Future directions for EC8: Report 1

A report by EAEE Working Group 1

Contents

Executive summary

This document is the first report published by WG1, a Working Group of the European Association for Earthquake Engineering entitled 'Future directions for Eurocode 8'. WG1 was established in 2013 to make recommendations for future editions of EC8. It comprises 18 seismic engineering experts drawn from nine countries. WG1 did not set out to make detailed proposals for revisions to specific clauses of the Eurocode but rather to propose the broad directions and general principles that should be followed. Its work was directed at both for the 'Second Generation' of EC8, being prepared at the time of this report's publication, and also towards a future 'Third Generation' of EC8.

This first report is published at a time (December 2018) when a substantial number of the drafts of the second generation of EC8 are available, some in a form expected to be nearly final. It has therefore been decided to publish the recommendations of WG1 to date, taking account of those drafts. Many of WG1's recommendations have been adopted in the second generation drafts available to date. Therefore, the report identifies which of its findings have been possible to incorporate into the second generation drafts, and which might need to be considered for the third generation. Most of the WG contributed sections to the report, which presents a consensus view of the WG. It is the intention to prepare a second report, to be published during 2020, which looks exclusively towards the third generation.

Both this report and the second one are restricted to considering building structures. In due course, the Working Group will consider whether to extend its work to non-building structures, such as bridges, included within the scope of EC8.

1 Introduction

In 2013, the European Association for Earthquake Engineering (EAEE) established a working group (WG1) entitled 'Future directions for Eurocode 8'. Its terms of reference (TORs) were as follows:

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) *(NB: not covered at all in this report).*
6) Prepare notes on additional aspects to consider for the seismic retrofit of buildings & bridges. *(NB: this report covers only the retrofit of buildings).*
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.

The present report addresses all these TORs to some extent, except that no direct reference is made to non-building structures. It is intended as a concise statement of the views and recommendations within the WG on its TORs, and takes the form of bullet-point summaries. It is intended to set out broad principles, and does not propose detailed redrafts of specific clauses.

This report was finalised when final drafts were available from two of the project teams working on revising the original edition of EC8 (i.e. the first generation of EC8 ratified between 2004 and 2006), and when preliminary drafts were available from two more. Many of the recommendations in earlier unpublished drafts of this report have already been adopted by the Project Teams for the second generation of EC8; note that eight of the WG members also serve or served on these EC8 Project Teams. The WG therefore considers that its work in assisting the drafting of the second generation of EC8 is now complete (item 3 of the TORs). This report sets out to record its work to date and identify which of its recommendations are likely to be adopted in the second generation of EC8 and which might need to be considered for the third generation. Section 11 of the report summarises the likely adoption or otherwise of its recommendations in the second generation; section 11 also serves as a concise summary of the WG's views. It is not the intention to critique the drafts made by the second generation project teams.

Recommendations directed solely towards the third generation of EC8 (item 4 of the TORs) will be made in a second report planned for publication in 2019 (see section 12). The report will review WG1's current ideas for EC8's development and modify them as necessary, accounting for those likely to be adopted in EC8's current revision. Also, further, possibly more radical, suggestions will be added; a provisional list is given in section 12. The intention is to present an agreed final version of the second report during 2020.

Both this report and the second one are restricted to considering building structures. In due course, the Working Group will consider whether to extend its work to non-building structures, such as bridges, included within the scope of the Eurocodes.

The membership of the group was composed of 18 seismic engineering experts drawn from nine countries (see Appendix A.) There were two observers from JRC Ispra, an organisation which also provided some administrative support. 15 members of the group contributed first drafts of the various sections of the report, but the final version has benefited from review and modification by the full membership. It represents the consensus view of WG1.

2 Defining design ground motions

2.1 Preamble

The proposals in this section account for the information pertaining to the seismic hazard at a location that can now be freely and universally disseminated to engineers in a manner that is clear and efficient, using technologies that are mainly web-based. The detail, reliability and general availability of this information is many times greater than was available at the time of drafting the first generation of EC8. Recommendations specifically directed towards the third generation of EC8 are given in section 2.6.

2.2 Definition of the Seismic Hazard

- The use of seismic zonation as envisaged by the current (first) generation of EC8 is increasingly out of alignment with the current state of practice in seismic hazard assessment, and should no longer be continued. The full suite of seismic hazard outputs should be available, including ground motion values for multiple return periods.
- In addition, earthquake scenarios consistent with the hazard at the site of interest should also be provided. These can be identified by disaggregation of the hazard, and should be disseminated in a similar manner to that of the ground motions values themselves.
- The definition of the horizontal component of ground should be clarified and future seismic hazard assessments should ensure consistency with the required definition. Current practice in Europe considers the horizontal ground motion as the as-recorded geometric mean of the two components (Akkar et al., 2014). The use of the most directionally adverse horizontal ground motion, or envelope of the most adverse directional response across the spectrum is a topic of ongoing debate (Stewart et al., 2014). Further research is needed to assess the performance implications of adopting measures taking into account the directionality of horizontal ground motion. Further discussion is provided by Grant (2011) and Nievas & Sullivan (2017).
- Given the publication of recent Pan-European active fault databases, consideration should be given to defining a “near-fault” zonation, sites within which special consideration may be required.

2.3 Site Categorisation and Soil Amplifications

- Soil classes C and D encompass a wide range of conditions with different seismic amplification characteristics. Further sub-categorisation within the B, C and D classes should be considered, potentially adopting the classification scheme proposed by Pitilakis et al. (2013) which utilises the period of the peak of the horizontal to vertical spectral ratio (T_0) as a means of discriminating between the different sub-categories within this class.
- Nonlinearity in the amplification factor for strong motions on softer soils has been widely observed in ground motion records, and is supported by a strong theoretical basis. Nonlinear soil amplification models have also been proposed for Europe by Sandikkaya et al. (2013), based on a data set of observed global records. These and other similar published models, with potential updates or modifications, should be considered as potential long-term replacements for the current amplification factors.

2.4 Characterisation of the Response Spectra

- It is proposed that the current definition in the code of the elastic response spectrum on rock is:

EITHER replaced with the uniform hazard spectrum (UHS) on reference rock for each site

OR is retained but with the controlling parameters (T_B, T_C, T_D , F_0 [currently fixed at 2.5]) made available for each site.

Both these proposals assume that additional information pertaining to the seismic inputs for a given site can be disseminated to engineers in an open and practical manner, via a web portal or similar means.

- The elastic response spectrum should be constrained by the hazard for a broader range of periods than is envisaged in the current Eurocode, up to and including 10 s. If adopting the simple parameterisation anticipated in the previous bullet point, this may require that additional parameters of the spectrum are locally calibrated to ensure compatibility with the UHS.
- These additional parameters may include:
  - the exponential parameter α describing the decay from the spectral peak, currently set at -1
  - parameters controlling the shape of the long-period end of the spectrum, T_E and T_F.
- Recent research into the influence of damping modification on spectra has established that the modification factor, ξ, may be conditional upon the causative earthquake scenario. It is proposed that ξ should be defined in such a manner as to be consistent with the controlling scenario determined previously. Furthermore, consideration should be given to the identification of near-fault regions where alternative formulations for ξ may need to be applied.
- Vertical to horizontal ratio has also been shown to be dependent on the magnitude of the earthquake and the distance of the site from the rupture. It is therefore proposed that this term be specified either as a function of the parameters of the controlling scenario, or in terms of a conditional amplification spectrum anchored to the controlling scenario for the structure in question.

2.5 Time-History Selection and Scaling

- The minimum number of accelerograms used in the analysis should be raised from three to seven (Booth & Lubkowski, 2012), or to eleven (as for FEMA, 2015)
- In accordance with the proposed modifications to the elastic response spectrum, several options can be considered for the definition of the target spectrum:

  i) adoption of the uniform hazard (or closely parameterized) spectrum

  ii) application of a conditional spectrum (e.g. Baker, 2011)

  iii) as the envelope of multiple conditional spectra where inelastic and higher mode responses are such that a single conditional spectrum may not be considered conservative (e.g. the conditional spectrum falls below 90 % of the uniform hazard spectrum).

Option iii) is more conservative than ii), but may be more appropriate when the intent is to ensure the time-histories give a good match to the spectrum over a broader range of periods without necessarily requiring that the scaled histories match or exceed the target spectrum over such a broadband as is implied by the UHS.

- The use of spectral matching should be anticipated, and where this is used, the resulting spectrum should not fall below the target spectrum for the required period range (again, in line with FEMA P-1050-1). Where artificially generated records are used, further requirements regarding their characteristics, such as energy content or duration, could also be considered.
- For sites located close to active faults, or where near-fault effects can be demonstrated to contribute significantly to the expected ground motion at the site, an appropriate number of the ground motion records should include near-fault and directivity effects. Potential means by which this number could be identified are discussed in ATC-82 (NIST, 2011) and Almufti et al. (2015), but further work is needed to develop specific recommendations suitable for inclusion in a code suitable for use for European sites.

2.6 Additional recommendations for consideration for the Third Generation of EC8

- The selection of time histories could be made hazard-specific and structure-specific (Dolšek and Brozovič, 2016), as well as site-specific. Such an approach would allow risk-based decision-making to be made using only a limited number of time histories, thus facilitating the use of nonlinear dynamic analysis.
- The influence of basin amplification effects and topographic amplification is anticipated in the current Eurocode. Further research is needed to ascertain the best means, if any, by which such conditions can be parameterized in a manner that is practical to implement in a more consistent and satisfactory manner.

3 Areas of very low, low, moderate and high seismicity

3.1 Classification of level of seismicity

- The first generation of EC8 classifies the level of seismicity into three categories:

  very low (where no special seismic measures are required)

  low (where in essence lateral strength checks but no seismic detailing are required)

  high (for which the full provisions of EC8 apply).

