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Seismic unreinforced masonry design and the climate emergency

DENIS CAMILLERI

Much has been written in *The Structural Engineer* over the past few years about the need to be lean in our structural designs. This is due to around 67% of the upfront embodied carbon emissions of buildings being accounted for by the structure.

With engineers being at the forefront of climate action, traditional masonry construction can deliver substantial carbon benefits. This form of construction, representing the majority of family homes, is advocated as providing better thermal, sound and fire rating properties, together with added geometric stability. It is also an economic form of construction.

Recent research undertaken into the seismic *q*-values in EC8, as outlined in equation 3.14, notes that for unreinforced masonry (URM) this is quoted at a platonic 1.5.

$$S_d\,(T) = a_g \cdot S \cdot 2.5/q$$

As quoted in Morandi *et al.* (2020)[1]:

'Recent earthquakes as the 2012 Emilia earthquake sequence showed that recently built URM buildings behaved much better than expected and sustained, despite the maximum PGA values ranged between 0.20–0.30g, either minor damage or structural damage that is deemed repairable.

'Using a q-factor equal to 1.5–2.0, as suggested by some seismic codes like the current version of EC8, were found to be overly conservative and in contradiction with the experimental and post-seismic evidence. It was evident that it was practically impossible to satisfy strength safety checks for any configuration of two- or three storey URM buildings for PGA greater than 0.10g.

'As a result of the investigations, rationally based values of the behaviour factor q to be used in linear analyses in the range of 2.0 to 3.0 are proposed for well-constructed box behaviour URM buildings.'

It is noted that two current IStructE publications, together with courses on seismic design, refer solely to concrete and steelwork as structural materials. Noting the importance of seismic masonry, an IStructE publication would be helpful, to demystify the seismic design of simple masonry buildings. This should ensure that more seismic design checks are undertaken in structural design offices.

Reference:

1) Morandi P., Manzini C.F. and Magenes G. (2020) 'Application of seismic design procedures on three modern URM buildings struck by the 2012 Emilia earthquakes: inconsistencies and improvement proposals in the European codes', *Bull. Earthquake Eng.*, 18, pp. 547–580; doi.org/10.1007/s10518-019-00650-z

There is a worldwide challenge to provide affordable, safe homes for vast numbers of people. In areas at risk from earthquakes, most of these homes must use masonry (including substandard masonry) and they will largely be 'non-engineered'. Much seismic engineering is focused on complex dynamic analysis and so on. That is needed, but more people are probably at risk in non-engineered buildings. The engineering community's challenge is to formulate construction rules that pragmatically protect most people, most of the time. The best way of doing that is probably to observe what actually works, as Denis suggests.

Equal importance: safety and sustainability

JOHN ORR

At first glance the title of Andrew Lawrence *et al.*'s Viewpoint article (November/December 2023) appears to go against the Institution's 2019 commitment to treat sustainability and the climate emergency with equal importance to life safety. However, my interpretation of the article is in fact that the authors are saying that they believe training must be our highest priority – the issues they raise are ones of knowledge and competence. A competent engineer must balance throughout their design process both safety and sustainability – the two go hand in hand, and neither can be approached without deep engineering understanding.

My concern with their framing is that it may reinforce a culture of 'adding a bit of fat', or a 'sleep at night factor', which is an unsatisfactory way to approach any design, from the perspective of both safety and sustainability. Improving how we design requires us all to understand the gaps in our knowledge – perhaps the Johari window has a place in the informed design process. I fully support the authors' desire for our industry to learn from mistakes. Developing a no blame culture would be a huge step towards enabling this. If aerospace can do it, why not structural engineering?

Let's not fall into a trap of believing designs have to be safe or sustainable. They have to be both and we have to use our professionalism as appropriate. There are many circumstances where there is deep uncertainty about capacity and providing robust solutions is entirely appropriate. It also does nothing to aid the sustainability agenda if we need to replace failed structures. As for no blame, read the CROSS reports so we can all avoid repeat errors.

Trouble with engineering

BEDE RODEGHIERO

The art and craft of engineering is being buried. Not by fee pressure, poor education, over-reliance on software or AI, but by corporate mentality and culture. This is having serious consequences, in the propagation of both energy-wasteful and unsafe structures. Nothing conspiratorial; we simply got here the usual way, through human laziness and greed.

Corporate engineering consultants talk sustainability in wonderful terms

Seismic design of residential structures

MIKE FORDYCE

To follow on from Denis Camilleri's contribution (January 2024) on seismic unreinforced masonry design and Verulam's response about 'non-engineered' buildings, and the challenge to provide affordable, safe homes, I would suggest that there is much that could be learned from our New Zealand members.

