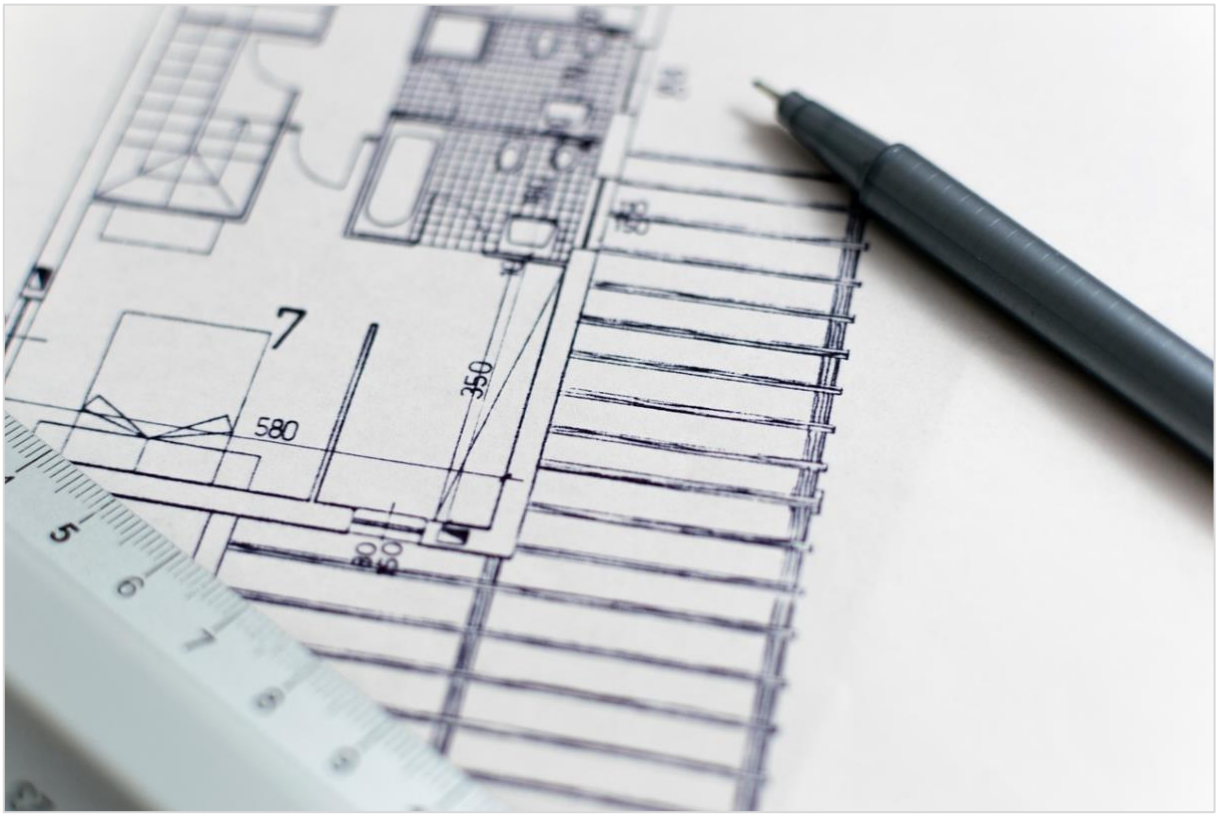
The expert view: a discussion about structures

Interviewer: Gareth Byatt – Principal Consultant, Risk Insight Consulting
Interviewee: John Orr – Professor of Structural Engineering at The University of Cambridge

May 2023



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John,

Thank you for making the time to talk with me about getting smarter with the design of the urban built environment. Could we begin this interview by summarising your background and experience, and the work you do?