- This report endorses the principle of tailoring the stringency of seismic design specified to the level of seismic hazard.
- The definition of these levels of seismicity will need to be reviewed for the second generation of EC8; currently it is based on peak ground acceleration.
- Consideration should be given to adding a fourth level of seismicity, namely moderate seismicity, requiring seismic design measures intermediate between those for low and high.
- Consideration should be given to linking the level of seismic design stringency to both the level of seismic hazard (e.g. low, moderate or high) and also the building function (e.g. the consequence class of the building). This would follow US practice of the last 20 years.

3.2 Areas of moderate seismicity

- In order to be able to address better questions of the design engineers and of the population, a well-structured communication should be prepared on the quantification of the actual seismic risk in moderate seismic zones, including return periods, soil effect and so on. Due regard should be given to the considerable uncertainties which apply in areas of moderate seismicity.
- Promote a level of design and detailing intermediate between DCL (i.e. non-seismic detailing requirements only) and DCM (full seismic design and detailing), aimed at providing a controlled but sufficient safety level. Due account should be taken that protection must be provided against rare, ‘unexpected’ events; capacity design provisions will be needed to ensure this. See also section 7.1.
- As far as possible (and reasonable), avoid any complicated calculations.

3.3 Areas of low seismicity

- Clarify the relative impact of wind and seismic actions on design and suggest guidelines to identify the requirements additional to those needed for wind actions, in order to reach a sufficient safety against earthquake actions in low seismicity regions.
- Design procedures suitable for low seismic regions will differ from those required for moderate seismicity and may allow further reduction of complexity. See also section 7.

3.4 Additional recommendations for consideration for the Third Generation of EC8

- The WG’s second report will consider the extent to which these recommendations have been implemented in the Second Generation, and in the light of this make recommendations for the Third Generation.

4 Performance objectives

4.1 Introduction

Sections 4 (performance objectives) and 5 (analysis), unlike the others in this report, take as their starting point the draft version of EC8 Part 1 (general and material-independent provisions) tabled at the SC8 meeting in October 2018, and do not consider the first generation, current edition of EC8. The intention of both sections 4&5 is to consider ways in which a third generation might develop further from that draft (SC8 document number N740, hereafter referred to as the Draft); it is not intended to provide recommendations of how the Draft might be changed prior to ratification.

4.2 Definition of performance objectives in the Draft

The Draft states the following general Performance Requirement for all structures designed to its provisions:

> Structures shall be designed so that, in the event of earthquakes, the following objectives are met with an appropriate degree of reliability:
>
> — human lives are protected;
> — damage is limited;
> — facilities important for civil protection remain operational.

In order to meet this overall Performance Requirement, the Draft requires only that the Significant Damage (SD) limit state (defined below) to be verified – i.e. the clauses for SD in the standard should be satisfied. However, National Authorities or other relevant parties can require that additional limit states of the four defined should also be verified. It is noted that quantitative definitions (e.g. crack widths in concrete) of the limit states are introduced in relevant parts of EN 1998; the generic definitions are as follows.

> **Near Collapse (NC)**: the structure is heavily damaged, with large permanent drifts, but retains its vertical-load bearing capacity. Although vertical load bearing capacity is retained, large permanent drifts are present. Most non-structural components, where present, have collapsed.
>
> **Significant Damage (SD)**: the structure is significantly damaged, possibly with moderate permanent drifts, but retains its vertical-load bearing capacity. Non-structural components, where present, are damaged (e.g., partitions and infills have not yet failed out-of-plane). The structure is expected to be repairable, but in some cases may be uneconomic to repair.
>
> **Damage Limitation (DL)**: the structure is only slightly damaged and economic to repair, with negligible permanent drifts, undiminished ability to withstand future earthquakes and structural members retaining their full strength with a limited decrease of in stiffness. Non-structural components, where present, exhibit only minor damage that can be economically repaired (e.g. partitions and infills may show distributed cracking).
>
> **Fully Operational (OP):** the structure is only slightly damaged and economic to repair. Systems hosted by the structure remain in continuous operation.

4.3 Quantification of reliability levels in the Draft

The Draft of EC8 Part 1 states that the basic Performance Requirement (see section 4.2) should be met with an 'appropriate' degree of reliability. An Informative Annex is provided for the simplified estimate of the annual probability of exceedence of a specified limit state. The Informative Annex states that for structures of consequence class CC2, the target annual probability of exceeding the NC limit state is $P_{t,NC,CC2} = 2\times10^{-4}$, unless the relevant Authority or the National Annex gives a different value.

The final PT draft of the revised version of EN1990: Basis of structural design contains Informative Annex C 'Code calibration and reliability analysis' which contains the following note.

NOTE Target reliability are given in the National Annex. In Table C.1.2 tentative values are given, to assist national authorities to define values applicable in a country.

Table C.1.2 — Tentative target reliability requirements related to one-year reference period and ultimate limit states (excluding seismic limit states)

Consequences of failure (see Table 2.1)	Consequence class		
	CC1	CC2	CC3
$P_{f,a}^{tgt}$	10^{-5}	10^{-6}	10^{-7}
β_a^{tgt}	4,26	4,75	5,20

Note that Table C.1.2 relates to ultimate limit states, while specifically excluding seismic limit states. Note also that the target reliability associated with seismic action in the Draft of EC8 Part 1 referred to previously (i.e. $P_{t,NC,CC2} = 2\times10^{-4}$) is significantly lower than the target reliability defined in Table C.1.2 by the draft of EN1990. However, the NC limit state in the case of seismic action allows significantly greater damage than that associated with the ultimate limit state considered in EN1990.

4.4 Recommendations for consideration in the Third Generation of EC8

4.4.1 Description of limit states

- The relationship between the Performance Requirement (section 4.3) given by the Draft and the Limit States defined (section 4.3) should be clarified. A particular issue is that if SD is the only limit state which is required to be verified, then the confidence with which the Performance Requirement is achieved may be questioned, particularly with respect to damage limitation.
- The likelihood and severity of damage in a design for SD limit state using the q factor approach will depend on the value of q, and hence ductility level, adopted.
- The parameters describing the limit states may be more accessible to engineers if they are set in terms of structural parameters (crack widths, drifts etc) in addition to consequences for the users (life safety, repairability etc). Structural parameters are more immediately amenable to calculation by engineers.
- For the DL limit state, repair costs and recovery time are significant parameters. These parameters are likely to affect structural elements in a different way from non-structural elements (equipment, services, finishes).

4.4.2 Requirement for which limit states should be verified in design

- The delegation to National Authorities of which limit states beyond SD must be verified should be reviewed. The lack of appreciation that 'code compliant' structures may be safe but unviable after the 'design' earthquake has in the past caused confusion and dismay among non-technical stakeholders, and is not always appreciated by engineers.

4.4.3 Need to quantify reliability levels

The incomplete quantification in the Draft of reliability levels associated with the various limit states has three important consequences.

(i) Communication between clients/stakeholders and the design team on the reliability with which the life safety and immediate occupancy objectives are met is made difficult. This is discussed further below.

(ii) It is difficult to judge whether the proposals for the improvement of other parts of the standard are adequate or not because the point of comparison does not exist.

(iii) Perhaps even more importantly, the adequacy of design procedures for new construction technologies is also made difficult.

It is recommended that further consideration should be given to appropriate levels of reliability to be associated with the limit states defined by EC8, taking due account of the following:

- the societal consequences of attaining a limit state to the various stakeholders and their resilience goals, bearing in mind the different impacts of seismic events in densely populated, as opposed to sparsely populated, areas;
- the views, preferences and perceptions of the various stakeholders of what a tolerable level of risk is, recognising that probabilistic language is specialist and complex, and most non-engineers (and many engineers, too) do not understand it. The language used in the discussion of risk, reliability and performance among the wide spectrum of stakeholders therefore needs very careful attention;
- the general principles of the Eurocode suite, including the need for compatibility with EN1990, the requirement to maximise sustainability and the freedom of National Authorities to set their own safety levels;
- the great uncertainty associated with the calculation of reliability levels, given the high levels of epistemic uncertainty;
- the relationship between the description and definition of a limit state (loss of function, threat to life, cost of damage, etc) and the metric used by engineers to measure attainment of the limit state (drift, plastic strain, etc). This relationship is of course at best highly uncertain and approximate. Note that different metrics (drift, plastic strain etc) tend to be used for the design of new buildings than the metrics (hardness of bars, crack widths etc) used for the assessment of earthquake damaged building. See also section 10, bullet point 3.
- the means by which the target reliability level reflects the building's function, expressed by its consequence class;
- the definition of reliability as the exceedence of a given limit state within the structure's lifetime, not the exceedence probability for a set of ground motions with a given return period. The 'hazard curve' (variation in hazard level with return period) is thus important, and is significantly different in areas of low seismicity from that in high seismicity.

5 Methods of analysis

5.1 Introduction

The basis for this section is set out in section 4.1 – i.e. it takes as its starting point the September 2018 draft of the non-material specific sections of EC8 Part 1 (the Draft).

The Draft defines two types of linear-elastic analysis (lateral force method of analysis, modal response spectrum analysis) and two types of non-linear analysis (pushover analysis, response history analysis) for estimating seismic demand on buildings. All these methods can be used in future generations of the standard, but the concepts of use of these methods should be further developed.

5.2 Recommendations for consideration in the Third Generation of EC8

5.2.1 Linear-elastic analysis

- **Limitations on the use of linear elastic analysis**

  This method is well established, conceptually simple and has a long history of use by design engineers. On the other hand, the seismic performance of buildings designed by linear elastic analysis is highly uncertain. In the Draft of Part 3, it cannot be used to verify the Near Collapse limit state for existing buildings, but the Draft of Part 1 has no restrictions on its use for new buildings.

  It is recommended that consideration should be given to requiring non-linear methods to verify the Significant Damage limit state for a number of cases, including very tall buildings (section 8.3), certain types of mixed structures, (section 7.6), novel 'beyond code' structures (section 8.1) and buildings with elevated consequence class.

