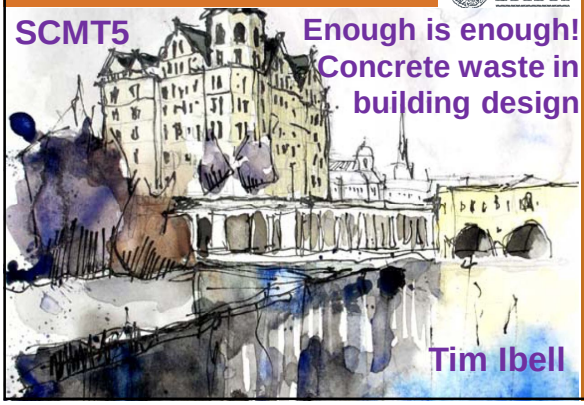
SCMT5

Enough is enough!
Concrete waste in building design



Tim Ibell

Climate change

Climate change

equals

Climate change

equals

WAR

$10,000,000,000,000

$10,000,000,000,000

($1 bills stacked up to moon and back again)

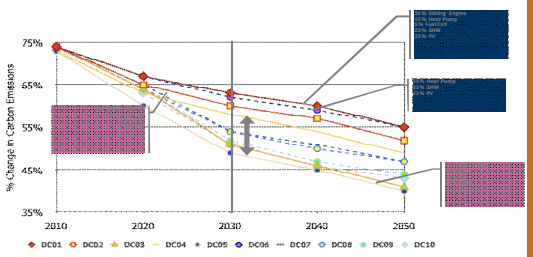
$10,000,000,000,000

(1% savings pays for all drug discovery)

Three issues:

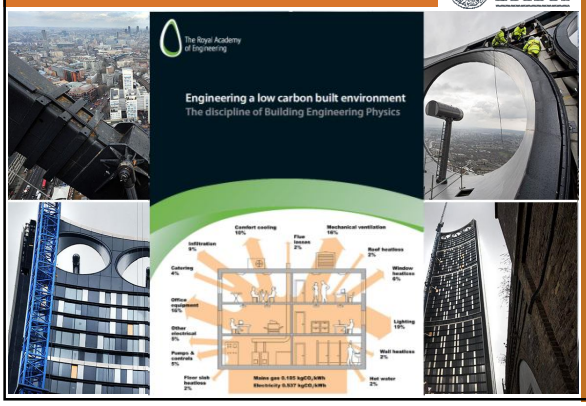
1. **Operational energy**
2. **Material efficiency**
3. **Appropriate loads**

