3.Lean design

Structural fire safety when responding to the climate emergency

Luke Bisby urges structural engineers to improve their understanding of 'fire resistance' as the profession looks to innovate rapidly in response to climate change.

As a member of the Standing Committee on Structural Safety (SCOSS) and Confidential Reporting on Structural Safety (CROSS), I was asked to offer some thoughts on possible fire safety pitfalls that might be relevant in the light of the IStructE's important work to address the climate emergency.

Given the enormous impact of structural engineering decisions on carbon emissions[1], it is clear that structural engineers have a moral obligation to urgently take action to address the climate emergency.

New design approaches and new technologies bring with them new hazards; they at least partially invalidate experience as a means of having confidence in our designs; they invariably introduce new and different, potentially unexpected, failure modes. Safety-critical disciplines are therefore wary of change. The history of engineering is littered with failures – some of them disastrous[2] – that have led to learning and to changes to our practice.

Of course, new technologies and approaches themselves inevitably catalyse new learning and understanding; however, we must recognise that our powers of foresight are not complete. The collective experience of our profession has taught us there are some failure modes that we may not anticipate – where we will be forced to learn from our errors and mistakes, rather than our successes. Learning from failures is rarely a 'sustainable' approach.

We must therefore constantly scan the horizon for failure modes that may lurk just out of sight. And we must be ever more vigilant in this during times of rapid innovation. An alternative could be to walk blindly into the future, perhaps because the consequences of not acting are greater than the consequences of continuing on our current path. But surely such an approach must be taken only as a last resort.

At times of rapid innovation, it is crucial that members of the structural engineering community constantly reflect on safety, and thus on the structural fire safety assumptions and simplifications that are inherent in their designs. The increasing use of mass timber as primary structure for high-rise buildings has recently received considerable attention in this regard[3], but more conventional building materials such as reinforced concrete[4] and structural steel[5], particularly when applied in novel ways, including lean, modular and offsite construction, each present their own, admittedly very different, challenges in this context.

'Fire resistance' design – the conventional framework

For the vast majority of structures, adequate structural fire safety – adequate for the protection of life, that is – is *presumed* to be provided by ensuring that the individual structural elements (or partitions) from which a structure is constructed have appropriate 'fire resistance' ratings[6].

My own experience suggests that many structural engineers, both in the UK and elsewhere, have only a cursory understanding of the fundamental basis of 'fire resistance' design, or of the fire safety design framework that they themselves are routinely applying in projects.

For instance, it is my experience that few structural engineers understand what 'fire resistance' is, how (or *why*) 'fire resistance' tests are performed, or the extent to which such testing and assessment captures (or indeed fails to capture) either the thermal environments or the mechanical boundary conditions, loading or deformations of a structural element or a system of elements during a real building fire.

Many structural engineers (and other building designers) fail to understand that the prescribed periods of 'fire resistance' given, for instance, within Table B4 of Approved Document B in England and Wales[7] do not represent actual periods of time in a real fire.

These issues are worth careful consideration by structural engineers seeking to optimise building designs or introduce material or other innovations. For example, how can a multi-parameter optimisation of a structural design be confidently undertaken without deeply considering the consequences for structural fire safety?

'Fire resistance' design – uncertainty and conservatism

The evidence that the existing 'fire resistance' design framework is providing an adequate *level of safety* in buildings is largely historical. Notwithstanding the reality that fires that are sufficiently severe to seriously challenge loadbearing structures are comparatively unlikely, we only rarely observe significant structural failures in real fires. Applying the *argument from ignorance* could lead to a conclusion that this absence of evidence confirms that our coarse, conservative and unrealistic 'fire resistance' design framework – despite its many documented shortcomings[8] – is indeed delivering societally tolerable fire safety outcomes.

My own view is that, by and large, structural engineers don't actually *know* what level of safety is being provided by the existing 'fire resistance' design framework. We struggle to rigorously quantify the error bars that are inherent in most of our structural fire design decisions; or even to

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rigorously quantify what level of safety might be considered acceptable[9].

As a profession, we don't have a very good handle on which aspects of our design framework lead to our apparent conservatisms – so we don't know which conservatisms can be stripped away without unacceptable consequences.

It may be that none of the above uncertainties have mattered much up until recently; in a world where structural materials and structural design approaches slowly evolved over decades; when crawling innovation was tempered by an occasional warning and readjustment following a near miss, or evidence from a minor failure. But in the face of the climate emergency, the luxury of slow innovation over decades no longer appears to be available.

Given the above uncertainties, to what extent might the necessary optimisation and increased ultilisation of our structures, or the application of new materials and structural systems, erode our apparent fire safety conservatisms? Without proactively identifying and tackling these questions, might the number and magnitude of fire safety failures become unacceptable? To what extent can we continue to rely on a century-old 'fire resistance' design framework, even if we believe that it has (so far) served us well?

And critically, how can structural engineering professionals be proactive in thinking about the potential fire safety pitfalls that might result from our climate emergency-driven evolution and innovations, so as to avoid sleepwalking into future tragedies?

Raising awareness

It is impossible for structural engineers to begin to address the above questions if, as I have already observed, many in our profession have only a shallow understanding of the existing 'fire resistance' design framework.

I believe that if the structural engineering profession is serious about explicitly addressing the structural fire safety challenges arising from optimisation and innovation in structural materials and systems, a significant effort is needed to raise the bar(s) of knowledge and awareness in this area. Only suitably competent structural engineering professionals will be equipped to feel the requisite *chronic uneasiness*[10] regarding such matters throughout their working lives.

To assist structural engineers in this regard, my colleague Angus Law and I recently set out our own understandings of the origins and intent of 'fire resistance', as deployed within the UK's regulatory context[8].

And so to the future

Given the enormous impact that structural engineering decisions have on carbon emissions, structural engineers have a moral obligation to act quickly – through optimisation, innovation and evolution – to address the climate emergency. However, structural engineers also have legal and professional obligations, e.g. under the Building Regulations 2010[11] (England and Wales), to ensure that all buildings:

- 'shall be constructed so that in the event of an accident [including fire] the building will not suffer collapse to an extent disproportionate to the cause'
- 'shall be designed and constructed so that, in the event of fire, [their] stability will be maintained for a reasonable period'.

These functional requirements are mandatory and apply to all buildings. In the UK, upcoming legislation via the Draft Building Safety Bill[12] is also likely to increase the obligations on designers to develop credible 'safety cases' to demonstrate that measures exist to mitigate all relevant hazards (including fire) and/or their consequences.

The optimisation, innovation and evolution that is necessary in structural engineering can only be achieved if we raise our collective competency and the working relationships between chartered structural engineers and chartered fire engineers become closer, more collaborative, and more explicitly linked. I'm encouraged in this regard that the IStructE's CROSS scheme is, in partnership with the Institution of Fire Engineers, being expanded in 2021 to include confidential reporting on fire safety. Increased fire safety competency and collaborative working will hopefully become the norms in the future.

Until then, my hope is that all structural engineers will reflect on some of the ideas presented in this article as they continue to work towards addressing the climate emergency; all the while feeling accordingly uneasy.

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