- **Development of the q factor method**

  The main uncertainty in using elastic analysis methods occurs due to inconsistency between the use of linear elastic procedures and performance objectives which are associated with highly nonlinear building behaviour. Consideration should therefore be given to improve and calibrate the q-factor method by developing greater insight into the interaction between various factors, including forces/displacements derived from linear elastic analysis, design seismic action, distribution of seismic hazard with return period, randomness of nonlinear seismic response of structures and performance objectives when expressed in probabilistic terms, (e.g. Žižmond, Lazar Sinković and Dolšek, 2018), and the uncertainty in estimating the elastic stiffness.

5.2.2 Non-linear analysis

- **Use of non-linear analysis to verify final design of structures sized using linear and other methods of preliminary design**

  The design checks using nonlinear analysis and first principles should be developed, with the aim of allowing the explicit check of performance objectives. This would enable nonlinear analysis to be used to verify the results of a design based on linear elastic q-factor analysis, capacity design and standard detailing rules. Such an approach would also allow verification of other direct design procedures, which are not directly referred to in the standard.

- **Quality plans associated with non-linear time history analysis**

  Quality plans are required by the Draft for structures in High Seismicity areas. A review is proposed of the need for additional requirements for cases where non-linear time history analysis is used, including the need for peer review (see section 8.3.2(ix)), and the necessary qualification of the engineer responsible for the design. The extent to which this should covered in National Annexes also needs to be considered.

- **Intensity-based assessment (see Dolsek and Brozovic, 2016)**

  The concept of intensity-based assessment for risk-based decision making should be developed in the case of nonlinear response history analysis, which may be applied in conjunction with pushover analysis. The scope of this concept is to check the adequacy of design of a new building or of the strengthening of an existing building by time-history analysis for only a few ground motions which are scaled to an intensity level which is site-specific, structure specific and depend on target reliability for a designated limit state.

6 Design of foundations & retaining structures

6.1 Deformation based design of geotechnical structures

- With few exceptions, seismic design and assessment of foundations and non-gravity retaining structures is currently carried out within a strength-based approach, which leads to two major consequences:

(i) no account is made of energy dissipation in soil or foundation-soil interface and possible reduction of seismic actions on the above-ground structure

(ii) deformations of foundations and retaining structures are usually accounted for only in the verifications at the ultimate, but not at the damage limit states.

- EC8 currently specifies mainly strength verifications based on pseudo-static approaches, although the introduction of the model factor γ_{Rd} partly reflects some allowance, however not explicitly quantified, for permanent displacements.
- The drawbacks of current practice are
  - the elastic requirement for seismic design may lead to uneconomic oversized foundations
  - foundation retrofitting of existing or damaged structures is practically impossible to be accomplished under the requirement of elastic behaviour.
- Extensive recent research, supported by experience from international design projects, has clearly shown that sharing the yielding capacity between foundation and superstructure is an effective means to reduce the ductility demand on the superstructure, by providing a complementary, economic and very effective source of energy dissipation.
- The consequential degradation of the foundation system, expressed in terms of permanent foundation settlements and/or rotations, turns out to be in most cases to be limited and well below the serviceability limit states.
- Foundations <u>can and should be allowed to yield during earthquakes</u>; as a result of a temporary attainment of their bearing capacity, the consequent amount of energy dissipation can be substantial, as well as the reduction of seismic actions on the super-structure. The resulting permanent deformations of the foundation system are generally small and can be reliably computed. 30 years after the introduction of capacity design principles, it is time for their extension to the foundation system, which will lead to a much more rational and integrated approach to seismic design and to closer cooperation between structural and geotechnical engineers.
- It is therefore recommended that a radical modification of the current procedures in EC8 Part 5 is made by the introduction of allowance for the effect of non-linear dynamic interaction of the overall soil-foundation-structure system. A rational and integrated approach to seismic design of foundations and structures is proposed, which is expected to involve a controlled share of ductility demand between the superstructure and the foundation. This will have the major advantage of considerably reducing the seismic demand on the superstructure, at the price in most cases of negligible deformations of the foundation system, and it will assist in making more realistic (and less conservative) assessments of existing structures.

6.2 Design for liquefaction

- Evaluation of liquefaction hazard is a topic that should be revisited: the present situation evaluates the onset of liquefaction (triggering) given an earthquake scenario and requires a minimum safety factor (force based approach) to protect the structures.
- Consequences on the structures of the occurrence of liquefaction should be examined in the framework of performance based design.

- In addition, an integrated probabilistic approach, including the probability of occurrence of the earthquake, of a given elevation of the water table and probabilistic evaluation of the soil resistance should be developed to provide a more rational evaluation of the risk.

7 Design of new building superstructures

7.1 Levels of ductility

- At present there are three ductility classes for steel and concrete structures ~~and one sub-class for reinforced concrete structures~~

i) Low (DCL), in which the structure is sized for sufficient strength and stiffness to resist seismic actions, but detailed according to EC2

ii) medium (DCM)

iii) high (DCH)

~~iv) plus the wall type "Large lightly reinforced walls" as a subclass of DCM~~

For the future, it would to modify the ductility classes, as follows:

- The following solution is proposed:
    - A class similar to the present DCL, which follows the design guidelines of EC2 for concrete (and corresponding codes for other materials) and some additional detailing rules, which ensure that the structural elements reach some small level of ductility. No stringent capacity design rules are applied. It is envisaged this solution would be restricted to low seismicity areas (see section 3.3).
    - A moderate ductility class, changed from the present DCM, which is based on EC2 for concrete (and corresponding codes for other materials) and some additional detailing rules, which ensure that the structural elements reach some level of ductility. Basic capacity design procedures are applied and the probability of brittle failure modes such as shear failure of reinforced concrete structural elements should be reduced by applying an additional safety factor. It is envisaged this solution would be restricted to moderate seismicity areas (see section 3.2).
    - A high ductility class, changed from the present class DCH, which corresponds to today's DCM or a class between DCM and DCH and applies rigorous capacity design rules. It is envisaged this solution would be required for high seismicity areas (see section 3.3), unless the designer wants to implement a more ductile design, in which case a displacement-based assessment using a non-linear analysis procedure could also be permitted.
- It is recommended to establish a procedure for determining behaviour factors, because at present, they are largely based on empirical observations and it is often not clear how certain factors were derived. The establishment of such a procedure, the publication of all analysis on which the choice of the behaviour factors are based would have the following advantages:
    - The derivation of the behaviour factors would be traceable;
    - The deformation capacities of structural elements that undergo inelastic deformations could be explicitly considered; this is in particular important for structural elements where the current database might still be insufficient and the behaviour factors should be updated in following revisions of the code (e.g. certain masonry typologies).
- Such a procedure would also be in line with the striving to reinforce the mechanical basis of EC8, i.e. a basis founded on transparent scientific principles rather than empirical observations.
- It would further open up the possibility to develop procedures for mixed structural systems (section 7.6), which are at present only partially covered by the force-based design procedure.

7.2 Concrete

7.2.1 Cornerstones of the success of the current EC8 approach

- The following principles are considered the cornerstones of the success of EC8 guidelines for RC structures; these should be reinforced in future revisions:
  - Capacity-design rules ensure a ductile behaviour of structures subjected to displacement demands in the inelastic regime.
  - Design and detailing guidelines strive for a good balance between simplicity and accuracy.
  - Underlying engineering models are made transparent whenever possible.

7.2.2 Suggestions for principal considerations when revising the code

- It is proposed to reinforce the mechanical basis of all aspects of the RC section and use mechanical models (i.e. models based on the principles of structural mechanics) or semi-empirical models with a visible mechanical basis whenever possible. Mechanical models have the advantage that
  - The underlying assumptions are more clearly visible than for empirical models.
  - The scope of application can therefore be more easily understood and the model can be applied with greater confidence somewhat outside the scope of its original intention if necessary.
- Future generations of EC8 will always have to find again a new balance between code, text book, length and details provided. To find this balance it might be helpful to address the following issues:
  - Should a commentary be provided?
  - What knowledge is assumed by the user of EC8 with regard to reinforced concrete? I.e. which concepts are known to the user and do not need to be explained in the code or commentary.

7.2.3 Aspects that are in need of revision:

- Capacity design principles of DCM and lightly reinforced walls

In the present code, the shear demand V_{Ed} of walls designed for DCM (EC8 Part 1 cl. 5.4.2.4) and large lightly reinforced walls (5.4.2.5) is not based on the flexural resistance but on the shear demand obtained from the analysis ($V_{Ed'}$). Hence, the design of these walls does not fully follow capacity design principles and it is recommended to check whether this was intended or whether $V_{Ed'}$ should be replaced by an expression that is a function of M_{Rd}.

- Capacity design principles

Guidelines to incorporate these principles have been well developed for cantilever walls with rectangular or barbelled sections. In future, design guidelines should also comprise

  - effect of the out-of-plane strength of slabs on the flexural strength of coupling beams as well as on the axial force in walls
  - capacity design of flat slab systems that are often combined with RC walls and gravity columns (Fardis, 2013) including prediction of design forces in slab-column connections and slab-wall interfaces
  - capacity design actions in RC frames in regions of low to moderate seismicity where typically a full sway mechanism does not form.

- Lap splices in critical regions

Apparently in contradiction with typical test results on ductile walls, current rules for the splicing of bars do not explicitly exclude the splicing of bars in critical regions (EC8 Part 1 cl. 5.6.3). As a result, a new textbook promotes the splicing of longitudinal bars in critical zones of walls designed for DCH

(Sucuoglu and Akkar, 2014). A short statement on this aspect, which either allows or excludes lap splices in critical regions, could add clarification.

- Shear amplification factors

Current shear amplification factors are based on the analysis of cantilever walls but are applied to other kinds of structural systems. This is an example of a model which is applied well beyond its original scope. Future provisions should cover a larger range of systems. Such studies are already underway (e.g., Sullivan, 2010; Fox et al., 2014; Rejec et al., 2014).

- Modelling guidelines

It is proposed that guidelines for the nonlinear modelling of reinforced concrete elements should be introduced. Principal effects that should in general be considered when modelling walls should be listed (e.g. strain penetration into foundation, shear deformations, flexural deformations, lap splice deformations, …). For a particular problem, the engineer can choose to neglect some of these phenomena if it is outlined why it is considered of lesser importance.