Operational energy



Near & Long Term Targets

Based on the BRE's Step Change 2 Scenario

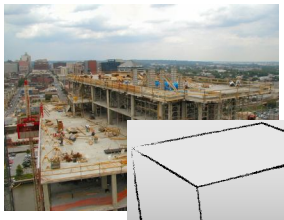


Material efficiency

Material efficiency

We don't make walking sticks

Fabric formwork

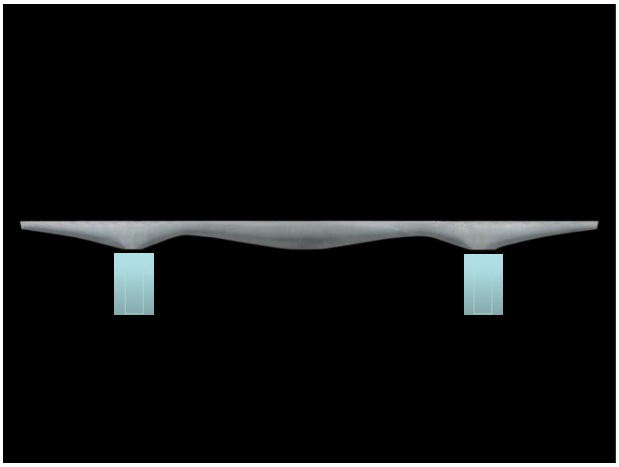


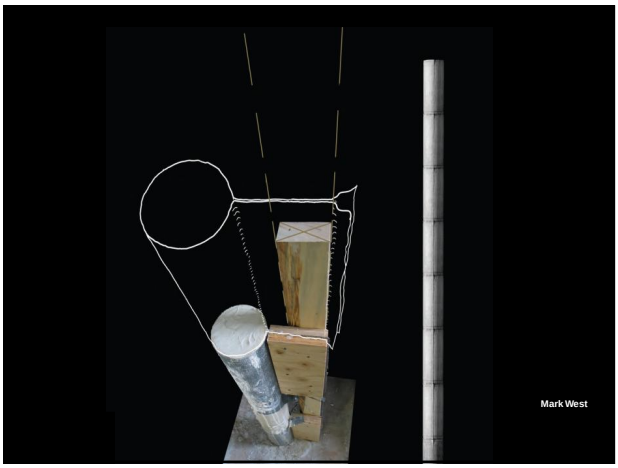
- Deadweight
- Energy use

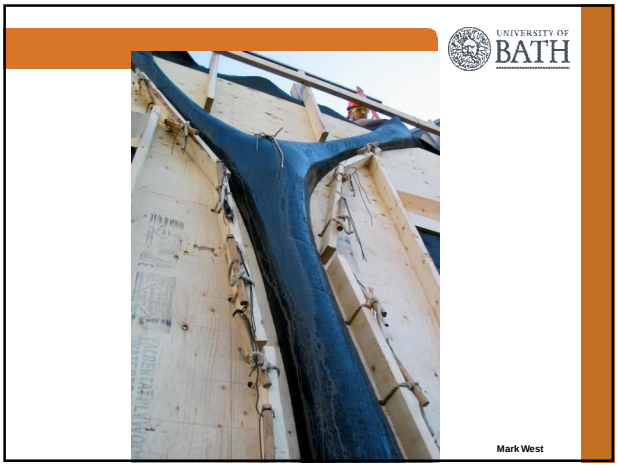
Fabric formwork

put material where you need it
optimise your design

concrete is a fluid
that sets like rock




Mark West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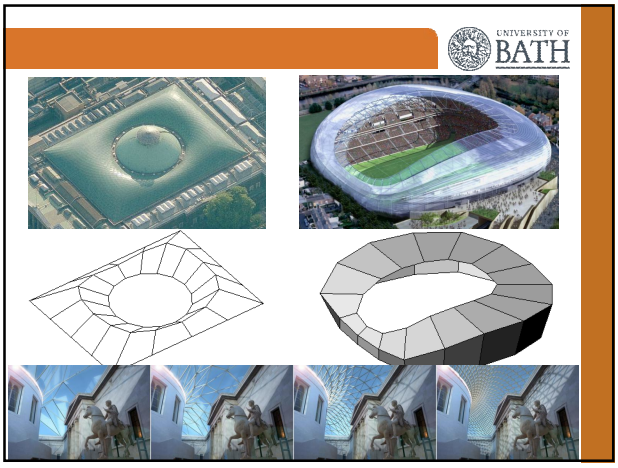
Mark West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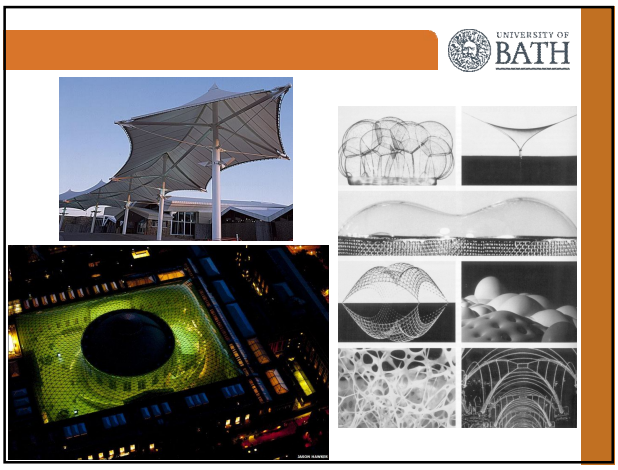
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Loading

Real performance

- Design loadings too high
- We do not measure loads
- Risk mitigation is via materials
- If lighter, user issues?