CROSS-AUS has recently received a couple of reports that relate to the seismic design of residential buildings that have drawn attention to the following New Zealand standards:

- NZS 4229:2013 *Concrete masonry buildings not requiring specific engineering design* **(www.standards.govt.nz/shop/nzs-42292013)**
- NZS 3604:2011 *Timber-framed buildings* **(www.standards.govt.nz/shop/nzs-36042011)**

Thus, rather than reinventing the wheel, a good starting point for any IStructE publications on this topic would be to engage with our colleagues in New Zealand and I suspect that both SESOC **(www.sesoc.org.nz)** and Engineering New Zealand **(www.engineeringnz.org)** may already have such guidance material available.

Mike's advice is useful. New Zealand has the curse of living with severe seismic activity. On the plus side, the New Zealand engineering community is well respected for its seismic expertise generated by having to control the risks from where they live. Moreover, the New Zealand engineers are almost uniquely placed to respond to the vital question: does the advice actually work?

New Zealand seismic masonry code

DENIS CAMILLERI

Thanks to Mike Fordyce (February 2024) for supplying useful links to New Zealand seismic masonry and timber standards and suggesting to engage with New Zealand colleagues on this topic.

I have browsed briefly through the 169-page masonry publication, inclusive of good seismic detailing practice, and I would like to query the following:

- I have noted that New Zealand is subdivided into four seismic zones. Probably presently reduced to three seismic zones.
- The lowest seismic zone is noted to have a peak ground acceleration (PGA) <0.15g and the highest seismic zone at >0.3g.
- Eurocode 8 notes very low seismicity to have a PGA <0.04g and for low seismicity <0.075g.
- High seismicity then tends towards a high of PGA 0.4g, compatible with the New Zealand standards.
- So, it appears that there is not agreement on the low seismic range.

The New Zealand masonry standard then notes the height for buildings not requiring specific engineering design is to be not higher than 10m. Eurocode 8 includes a table for simple buildings, whereby buildings four storeys high may be undertaken. Table 9.3 in EN 1998-1:2004 provides guidance up to a PGA of 0.15g for unreinforced masonry. The revised EN 1998-1-2:2021, still awaiting approval in table 14.3, notes fewer conservative recommendations, again for unreinforced masonry. Four storeys are allowed up to a maximum PGA of 0.16g, three storeys up to 0.24g and two storeys up to 0.3g.

For the low seismic zones as per Eurocode 8, it should probably be considered to go above the four floors stipulated.

If the above deductions are considered in the affirmative, the query is now what should be the best way forward?

The damage in earthquakes is not solely related to the PGA but also to the nature of the supporting ground and to the duration of seismic shaking. Seismic design practice also draws a balance between affordable cost and tolerable damage. Hence it is not inevitable that codes for different regions match precisely. What is required is field observation of how 'non-engineered structures' actually perform. Only by such observations will we eventually arrive at suitable code design strategies.

Masonry buildings in New Zealand

JASON INGHAM

Recent letters have drawn attention to opportunities and risks associated with unreinforced masonry (URM) or non-engineering masonry buildings in regions of moderate to high seismicity (Denis Camilleri in January 2024, Mike Fordyce in February 2024), and that New Zealand structural engineers have had some significant experience with this topic in recent years.

In New Zealand, the 1931 Hawke's Bay earthquake was the genesis event that led to the formation of Standards New Zealand, the evolution of national legislation for the seismic design of buildings, and the eventual outlawing of URM building construction that was phased out entirely in 1965.

Further, recent legislation following the Canterbury earthquakes[1] and the associated development of a national methodology for the seismic assessment of existing buildings has categorised all URM buildings as being potentially earthquake prone, with the owners of these buildings having the responsibility of demonstrating that their buildings have adequate earthquake capacity via detailed calculations or seismic strengthening, or otherwise being obligated to demolish their buildings within a prescribed time frame.

So, while it is acknowledged that URM buildings are prevalent worldwide, and that this is a common form of construction in some developing countries, including developing countries having moderate to high seismicity, the New Zealand viewpoint that has prevailed for many decades is that URM buildings pose an unacceptably high risk to occupants and nearby pedestrians.

The national methodology for assessing URM buildings notes that, because these buildings lack any form of reinforcement, the term 'ductile' is inappropriate. However, as noted by Morandi *et al.*[2], URM buildings are often observed to perform better in earthquakes than might at first be expected.

One attribute that indirectly is beneficial is that URM buildings have short natural periods of 0.2–0.4 seconds, and the earthquake excitation at this period range is heavily damped as the high frequency waves travel through the ground, such that shaking in the period range of interest is heavily attenuated. This issue is well known to seismologists but less well appreciated by structural engineers. So, in most cases, severe damage to URM buildings is attributable to shallow earthquakes occurring in relatively close proximity to the building.

