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KEY ASPECTS IN THE REVISION OF MATERIAL-DEPENDENT SECTIONS OF EUROCODE 8 PART 1

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ABSTRACT

The revision first consists in the definition of design ductility classes more practical for users. Three ductility classes are defined, DC1, DC2 and DC3. Class DC1 corresponds to a design made without considering Eurocode 8 material dependent sections. It is equivalent to DCL class of EN1998-1:2004, still with a behavior factor q=1,5. Design to Class DC2 is also made with the same rules as for actions like wind or gravity, but a behavior factor q equal to 2 or more is justified by detailing providing appropriate levels of over-strength coupled with some simple ductility provisions. Design provisions for structural systems not covered in the previous edition are incorporated: concrete flat slabs, buckling restrained braces or dissipative connections. Rules are improved in the sense of clarity and simplicity, but also greater accuracy. A thorough updating of the specific rules for timber buildings is made, based on a strong research push. Rules for masonry buildings, which were characterized by an important number of nationally determined parameters are now better harmonized. A section on aluminium structures is introduced. Finally, guidance is developed for infill and cladding panels.

Keywords: Eurocode 8; Revision; Materials

1. INTRODUCTION

Material dependent sections in Eurocode 8 Part 1 define design rules specific to each construction material: reinforced concrete, steel, timber, masonry, etc… The revision of those sections is under way. It started officially in July 2017 with the appointment of a Project Team composed of Katrin Beyer (EPFL), Humberto Varum (University of Porto), Raffaele Landolfo (University of Naples Federico II), Massimo Fragiacomo (University of L'Aquila), Dimitrios Lignos (EPFL Lausanne) and André Plumier (University of Liege), leader of the team.
The revision aims at several objectives: increasing clarity and ease of use, simplification of rules; matching critical comments made by National Standardisation Bodies; reducing the number of nationally determined parameters; and updating the document by considering the results of research developments since 2004, year of edition of the existing version of Eurocode 8.
Some aspects of the code will be new, in particular the definition of ductility classes, the availability of data for the analysis of structures by pushover analysis and a section on aluminium structures.
The revision of Eurocode 8 material dependent sections will be concluded in early 2020.
The explanations given here indicate trends of the revision process.

2. DUCTILITY CLASSES

Three ductility classes are defined, DC1, DC2 and DC3, with the intention of facilitating the designer's life in the context of European seismicity while keeping an equal level of reliability in all ductility classes.

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Class DC1 corresponds to a design made without considering Eurocode 8 material dependent sections. It is equivalent to DCL class of EN1998-1:2004, still with a behaviour factor q=1,5, but its applicability is extended to higher seismicity zones than the formerly "recommended" maximum design PGA = 0,1g. However, this allowance will suffer some restrictions which can bear on different parameters for different materials. The restriction can be on the seismicity level above which DC1 design is not recommended (PGA=0,2g for instance), on structural typologies (unreinforced masonry, irregular structures, degree of redundancy) or linked to the absence of quality control during construction. Nevertheless, the opening to DC1 design for most of Europe allows seismic design with the same rules for earthquakes as for other actions like wind or gravity, which means a significant step to ease design.

Design to Class DC2 has similarities to DC1 design. Seismic design is also made with the same rules as for actions like wind or gravity, but a behaviour factor q greater than 1,5 can be used in the analysis if the design respects specific detailing defined in a ready to use and easy form for each material. The analysis of the structure is elastic, but the behaviour factor q is raised to q=2 or more, depending on the material and the structural type. Design rules for global ductility of the structures are not of application so that DC2 design is basically like DC1 (or former DCL). The use of a q factor equal to 2 or more is justified by detailing providing appropriate levels of over-strength coupled with some simple local ductility provisions, like for instance more stirrups in critical zones of RC structures. These local ductility provisions may involve capacity design at the section level or within components of a connection in order to promote yielding in one dedicated component.

