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FUTURE DIRECTIONS FOR EUROCODE 8

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Abstract

By the middle of the 21st Century, the practice of earthquake engineering is likely in many respects to be very different from its current form. Seismic standards will have to change radically, too. This will pose particular challenges for European structural standards (Eurocodes); their revision process is inevitably time consuming since the 34 member states of CEN, the European Committee for Standardization, must all be given ample opportunity to contribute fully. A ‘Second Generation’ of the Eurocodes is currently being prepared, which is expected to be fully ratified by 2025. However, because of the long timescales involved and the need for radical changes, it is already timely to start preparing for the ‘Third Generation’ of Eurocodes, expected to be published by the middle of the 21st century.

This is the task being undertaken by a Working Group (WG1) of the European Association for Earthquake Engineering (EAEE) with respect to Eurocode 8 (EC8). WG1 comprises 19 seismic engineering experts drawn from nine countries. It does not set out to make detailed proposals for revisions to specific clauses of EC8 but rather to propose the broad directions and general principles that should be followed. Its first report was published at the end of 2018 and is freely available on the EAEE website. It hopes to publish its second report before the end of 2021.

The paper considers first the fundamental roles that seismic standards must play, and how these roles may need to adapt in future. It is suggested that the fundamental roles, which are very different from each other but are all required, can be classified as follows:

- Provision of regulatory material
- Setting out the best consensus technical advice
- Defining performance standards

The paper then sets out some preliminary ideas that WG1 are considering for carrying EC8 forward into the mid-21st century. It groups these ideas into three distinct topic areas, as follows:

- Technical matters
- Setting performance standards
- Implications for EC8 of future radical changes in our profession

It is too soon for WG1 to provide firm recommendations for the direction EC8 should take into the mid-21st century, but it is hoped that the ideas presented in this paper will generate debate and lead to comments, feedback and suggestions from the wider seismic engineering community, which WG1 would greatly value.

Keywords: Eurocode 8, seismic standards, performance standards, future technology

1. Introduction: EAEE Working Group 1

In 2013, the European Association of Earthquake Engineering (EAEE) established a Working Group, entitled 'WG1: future directions for Eurocode 8'. Its current composition is given in Appendix 2 and comprises 19 experts based in nine different countries. WG1 did not set out to give detailed advice on the technical content of revisions to Eurocode 8 [1], (hereinafter EC8). Rather, inspired by the seminal US document 'Vision 2000' [2], it sought to provide, well in advance, broad principles for the future development of the standard. Its first report [3], published at the end of 2018, made proposals for both the 'Second Generation' of EC8, currently being written and expected to be ratified finally by 2025, but also for a 'Third Generation', which might appear sometime after 2035. At the time of writing (January 2020), near final drafts of all parts of the Second Generation of EC8 have been circulated, after being extensively debated by the European earthquake engineering community, and it is not expected that major changes will be introduced at this stage. Therefore, WG1 is currently considering solely the Third Generation of EC8; it hopes to publish its second report before the end of 2021.

Formal work on drafting a future Third Generation edition of EC8 is unlikely to start for another decade and might not be ratified until nearly 2040. To make recommendations for an event so far ahead might seem unwise, when all that can be said with confidence is that the world will be a very different place from the one we live in now. That applies not just to the specialism of earthquake engineering or the profession of structural engineering, but also more widely to the social, economic and political environment of the mid-21st century in which engineering standards will apply. Still, this is exactly what WG1 is attempting; the changes to EC8 required by then are likely to be so radical that we should already be starting to think about them.

Futurology is useful if it makes people think and be open to open to new possibilities; I believe this is true, even if some – or most – of its predications and assumptions turn out to be rather wide of the mark. The January 2020 special issue of the Structural Engineer [4] does not shy away from taking a 20 year overview; it is entitled '2040 vision: will changing attitudes and technological advances usher in a sustainable and human-centric future for structural engineering?'. As reported below, WG1 will examine some of the issues discussed by the 13 papers in that special issue, specifically in the context of earthquake engineering.

In what follows, I have used the terms 'standards' and 'codes' interchangeably, as referring to officially approved documents providing procedures for engineering (in our case structural) design, whether or not they have the force of legal documents.

2. The role of structural standards: what changes might be needed by the mid-21st century?

Structural standard may serve a number of purposes; I suggest that the following are the main ones. Note that they are very different in nature. The first two concern primarily technical matters, but the third does not; it addresses the non-technical problem of what society really wants (or what certain actors in the society think it should want).

1) Standards are official documents, often with legal status, which set out minimum requirements aimed at protecting society and its citizens from harm.
2) They are 'quasi-textbooks', providing information to design engineers on the best current practice and scientific knowledge – information which has been prepared and debated by the best available experts and which can be considered as a consensus position.
3) They provide a statement of the performance standards that should be achieved in design. The technical provisions of 1) and 2) should aim to achieve the performance standards defined in 3).