The second point to note is that while URM buildings are not ductile, they do have very high damping as all the brick-and-mortar joints deform backwards and forwards during shaking on each and every joint plane, consuming considerable energy. And a further point to note is that many URM fail mechanisms have significant post-peak displacement capacity due to attributes such as in-plane or out-of-plane rocking, or bed joint sliding. Although URM buildings are not ductile, for the majority of failure mechanisms these buildings are also not brittle, even if they have low strength.

This combination of elevated damping and non-brittle response can be accounted for in existing methodologies in several ways (in conjunction with paying careful attention to the governing failure mechanism), including the adoption of heavily damped spectra instead of the usual 5% damped spectra, or use of the *q* factor as is adopted in the Eurocode to account for the observed field response being superior to expectations.

The New Zealand methodology is similar to the Eurocode approach, where a reduction factor of three can be applied to 'elastic' equivalent static loads for non-brittle failure mechanisms. An interesting quirk of the methodology is that the mathematics can be interpreted as either the demand being reduced by three or the capacity being increased by three. Typically, the reduction factor is applied to the demand, but in reality perhaps the more correct interpretation is that the buildings are three times stronger than expected? But neither statement is ideal, and the better interpretation is that these buildings are heavily damped with significant post-peak non-ductile capacity.

Fordyce also referred to NZS 4229 for the non-specific design of reinforced concrete masonry buildings[3]. Although the current document is dated 2013, the original release date was 1999 and the document was authored based on a substantial amount of full-scale laboratory experimental testing to augment and validate rational analysis. This document specifically applies to partially or fully grouted reinforced concrete masonry and limiting criteria for the overall configuration of buildings that fall within the scope of the standard are clearly defined. In simple terms, the design philosophy is that vertical reinforcement (widely spaced by typical New Zealand standards) in walls responding out-of-plane spans between the foundation and reinforced horizontal bond beam, and the bond beam is responsible for distributing seismic demands to the companion in-plane loaded walls. So, although the document is written for use by non-engineers, the underlying logic for the document is based on well-established design practice for reinforced concrete masonry.

As a closing statement, it would seem obvious that engineering design documents based on comprehensive research and practitioner experience should be transferable between countries. However, there is a long history of well-meaning engineers visiting countries and communities where such documents and skills are poorly known, conducting various forms of training, and then departing only to find that the local people revert to their earlier practices and ignore much or all of the resources that were provided to them. Past experience suggests that the transfer of knowledge from developed nations to developing nations involves complex social issues and sustained efforts over a long time.

Many thanks for this detailed feedback. For readers not versed in seismic engineering it might be helpful to point out that the worldwide community of specialists have developed their skills by repeated observation of what happens in real earthquakes: looking at the damage and trying to correlate it with design technique. That opportunity is absent in most of our structures because they are never subjected to full design loading. In contrast, earthquake forces can be so large that damage is inevitable and the design strategy is to 'survive'. Huge numbers of people across the Earth are at risk in URM buildings and building in survivability at affordable cost is challenging.

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Legislation for design checks

STEVE LIESKE

With regard to Alan Rose's contribution entitled 'Legislation for design checks' (April 2024), I agree with the underlying principle of structural input being carried out by suitably experienced engineers. If works are prepared by a 'junior' engineer, then checking must be done by an experienced engineer.

I worked for many years in the office situation, before going solo. Quite often I will carry out what I call 'quick' designs to provide structural sizes for the client/contractor, to keep the site works moving. Full calculations for building regulations approval then follow later. A requirement for full drawings/calculations at an early stage in any project could well delay the site works.

However, I am strongly opposed to the second suggestion. Structural design does not need to be carried out/checked by a chartered engineer! I have known chartered engineers who basically run a company, but who have little practical (current) experience of detail design/site works.

If it became an official requirement that structural output must be checked by a chartered engineer, many areas of building works would grind to a halt and be dramatically delayed. This would be particularly applicable to relatively small, domestic projects. I, for one, would be out of business! I have been in practice as a one-man band since the early/mid 1990s, and have never had a problem with building regulations, or with the final outcome of any build.

We can all agree that structural design is best carried out by suitably experienced engineers. Alas, much anecdotal feedback suggests that this frequently does not happen. Moreover, there is other anecdotal evidence showing that even designs by chartered engineers go wrong. The world is moving in the direction of having to demonstrate competence and there are challenges on how to do that: the debate is over how best to do that to minimise safety risks and financial risks plus use our industry's skill resources to their best advantage. The following letter highlights the sort of problems that arise.

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When is an engineer not an engineer?

ANDY FEWINGS

I was recently appointed to check a simple design at the request of a contractor working nearby, who had concerns regarding a previously completed design. One beam he noticed was a 152 × 89 UB16 carrying a cavity wall, plus floor and roof loads, but it had no plate specified to create the width required. This beam was almost 5m in span and failed both in stress and deflections.

