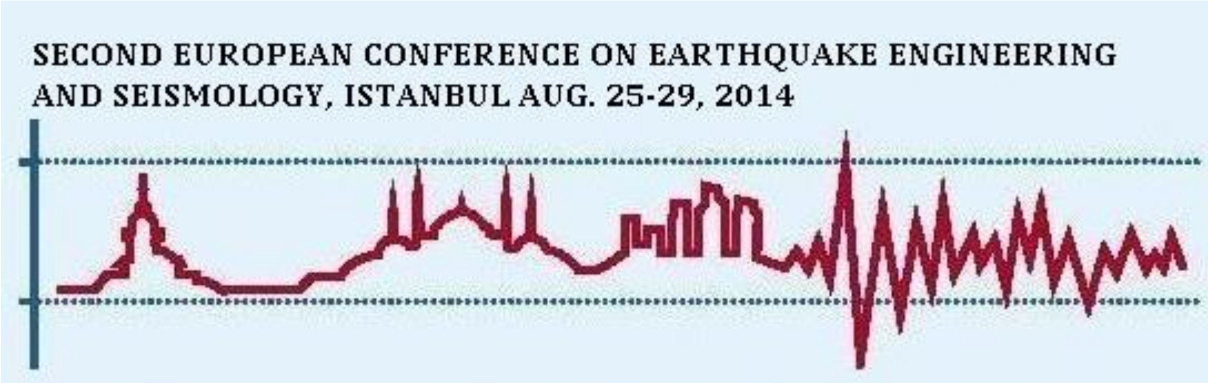

EXPLORING POTENTIAL DIRECTIONS FOR SPECIFYING DESIGN GROUND MOTIONS IN EUROCODE 8

Graeme WEATHERILL[1], Helen CROWLEY[2], Vitor SILVA[3], Damian GRANT[4]

As the European earthquake engineering community commences the process of development for forthcoming revisions to Eurocode 8, the opportunity arises to evaluate current practice in characterising input ground motions for design and assessment of structures. Such an evaluation is a critical element in the process of updating design codes, as there is a clear need to ensure that code requirements represent the state-of-the-art in terms of seismic design, whilst maintaining the practicality of implementation. It is also opportune to consider where, and how, to strengthen the interface between the seismological and engineering communities in order to ensure clarity and consistency in the requirements needed from the input seismic hazard analysis. The intent behind this analysis is to identify where current definitions of the seismic input in building design codes are potentially falling out of alignment with the state-of-the-art in seismic design, and vice-versa. In the spirit of initiating debate on these critical issues, we outline several key areas where substantive changes may be required to the current design code, and potentially to seismic hazard practice, in order for the code to better-align the seismic input with design requirements. We focus on several key areas where changes may be likely to occur, and thus where research should be concentrated in the coming years: the definition of the required seismic input levels and the characterisation of the response spectrum, the classification of geotechnical conditions and calculation of site amplification, and provisions for strong motion record selection and scaling for use in dynamic analysis.

An initial problem identified in existing design practice is that seismic input based on a uniform level of ground shaking, as it is currently defined in most codes, does not necessarily provide a uniform probability of collapse. To ensure consistency in the expected performance of structures designed in accordance with the code provisions, it may be necessary to define the seismic inputs in terms of a risk-targeted input (e.g. Luco et al., 2007). This approach involves the definition of seismic demand that leads to a uniform seismic risk nationally, whether this demand is being defined in terms peak ground acceleration/spectral acceleration for the force-based methodologies, or alternatively in terms of spectral displacement for the displacement-based design approach. The endorsement of such methodology would implicitly guarantee an equal level of safety regardless of the technique that is adopted for the design of new structures.