- Engineering demand parameters for displacement-based approaches

EC8-Part 3 currently specifies the chord rotation as the engineering demand parameter for the displacement demand, which is in particular suitable for nonlinear static analysis of equivalent frame models. As nonlinear time history analysis and more complex membrane, shell or solid element models might become common in seismic analyses, future codes might reconsider the application of other, more local engineering demand parameters such as, for example, strains. It is recognised, however, that such engineering demand parameters call for advanced regularisation techniques before they can be used for seismic assessment (Bazant, 1976).

- Displacement-capacity estimates

EC8-Part 3 already contains chord rotation capacity equations for a large range of element configurations such as RC walls with and without lap splices in the plastic zone and smooth or deformed bars. Such equations need to be continuously refined and validated against new research; a first revision of these equations is already available (CEN, 2013). The further development of these equations should aim at

  - developing limits for engineering demand parameters for new limit states that are introduced in future versions of the code
  - reducing the variability of the predicted to observed displacement capacity and quantifying this variability while maintaining at the same time a good balance between simplicity and robustness
  - reinforcing approaches based on structural mechanics for the prediction of the displacement capacity as they can be extrapolated to element configurations where the data base is sparse, such as core walls,
  - addressing the displacement capacity of degrading systems considering realistic cumulative damage demands.

7.3 Steel and steel/concrete composite

7.3.1 General

- This contribution is based on a comprehensive review (Landolfo *et al*, 2013) by the Technical Committee "Seismic Design" of the European Convention for Constructional Steelwork (ECCS). This document intends to "…trace the guidelines for updated European seismic codes according to the worldwide research activities…" and represents the most consistent document published to date directed towards such an objective for steel structures. It describes a series of issues that would need clarification and/or further developments, and is organized in twelve sections that are listed hereby with a summary of the future needs identified for each of these issues.

- Steel structures designed to the first generation of Eurocode 8 have proved to perform quite well in earthquake situations (in experimental conditions and during real earthquakes). As a consequence, it is considered that both for the second and third generations, no revolutions are necessary regarding steel structures.
- The main issue is that the application of the current rules is somehow black or white (in other words, nothing or the full set of rules), leading in many circumstances to final designs that are not fully tuned to the actual seismic demand. This requires thus a better control of a number of parameters or phenomena, as discussed in the sections below.
- Some of the issues identified in the ECCS document are likely to be handled in the second generation of Eurocode (revision currently under preparation) but it is clear that some others still require intensive preparation work and are thus to be seen as perspective for a third generation. The present section focuses mainly on these long-term needs, that are not or only partially covered in the current draft versions of the 2nd generation of Eurocode 8, and remain thus relevant for its third generation.

7.3.2 Selection of steel toughness:

- Guidance is needed on values of strain rates and design temperature in the seismic conditions.
- Studies on realistic strain rates including local mechanisms (size of plastic zones, formation of crippling, notch effects…) need to be carried out. The observations shall be compared to other restrictions in the Code, namely to check if the formation of large buckles is to be expected when following the restrictions placed on rotation and sway.

7.3.3 Local ductility:

- Cross-section classification based on criteria other than the b/t ratio adopted by EC3 should be used for members in bending. Alternatively, the influence of the cyclic loading on the local ductility should be taken into consideration when setting b/t ratios for seismic loading situations.
- The possible use of slender cross-sections (and specifically of cold-formed members) along with a behaviour factor larger than 1.0 could also be investigated.
- Specific criteria should be proposed for rectangular and circular hollow sections as well as acceptance criteria for plastic deformations in the braces of concentrically braced frames.

7.3.4 Design rules for connections in dissipative zones:

- A thorough examination of existing experimental results and possibly an additional experimental program would be necessary in order to compile a set of rules for seismic-resistant joints. A harmonization of European and US rules for the qualification of seismic performance of components would be useful, allowing easier comparison of available results and a larger database of seismically-qualified beam-column joints. More detailed information is needed on the experimental procedure used to qualify beam to column joints for the use in seismic applications. An annex to EN 1998-1 or an independent standard/guideline would be appropriate, containing guidance in performing the qualification tests and processing of the results.
- Provisions for lateral restraints at plastic hinge regions and along the beam in the seismic design situation are needed to be introduced in EN 1998-1.

- As is the case for moment-resisting beam-column joints, design guidelines for typical braced connections are needed for seismic applications. Indeed, for this case the key question is how long the plastic zones must be, if they are limited e.g. to gusset plates.
- Furthermore the possibility of plastic rotations by means of ductile end plates shall be investigated. This would allow for stiff frames (in elastic stage) and for controlled plastic rotations so far required (crucial e.g. for column bases).

7.3.5 New types of links in eccentrically braced frames

- Extension of code provisions and development of design guidelines for new types of links, such as tubular links or replaceable (bolted) links is needed.

7.3.6 Behaviour factors:

- Behaviour factors associated with V-braced configurations should be reconsidered and values should be included for braced frames with configurations other than X or V.
- The concept of dual frames should be clarified and investigations are also needed to cover hybrid solution that go beyond the current scope of EC4 and EC8 (e.g. concrete elements reinforced by steel profiles or dual systems combining concrete walls and steel frames).
- Further studies are also needed in order to provide code behaviour factors accounting rationally for both structural characteristics and ground motion properties. See also section 5.2, second bullet point and section 7.3.67.1, third bullet point.

7.3.7 Capacity-design rules:

- Background studies on the efficiency of capacity design rules of EN 1998-1 with consequent simplifications and homogenisation of code provisions should be carried out.
- Further studies are needed to assess the influence of axial forces in columns on the local and global ductility of frames as well as to assess the necessity to consider the possibility of plastic hinges forming away from the beam ends when determining design shear forces in beams.

7.3.8 Design of concentrically braced frames:

- The appropriate model for compression diagonals in CBFs for elastic analysis deserves further attention. Guidance on the structural modelling in the case of response spectrum analysis is needed.
- Extension of code provisions to built-up cross sections (double-angle or double-channel) is required and guidance on design and detailing of brace to beam and column connections needs to be provided.

7.3.9 Dual structures (Moment Resisting Frames combined with Concentrically or Eccentrically Braced Frames)

- Further studies are needed to establish the necessity to provide MRFs in dual structures with a minimum level of strength and/or stiffness. In addition, the effect of sequential development of plastic mechanisms should be investigated.

7.3.10 Drift limitations

- A number of shortcomings are identified regarding the damage limitation criteria (inconsistency with UBC, limitation based only on the deformation capacity of non-structural elements, arbitrary choice of the return period…). All these aspects should be reconsidered.

- Shortcomings or missing background are identified in an number of cases regarding the deformation demand to be used in performance-based design or the damage limitation criteria to be used even in a classical force-based design. These should be reconsidered and clarified.
- Moreover, there is a whole model-code available (Sullivan *et al,* 2012) based on the works of Priestley, which provides a Direct Displacement-Based Design method.

7.3.11 Low-dissipative structures:

- A need is identified for the development of simplified intermediate rules, less severe than DCM and DCH rules but allowing the justification of a sufficient reliability level with moderate but sufficient ductility of the structures.
- Background studies are also needed to detect the possible weaknesses of DCL design in moderate to high seismic regions and to define the required elastic overstrength required to provide a safety level equivalent to a DCM or DCH design, together with the definition of clear criteria allowing demonstration of the post-earthquake operability of a structure.
- See also the discussion in section 7.1.

7.4 Masonry

7.4.1 Introduction

- In the current version of EN 1998-1:2004, the number of Nationally Determined Parameters (NDPs) for new masonry buildings is higher than for any other construction material covered by the code
- However, due the great variety of masonry construction styles and types which were developed locally in parallel over many years and the consequent variation not only in seismic performance but also the form of analysis method needed to design them, the aim to reduce the NDPs in the second generation of EN 1998-1 without confining and limiting local traditions will be only partly achievable.

7.4.2 Aspects that need fundamental review in the current revision of EC8 (second generation)

- Introduction of displacement based non-linear design.
- Establish drift limits for masonry structures to achieve serviceability performance objectives, with drift limits dependent on the masonry typology.
- Refinement and description of modelling methods (e.g. for slabs, spandrels, lintels).
- Revision of q-values and introduction of overstrength values.
- Revision of methods for simplified masonry.
- Definition of out of plane design.
- Clearer definition of limit states (damage limit state, live safety, collapse etc.).
- Procedures for reinforced masonry (e.g. horizontal reinforcement only).
- Procedures on confined masonry.
- Procedures for mixed structures (RC and masonry).
- Non-structural infills (development of a procedure or rules for non structural masonry infill walls).
- Material properties (mean strength values for nonlinear analysis, robustness, head and bed joint configurations).

7.4.3 Recommended topics for review in future revisions of EC8 (third generation)

- The code should be set up like a guideline, rather than purely a code, so that non earthquake specialised engineers should be also able to make a proper seismic design/assessment of masonry structures.
    - Especially in case of state of the art methods such as currently used nonlinear pushover methods, the user should be guided through the process step by step.
    - Clearly understandable decision flowcharts or decision trees should be included into the code to increase user friendliness.
    - The above mentioned points should be either included into the code itself as an informative annex or as an additional but official CEN document
- The style of the code which is currently formulated as a legal document and written in a very legal "language" should be reformatted completely towards a user friendly building code with some explanations.
- Currently the masonry chapter is strongly focused on unreinforced masonry, and the user is left alone to some extent when designing confined and reinforced masonry. More details are needed for masonry types other than unreinforced masonry.
- A strong focus should be given in the third generation on the chapter of "simplified masonry buildings". One aim can be, to have this chapter completely revised in order to ensure that safe designs for simple masonry buildings (limited in applicability due to storey number, PGA and regularity) can result without the need to use specialist expertise or software. Consideration should be given to redesigning the basic concept of this chapter completely.
    - Moving away from tabulated values toward to a simple resistance vs. exposure check. This will obviously depend on the ability to redistribute the shear resistances between the shear walls in one story under the condition of having a diaphragm slab. According to the current EN 1998-1:2004 there is a limit of only +25% / - 33% of shear redistribution permitted.
- The possibility of using innovative masonry materials or bonding styles should be opened wider than it is currently. A new section of the code is proposed which identifies the data that producers must declare when introducing innovative products to the market. This should be drawn up so that the provisions of EC8 can be applied, using the declared values of the producers.