In Class DC3, criteria bear on both the promotion of local and global ductility. DC3 design is meant for structures with q factor ranging from 3 and to q=6,5 depending on structural types and on the intensity of measures taken for local and global ductility. Design Class DC3 in fact merges former DCM and DCH classes.

3. STRUCTURE OF EACH MATERIAL SECTION

In EN1998-1:2004, two different organisations could be found for material sections.

The first type of text organisation was used for the sections on steel, composite steel-concrete, timber and masonry. Rules are defined by structural types (Moment resisting frames, concentrically braced frames, etc…), so that in each structural type, one would find rules for DCM (Ductility Class Medium) and DCH (Ductility Class High).

In the second type of text organisation, which is the one used for reinforced concrete structures, rules are presented for all structural types in ductility class DCM and then for all structural types in ductility class DCM. This second organisation was the cause for many repetitions and many clauses in DCH redirecting the reader to clauses in DCM.

The revision will manage the text in such a way that, for each material, DC2 and DC3 rules are given by elements in each structural type.

Complete presentation and rules for the application of pushover analysis to design are now given in the revised Eurocode 8 material independent sections. For the global coherence of the revision, data necessary for the use of the pushover method will be presented also in the material dependent sections. The data are force F-deformation D relationships defining local non-linear behaviour in critical zones or elements of dissipative structures. They will be expressed with the definition of the chord rotation curves (or extension/shortening or shear/distortion) considered to define plastic zone dimensions necessary to establish plastic hinge yield and ultimate rotations (or panel yield and ultimate shear distortions, etc…). These data shall be provided for the "fully operational" OP and "significant damage" SD limit states envisaged in design and will have coherence with the limit state and formulation in Eurocode 8 Part 3 on assessment of existing structures, where the reference limit state considered is the Near Collapse or NC limit state.

4. REINFORCED CONCRETE BUILDINGS

Buildings with flat slabs are currently used in many European countries, but in EN 1998-1:2004 concrete buildings with flat slab frames cannot be used as primary seismic elements. They may be designed for Ductility Class Low (q=1,5). Alternatively, a higher ductility class may be considered if there is a primary structure of a different nature, in which case the slabs and the supporting columns may be considered as “secondary” seismic elements. However, research has shown that ductility can also be achieved in flat slabs systems, at the expense of special detailing (Bompa, 2017) (Varum, 2017). Design rules taking into account cyclic bending and punching will be introduced for this type of structural systems in the revision of Eurocode 8.

The section concerning precast concrete structures will be revised at the light of an important research work realised in Italy and Slovenia, published in (Negro et al., 2012), (Zoubek et al., 2015), (Colombo et al., 2016, a), (Colombo et al., 2016, b).

5. STEEL BUILDINGS

The revision of the section on steel buildings is principally based on an assessment of Eurocode 8 provisions made by ECCS, the European Convention for Constructional Steelworks (Landolfo et al., 2013).

The revision will bear on the following aspects.

For a correct application of capacity design, the actual yield strength of dissipative zones, which can be much larger than the nominal one, will be estimated on the basis of recent statistics; this will result in revised material overstrength factor γ_{ov}.

Local ductility of steel members in compression and bending is at present associated to the classes of sections specified in EN 1993-1-1: 2004. The classification of member ductility accounting for both cross-section slenderness and member slenderness will be introduced.

The possibility of using slender cross sections, typical of cold-formed members and of welded built-up sections, will be developed, along with a section on light gage structures made of cold formed sections, a type of constructions in rapid extension.

In Moment Resisting Frames (MRFs), the full plastic moment resistance of beams is developed in plastic hinge regions when full-strength beam to column connections are employed. Lateral-torsional buckling should be prevented by providing lateral restraint, but this fact was not explicit in EN1998-1:2004. It should also be checked that requirements for lateral restraint at plastic hinges in EN 1993-1-1 are applicable for inelastic cyclic loading. This point will be clarified (Alavi, 2017) (Giordano, 2017).