These three are now discussed in turn.

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2.1 Standards as 'official documents'

This aspect emphasises the controlling nature of standards. There is no doubt it is required; for example, the horrific deaths of 72 people in the fire which engulfed the Grenfell Tower, London, in 2017 after its refurbishment (Mann, [5]) are widely seen as in part due to the failure to apply building regulation restrictions, perhaps because of regulatory failures coupled with commercial or other pressures. The technical knowledge to prevent the Grenfell Tower tragedy was widely known at the time of its refurbishment, but was not applied. Society – at least within Europe – expects its elected authorities to try and ensure that the built environment it inhabits is safe, not least from the effects of earthquakes.

There are however downsides to the regulatory role of standards. At worst, structural designers regard them as legal documents which not just they, but the structures themselves, *must* obey and which exempt them from the need to consider any engineering aspects of the problem – in other words, from the need to think. This is dangerous not just because code provisions are not infallible; the pre-Northridge provisions in US standards for steel moment frame connections provide one famous example of provisions which were well-defined, but unsafe [6]. Arguably this was a failure of the international profession as much as of the code drafters. More significantly, code provisions are *minimum* standards which are not always appropriate, and not always applicable in unusual situations. There is also the danger that by being too prescriptive, standards stifle innovation and prevent the best state-of-the-art being built.

The Third Generation of EC8 will need to keep its regulatory role firmly in sight (not much danger of that, I think!) whilst still encouraging engineers to be 'ingenious' and adaptive in fast changing circumstances.

2.2 Standards as the best current consensus on structural knowledge

This aspect emphasises the technical content of standards as an essential tool in the armoury of structural engineers. Standards aim to give access to the best current advice over a more complete range of topics than most engineers could hope to master. Their use also provides some protection against accusations, after some failure, that an engineer has not considered everything that could have reasonably be foreseen. Achieving technical excellence has always been a fundamental goal of the drafters of European structural standards, including EC8, and one of their principal attractions and selling points. I personally hope that this goal will not be lost; however, the danger is that it pushes the code drafters into their own specialist ghetto, without considering the wider societal implications. Tanya De Hoog [7] writes

> 'For the engineering profession, it is time to adopt a more human-centric focus to better leverage technological innovation and use it to make a greater contribution to our society.'

I explored similar ideas specifically relating to earthquakes in my Mallet-Milne lecture: 'Dealing with earthquakes; seismic engineering as if people mattered' [8], and I believe the issue has implications for how EC8 is developed. For example, does the goal of achieving technically excellent codes apply in a different way to European standards than it does to Nepalese ones?

There are also fascinating implications of the knowledge-based aspect of standards for their relationship to the AI systems widely expected to take over some of our role as seismic engineers by 2040 (and probably well before!). This is discussed in a bit more detail later.

2.3 Standards as setting performance goals

The question of what performance standard should be achieved by a structure is one that is fundamental to its design, although usually it is implicitly assumed that 'code compliant' answers it sufficiently. Unless it is known what performance standard was aimed at by the designer of a structure, it can't be judged whether or not the structural design was successful. 'Performance based design' is of course now the fashionable procedure for earthquake engineers, although I would argue that it dates back to the development of limit state design principles by the Russians in the 1940's. The point here is – who should set those performance goals? It is a quite different issue from the setting of technical provisions; the technical provisions are the province solely of the engineering experts, but the goals they aim to achieve affect the whole of society. In the past, the goals for EC8 have been agreed by a room full of European earthquake engineers. That seems to me to be

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unnecessarily restricted, and it is something on which I hope WG1 will be able to provide guidance. I return to this in Section 3.2.

3. Topics to be addressed in WG1's Second Report

3.1 Technical matters

New advances in technology clearly have a direct impact on what goes into a standard. As knowledge advances, incomplete and outdated methods need to be replaced with more satisfactory ones; for example I have little doubt that our understanding of seismic ground motion will improve just as significantly in the next two decades as it has in the last two, and this will change the way standards specify design ground motions. It is not just scientific knowledge that will lead to the need for changes; new methods of construction are being developed for greater efficiency which reduce carbon footprint (for example, Campbell *et al* [9]) and these will have to be addressed. There is little doubt this will receive far more emphasis in 2040 than it does now; for example, the favourable carbon footprint of seismic-resisting timber structures may lead to as much or more material in the Third Generation EC8 on timber structures than on reinforced concrete or steel ones. More broadly, the need to allow for innovation to be introduced while ensuring reliability and code compliance, may lead to changes in practice, including the way that standards specify the design review process. Current progress within WG1 on developing its ideas on these topics is presented in my 2019 SECED conference paper [9].