7.5 Timber

7.5.1 General

- The chapter on timber buildings in EC8 Part 1, Section 8 (CEN 2004), is composed of only 5 pages and has remained basically unchanged since the ENV version of 1998.
- However, even recognizing that the current code provisions need a comprehensive revision, the whole structure of this chapter and the basic concepts and design philosophy should remain unchanged in order to keep consistency with the other parts of EC8.

7.5.2 Aspects that need fundamental review in the current revision of EC8 (second generation)

- Revision of the current list of materials for dissipative and non-dissipative zones including new types of wood-based construction materials and other types of panels commonly used in construction practice.
- Inclusion of widespread construction systems such as the cross-laminated (CLT) technology and the Log House system.
- Capacity based design rules, detailing provisions and overstrength factors for dissipative zones are currently totally missing for most of the structural types.
- Revision of the values of the behaviour factors q and proposal of values in the case of mixed system (e.g. light frame and CLT; CLT and reinforced concrete). See also section 7.6.
- Clarification of the concept of static ductility and proposal of minimum values needed at the different scale (fastener, joint, subassembly) to attain a certain value of the behaviour factor q.
- Inclusion of a performance-based alternative to the prescriptive rules currently given for maximum diameter and minimum slenderness of the fasteners in the dissipative zone.
- Modification of the current values for the partial safety factor for material properties to be used according to the concept of dissipative and non-dissipative behaviour.
- Provisions for making in-plane flexibility estimates of floor diaphragms for design purposes.
- Provisions for the application of non-linear static (pushover) analysis of timber structures.

7.5.3 Recommended topics for review in future revisions of EC8 (third generation)

- The third generation of the EC8 will have to cover a number of issues related to the use of timber for medium and high-rise buildings (10 to 30 storeys) and for dismountable buildings, including the following issues.
- More detailed provisions on non-linear static and dynamic analysis methods should be provided in order to foster their use in seismic design. The product certification by the European Timber Association (ETA) and the CE (Conformité Européene) marking based on product standards for connections and fasteners should contain also details about the non-linear properties of such elements.
- Provisions for the use of displacement-based design methods (such as the direct displacement based design method and the N2 method) as an alternative to the force-based procedure, particularly for the design of tall wood buildings or for the design of buildings with different lateral load resisting systems.
- Some guidance for the seismic design of dismountable buildings and for the retrofitting of existing timber and non-timber buildings using wood-based products.
- Guidelines on the design of tall (10 storeys and more) timber buildings.
- Recommendations for the estimation of the connection ductility in the dissipative regions including reinforcement methods to avoid brittle failure modes such as splitting, shear plug, etc.
- Clarification of the concept of static ductility and proposal of minimum values needed at the different scale (fastener, joint, subassembly) to attain a certain value of the behaviour factor q

7.6 Structures built from hybrid or mixed construction material

In the current version of EC8, guidelines for the design of hybrid structures are largely missing. Hybrid structures are buildings where two different lateral load resisting structural systems made of the same or different materials are used at the same level (systems working in parallel) or at different levels (systems working in series).

Since examples of hybrid structures are becoming more common (e.g. steel bracings with reinforced concrete walls; masonry walls and r.c. walls and moment resisting frames; heavy timber walls and reinforced concrete walls; heavy timber walls and light-frame timber walls; etc.), the new generation of EC8 should include a new section dealing with these types of structures. The following points outline the content and principles of this section.

- The new section should contain q-factors for the most common types of hybrid structures, conservative guidelines for the choice of q-factors for hybrid structures that are not explicitly covered and guidelines on the use of more advanced analysis techniques for the evaluation of hybrid structures.
- Specific analytical relationships to assess the behaviour factor q of the hybrid structure should be established for a number of commonly used hybrid structural types, including:

(i) mixed concrete/CLT (cross laminated timber) or light-frame timber structures
(ii) mixed steel/CLT or light-frame timber structures
(iii) mixed masonry/ CLT or light-frame timber structures
(iv) mixed CLT /light-frame timber structures
(v) mixed concrete/steel structures (i.e. structures where one part is built in concrete and another in steel, as opposed to composite steel/concrete structures)
(vi) mixed masonry/concrete structures (as distinct from concrete frames with masonry infill, which are currently covered in the standard)

These behaviour factors should be evaluated based on a clear procedure that needs to be established.

- The analytical relationships should be related to the ratio between the total lateral resistance or stiffness of the less ductile system and the total lateral resistance of the building in the reference direction. In order to establish these relationships, non-linear static or dynamic analysis should be performed on a representative number of different combinations of the two systems following the modelling and analysis guidelines of EC8. These methods should be allowed to reduce conservatism in design of 'common' systems for which q factors are provided in EC8; non-linear methods should be required in 'non-standard' systems not covered by EC8.
- Special consideration needs to be given for developing rules for buildings with different lateral load resisting systems and/or different materials at different levels, for example:
    - lower storey with concrete or steel and upper storey with CLT or light-frame timber system
    - lower storeys with CLT and upper storeys with light-frame timber system

Explicit non-linear analysis may be required in some cases of the systems listed above.

- Special care should be given to the design of the connection between the two different systems, which should be designed considering over-strength requirements or which needs to have a sufficient deformation capacity.

8 Design of buildings with special characteristics

8.1 Seismically isolated and other specially engineered buildings

8.1.1 General

- Field evidence collected in the last 20 years has suggested that buildings making use of technologies broadly described as "seismic protective systems", such as seismic isolation, have performed well. Therefore, future editions of EC8 should not just allow such systems, but actively encourage them.
- The current Chapter 10 of EC8 Part 1 sets out a conceptual framework that is useful for scheme design of base-isolated buildings. It does not include other types of seismic protective systems, such as distributed supplemental damping devices, and also does not consider "partial isolation", where superstructure yielding is allowed. It also does not explicitly take into account the enhanced performance objectives that would generally be targeted with such a design.

8.1.2 Aspects that need fundamental review in the current revision of EC8 (second generation)

- A clear framework needs to be defined for targeting enhanced performance, particularly for structures utilizing these special technologies.
- The various relevant Eurocodes and Euronorms should be harmonized.
- The role of q factors greater than 1.0 (allowed for buildings only in EC8 Part 1 cl. 10.7) should be justified and rationalized based on adopted performance expectations for different structural types.
- Similarly, requirements for the "damage limitation" limit state need to be improved, particularly since seismically isolated structures typically target this performance.
- The current linearization methods for analysis may overestimate the damping level and should be reviewed.
- Specification of bi-directional loading on isolation bearings needs careful review, because the bearings often have to resist the peak ground motion in any direction. The issues are further discussed in section 2.2., third bullet point.
- Simplified procedures, suitable for conservative design of relatively simple structures, possibly based on the current requirements in cl. 10.9.3 of EC8 Part 1, should still be available to the designer.
- Design rules for distributed supplemental damping systems should be drafted.

8.1.3 Recommended topics for review in future revisions of EC8 (third generation)

- Design rules for other seismic protective systems (including rocking systems and any other novel technologies that are developed in the interim) should be drafted.
- Performance-based, non-prescriptive rules for "cutting edge" structures should be developed, along with qualification procedures (including the need for peer review) involved. These provisions would apply generally, and not just to those structures employing special seismic protective systems.
- Design rules for partially isolated structures (allowing yielding of the superstructure) and semi-active or active devices, could also be adopted if there is demand for these from the engineering community
- Review the extent to which the recommendations for the second generation document were achieved, and fill gaps as necessary.

8.2 Innovative materials

- EC8 aspires to be a 'state-of-the-art', advanced code. To remain so it should also give space to innovative materials, which are therefore not (yet) codified. Nevertheless, it should set a framework for the validation of such systems.
- Non-codified systems and materials should respect the following key principles of EC8:

(i) Systems and materials should use conservative approaches for estimating the displacement capacity and strength capacity.
(ii) The systems and materials should be reliable.
(iii) The response of the systems should be predictable within practical means available to the engineer.

- The fundamental mode of operation should be demonstrated by

(i) experimental tests with measurements of local and global deformation quantities and global force quantities. If the new material is sufficiently similar to a codified one with regard to material properties and construction technique, existing tests can be used for validation.
(ii) Validation of a numerical model against these experimental tests using the quantities described above.
(iii) Analysis of the configuration to be tested and sensitivity study on relevant parameters.
(iv) The final analysis should in general comprise nonlinear response history analysis.

- The WG's second report will consider the extent to which these recommendations have been implemented in the Second Generation, and in the light of this make recommendations for the Third Generation.

8.3 Tall buildings

8.3.1 Overview

- International definitions of 'tall' buildings vary, with threshold heights in the range 50m to 70m.
- *Performance based design* (PBD) rather than *strength based design* (SBD) is particularly appropriate for tall buildings and should become a mandatory code requirement in EC8. In contrast to SBD, PBD measures tend to be *non-prescriptive*, specifying only a variety of performance goals, while limiting prescriptive rules for demonstrating how they are achieved.
- Recent material on PBD design of tall buildings has been published in California as guideline documents (SEAONC, (2007), SFDBI (2014), LATBSDC (2005 to 2015), PEER/TBI (2010), PEER/ATC (2010)), as a recommendation document by the CTBUH (2008), a draft guidance for the city of Istanbul (Aydinoglu, 2011) and recently as special provisions in the new Building Seismic Design Code of Turkey (AFAD, 2019). This material has now reached considerable maturity and could form the basis for clauses in EC8.
- International consensus, as represented by the references cited above, is for a three stage design process:

1) A preliminary design stage, with or without prescriptive elements, based on linear analysis and capacity design principles, similar to current force based design procedures in EC8. The subsequent evaluation stages may require substantial modification to the preliminary design to achieve the required performance objectives, demonstrating the importance of these stages for tall building design
2) A largely non-prescriptive serviceability performance evaluation under a short return period (under 100 years) earthquake, for which an essentially elastic performance is required.