In Concentrically Braced Frames (CBFs), EN 1998-1:2004 relies on tension diagonals as reliable dissipative zones, while compression diagonals are considered to have a negligible contribution to the energy-dissipation capacity due to buckling. The reason for this assumption is that, due to buckling, compression diagonals would be rendered totally ineffective in resisting lateral loads at the ultimate limit state. However, at initial stages of seismic loading, both compression and tension diagonals are active so that the EN 1998-1:2004 code model is a reasonable approximation at the significant damage limit state only. The revision of Eurocode 8 will promote a tension-compression model in which both tension and compression braces are accounted for. Thereby the lower bound limit $\overline{\lambda} \geq 0{,}3$ for the brace normalized slenderness $\overline{\lambda}$ can be disregarded, while the upper bound $\overline{\lambda} \leq 2{,}0$ is retained. The brace normalized slenderness is computed assuming the buckling length equal to the whole length between connections of diagonals or part of diagonals. The required strengths of non-dissipative elements are evaluated by mean of plastic analysis considering the brace under tension attaining its maximum resistance and the most unfavorable condition between brace in compression attaining its buckling resistance or its post-buckling resistance. Concerning the distribution of plastic deformation over the building height, the limitation of the variation of overstrength over the building height currently required by EN 1998-1:2004 will be replaced by introducing moment-resisting joints in the braced bays and restraining the diagonals at roof storey in the elastic range. The columns of the braced bays are verified against combined bending and axial compression. The proposed revision eliminates the need to use different methods to analyse and design X-braced and V-braced CBFs (Costanzo, 2017) (Nip, 2013) (Faggiano, 2016) (Sahoo, 2017).

In EBFs (Eccentrically Braced Frames), more attention will be given to systems with vertical links (Nastri, 2015) and in general to feasable rules on overstrength of the links.

Going to more specific detailing, design rules will also be provided about:

- Diagonal braces made of double-angle or double-channel cross section shapes for braces; such braces are frequently encountered in European countries with low-to-moderate seismic intensities;
- MRF-EBF Dual Systems with Vertical Links;
- Connections of braces to beams and columns;
- Recent specific types of dissipative structural elements like BRBs (Buckling Restrained Braces) and dissipative connections (Vayas, 2017);
- Concentrically and eccentrically braced frame using such dissipative elements.

6. COMPOSITE STEEL CONCRETE BUILDINGS

A revision in the direction of simplification will be realised. In EN 1998-1:2004, the section on plastic resistance of dissipative zones envisages the case of duplication of non-ductile reinforcement by ductile ones in the slab of steel beams plus slab, which requires consideration of an upper and a lower bound of plastic resistance for capacity design issues. This will be removed and reinforcement in the slab in the beam hogging moment zone will be prescribed as ductile.

Similarly, the definition of effective width of slab specific to Eurocode 8 for the elastic analysis of MRFs will be removed. This is justified by sensitivity studies on the subject performed within SC8 WG2, which have demonstrated that Eurocode 4 data conclude practically to the same seismic action effects in beams and columns of MRFs as the presumably more accurate design data of EN 1998-1:2004.

The section on connections will be improved by consideration of partial strength connection, if ductility of such connections is dealt with in Eurocodes 3 and 4 in the course of the revision of these documents. Some existing sections could be removed, because they correspond to structural typologies which are not used in Europe; it is for instance the case of composite steel-concrete walls with a steel plate web.

7. TIMBER STRUCTURES

Due to a lack of research on the subject at the time, the section on timber buildings of EN1998-1:2004 was rather poor. For this reason, important research efforts have been made since then (Brandner, 2016) (Sartori, 2013) (NBC 2010) (Sustersic, 2015) (Bedon, 2015) (Gavric, 2015) (Wanninger, 2014) (Sancin, 2014) (Rinaldin, 2013) (Fragiacomo, 2012a) (Fragiacomo, 2012b).

The revision will provide design rules which are specific to an enlarged number of typical timber building typologies with wood-based materials. The envisaged typologies are cross laminated timber buildings, light frames, log house buildings, moment resisting frames, post and beam buildings and vertical cantilever systems.