On checking the other elements designed, every beam was incorrectly designed, and one would certainly have failed. The 'designer' had taken full lateral restraint for all steels, none of which had such restraint and no bearings were designed either. One steel above bifold doors within a traditional, external cavity wall had been specified as 2/195 × 47 timbers. In my 47 years of designing almost anything structural, I have never seen anything so blatantly wrong.

The fact that this even got to site was due to the client going down the building notice route, as opposed to the full plans route and it was only a vigilant contractor who spotted the potential problems. Small projects such as these are the lifeblood of many one-man band engineers but there is nothing to stop anybody downloading simple beam design software and claiming to know how to design structural elements.

My point is this: when I researched the 'designer' there was no record of them as an engineer anywhere, and it turns out that they were a person claiming to be a structural engineer, employed by an estate agent, who had done the building survey themselves. I believe that the Royal Institute of British Architects has legal powers to prevent anybody using the term 'architect' when they are not qualified, and I would ask the question as to why the IStructE has no such powers, which I believe is the case?

This is one more good example of the sort of problems that arise. It also illustrates that the term 'design' is not limited to the stress sizing of beams. Here, the task included the geometric aspects of selecting something wide enough to support whatever it was carrying. Mr Fewings' last paragraph is alas correct, but there are moves afoot to try and assure competence in people carrying out structural work.

Seismic design of masonry

DENIS CAMILLERI

Another contribution from Jason Ingham (April 2024) delved further into New Zealand seismic unreinforced masonry (URM) resilience.

An interesting observation is that it was the 1931 Hawke's Bay earthquake that initiated the legislation for seismic design of buildings in New Zealand. In Europe, it was the 1755 Lisbon earthquake that is considered the starting point of modern seismology, with one of the earliest building laws being the proposal that no building should be taller than the street width and should be limited to two storeys.

This contribution then notes that the 1931 earthquake initiated the outlawing of URM constructions, which were phased out as of 1965. Following the 2011 Canterbury earthquake, the onus was placed on owners to either prove that their URM constructions had adequate earthquake capacity, or else have them demolished.

As noted, the New Zealand URM viewpoint runs counter to Eurocode 8, in which URM constructions are taken as more resilient to seismic effects, as also reported by Morandi *et al.* (2020).

The author then outlines some

← New legislation following Canterbury earthquakes requires URM buildings in New Zealand to be strengthened or demolished

superior characteristics of URM constructions in defining them as possessing an elevated damping and non-brittle response. A comparison is then made with the Eurocode *q*-factor and the New Zealand standard reduction factor of 3, as applied to the elastic equivalent static load.

If an exercise is undertaken to merge these two methods, then possibly the rationale between the NZ standards and Eurocode seismic behaviour of URM buildings may also converge.

All design techniques can only be assessed by responding to the question: do they work? This is particularly relevant to earthquake design where observations of what survives can be as useful as observations of what fails. Hopefully, the Earthquake Engineering Field Investigation Team (EEFIT) will report on the recent severe Taiwan earthquake, but low casualties and damage appear testimony to the adequacy of good seismic design practice.

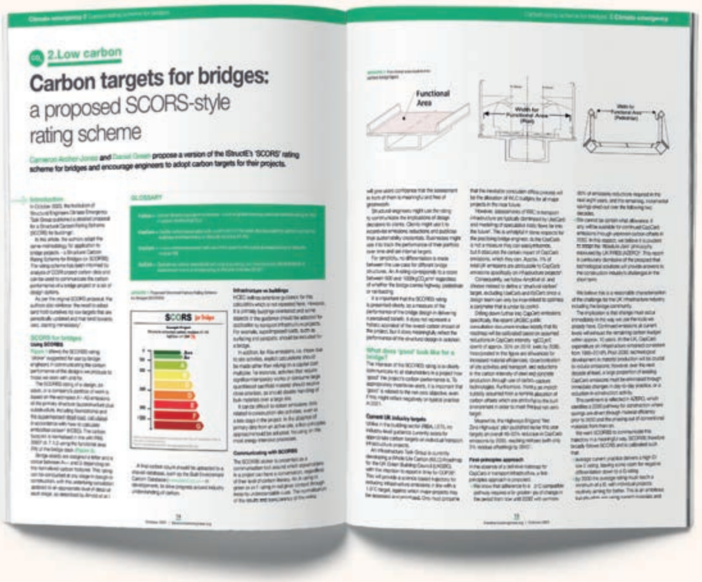
Carbon in bridges: call for data

DAN GREEN

It was a pleasure to attend the reliably fascinating International Association for Bridge and Structural Engineering (IABSE) Symposium in Manchester from 10–12 April this year. The conference grappled enthusiastically with its central theme of 'Construction's role for a world in emergency' and I was gratified to see the Structural Carbon Rating Scheme for Bridges (SCORBS), proposed in *The Structural Engineer* by Cameron Archer-Jones and myself two and a half years ago **(https://doi.org/10.56330/PAPI6611)**, in widespread use among presenters.