3) A largely non-prescriptive collapse level performance evaluation, under a long return period (typically 2475 years) earthquake, where the objective is a low risk of partial or total collapse. Ductile elements must be restricted to acceptable levels of damage, while brittle elements must remain elastic and retain their gravity load carrying capacity. Non-linear response history analysis is used.

8.3.2 Aspects that need fundamental review in the current revision of EC8 (second generation)

• The current version of EC8 contains no specific provisions for tall buildings. However, all the basic elements are already present in EC8 Parts 1 & 3 for the development of a PBD procedure for tall buildings. They will need development in a number of aspects, as outlined below, all of which are considered achievable during the current evolution.

(i) Criterion for the definition of tall building:
The most practical criterion is the total height measured from the lowest or average soil level.

(ii) Mandatory use of PBD, as noted above, based on the steps outlined below.

(iii) Description of a multi-stage performance-based seismic design procedure:
The three-stage procedure discussed above may be adopted. Alternatively, the preliminary design stage could be omitted, giving a two-stage procedure.

(iv) Definition of a service-level earthquake to be used for serviceability evaluation:
Service-level earthquake is generally defined as an earthquake with 43 years return period, which corresponds to a 50% probability of exceedance in 30 years.

(v) Definition of serviceability evaluation criteria:
This may be realized by reformulating and unifying the performance requirements and compliance criteria currently given in EC8 Parts 1&3.

(vi) Provisions for distributed plasticity approach:
Regarding non-linear modelling and performance criteria, in addition to the existing clauses in EC8 Parts 1&3 based exclusively on *lumped plasticity (plastic hinge) approach*, the *distributed plasticity approach* including *fibre* modelling and associated performance criteria in terms of *strain capacities* need to be specified, which are particularly essential for the core walls of tall buildings.

(vii) Revised provisions for time-history representation of ground motion
Selection of recorded accelerograms should be exclusively specified based on site-specific probabilistic seismic hazard estimation studies with scaling procedure given in cl. 3.2.3.1.2(4) of EC8 Part 1 modified to exclude the effective peak ground acceleration requirement, to increase the minimum number of accelerograms from 4 to 11 (at least 7) and to allow for the ground motion selection and scaling through *conditional mean spectra*. See also section 2.5.

(viii) Special provisions for diaphragm design:
Special provisions need to be added to cover the design of diaphragms at the critical *transfer floors* at the transition from the tall building tower structure to the podium or the basement structure.

(ix) Establishment of peer-review system:
A *peer-review system* needs to be specified, which would define a *peer review board* composed of a number of experts continuously reviewing the design during the full course of design with a final approval. The same system may be applied to the design of base-isolated buildings.

(x) Seismic instrumentation:
Special provisions on *seismic instrumentation* need to be specified, combined with wind and other structural health monitoring systems.

8.3.3 Recommended topics for review in future revisions of EC8 (third generation)

- Tall building seismic design is a rapidly developing field. The Third Generation will need to account for the latest developments, which may include progress on the research topics listed in section 8.2.4.
- The recommendations in section 8.3.2 above which are not accepted for the final draft of the Second Generation of EC8 should be revisited.

8.3.4 Recommendations for future research

- Significant developments and research effort are likely to include nonlinear modelling, seismic ground motion representation and nonlinear analysis techniques. Specific issues are as follows.
    - Nonlinear modelling procedures of reinforced concrete walls and diaphragms, including shear behaviour and bending-shear interaction. See also section 7.2.3, third bullet point.
    - Investigation of dynamic shear amplification effects in cantilever type core walls and shear migration effects between the yielding and non-yielding walls of the coupled core wall systems. See also section 7.2.3, third bullet point.
    - Modelling of floor slabs and particularly those in transfer floors including complex nonlinear soil-structure effects between floor slabs, basement walls and the surrounding soil, which would also affect the specification of *foundation input motion* through kinematic interaction.
    - Development of probabilistic performance-based design applications giving explicit emphasis to the minimisation of the *seismic risk*. See also the discussion in section 5.
    - Less stringent design and analysis requirements could be developed for tall buildings in areas of low and moderate seismic areas, perhaps using some of the procedures for base isolated structures given in cl. 10.9.3 of EC8 Part 1.

8.4 Simple buildings in areas of high seismicity

- Rules should be provided which allow rapid, but safe seismic design of buildings without special or complex features, where the principal performance objective is meeting the ‘life safety’ objective. The performance objective for the ‘serviceability’ limit state would only be met at the rather low level of reliability achieved by the current draft of EC8.
- The proposals below are intended for conventionally engineered structures in concrete, steel, timber or masonry. Separate proposals should be prepared for low rise (say up to 3 storeys) masonry or timber buildings, using traditional (vernacular) construction methods.
- The ISE/AFPS manual (ISE/AFPS 2010) defines the features that determine whether or not a building is ‘simple’ in terms of the following. These could form the main basis for the definition in future editions of EC8 but it is noted where it might differ.
    - Site conditions – no very soft, liquefiable or unstable soils or slopes or proximity to active faults
    - Height – up to 40m for steel and concrete, but other limits would be appropriate for timber and masonry
    - ‘Moderately’ regular in plan and elevation (the term ‘moderately’ is quantified in the Manual)
    - Structural type – the Manual only covers concrete frames and walls, braced or moment steel frames only; this should be extended to masonry and timber.
    - No upper limit on a_{gmax}

- The Manual only covers DCM, but the DCM/DCL distinction is likely change radically, so this will need review.

- The simplification could take the form of the following.
  - Analysis – essentially as in the first generation of EC8, i.e. equivalent static up to a certain height, and then maybe 3D response spectrum analysis for taller buildings within the general height limit of 40m
  - Detailing – perhaps 'deemed to satisfy' steel braced and moment connections, and concrete confinement standard details, with equivalent rules for masonry and timber buildings.
  - Design aids – charts, graphs and macros to produce rapid solutions for design.
  - Simplified foundation design for surface foundations (but perhaps not piles)
  - Design is for ULS strength and ductility. Capacity design provisions would still apply, but might be simplified (e.g. for the shear capacity design rules for beams and columns).
  - Damage limitation is by largely qualitative rules for non-structural elements.
  - Masonry infill in concrete frames dealt with by simple prescriptive rules

- Although all of these recommendations are possible for the second generation of EC8, because no new concepts are involved, in practical terms because of timescales, it is likely that they will need to wait for the third generation before being realized. This will be revisited when the WG prepares its second report.

9 'Non-structural' elements and building contents

- Damage to non-structural (NS) elements can cause significant disruption, monetary loss, downtime, injuries and even loss of life.
- Damage observations following numerous earthquakes have demonstrated that NS elements are very vulnerable and improving the performance of non-structural elements will be a key step to mitigating seismic risk in the future.
- Various tools for performance-based seismic design of non-structural elements, similar to those developed for structural design, are currently available.
- Despite the points above, only a limited number of provisions for NS elements are included in the current version of EC8. Future versions of EC8 should therefore be revised to include more detailed provisions for NS elements, recognizing their importance for both seismic design and seismic assessment.
- For design, it is argued that a new section should be provided in a future version of EC8 Part 1, dedicated specifically to the subject of non-structural elements, just as there are currently sections for different structural typologies (reinforced concrete, steel, timber etc.). Such a section should have the objective of setting out minimum detailing requirements whilst also encouraging a performance-based seismic design approach. Current clauses in EC8 relevant to non-structural elements will need to be revised to ensure consistent treatment of both acceleration- and displacement-sensitive non-structural elements, for clearly defined limit states.
- Requirements for qualification testing and detailed guidelines for verification through design, could prove to be a simple but very powerful means of reducing the risk posed by non-structural elements in new buildings (or in the refurbishment of existing buildings).
- From an assessment viewpoint, it is apparent that better consideration of non-structural elements should lead to a more accurate indication of both the likely structural response and also the overall extent of damage in a building, which is important when trying to identify effective retrofit strategies. To this extent, more detailed requirements to consider the stiffness and energy dissipation offered by non-structural elements when undertaking analysis of a building would help achieve this. In addition, the possible provision of reference/nominal values of the resistance of common types of non-structural components against acceleration and deformation demands, could offer an effective means of gauging the performance of non-structural elements within an assessment process.
- Future versions of EC8 must take steps to encourage refined evaluation of non-structural elements within seismic assessment, so as to better understand the likely damage in buildings and move towards evaluation of modern performance indicators (such as likely repair costs or repair time) that are relevant to decision makers.
- A refined consideration of the seismic design and retrofit of non-structural elements is imperative also for the sustainable use of natural resources, which is particularly important given the new EC mandate to CEN regarding sustainability considerations within the second generation of Eurocodes.
- The present formula for floor spectra in EC8 Part 1 is highly oversimplified and needs refining.