Since the development of the present Eurocode 8 design spectrum, many seismic design codes worldwide have adopted a means of characterisation that is not dependent exclusively upon PGA but may be anchored to multiple spectral periods. Given the wide disparity in both the absolute level and the spectral characteristics of the ground motion hazard across Europe, there is a pressing need for flexibility in the characterisation of the design spectrum, beyond the two-spectrum approach currently

[1] Researcher, European Centre for Training and Research in Earthquake Engineering (EUCENTRE), Pavia, graeme.weatherill@eucentre.it
[2] Senior Researcher, European Centre for Training and Research in Earthquake Engineering (EUCENTRE), Pavia, helen.crowley@eucentre.it
[3] Senior Researcher, European Centre for Training and Research in Earthquake Engineering (EUCENTRE), Pavia, vitor.silva@eucentre.pt
[4] Associate, Arup Advanced Technology + Research, London, damian.grant@arup.com

supported by the code. Recent seismic hazard projects, such as the pan-European SHARE model, have defined the ground-shaking hazard at multiple spectral periods up to 4 seconds. This greater expansion of available hazard information can permit either direct use of the uniform hazard spectrum for design purposes, or, if a simpler parameterisation is required, to provide a harmonised standard for defining the constant acceleration, velocity and displacement corner periods of the design spectrum according to the local characteristics of the hazard from region to region. In addition, if wider adoption of displacement-based design practice is anticipated, this may require the characterisation design spectra for longer spectral periods, up to and possibly exceeding 10 s if considering a secant-period based displacement-based method (e.g. Priestly, 2007). Accompanying this, therefore, is the need to ensure that uniform hazard spectra can be defined for longer periods, and that the displacement corner period (T_D) is well constrained for the location in question. Consequently, pan-European maps of seismic hazard should consider this requirement within the selection of strong ground motion prediction equations.

The characterisation of amplification by local site conditions, including those from soft soils as well as other factors such as basin resonance or topographic amplification, throughout design codes worldwide retains the use of design amplification factors specific to the site category, typically defined by the 30-m shear-wave velocity or standard penetration test. Suggestions for modifications to both the classification scheme and the amplification factors, such as those of Pitilakis et *al*. (2012), would potentially minimise the change in practical application whilst improving the characterisation of non-linearity in the site amplification factors. In practice, it is likely that this approach may be retained for the widest application to "ordinary" structures. For tall, or otherwise complex, structures it may be more appropriate to extend provisions to guide site-specific analysis practices to model amplification using detailed geotechnical information via nonlinear analysis. To facilitate this transition, careful attention must be paid to the manner in which uncertainties in the site response should be incorporated into the design process, and, if necessary, where seismic hazard input may need to be revised in order to ensure correct treatment of the uncertainties in these applications.

In addressing the needs of analysis for complex structures, or structures of higher importance, the use of dynamic analysis in design is now standard practice. At present, Eurocode 8 provides a minimal set of guidelines on the selection and scaling of time histories for dynamic analysis. Given the subsequent developments in this field, however, there is a clear need to expand these requirements and provide greater clarity to engineers regarding the application of these methodologies. In particular, future provisions should indicate (either within the code itself or a supporting commentary) how to identify records relevant to the seismic hazard at the structure, the definition of the horizontal ground motion, permissible methods for defining the design spectrum to which the records should be scaled, anticipating a transition toward the use of conditional spectra (e.g. Baker, 2011, Lin et al., 2013) and how to select and scale pairs of records for bi-directional analysis.

In the pathway towards development of the new European design code the potential points of interaction between the engineering community and the seismological community must be carefully addressed. Where design practices are evolving, it is through the needs of design codes that the objectives of seismic hazard analysis should be guided. Conversely in assessing the potential design and assessment methods that may be considered permissible within the scope of future design codes, the feasibility of constraining, in a timely and accurate manner, the appropriate seismic inputs should also be appraised. Potential pilot studies in selected areas of Europe may be helpful to identify the issues emerging in practice, and the potential pitfalls of adopting specific recommendations in the design code. These studies should operate end to end, from hazard analysis to structural performance assessment, in order to understand how to constrain the seismic input necessary for design, how to apply this information in design, and the potential consequences in terms of the seismic risk to the structures and the cost-benefit of the proposed design methodologies.

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