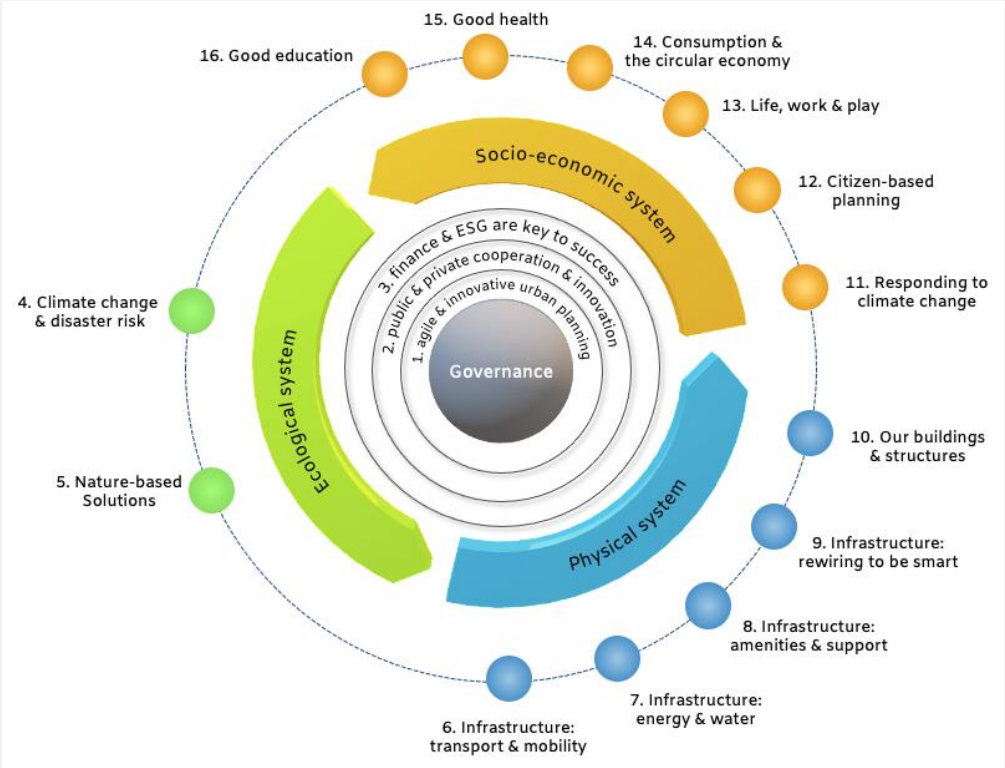
John: *Thanks Gareth. I'm a Professor of Structural Engineering at the University of Cambridge. My research focuses on minimising embodied carbon – in short, how to use less material in building design by learning from real performance.*

I studied Architecture and Civil Engineering at the University of Bath, a degree that instilled in me the need for interdisciplinary design – I'm still amazed this model is not replicated more often; we train our students in silos.

I stayed at Bath to complete a PhD, which looked at how we can create optimised concrete structures that put material only where it is needed. We can achieve this by rethinking the moulds we use for concrete – replacing the rigid steel and timber boxes that give us the rectangular shapes we associate with concrete with flexible moulds – literally pieces of fabric or flexible membranes – that if held in the right way can create optimised geometries.

I've since this time led around £11M of UK funded research projects looking at all aspects of design and embodied carbon – from the culture of design in MEICON (www.meicon.net) to automating concrete construction in ACORN (https://automated.construction). I also work with the Cambridge Centre for Smart Infrastructure and Construction (CSIC), looking at how we can learn from buildings to improve design practice.

Gareth: Thanks for this overview, John. I'd like to link our discussion points about cost-effective and intelligent building and structural design with an urban system I use for urban environments (per the diagram below), which links to the 17 UN Sustainable Development Goals (the SDGs) and the 2030 Agenda. By linking our discussion points to this urban system (point 10 – our buildings and structures – in the "urban wheel"), I hope we can show how improving the way we design and build the physical environment links to how we can improve urban areas all around the world.



Urban system image by author

Gareth: You mention funded research projects just now. What projects and research are you involved in at the moment to improve the structures and the built environment we create and live in?