3.2 Setting performance standards

New ways are needed to engage the wider community in setting performance standards; they should not only be widely acceptable outside our profession but also (if possible) actively supported. Currently, seismic specialists find it hard to seek this wider engagement in code drafting. As reported in [10], when preparing standards for the use of smart technology in cities [11], the British Standards Institution is understood to have been successful in engaging not only with technical people but also with city leaders; it is hoped that WG1 may be able to make some implementable recommendations based on this experience, aimed at helping a wider range of people being involved in setting its performance standards. The potential negative impact of earthquakes on a large city is surely of comparable size to that of the potential positive impact of smart technology, so it should be possible to persuade city leaders, if no-one else, to engage in setting seismic performance goals, even if their city hasn't experienced a significant shake in the last few decades (or election cycles). However, this isn't easy do; for one discussion of why, see sections 3.6 and 3.7 of [8]. It might also be noted that introducing smart technology into a city gives plenty of opportunities for obtaining lucrative contracts; of course, there are also commercial opportunities resulting from making a city more seismically resilient, but I suspect they will never be as great.

One of the difficulties here is that, naturally, an expert committee drafting a seismic code is going to concern itself with seismic performance standards. However, outside the seismic ghetto, other things may seem more important; see Figs 1 and 2, which I believe should be made compulsory viewing for earthquake engineers. Fig 1 shows that all natural hazards contribute only a small amount to the cause of death overall, while the contribution of earthquakes to death is an almost invisible spot. Fig 2 suggests that the local community may view natural features such as rivers and volcanoes in a very different light from an engineer coming in with no knowledge or understanding of the lives of local people.

Tanya De Hoog [7] writes

> 'By seeking wider collaboration as a profession, we can share knowledge and further engineering practice, raising the standards of care *beyond public safety and environmental protection to measures of social value.*' *[italics added].*

Beyond raising importance factors by a few percentage points for items of cultural heritage, it is hard to think exactly how measures of social value could be introduced into EC8; indeed, it might be hard to persuade its drafters that they should. Perhaps one day, the social vulnerability maps being produced by the Global Earthquake Model foundation (www.globalquakemodel.org) might be used to inform seismic designs in the

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way that its seismic hazard maps[1] are today. That time may be a long way off; however, I believe that we should at least think the matter through and consider whether considering issues of social value might be both fruitful and possible. One issue concerns the trade-off between seismic and non-seismic performance requirements; an example might be the imperative to reduce the carbon footprint of structures balanced against their ability to resist a rare earthquake unlikely to occur within the next few generations, but still possible. How do we balance the desire to seismically protect the citizens of (say) Istanbul or Karachi against the need to keep habitable as much of our planet as possible? I have no idea how this question can be resolved and would very much welcome any help that others can bring.

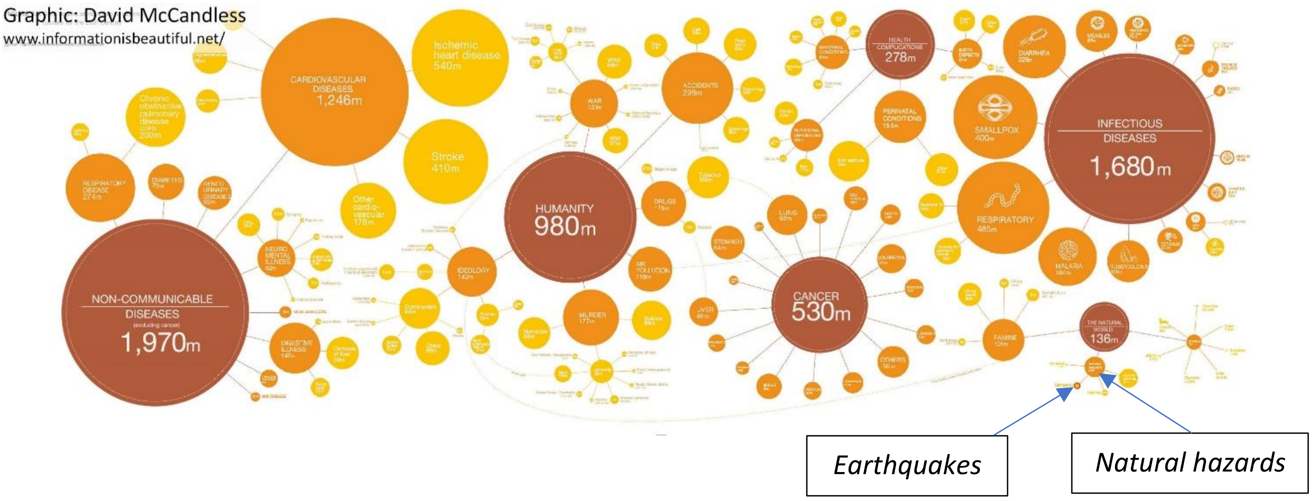
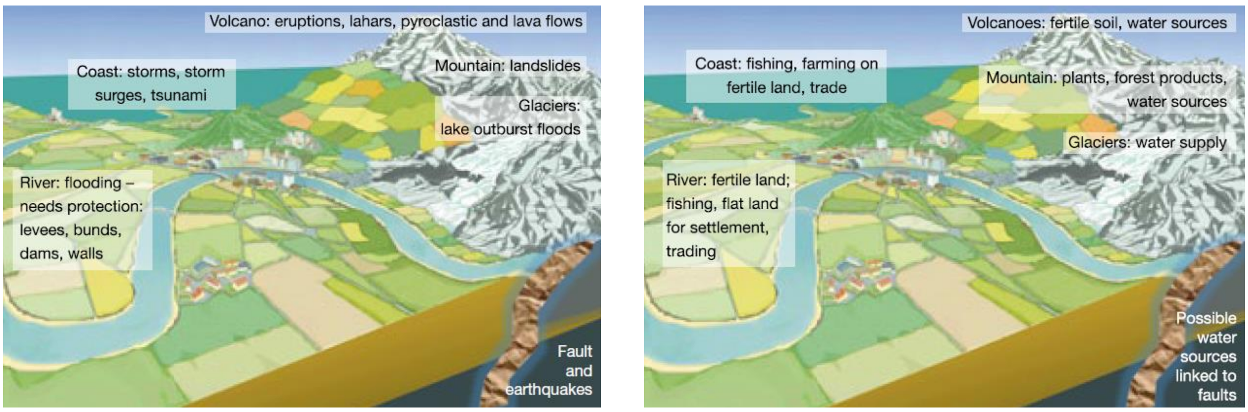