It struck me how quickly time has flown and how far the conversation has moved on, with rapid behaviour changes embedding across the industry. This is a continuous challenge though; we mustn't stand still, and we must renew our efforts to drive down embodied carbon emissions via every means available. The Net-Zero Bridges Group (NZBG) is currently looking to update the benchmarks proposed in SCORBs with more data and more input from across the industry. If readers could help provide anonymised project-level data to inform this, please get in contact – either via your company's NZBG representative (if your organisation is already a member) or by contacting us through our website: **www.netzerobridges.org**.

Readers are invited to assist Mr Green if they can. As Mr Green writes, this is a continuous challenge and one of the most pressing tasks we all face is how to design for a world already in an emergency. We have only to look at April's horrendous flooding in Dubai to see what can happen. British insurers have just reported a record year of claims from adverse weather events after frequent storms and significant flooding[1]. 2022's summer heatwave reportedly contributed to a 45% rise in subsidence cases[2].



2. Low carbon

Carbon targets for bridges: a proposed SCORS-style rating scheme

Cameron Archer-Jones and Daniel Green propose a version of the IStructE's 'SCORS' rating scheme for bridges and encourage engineers to adopt carbon targets for their projects.

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1) Association of British Insurers (2024) *Weather damage insurance claims worst on record* [Online] Available at: www.abi.org.uk/news/news-articles/2024/4/weather-damage-insurance-claims-worst-on-record (Accessed: April 2024)

2) Association of British Insurers (2023) *Sinking UK – last summer's record-breaking heatwave leads to surge in insurance payouts for subsidence* [Online] Available at: www.abi.org.uk/news/news-articles/2023/3/sinking-uk--last-summers-record-breaking-heatwave-leads-to-surge-in-insurance-payouts-for-subsidence (Accessed: April 2024)

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Codes for seismic design

NICK ECKFORD

I was interested in the letter from Denis Camilleri (May 2024). Not least because I was in Christchurch the day before their devastating earthquake in 2011. We had moved on to Dunedin (some 200 miles away) and felt the shocks there some five floors up in an hotel, though there was no visible damage.

While at Christchurch I noted many buildings had suffered damage due to previous earthquakes, though the damage resulting from the 2011 one far exceeded what had happened before. Returning briefly about a week later, I could see that even modern buildings, presumably built in accordance with the then codes, suffered often quite severe damage.

You tend to forget that it is not just the buildings that suffer. Underground services can be severely affected. The locals had to sort out drainage problems as a matter of urgency, and the internet was awash with examples of interesting 'netties'.

My understanding of the earthquake codes is that they result from local experience. The type of earthquake can, and will, vary depending on local geology and other factors. The relevant codes are developed locally to suit the experience of those involved. While there is a good deal of commonality, different areas in the world suffer different earthquakes and a universal code would inevitably have compromises that do not necessarily reflect conditions in a particular locality.

The physics of building earthquake response are universal, but the input motion depends on the locality and is fundamentally uncertain. The input can vary in frequency content, peak acceleration and shaking duration. As Nick writes, local ground conditions are a key factor and, in Christchurch, there was widespread soil liquefaction, which accounted for much structural damage.

Covered timber bridges

GREG KELLY

Re: *Successful timber bridge design – a pedestrian/cycle bridge perspective* in *The Structural Engineer* May 2024. This is a comeback that I am rooting for. Hooray for covered bridges! And what, what? A brand-new take on the concept from StructureCraft! So pretty.

I grew up admiring the craftsmanship and engineering of covered bridges in New England. They were an elegant solution to preserve the wood structures and timber bridge decks. Modern bridge materials are much more durable, but for this pedestrian bridge [Bridge of Dreams, Princeton] the team chose a wooden deck, so the cover will certainly help a bit.

Thanks to Mark Porter and Drew Willms for sharing your inspiring work.

You don't have to go to New England to see covered timber bridges: try the park in Birkenhead, UK (Grade I listed landscape) with its 'Swiss' bridge dating from 1847.

Concrete answer for circular construction

AMMAR AL GHABRA

Spotted in *The Structural Engineer* April 2024: *A concrete answer for circular construction: Three prototypes reusing saw-cut elements*.

Think about this: Old concrete equals new opportunities! Instead of wasting it, we're turning it into awesome new structures. It's like playing Tetris on a massive scale!