- Surely, buildings are our laboratory!

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Material Efficiency In CONstruction

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF BATH

MEICON

Minimising Energy in Construction

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Material Efficiency In CONstruction

Mic on!

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3.2.1 Question 1: Maximising material utilisation is a key design criterion for me (frequency, n = 129)

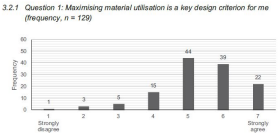

Figure 7: Q1

Median = 5

3.2.2 Question 2: The material utilisation of each structural element in my designs is normally close to 1.00 (n = 129)

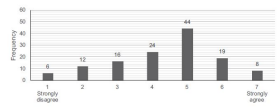

Figure 8: Q2

Median = 5

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3.2.3 Question 3: The oversizing of structural elements during initial or concept design stages is normally appropriate (n = 129)

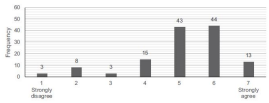

Figure 9: Q3

Median = 5

3.2.4 Question 4: An easily constructed structure is more valued by the whole design team than a materially efficient structure (n = 129)

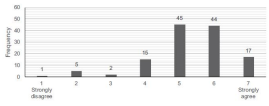

Figure 10: Q4

Median = 5

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3.2.8 Question 8: My clients or design team normally require me to minimise total embodied energy (n = 129)

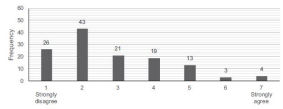

Figure 14: Q8

Median = 2

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3.2.9 Question 9: The material utilisation of a structural design is normally presented to clients (n = 129)

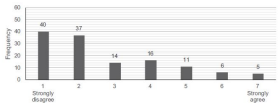

Figure 15: Q9

Median = 2

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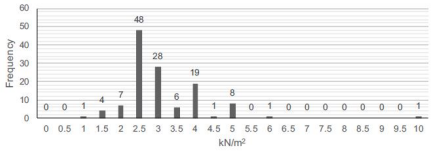
3.3.3 Question 14: Imagine you are designing a new multi-storey office building for a financial services firm in the centre of a city. What CHARACTERISTIC value of imposed vertical floor design load in the office spaces would you use, excluding any allowance for moveable partitions? (n = 124)

This question allowed the participants to enter their response as a number. The histogram distribution of responses is shown below.



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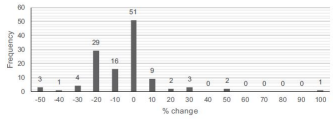
3.3.8 Question 19: Imagine you are solely responsible for rewriting your local structural design code. What percentage changes, if any, in imposed design loading would you introduce? (n = 121)



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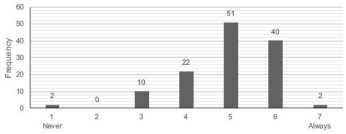
3.4.1 Question 20: In your experience, how often does the serviceability limit state govern the size of structural elements? (frequency, n = 127)



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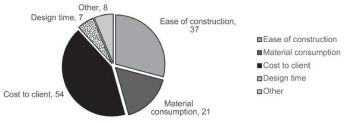
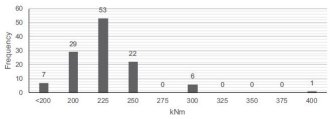
3.5.1 Question 23: You are asked to design the floor plate in a multi-storey building. Which one of the following has the biggest influence on your final design: (frequency, n = 127)