John: *I've been fortunate to have recently received funding to travel extensively overseas, on a 'fact finding' mission called Minimising Cement in Construction (MICON). With business-as-usual construction estimated to consume some 80% of our 1.5ºC global carbon budget, we know that simply improving energy efficiency in primary material manufacture will be insufficient to deliver net zero.*

The MICON grant is focused on 1) improving international cooperation and 2) demand reduction through better design. The importance of working internationally is highlighted by considering that reducing cement production in China by just 8% (roughly) would be the same as shutting down every cement plant in the EU28 – and we know that an 8% reduction in cement in buildings is easy to achieve. Demand reduction is my second focus, in contrast to most cement sector roadmaps that focus on carbon capture since demand reduction can be done right now (and CCUS is always promised to be just a few years away). Intertwined with this are related topics of measuring performance, improving construction practice, designing more efficiently, and putting the right material in the right place.

A second important area of work is my role with the Institution of Structural Engineers. I have co-authored their guide "How to calculate embodied carbon" and we continue to review and refine this guide, with Version 3 in the works at the moment. Seeing the advice being put into practice has been great.

At a more research level, I am co-investigator on "SHUTTERING", which is building on previous work in flexible moulds, by using auxetic fabrics to bring additional benefits[*] - this is a project jointly led with the University of Exeter. With colleagues in Canada, I have been involved in the design of a demonstrator building, for which some really interesting tests on the fundamental behaviour of optimised concrete beams have been undertaken. I also continue to supervise a full complement of PhD students, all working on topics related to improving design.

Gareth: This is very interesting – there's a lot happening, I can see. I know also that in 2017 you led an Engineering and Physical Sciences Research Council (EPSRC) funded research project called "Minimising Energy in Construction" (MEICON, which is separate to the MICON project you mentioned just now), linked to an Energy Feasibility Studies review.

I know that MEICON is focused on reviewing how the built environment can be designed cost-effectively, with whole life cycle energy consumption minimising materials required for the best life cycle performance. This of course can lead to reduced carbon and other greenhouse gas emissions. Looking back at the outcomes from and recommendations made by the MEICON project, are you seeing positive examples of change, with more efficient design and construction, and if so, can you provide a few examples?

[*] https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/W019027/1

John: *The MEICON project was and continues to be really interesting – it highlighted to me the extent to which this is a cultural problem as much as a technical one. We know from the first MEICON survey we undertook that designers want to do the right thing, but too often other pressures (like money and time!) get in the way.*

In the first MEICON report, we published 18 "industry questions" and 21 "research questions" with the hope that these would be taken up by anyone interested in the topic. One thing that is certainly evident is that interest in embodied carbon has gone through the roof in the last five years – but I think that's just a happy coincidence!

Certainly, I've been pleased to see that work from MEICON, for example, on floor loading is being taken up by industry and we are now working with specifiers and industry bodies to see how guidance should be updated. There seems to be a real appetite amongst designers to positively challenge some of the old assumptions of what we 'should' design for.

One further positive is that the IStructE now requires all entrants to the "Structural Awards" (their flagship award held annually, which I am Chairing for the first time this year) to include an embodied carbon calculation, following the guidance I mentioned earlier.

One final point is perhaps that I do keep getting asked to speak about MEICON, so whilst it is now a few years old, the topics are still relevant. I am also in the process of writing up a MEICON-2 grant as a follow up project, so watch this space…

Gareth: It's great to hear that the outputs from the MEICON project are being used. I understand that the survey you mentioned, to examine culture and practice in structural engineering design, has been re-run in late 2022 and early 2023. It will be interesting to see whether there have been changes in people's views and practices in structural design, six years on from the last time the survey was run.