Why it's awesome:

1) Eco-friendly: We're talking less trash and more treasure.

2) Innovation station: These ideas aren't just new – they're revolutionary.

3) Future goals: This is how we sprint towards those net zero targets!

What if we reused the concrete rather than crushing it? Think about the potential of repurposing structural materials to enhance sustainability.

Could you incorporate any of these solutions in your designs, especially in refurbishment projects? It's time to inject some vintage vibes into modern constructions!

Let's be creative and explore options and techniques! Pushing the envelope on what we can achieve with circular economy principles.

All innovative ideas are welcome. But reuse is not actually revolutionary, Hadrian's Wall may not be at its original height, but its stones were widely used in later buildings. St Andrew's Church in Corbridge, UK, incorporates an entire Roman arch, no doubt conveniently salvaged from the nearby site.

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Cleaning up the profession

GARY SMITH

I read with interest several letters in *The Structural Engineer* relating to 'when is an engineer not an engineer' and debates relating to gaining chartered status. This topic has been rolling on for years and I believe it's time we protected the profession now and in the future. Becoming a chartered member of the Institution of Structural Engineers does not instantly mean you become more knowledgeable than your peers, but it does demonstrate to the wider public that you have met the minimum standards required to be a chartered member.

If anyone can carry out structural engineering services, then we are in trouble. Designs we have been asked to review and re-calculate recently have been carried out by planners, architects and other so-called 'designers' using software available on the web for £200. The designer's information was withheld, the code is outdated and the input parameters were incorrect.

I strongly believe that the time has come to clean up the profession, and minimise risk to clients and contractors by ensuring that all structural designs are either designed or checked by a chartered structural engineer, and that this becomes a minimum requirement for building control.

This topic is clearly creating much renewed interest from members. Surely it is time for the Institution to reflect on members' feelings and determine what, if any, action can be taken? Given the developing Building Safety Act regime and the Institution's avowed dedication to 'safety', it would appear the time is ripe.

Regent Street disease references

COLIN DENT

Having read the June 2024 issue of *The Structural Engineer*, I would like to add two further references to the article *Historical defects in buildings – No. 6: Regent Street disease*.

Historic Scotland's *Technical Advice Note (TAN) 20 – Corrosion in masonry clad early 20th steel framed buildings*[1] is well worth a read, and can be downloaded as a PDF.

It was authored by Peter Gibbs, who also produced the Corrosion Prevention Association's *Monograph No. 7: Cathodic protection of early steel framed buildings*[2]. The original front cover of this includes a photograph of Regent Street.

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Many thanks for these useful references. The fact that they exist highlights the reality of corrosion problems in older structures. Assuring durability is a key component in any design and should be a factor in assuring sustainability: we want long lives.

Codes for seismic design

DENIS CAMILLERI

I appreciate Nick Eckford's personal experiences forwarded about the devastating 2011 Christchurch earthquake – 11 on the Modified Mercalli (MM) intensity scale – (June 2024). Further to seismic analysis and structural seismic codes, it is noted that post-earthquake surveys undertaken on collapsed buildings, and also rarely on buildings that remain standing, provide important insights to gauge why those buildings did not collapse during an earthquake.

It is to be noted that the seismic Eurocodes and the US codes encompass a large number of countries (more than 27 countries and 50 US states), with the Eurocode national annexes catering for the site-specific requirements. However, the relevance of the post-seismic surveys is to be appreciated in understanding further the local characteristics of particular localities.

Last September my son and nephew were on separate holidays in Morocco coinciding with the time of the MM7.5 earthquake. At the time, I could not understand why more than 3000 people lost their lives. Most deaths were noted to have occurred in villages higher up in the mountains where buildings were levelled.

With the on-site feedback later provided, I then understood that when mud and clay brick – the traditional materials used for adobe construction in this region – turn to rubble, they leave fewer air pockets than more modern structures made with concrete and rebar. This explained the large number of deaths occurring: trapped occupants had much less chance of surviving.

Rebuilding should now be undertaken as per resilient design principles, catering also for the effects of any future rockfalls. This does not mean, however, that the design will reduce the risk, or even the consequences, to zero: that is not possible.

Resilience results in significant damage to infrastructure, but gross loss of life should be avoided and the infrastructure should be repairable.

Denis has provided useful insights. Seismic design can be very difficult since we need to accept that providing full protection at affordable cost is scarcely an option. What we can do is design so that 'failure' is constrained to 'tolerable damage' and we can formulate design strategies to minimise risks to life. Denis's comments on the form of adobe collapse suggests options and opportunities for improvement.

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Dampness and timber decay

RICHARD HERNON

I refer to the Technical article and CROSS Safety Report in the July issue of *The Structural Engineer* dealing with dampness and timber decay.