3.5.2 *Question 24: Imagine you are undertaking the detailed design of a flexurally dominated floor beam. The flexural design effect of the actions ("Ed") on the beam at mid-span is 200kNm (including partial factors). The beam is to be a fabricated steel section. What value for the flexural design resistance ("Rd") of the beam at mid-span (including partial factors) would you choose? (n = 118)*



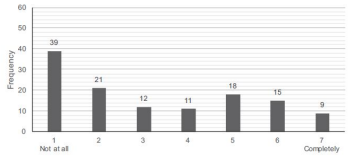
3.5.4 *Question 26: Thinking about your professional practice, which of the following would be the prime reason for an element to have a design resistance that is greater than the design effect of the actions on the element? (n = 126)*

Table 9

Response (years up to)	Number	%
The span, loading, or layout might change before construction.	38	30%
I am uncomfortable with the design effect of the actions being equal to the design resistance of the element.	12	10%
I don't trust the factors of safety in design codes	0	0%
I like to build in a bit of spare capacity just in case.	24	19%
The building might change use later in its life.	21	17%
Other	31	25%
	126	**100%**

And no more!

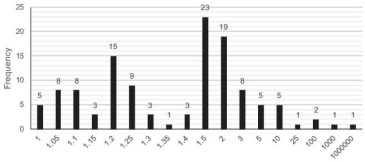
3.6.1 *Question 27: How feasible do you think it would be to introduce into design codes a limit on how much greater the Design Resistance of a structural element could be as compared to its required capacity? This would prohibit engineers from designing elements with a capacity greater than this upper limit. (frequency, n = 125)*



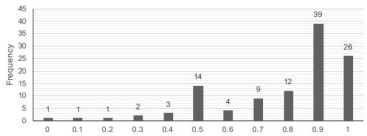
3.6.2 *Question 28: Imagine that such a limit is introduced into a design code. The Design value of resistance ("Rd") for each element must be greater than the Design effect of the action ("Ed") AND less than "Beta" multiplied by "Ed", where "Beta" is a number ≥1.00. This relationship is shown in the equation below. What value of "Beta" would you be happy, as a structural designer, to see in a design code? (n = 120)*

$E_d \leq R_d \leq \beta E_d$

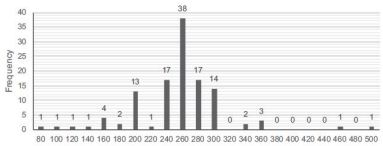
E_d = Design effect of action
R_d = Design value of resistance
$\beta \geq 1.00$



3.6.4 *Question 30: Imagine instead that an average material utilisation across all structural elements is introduced as a codified design requirement. What minimum value of material utilisation should be achieved by structural designers? (n = 119)*



3.7.1 *Question 31: How deep (in mm) would you expect a two-way spanning flat slab in an inner-city office building to be, if the column spacing below it is 7m x 7m? (n = 117)*



3.7.2 *Question 32: Imagine you are designing the steel beams in a floor plate of the multi-storey office building shown below. This floor plate is repeated multiple times. There are a large number of beams with varying spans. The floor load is constant across the area. Thinking about the beams only, approximately how many sets of calculations would you probably undertake to size the beams across the floor plate? (n = 124)*

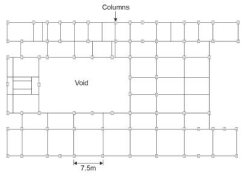
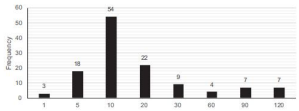