10 Retrofit of buildings

- *More extensive advice specifically directed towards earthquake damaged buildings.* Although Part 3 currently states that damaged as well as undamaged buildings are included in its scope, the first generation had very few specific recommendations related to damaged structures, and this is unlikely to be changed by the current revision. In the Third Generation of Part 3, consideration should be given to adding a section focussing specifically on retrofit of damaged structures. This might also refer to the principles for establishing building reparability. There are several possible provisions in order to define reparability thresholds; they may be related to: loss of lateral load capacity (theoretically computable in different ways among which the modification of plastic hinge properties or by means of nonlinear dynamic analyses); columns' residual inter-storey drift; extent of damage to structural and non-structural elements (economic convenience).
- *Definition of applicable conditions for local interventions*. Local intervention seeks to improve seismic behaviour by modifying individual elements (for example beam-column joints) without modifying overall structural behaviour. The use of a local strengthening strategy may significantly improve the seismic capacity of an existing building by avoiding the failure (especially the brittle failure) of vulnerable elements. This strategy may result in a satisfactory and cost-effective strengthening solution and it is applicable unless it results in significant change of mass, stiffness, structural damping values, and thus, in general, of the structural dynamic properties. However, establishing whether a local intervention affects overall structural response is strongly susceptible to interpretation. It is therefore proposed that the conditions of applicability of local interventions should be properly addressed in future generations of Part 3.
- *Non-structural elements in existing buildings*: performance objectives – easy modelling procedures and/or acceptance criteria - should be provided for non-structural elements in order to ensure that damage to these systems does not affect life safety (e.g. to protect life safety of the occupants against the overturning of internal partitions). The current version of EC8 Part 3 has only one short paragraph relating to non-structural elements which recommends the same procedures as for design in new construction, and this situation is unchanged in the current draft. Given the great significance of damage to non-structural elements both economically and for life safety, more extensive provisions tailored specifically to existing construction is recommended for the Third Generation of Part 3. These would have to account for the different range of skills needed from those required for structural assessment; for example, the continued operation of plant during and after an earthquake requires mechanical rather structural engineering skills. See also section 9.
- *Identification of buildings that present a significant risk to life safety*: basic principles and rules should be outlined in future generations of EC8 to easily identify existing buildings particularly vulnerable against seismic actions. In particular, simple criteria to establish significant risk due to plan and elevation irregularity, potential soft story-mechanisms and local brittle failure mode may be useful to determine a simple index to preliminary assess the building risk to life safety. To this end, the possibility should be considered for the Third Generation of Part 3of including building type specific checklists ('experience databases') which identify typical characteristics associated with significant damage in past earthquakes. The viability of establishing such checklists would depend on being able to account for the very wide range of different construction methods and materials used across the CEN area.
- *Performance objectives for historical buildings*: Recent earthquakes have clearly shown the high vulnerability of historical and monumental buildings. Although they may be considered as a particular category of structure and National Authorities may identify provisions to provide an improvement of their seismic capacity, in the Third Generation of EC8 performance objectives to preserve these

structures and their high value contents need to be more clearly identified. The use of different hazard levels may be associated to the definition of suitable performance objectives, explicitly calibrated for this class of building.

- *Life cycle cost (LCC) procedure* can become an essential component of the design process in order to control the future cost of the building. Expected loss, including damage and repair costs, is an important parameter for structural design. The combination of economic theory and computer technology allows for a more developed approach to the design and construction of structures than ever before. The retrofit strategy should address at identifying the most cost-effective strengthening intervention and safety level for existing structures, in the structural life time. To do this, it is necessary to identify the optimal strengthening level, computing on one side the costs to strengthen the structure at different performance levels for each strategy, and, on the other side, the expected seismic loss in the structural life time. Basic procedures of LCC analyses may be required in order to define by a quantitative procedure the effectiveness of a retrofit strategy. Consideration should be given on whether LCC procedures should be directly referred to in the Third Generation of EC8, or whether they should be dealt with by other publications, which might include material cited as NCCI (non-conflicting complementary information) by National Standards Bodies.

11 Recommendations adopted in current drafts of second generation of EC8

Section No	Section Title	Recommendation in this report	Comment on inclusion in second edition of EC8
2	**Defining design ground motions**		
2.2	Definition of the Seismic Hazard	The full suite of seismic hazard outputs should be available, including ground motion values for multiple return periods.	Anticipated reference to SERA fulfils this at least partially. Provisions expanded to include more hazard information. National Annexes required to supply hazard parameters
		Definition of horizontal motion needs to be defined (geometric mean, maximum in any direction, etc)	Not yet included
		European fault database	Partly included. Provision made for specific analysis in near-fault regions. Compatible near-fault zonation can be delivered from SERA. Note that 2^{nd} Gen EC8 is a little more proscriptive here than before, anticipating special investigation in near-fault regions. A European fault database is available and the criteria set in EC8 5.1.1(5) could be used to define a European near-fault zonation. We can deliver this in SERA (though not explicitly requested) and add to the anticipated normative annex, although it is just as unlikely consensus will be achieved here as it is that it will be achieved for the PSHA.
2.3	Site Categorisation and Soil Amplifications	Subcategorization of soil classes	Fully included
		Non-linear soil amplification effects	Fully included
2.4	Characterisation of the Response Spectra	Definition of response spectrum	Mainly included
		Vertical to horizontal ratio	V/H section revised, but conditioning not addressed
2.5	Time-History Selection and Scaling	Number of time histories	Fully included
		Definition of target spectrum & spectral matching	Fully included (informative annex C)
		Requirements for artificial time histories	Fully included (informative annex C)
2.6	Other issues	Hazard specific selection of time histories	Not included
		Advanced consideration of basin and topographical effects	Not included
3	**Areas of very low, low, moderate and high seismicity**		
3.1	Classification of level of seismicity	Definition of seismicity zones	Fully included
		Link seismic design stringency to seismic zone	Fully included
3.2	Areas of moderate seismicity	Provide guidance on seismic hazard assessment	Addressed to some extent
		Provide intermediate detailing rules	Expected to be included

		Link wind and seismic design rules for ease of use, and avoid complexity to the extent possible	Not included
		Avoid any complicated calculations	Addressed to some extent
3.3	Areas of low seismicity	Provide separate, and more simple, procedures than is the case for moderate seismicity.	Expected to be included
4	**Performance objectives**		All proposals in these two chapters are directed towards ways of developing the Third Generation of EC8. However, selected issues could be addressed in the development of the Second Generation of EC8 if SC8 still needs to make decisions about them on the basis of comments of CEN members
4.4.1	Description of limit states	Clarify relationship between achieving Performance Requirement and achieving the four Limit States	
		Consider relationship between ductility level and SD Limit State description	
		Consider adding Limit State descriptors in terms of structural parameters (crack widths, drifts etc)	
		Consider adding repair cost and downtime indicators to DL Limit State description	
4.4.2	Requirement for which limit states should be verified in design	Review consequences of delegating choice of Limit State beyond SD to be verified to National Authorities	
4.4.3	Need to quantify reliability levels	Consider provision of target reliabilities for each Limit State (LS), considering the following:	
		Societal consequences of LS exceedence	
		Stakeholder views	
		Need to respect national independence for setting safety levels, and general compatibility with Eurocode principles	
		Large epistemic uncertainty in reliability calculations	
		Relationship between LS attainment and structural metric	
		Relationship between reliability level and consequence class	
		The need for reliability estimates to consider the seismic hazard environment	
5	**Methods of analysis**		
5.2.1	Linear-elastic analysis	Limitations on the use of linear elastic analysis	
		Development of the q factor method	
5.2.2	Non-linear analysis	Use of non-linear analysis to verify final design of structures sized using linear and other methods of preliminary design	

		Quality plans associated with non-linear time history analysis	
		Develop intensity-based assessment	
6	**Design of foundations & retaining structures**		
6.1	Deformation based design of geotechnical structures	Deformation controlled design which permits limited and quantified sharing of ductility between sub- and super-structures has many advantages over strength controlled design. It should be developed and promoted	It is understood that the revised draft of Part 5 will adopt these principles
6.2	Design for liquefaction	In line with the above, design for liquefaction should proceed by assessing consequences in relation to performance goals, thus using a deformation based approach rather than one based on safety factors.	
7	**Design of new building superstructures**		
7.1	Levels of ductility	Reduce number of ductility classes to DCL (as at present) and DCM (similar to, or somewhat less stringent that currently, while maintaining capacity design requirements) Implement high ductility demand designs through non-linear analysis, rather than DCH, which should disappear	The provisions on ductility classes have been substantially modified, although three ductility classes have been retained (DC1, DC2 and DC3). *For concrete and steel structures*, DC1 and DC3 broadly correspond (in terms of behaviour factors, design requirements and detailing) to the former DCL and DCM. DC2 corresponds to an intermediate ductility class. *For timber and masonry structures*, there was previously no classification into ductility classes. Timber structures can now be classified as DC1, DC2 or DC3 with similar intent to the concrete and steel classification, but masonry structures remain unclassified.
		Refine methods for setting q factors, based on structural mechanics, to increase transparency and allow use of novel materials	q is now defined as $q_R q_S q_D$. Default values for all three components are provided. Values other than the defaults may be determined as follows: q_R is the component due to redistribution and may be determined from a pushover analysis. q_S is the component due to strain hardening, etc. It must be taken as 1.5 (or exceptionally 1.0 if appropriate). q_D is the component due to ductility, and can be defined as giving a 'sufficient margin' against ultimate capacity for the Near Collapse condition. Detailed advice is not provided.
7.2	Concrete	Rules should be based on capacity design principles, rational detailing and transparent models	Capacity design is adopted as a general principle in EC8, but the extent to which it applies to DC2 concrete structures

			has yet to be resolved for the Second Generation.
		Consider the need for a commentary and the user knowledge that is assumed by the rules	Background documents are being produced, but no commentary for users.
		Modify the rules currently given for: a) Capacity design shear amplification factors in walls	The formulae for shear in walls have been changed.
		b) Lap splices in critical regions of ductile walls	The admissibility of lap splices in critical regions of columns, walls and beams is not currently clear.
		c) Add rules for non-linear modelling	It is planned to add data for pushover analysis of beams, columns, walls, beam-column connections and flat slabs
		d) Consider engineering design parameters specified for meeting performance objectives, e.g. strain rather than chord rotation	The deformation parameters considered to check the performance objectives are based on the chord rotation for different types of RC elements.
7.3	Steel and steel/concrete composite	Modify or reconsider the rules for:	
		Local ductility	Still based on cross-section classes in the current draft
		Design rules for connections in dissipative zones	General principles are covered in the current draft; more elements available in the results of the project EQUALJOINTS
		New types of links in EBFs	The scope is enlarged in the current draft but can always be further enlarged
		Behaviour factors for braced, dual frames, and allowance for ground motion characteristics	The situation is improved in the current draft, but ground motion characteristics are not included yet
		Capacity-design rules	Situation is strongly improved in the current draft for most of the common structural configurations
		Concentrically braced frames	Analysis aspect are covered, but rules for special bracing types not yet
		Dual structures -MRF plus braced frame	Included in the current draft
		Drift limitations	Not included yet in 1998-1 nor in 1998-3
		Low-dissipative structures	Partially covered via the introduction of the DC1 class instead of DCL. Further improvements are however possible
7.4.2		Modify or reconsider the rules for:	