Something not mentioned, which I have had experience of in the past, is condensation on the incoming service water pipe, especially copper and steel pipes.

This can result in sufficient dampness to propagate dry rot in adjacent timbers.

I have seen door posts, architraves and skirtings in modern properties destroyed by dry rot feeding on the elevated moisture content due to such condensation.

Water service pipes in areas of high humidity, e.g. kitchens, ground-floor toilets/shower rooms should be insulated to prevent condensation and subsequent localised raised moisture levels.

We are probably not giving enough design attention to 'condensation'. There are many complaints about draughty old houses but at least the draughts minimised condensation. Modern window systems are so sealed that internal moisture has nowhere to go, resulting in mould and rot. BS 5250: 2021 *Management of moisture in buildings* provides design guidance on managing moisture risk. A recent HSE report (https://bit.ly/3AwDD08) discusses roof timber rot risk from condensation when spray foam insulation has been applied to timber sloped roofs. In some cases, the risk is high.

Earthquake resistance research project

ALAN PEMBERTON

I have been reading with interest recent correspondence in Verulam on the subject of building design for earthquake resistance. I have recently started a research project at Kingston University, London, investigating the potential of the no-fines concrete (NFC) construction method for post-earthquake reconstruction and particularly how this material behaves under seismic loading.

NFC construction was a building method widely used in the UK, primarily during the 1960s and 70s, for the volume construction of low-rise housing. The concrete mix comprises coarse aggregate mixed with water and cement. The wet concrete is placed into formwork in a single pour without the need for compaction and one team of construction workers can typically build the shell of a two-storey house every day.

NFC, at first sight, seems an unlikely material for reconstruction in regions subject to seismic activity. However, early in my career I assisted with a research project at a commercial laboratory trying to establish whether NFC construction would be a viable material for constructing seven-storey buildings in parts of the world subject to earthquakes. I believe that for commercial reasons this project was not concluded, but early tests on sample panels with light external reinforcement were promising so I considered it worth having another look now at what might be achieved with modern materials, particularly fibre reinforcement.

Clearly, the need for rebuilding housing stock after earthquakes is urgent and would place a massive strain on local resources of materials, labour and finance. Reliable construction techniques must be adopted that optimise available resources, achieve a reduction of casualties and structural damage in future seismic events and, most importantly, reassure populations that their rebuilt homes will be as safe as possible.

I have based my research on materials and resources that should be available in affected regions. A paper has recently been published in the *Journal of Materials in Civil Engineering* based on a study into the use of recycled aggregate sourced from the rubble arising from destroyed buildings in the recent earthquakes Turkey and Northern Syria and this in large part motivated me to undertake this project.

My proposed research is based on laboratory manufacture and testing of NFC sample elements made with recycled aggregate (RCA), comprising varying mix proportions, and reinforced with basalt fibre-based reinforcement. Initial test results in terms of compressive and flexural strength of samples made with RCA and fibre reinforcement show some potential.

As expected, after a sample fibre reinforced NFC element reaches its maximum load it starts to fragment and load capacity falls away. However, it doesn't disintegrate completely. Considering what happens to a building in an earthquake, provided sufficient elements of the structure retain some of their shape, the building should not collapse completely, and lives could be saved. Although there is extensive research on how concrete's constituent materials and structural elements made of those materials behave up until the point of failure, there is relatively little on how concrete structures behave post-failure. A good example is the Steel Construction Institute's publication *Single Storey Steel Framed buildings in Fire Boundary Conditions*. In this analysis the steel roof members are assumed to have failed due to the temperature effects of fire in the building. The recommendations show then how the walls of the building structure can be designed to avoid overall collapse in this condition.

This in turn raises the very difficult consideration of 'survivability'. Constructing a building in poorer regions designed to be resistant to the most severe earthquakes may be beyond local resources and finance. However, due to the urgent pressure to re-house populations, collapsed buildings are quite likely to be rebuilt in unreinforced masonry, a construction method that is generally regarded as unsuitable in such regions; it may well be beyond local resources to construct an earthquake-resistant reinforced concrete-framed building. Nevertheless, as Denis Camilleri notes (July 2024), future gross loss of life needs to be avoided.

I have found that the tunnel formwork system is used by one organisation carrying out large-scale housing projects in regions subject to earthquakes. NFC construction would in many ways be a very similar process. I am trying to gain a better understanding more generally of potential regional working practices that could be adapted for construction of low-rise buildings in NFC, recognising prevailing limitations on labour and construction plant and equipment. I would be very interested in engaging with

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parties who can help me in this area.

I would also be pleased to hear from anyone who has any general comments or questions regarding my research. Contact: **alan.pemberton.ceng@gmail.com**.