A set of rules will be provided for each typology: general rules, design rules at building level, design rules for connections. Detailing rules are also defined for components which can exist in various building typologies, like light-frame floors and roof diaphragms.

8. MASONRY BUILDINGS

Masonry buildings represent a very large proportion of low rise construction in Europe, but the provisions of EN 1998-1:2004 did not achieve a real harmonization of design provisions. This is evident from the very large number of Nationally Determined Parameters (NDPs) provided for masonry buildings. This is obvious if one considers the values of the behaviour factor q and the values ascribed to masonry bricks and blocks dimensions $t_{ef,min}$ or dimensional proportions (h_{ef}/t_{ef})max and (l/h)min. It is likely that the values given in National Annexes to EN 1998-1:2004 and in Eurocode 6 on masonry (EN1996-1:2004) represented in fact the national practice for dimensions additionally to well-founded structural stability considerations. Unfortunately, it seems that the present revision of Eurocode 6 will not eliminate this influence of national practice. It is envisaged in the Eurocode 8 revision process to give requirements without NDP's, stating the minimum values for $t_{ef,min}$ and $(l/h)_{min}$ and the maximum value for $(h_{ef}/t_{ef})_{max}$.

Since 2004, research efforts have been made on several topics:

- the influence of load history on the force-displacement response of in-plane loaded unreinforced masonry walls (Wilding, 2017);
- the estimation of stiffness, strength and drift capacity of stone masonry walls based on 123 quasi-static cyclic tests reported in the literature (Vanin, 2017);
- the development of analytical models for the out-of-plane response of vertically spanning unreinforced masonry walls (Godio, 2017);
- the modeling of diagonal compression test for historical stone masonry structure (Zhang, 2017).

The results obtained will contribute to the improvement of rules and requirements in EN1998-1.
The present rules for "simple buildings" which are mostly presented as NDP's, are disputable and inconsistent with post-earthquake field surveys. They will be revised. More generally, the project aims at the extension of the overstrength ratio concept to masonry, as foreseen for other materials. Design provisions for the prevention of out-of-plane collapse of masonry walls will be introduced.

9. INFILLS AND CLADDINGS

Framed buildings with masonry infills or with claddings are very common. Section 5 of EN 1998-1:2004 provided design provisions to account in a rather blind way for the presence of infills mainly aimed at avoiding detrimental effects caused by infills to the main structure. The intention in the revision of Eurocode 8 is to account for the beneficial effects, namely overstrength and energy dissipation, as well as their detrimental effects by definition of structural checks rather than by means of some modification of the behaviour factor q of structures. However, the subject is difficult, because exploiting masonry infills in the design of new buildings may entail higher design complexity and stricter quality assurance requirements (Colombo, 2016a) (Colombo, 2016b) (Varum 2015) (Varum, 2017). Additionally, recent earthquakes have shown that, in many recent buildings where the structure behaved properly, heavy damage in brick claddings and concrete cladding panels occurred. The design provisions for infilled frames will be extended to cover cladding elements and panels, together with other types of enclosures, with and without openings. It includes the evaluation of strength, stiffness and deformation capacity of such panels and requirements for their connections to the main structure.

10. ALUMINIUM STRUCTURES

To the contrary of all other structural materials covered by the Eurocodes, EN 1998-1:2004 did not include information regarding Aluminium structures. These structures cannot rely much on ductility and the design rules will essentially be about elastic design and overstrength design of connections.

11. CONCLUSIONS

Revision of Eurocode 8 is under way. The summary of actions necessary to finalise the process has been presented above. It shows the complexity of the revision process which is required to achieve simultaneously objectives which could lead each to so different final outputs.
Indeed, achieving an increase in clarity, in ease of use and in simplification of rules while at the same time incorporating the results of research developments in a complex field and providing data for pushover analysis is a challenge.
The project team in charge of the revision of Eurocode 8 material dependent sections is conscious of the difficulty of the task and will devote the best of its effort to bring this action to success.

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