Figure 40: Floor plate shown for Q32



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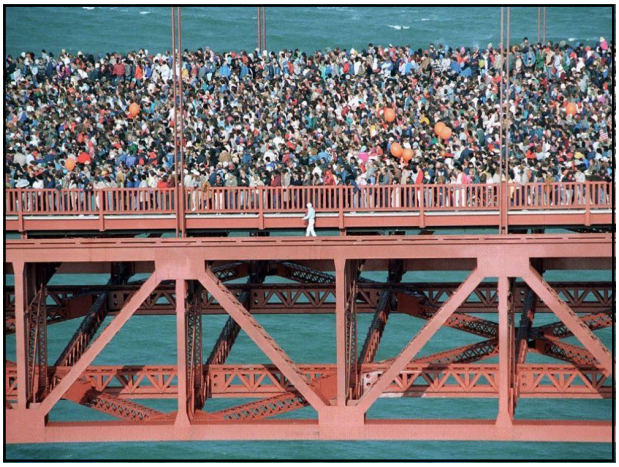
"Thank you for reaching out, however as a structural engineer I am not heavily involved in the energy/sustainability side of the industry. Please remove me from this request list."



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Material Efficiency In CONstruction

2.87kN/m²

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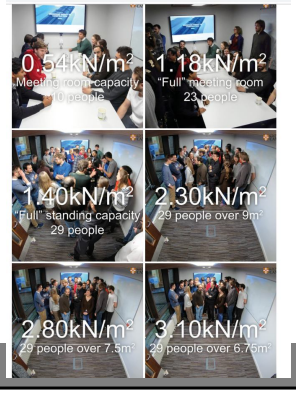

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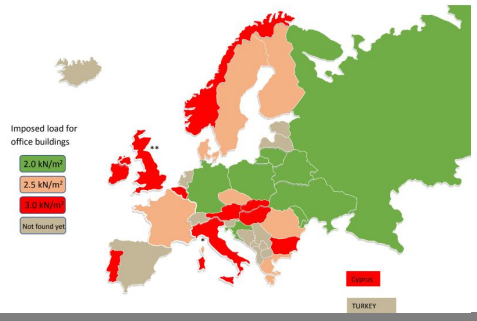
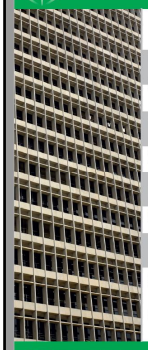


Minimising Energy in Construction

www.meicon.net



Design occupancy for office building with 16 floors and 30,000m² office area
Calculations are approximate to illustrate variation between disciplines.

Ventilation — 3,000 people

BSRIA Rules of Thumb Guidelines for Building Services 5th Edition, Table 3
10m² per person = 3,000 people

Space Planning — 3,750 people

BCO Specification for Offices, 2014
High Density = 8m² per person = 3,750 people
Low Density = 13m² per person = 2,308 people

Fire Design — 7,500 people

BS 9999:2017 Table 9: Typical Office Floor Space Factors
High Density = 4m² per person = 7,500 people
Low Density = 10m² per person = 3,000 people

Structural Design — 85,500 people

BS EN 1990, BS EN 1991-1-1
Ultimate Limit State, γ_q = 1.5 (partial factor for live load), α_n = 0.5 (reduction factor >10 storeys)
q_k = 3kN/m² over 95% of floor area (Typical value not including partitions or 5% more heavily loaded areas)
Total load ($\gamma_q \alpha_n q_k A$) = 64MN. Assuming each occupant = 0.75kN = **85,500 people**
Without area reduction α_n = *171,000 people*

Serviceability Limit State, γ_q = 1.0 (partial factor for live load), α_n = 0.5 (reduction factor for multi-storey)
Total load ($\gamma_q \alpha_n q_k A$) = 43MN. Assuming single occupant 0.75kN = **57,000 people**
Without area reduction α_n = *114,000 people*

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It's nuts!

Things to try to tackle:

- How best to measure loads?
- How best to separate out construction error from 'just in case' fat?
- Mean vs characteristic strengths?
- Separation of ULS from SLS loading? No comparison in severity.
- SLS requirements fit for purpose?
- Procurement processes to get to 'walking sticks'?
- Target carbon per square metre in buildings?
- Traffic light system in buildings?
- MOT for buildings?
- Challenge notion of 'flexibility in future use'?
- Get clients to drive material efficiency?

Thank you.

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brecicm
the BRE centre for innovative construction materials