	Masonry: recommendations for the Second Generation		
		Introduction of displacement based non-linear design.	Will be included in the revision of the 2nd generation EN1998-1
		Establish drift limits Refinement and description of modelling methods.	Will be included in the revision of the 2nd generation EN1998-1 and will be removed from EN1998-3
		Revision of q-values and introduction of overstrength values	Will be included in the revision of the 2nd generation EN1998-1
		Revision of methods for simplified masonry	Will be included in the revision of the 2nd generation EN1998-1
		Definition of out of plane design	Will be partly included in the revision of the 2nd generation EN1998-1
		Clearer definition of limit states for masonry.	Will be included in the revision of the 2nd generation EN1998-1
		Procedures for reinforced masonry	Will be included in the revision of the 2nd generation EN1998-1
		Procedures on confined masonry.	Will be included in the revision of the 2nd generation EN1998-1
		Procedures for mixed structures (RC and masonry).	Will be partly included in the revision of the 2nd generation EN1998-1
		Non-structural infills	Will be partly included in the revision of the 2nd generation EN1998-1
		Material properties of masonry	Will be partly included in the revision of the 2nd generation EN1998-1
7.4.3	Masonry: recommendations for the Third Generation	Include advisory guidelines for masonry, by flowcharts, informative annexes and supplementary CEN guidance documents	These recommendations are specifically directed towards the Third, rather than the Second, Generation of EC8
		Improve accessibility of language away from a 'legal' style to a more user-friendly one	
		Provide more guidance on masonry types other than unreinforced masonry	
		Complete revision of the rules for simplified masonry buildings	
		Provide for the use of innovative masonry styles, including required test values	
7.5	Timber	Modify or reconsider the rules for:	
		Revise list of materials for dissipative and non-dissipative zones	The list has been revised completely, including new wood-based and not wood-based panels such as OSB panels, CLT panels and GWB panels.
		Include systems such as the cross-laminated (CLT) technology and the Log House system.	The CLT and the Log House systems have been included.
		Provide much more extensive capacity based design rules, detailing provisions and overstrength factors for dissipative zones	Capacity design rules, detailing provisions and overstrength factors for dissipative zones have been provided for each structural system.
		Revise q factors and clarify associated assumptions.	The table including the q factors has been completely revised providing

			values for each structural system and ductility class.
		Performance-based alternative rules for fasteners.	Performance-based alternative rules for fasteners have been included.
		Modification of partial safety factors for material	The partial safety factors for material properties have been modified.
		In-plane flexibility estimates of floor diaphragms	Some prescriptive rules have been added in order to consider the floor rigid in the structural model without further verification, but no analytical method has been included for the estimation of the in-plane flexibility of floor diaphragms.
		Provisions for the application of non-linear static (pushover) analysis of timber structures	New provisions for the application of non-linear static (pushover) analysis of timber structures have been included
		Clarification of the concept of static ductility and proposal of minimum values needed at the different scale (fastener, joint, subassembly) to attain a certain value of the behaviour factor q	The concept of static ductility has been further clarified and a table with the minimum values needed at the different scale (fastener, joint, subassembly) to attain a certain value of the behaviour factor q has been included.
7.6	Hybrid structures (structures consisting of two separate structural systems or material)	Develop q factors for 'common' hybrid systems, based on non-linear analysis	Hybrid structures (other than steel/concrete composite structures, masonry infilled frames and frame-wall structures) are not expected to be covered in the Second Generation of EC8.
		Permit non-linear analysis to reduce conservatism of design in 'common' hybrid systems and require it for non-standard systems	
		Provide special rules for systems where the structural system or material changes with height, including cases where non-linear analysis is required	
		Provide rules on the elements connecting the various parts of the hybrid system	
8	**Design of buildings with special characteristics**		
8.1	Seismically isolated and other specially engineered buildings	Promote the use base isolated and other systems found to perform well	To be reconsidered in WG1's second report
		Revise current rules to cover distributed damping systems, partial isolation and design of 'special' structures for enhanced performance	Distributed damping systems are included, but other special structures are not.
		Modify, provide or reconsider the rules for:	
		Harmonize the various relevant Eurocodes and product standards.	Although drafts are not available for all relevant Eurocodes and norms (e.g., Eurocode 8 Part 2; EN 15129), harmonization appears to a priority of the various Project Teams and SC8.
		Use of *q* factors greater than 1.0, based on adopted performance	Provisions for seismic isolation still only apply to "full isolation" – in which superstructure remains elastic.

		expectations for different structural types.	
		Requirements for the "damage limitation" limit state need to be improved.	Standard performance check is defined as Significant Damage limit state (although elastic superstructure performance is still targeted). Reference to interstorey drift checks at Damage Limitation state has been added.
		The current linearization methods for analysis.	Relevant guidance on linearization of isolator response has been removed from Eurocode 8. It is expected that practitioners will therefore continue to use previous guidance, which may be unconservative.
		Bi-directional loading on isolation bearings.	Does not appear to have been considered.
		Simplified procedures, suitable for conservative design of relatively simple structures	Same as previous version.
8.2	Innovative materials	Respect basic principles for setting rules for the design of structures using innovative materials	To be reconsidered in WG1's second report
8.3	Tall buildings	Consider the following aspects a) Criterion for the definition of tall building: b) Mandatory use of Performance Based Design. c) Description of a multi-stage performance-based seismic design procedure:. d) Definition of a service-level earthquake to be used for serviceability evaluation: e) Definition of serviceability evaluation criteria: f) Provisions for analysis models using distributed plasticity approach. g) Revised provisions for time-history representation of ground motion h) Special provisions for diaphragm design i) Establishment of peer-review system j) Requirements for providing seismic instrumentation	Except item (g), which is partly covered in Annex C, all items have not been adopted by the current revision of EC8.

8.4	Simple buildings in areas of high seismicity	Provide simplified rules for the design of buildings without special or complex features, where the principal performance objective is meeting the 'life safety' objective	Unlikely to be achieved in the second edition of EC8
9	**'Non-structural' elements and building contents**		
		Include more detailed provisions for these elements, and place in a new section of EC8 Part, to emphasise their importance.	Not included
		Provide rules for design by both analysis and testing	Not included
		Give rules for the contribution of 'non-structural elements' to overall building seismic response	Not included
		Reconsider the current formula for floor response spectra	Proposed revised formula should be reconsidered
10	**Retrofit of buildings**		
		More extensive advice specifically directed towards earthquake damaged buildings	Not included; this part of the draft is unchanged from the current edition of Part 3.
		Provide rules for the applicability of local, as opposed to global, intervention strategies	Not included
		Provide more extensive rules for non-structural elements in existing buildings	Not included
		Provide rules for easy identification of buildings posing a high seismic risk	Not included
		Provide reference to performance objectives for historical and culturally significant buildings	It is understood that supplementary advice is being prepared to supplement the PT final draft of Part 3.
		Consider reference to the calculation of life-cycle cost	Not included

12 Provisional list of topics for Report 2: Recommendations for the Third Generation of EC8

The following gives a provisional list of topics that will be discussed in the second report.

a) Seismic hazard maps
   i) The treatment of epistemic uncertainty in seismic hazard maps for code purposes, and how epistemic uncertainty should affect code provisions.
   ii) Treatment of whether hazard maps for code purposes should be updated more frequently than other parts of the code.
   iii) The degree to which local factors (basin effects, topographical factors, fault proximity) should be taken into account to modify the regional hazard.

b) Performance & risk
   i) Accounting for risk when setting design ground motions, including social/group seismic risk, the subject of recent research at the EUCENTRE, Pavia.
   ii) The ways in which EC8, and its setting of performance objectives, could account for views of a community wider that the narrow technical community which currently drafts the code.
   iii) The future role of ductility as a design objective in the light of emphasis on economic and functional performance objectives

c) Analysis
   i) Inclusion of methods of energy-based methods analysis, as proposed by Michael Fardis in a keynote address to the 16th European Conference on Earthquake Engineering
   ii) Review of how important a role response spectrum analysis should continue to play in the 2020's.

d) Geotechnical
   i) Further development of displacement based design methods for foundations.
   ii) Further development of design methods for deep foundations.

e) Reinforced concrete
   The appropriateness of curvature ductility demand as the determinant of post-yield capacity in rc elements

f) Traditional construction
   The ways in which EC8 should address traditional construction not amenable to standard methods of engineering calculation applicable to steel or concrete buildings.

g) Retrofit
   The treatment of the seismic assessment and retrofit of buildings, taking into account the experience embodied in recent US and New Zealand documents and also in Europe, including Italian and Greek complementary guidance (NCCI) documents.

h) 'Ease of use'
   Fitting EC8 to the needs and convenience of design structural engineers. Aspects to consider might include:
   i) The medium in which the standard is published (paper, digital ….), and the extent to which digital capabilities of cross-referencing and automatic calculation of formulae might be used. BSI's 'Eurocode Companion' facility might give some ideas.
   ii) The manner and extent to which the standard should address the needs of buildings with special characteristics (very tall buildings, buildings on unusual foundation soils or in unusual seismo-tectonic conditions, high-tech seismic resisting facilities, advanced engineered materials, 3D printing of structures ……)

i) Advances in digital technology
   Review how digital developments in the next 10 years, including anticipated rapid advances in AI, might affect the ways in which structural engineers do their business, and what that might mean for standards.

In addition, the recommendations of the previous sections of this report which are not expected to be adopted in the Second Generation of EC8 will be reviewed. Where appropriate, they will be suggested for consideration in the Third Generation, modified as necessary.

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Appendix A: Membership of the Working Group

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