Alan is addressing a major problem: how to house people in affordable dwellings that offer a good degree of survivability for the occupants, i.e. accepting significant structural earthquake damage is tolerable. Responses to his last paragraph are welcomed.

Mystery wall construction

JONATHAN PREW

With reference to Robbie Synge's letter in the January 2024 issue of *The Structural Engineer*, I sent a copy to the British Brick Society. It seems the origin of this 'brick' has eluded them too: an enquiry being made to them in May 1981. It was noted the brick used in a house construction in Barnes, southwest London, *c*. 1830/40 was possibly a construction form to avoid paying the brick tax: which was abolished in 1850.

I also contacted the Brickwork Museum at Bursledon. They made the following observations.

- This method uses considerably less clay than a traditional brick, making it more economical in terms of quantity of clay required, shortened drying and firing times, and lighter to transport/handle.
- It is also possible this was made on a running-out machine, as were many land drains.
- It makes use of waste material.

Recently I received an update from the British Brick Society. They have now managed to track down this 'brick' as being to a patented design by architect John Taylor. A PhD thesis by Kathleen Watt in September 1990 entitled, *Nineteenth Century Brickmaking Innovations in Britain: Building and Technological Change*, available online at White Rose e-theses, outlines the design and manufacture of these bricks, which were formed by extrusion. Images from 1863 show the extruded shape together with the wall construction. The thesis mentions this construction being used at Hersham Lodge, which no longer exists.

The bricks were manufactured by the Broomhall Tile and Brick Company (Taylors Patents) Ltd, Bridgwater, Somerset. According to the National Archives, the brickworks closed between 1890 and 1916.

Robbie Synge has let me know that his wall was on Kings Road, Richmond, appearing in two locations: at the junction with Marchmont Road and along Chester Avenue off Kings Road. So, piecing together we have this type of construction at Barnes, Richmond and Hersham, i.e. all in southwest London. The expectation is that more of this wall type could possibly be expected to be found in this area.

As ever, the history of construction and construction materials is fascinating. And when you think about it, the humble brick must be one of the oldest and most useful products ever devised.

Regenerative design workshop

JAMES NORMAN

I was delighted to read the write-up of the Chatham House workshop on regenerative design (August 2024). This is an incredibly important conversation, which through the Structural Engineers Declare movement many of us have committed to. I agreed with everything that was said and found the summary constructive and well balanced. I would, however, like to suggest two additional points:

First, under educators (by which I assume you mean academics) there is also a need for much more research in this space, especially connecting academics to the questions that industry is raising.

Second, although supply chains were mentioned, there was no mention of specifications. The more time I have spent thinking about regenerative design, the more convinced I am that our specifications could have a major impact, at project, practice (by creating practice level clauses) and industry level.

Specifications can help create the positive feedback loops we need. They can enable nature thriving and facilitate placed-based design. I would encourage practitioners to search for opportunities to use specifications for change and share both the clauses and the impacts of changing clauses so we can develop together.

Any new topic feeds on the pooling of ideas and experience. So, please join in the conversation!

Part-time education

FIONA GLEED

I would like to reassure Mark Duckett – and Verulam – that part-time education does remain available, including apprentice routes at a variety of levels, for a range of engineering specialisms. I have spent two decades as an engineering academic, working predominantly on part-time qualifications and I would recommend the routes to both students and employers.

Changes around 2000 affected the routes for both CEng and IEng, with standard pathways of a degree followed by initial professional development. Even with the integrated masters (MEng) many engineers gain practical experience prior to graduation, either working for a year or more before university or completing vacation and sandwich placements during their degree. It is also possible to develop the education base in parallel, either through formal apprenticeships or as a part-time student. These often involve day or block release, with progression from further education to university alongside school leavers or as a direct entrant to later stages of a degree.

At the Open University, our engineering qualifications include a foundation degree with optional top-up, BEng, MEng and MSc, as well as allowing enrolment on individual modules. Students are able to study flexibly alongside their work, family and social commitments. Many of our tutors are also working as practitioners alongside their teaching role and our courses are accredited by various professional engineering institutions – though sadly not JBM, in part because soils and concrete are not easy to include in our home experiment kits and remote access laboratory!

And across the various educational pathways, engineering academics are keen to offer authentic practice experience, through projects such as the Design, Assemble and Dismantle (DAD) project featured elsewhere in the August issue of *The Structural Engineer*, and by working with practitioners as mentors, guest lecturers and on Industrial Advisory Boards. If you are interested in getting involved, please do look at the courses available locally and offer your support to the lecturers.

The Open University is an admirable institution and one we should be proud of having. There is an urgent need to let young people know all the opportunities that exist for careers in engineering and to inform them of the optional pathways so they can choose the ones best suited. This seems topical as many school leavers seem doubtful about traditional university entry and they may well be attracted to alternative routes.