John: *Absolutely – the survey has been re-run. Amongst other things, we hope we can gain more international perspectives on the points it covers about embodied carbon. I hope to have a final year student at Cambridge do their dissertation project this coming year on exactly the kind of analysis you mention.*

Gareth: I look forward to seeing the outputs of the re-run MEICON survey, John, and to hearing how MEICON-2 may take shape. You mentioned just now that there is an appetite for change to building design. I imagine this is taking shape through various actions, including skills development and the tools building designers use to work out how to minimise an embodied carbon footprint whilst maintaining structural integrity?

John: *Yes. There are lots of tools out there, but I would suggest that the tool doesn't itself make a good designer. Skills development is key. I think we need to focus on training people to be good designers first, and then the tools can sit alongside the creative human brain to help and assist them in doing good design.*

Gareth: We've talked about the work of designers. Is there enough innovation being taken by construction firms and the suppliers of the most common building materials, in your view? Construction has a reputation of being a laggard in adopting change, and therefore I wonder whether there is an inertia to changing building design and construction, linked to the highly competitive nature of the industry where profit margins are very small.

John: *There certainly can be a lot of inertia to making big changes – if your company is set up to build in a certain way, and you have all the tools to do that, and there is no economic reason for you to change, then why would you? There is certainly lots of innovation going on, but perhaps one area that we could focus more on is scaling up the good ideas (and scaling back the not so good ones…) when measured in carbon terms.*

There is plenty of beautiful, low carbon, high quality design and construction being done with natural materials, it's just not the mainstay of construction globally (which is still steel and concrete, in the main).

Profit margins are often small but remember that construction globally is enormous - perhaps 13% of Global GDP or US$10tr. Perhaps there is scope to rethink our growth model so that those aims from MEICON "built environment to be designed cost-effectively, based on whole life cycle energy consumption using minimum material resource for appropriate performance" become the norm.

Gareth: In my experience in the construction industry, contracts are key to what gets done, and what is left by the wayside. Are there particular contractual clauses that you think could be used and explored to help improve the cost-effectiveness and intelligent design and construction of buildings?

John: *I would say that we need to think about and consider the following:*

- *Most of the world just cares about cost!*
- *If a client wanted something zero carbon they could put that in a contract*
- *There would be a need to do this if the UK government passed Part Z (https://part-z.uk)*
- *Some firms may set themselves up to be the designers with a specific zero carbon brief and reject any clients who don't sign up to it – not completely crazy if lots of clients have big ESG policies they need to deliver on. Useful Simple Trust is a certified B corp, for example (https://www.usefulsimple.co.uk)*

Gareth: Thanks for these points and suggestions, John. Linked to the point above about contracts, how much can the attitudes of investors and clients large and small – from investors and clients of major new developments through to house owners carrying out extensions – influence how the built environment is being designed to be more efficient and use less carbon? I see this as part of the **socio-economic** urban system. I wonder if small, local innovations can be scaled up.

John: *I have a couple of thoughts on this:*

1) *Clients may ask for something that they don't need. Make sure you are solving the right problem to start with – perhaps the client thinks they need a new building, but they can achieve their aim within the estate they already own (NHS hospitals are a good example).*
2) *Some clients are aware of the risk of building high carbon – leading to unlettable spaces as the general public wise up on the impact of buildings (stranded assets).*
3) *Covering all possible clients, perhaps best done by Part Z or similar legislation, to make it required (even if the client is not aware of the impact of materials). I would say most people know about energy efficiency, but most probably don't know that current cement production methods create so much in the way of emissions, for example.*

Gareth: What would you say are the key things to ensuring that **ecological considerations** are embedded into cost-effective and intelligent building design? Do Nature-based Solutions (NbS) have a place in cost-efficient building design and construction?

