Update of CIDECT Design Guide No. 9 (Design Guide for Structural Hollow Section Column Connections)

The CIDECT Design Guide No. 9 was drafted referring to the 1992 version of Eurocode 3 and the 1994 version of Eurocode 8. These two Eurocodes were revised both in 2003. The CIDECT Technical Commission at this point attempts to update the DG 9 based on these new Eurocodes. Additional remarks are made on Section 2.1. Sections 7.1 and 7.4 are fully redrafted, because the revisions of Eurocode 8 were extensive. Chapter 7 of the DG 9 explains the fundamental concept of the earthquake resistant design. The descriptions generally follow the Eurocode 8 format. However, detailed design criteria are mainly based on experimental and theoretical investigations conducted in Japan and US.

2.1 Plain columns

The 2003 version of Eurocode 3 (CEN 2003) allows the use of the higher buckling curve “a_0”, instead of “a”, for hot finished hollow sections of steel grade S460. This is based on the fact that, in case of high strength steel, the imperfections play a less detrimental role on the buckling behaviour. Since Section 2.1 of Design Guide 9 is referring to the 1992 version of Eurocode 3, this section should add the buckling curve “a_0” to update its content. Accordingly, figure 2.1 should be replaced by the following figure.

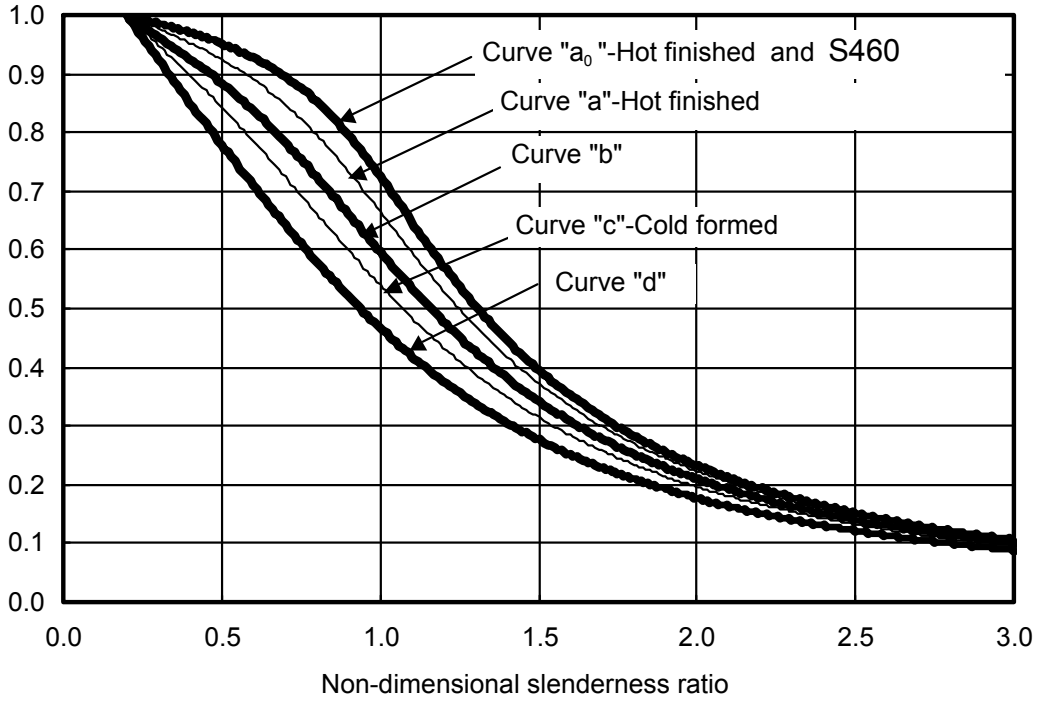

Figure 2.1 – Eurocode 3 column buckling curves

7.1 Low dissipative and dissipative structural behaviours (The previous title was Dissipative and non-dissipative structural behaviours)

Eurocode 8 (CEN 2003a) recommends the following two design concepts:

Concept a) Low dissipative structural behaviour

Concept b) Dissipative structural behaviour

In concept a) the action effects may be calculated on the basis of an elastic global analysis without taking into account a significant non-linear material behaviour. In concept b) the capability of parts of the structure (dissipative zone) to resist earthquake actions through inelastic behaviour is taken into account. The design concepts, structural ductility classes and upper limit reference values of the behaviour factors recommended by Eurocode 8 are summarized in the table below.