Fig 1. Causes of death during the 20th Century (graphic by David McCandless)



a) The engineer's view b) The local community's view

Fig 2. Different perceptions of the same landscape
(graphic by Terry Cannon *from* World Disasters Report: 2014 - Focus on culture and risk [12])

3.3 The changing practice of earthquake engineering

Structural engineering has changed completely since I started in the profession half a century ago with my slide rule, drawing board and British Codes of Practice that would fit into my back pocket. Yet the format of

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[1] https://www.globalquakemodel.org/gem?lightbox=dataItem-jtstx7xc

the standards themselves hasn't changed much; they have just longer, bigger and more complex. Surely we can do much better than that in the age of digital publishing, and the universal availability of tools to access it.

AI and machine learning are likely to make an even bigger impact on the way we do things as structural engineers, as explained by Dan Clipsom [13]. Certainly AI is like to have an impact on the way EC8 – and the Eurocodes generally - specify design reviews. But equally certainly it will have a deeper impact than just that. For example, the ability to attempt to optimise carbon footprint, based on trial designs of thousands of alternative seismic resistant systems, may well become routine. But will the attempts be valid – or even sensible? Seismic standards won't be able (I believe) to ensure that they will, but I think they will need to provide some tools for approaching the question.

4. Concluding remarks

There are of course huge uncertainties about the circumstances in which mid-21st century seismic engineers will find themselves. Despite that, this paper has argued that it is already time to start thinking about what developments might be needed in seismic standards to best serve engineers – and the wider community – a couple of decades from now. Working Group 1 of the EAEE has set itself the ambitious task of doing just that, and hopes to publish its findings by the end of 2021. As convenor of WG1, I would greatly value comments on the preliminary ideas set out in this paper, or suggestions on further avenues that we should be exploring.

5. Acknowledgements

Many of the ideas presented in this paper were developed from those coming from members of WG1, and the author gratefully acknowledges their support and contributions. However, the views expressed are those of the author, and do not necessarily reflect a consensus of WG1.

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Appendix 1: Terms of reference of WG1

1) Review state-of-practice and state-of-art methods in the seismic design of new buildings and their contents which are currently employed by engineers in Europe and elsewhere, and identify the ways in which EC8 currently does not address these methods.
2) Set out a long term vision for EC8 to be achieved by the year 2025.
3) In the light of the CEN proposals for the current evolution process, identify those changes necessary to achieve this long term vision which would be feasible within the current process.
4) Recommend changes to EC8 to take place during the subsequent evolution period, in order to achieve the long term vision more fully.
5) Prepare notes on additional aspects to consider for the seismic resistant design of non-building structures (bridges, towers & chimneys, pipelines, tanks, silos).
6) Prepare notes on additional aspects to consider for the seismic retrofit of buildings & bridges.
7) Deliver the report on the Working Group's findings and recommendations to the EAEE executive committee, with a copy to CEN sub-committee TC250/SC8.

NB: the second report of the WG will only cover buildings, as did its first report, so item 5) in the list above is not currently being addressed, and item 6) is only addressed for buildings.

Appendix 2: Membership of EAEE WG1

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