John: *When I talk about carbon, I will always show the UN SDGs as a reminder that carbon emissions are one part of sustainable design. Good design covers a range of possible ecological considerations.*

- *Design can be inspired by nature, but buildings are not natural so we shouldn't stretch that too far.*
- *We should work with nature and not against it – e.g. in hot countries, why do we build concrete towers and glass facades the same as we do in London? This makes no sense.*
- *Using natural materials, and natural forms (i.e. not rectangles!) is in my opinion more beautiful and makes for a better space – think Gaudi rather than brutalist.*

Gareth: Is there enough investment from the public sector and the custodians of national / state building codes (which vary around the world, with local context always being key) into decarbonising building materials and driving more efficient and better building design?

John: *I'm not too worried about building design codes. There is plenty that we can do within the scope of existing codes – using "the code made me do it" as an excuse is not great. Changing codes takes too long, and has too many interests, to be something we can rely on in the timeframe we need for carbon reductions.*

Gareth: Following on from this discussion point about building codes, what role do you think that Green Building Councils (GBCs) and other industry bodies can and should play in driving more efficient and better building design?

John: *I don't know much about GBC specifically. Overall, any certification scheme needs to account for embodied carbon in a rigorous and transparent manner, and make sure that embodied carbon is given the prominence it deserves in achieving some kind of sustainability rating.*

Gareth: One of the things that we have discussed recently, and it's come up in our interview, is the impact the cement industry has globally on the sustainability of the built environment. The global cement industry accounts for something like 3% of all global emissions, I think, yet from what I can see most of the industry is not changing how cement is made, and the construction industry still uses a lot of it. The International Energy Agency (IEA) – which, as of early 2023, state that necessary changes to the cement industry are not on track – has a dedicated section about cement on their website, and many other organisations focus on and produce reports about "greening the cement industry".

Can and will the cement industry change? I'm thinking about "the long tail" of the cement industry and the construction industry overall, not just the large materials producers and suppliers that talk about their demonstration and test plants for new production methods. Are there any new cement suppliers, and/or new ventures, that could upend the industry with new thinking?

John: *This is one of the aims of the MICON grant. I'm firmly of the belief that we must reduce our production and use of Portland cement. We currently use Portland cement in a lot of applications that don't make sense – yet we use it because it's cheap and easy to use and it is available everywhere. However, you can't make Portland cement without releasing CO_2 and so we must reduce our production of it.*

I don't think we will phase out Portland cement completely by 2050, although some people do! I would rather see the right material in the right place at the right time. In other words, use as little concrete as you need to, and use concrete only where concrete is the right material to use! Concrete is good in compression, and has high thermal mass, so let's make use of those attributes.

Demand reduction is a much more appealing prospect to me than carbon capture utilisation and storage – my worry with this is that it gives the impression that business as usual + CCUS = net zero. I think we need to focus on changing the business as usual to something more appropriate for climate design, and that means using less Portland cement.

One really exciting prospect in this field is work by colleagues at Cambridge called "Cambridge Electric Cement". This is the world's only zero carbon cement material, and is produced from deconstructed concrete buildings - https://cambridgeelectriccement.com

Gareth: Thanks for these insights into the cement industry, John (I appreciated your input to the paper that I wrote about cement and concrete back in 2019). I am very keen to hear how the work of Cambridge Electric Cement evolves.

On the residential construction side, which is of course a large part of the industry, I am following initiatives such as the Energy House 2.0 project. How much of your work and focus is on residential construction and are there any key areas of focus for it, in your view?

John: *I am certainly aware of some of this work, and retrofit is really important for the UK. But not something I focus on in research.*

Gareth: For my last question, what's the number one thing you'd like to be realised and achieved in cost-effective and intelligent built environment design in the coming years up to 2030?

John: *I would say we need to focus on the right material, in the right place, at the right time – if this could be a guiding principle to design, that could go a long way to reducing carbon emissions as it requires designers to think carefully about everything they specify. I would additionally want more focus on things we can do right now, as compared to putting all our hope on future technologies (such as carbon capture) which may or may not be available to us in due course.*

Gareth: Thank you very much for your thoughts and perspectives, John. I look forward to seeing how your work develops, and to seeing some good examples in the building industry of innovative designs to reduce embodied carbon.