Design concept	Structural ducitiliy classes	Range of the reference values of the behaviour factor q
Concept a) Low dissipative strucural behaviour	DCL(Low)	≤1.5 - 2
Concept b) Dissipative structural behaviour	DCM(Medium)	≤4 also limited by the values of Table 6.2
	DCH(High)	only limited by the values of Table 6.2

Note: Table 6.2 in Eurocode 8 shows the values of q for different combinations of the structural type and ductility class. See also figure 7.2 of this guide.

As is evident in the above table, Eurocode 8 classifies building structures into three ductility classes. The structure belonging to the low ductility class (DCL) is recommended only for the low seismicity zone. This zone is regarded as areas in which a design ground acceleration is not greater than 0.1g. The resistance of the members and connections should be evaluated in accordance with Eurocode 3 (CEN 2003) without any additional requirements.

The 1994 version of Eurocode 8 included a design concept of non-dissipative structural behaviour. This concept is applicable to very low seismicity areas in which a design ground acceleration is less than 0.05g. Such areas were excluded from the scope of the 2003 version of Eurocode 8.

Structures designed to concept b) should belong to ductility classes DCM or DCH. These classes correspond to the increased ability to dissipate energy in plastic mechanisms and hysteretic behaviour. Depending on the ductility classes the behaviour factor q is linked to the ductility demands on members and connections, hence to the class of steel sections, detailing rules, rotational capacity and so forth.

The 1994 version of Eurocode 8 specified only a ductility class DCH for structures with dissipative structural behaviour.

To illustrate the ductility demands stipulated in Eurocode 8, let us take an example of the structure designed to dissipate energy in the beams. The beam-to-column connection design should be such that the inelastic rotation capacity of the plastic hinge θ_{pl} is not less than 0.035

radian for structures of ductility class DCH and 0.025 radian for structures of ductility class DCM. These values are compared with the minimum inter-storey drift angle capacities specified in the FEMA design criteria (2000) (See sections 7.6 and 8.1 of this guide. It is assumed that the elastic drift of typical moment frames is usually in the range of 0.01 radian.). The ductility demand on the class DCH structure is roughly comparable to that on the special moment frame according to the FEMA criteria. The ductility demand on the class DCM structure is significantly greater than that on the ordinary moment frame according to the FEMA criteria (Now called the intermediate moment frame in the new AISC Seismic Provisions (2005)).

The past investigations on seismic design of steel building structures have been concentrated on the DCH structures, because the DCM structure was introduced into Eurocode 8 only recently. Further investigations are expected to develop those new designs conforming to the DCM structure, which should be verified to satisfy the ductility demands by cyclic loading tests and also be less costly than the DCH structures. The DCM structures will not be discussed any more in this design guide.

7.4 Joints in Dissipative Zones

Eurocode 8 defines the following criteria for seismic design.

1. Structural parts of dissipative zones should have adequate ductility and resistance until the structure sustains sufficient deformation without failing due to overall instability.
2. Non-dissipative parts of dissipative structures and the connections of the dissipative parts to the rest of the structure should have sufficient overstrength to allow cyclic yielding or local buckling of the dissipative parts.

To ensure the sufficient overstrength of connections Eurocode 8 specifies the following detailing rules.

1. The actual maximum yield strength $f_{y,max}$ of the steel of dissipative zones satisfies the following expression, $f_{y,max} \leq 1.1\gamma_{ov}f_y$

   where

   γ_{ov} The overstrength factor. The recommended value is equal to 1.25. When actual yield strength $f_{y,act}$ of the steel of each dissipative zone is determined from measurements, the overstrength factor is computed for each dissipative zone as $\gamma_{ov} = f_{y,act}/f_y$

   f_y The nominal yield strength of the steel of dissipative zones

2. Connections of dissipative parts made by means of complete joint penetration (CJP) groove welds (full-penetration butt welds) are considered to satisfy the overstrength criterion.
3. For fillet welded or bolted connections the following requirements should be met. These are also applicable to connections at the ends of bracings.

   a) (resistance of the connection according to Part 1-8 of Eurocode 3) ≥ $1.1\gamma_{ov}$ x (plastic resistance of the connected part according to Part 1-1 of Eurocode 3)

   b) For bolted shear connections bearing failure should precede bolt shear failure.

4. During construction it should be ensured that the yield stress of actual steel used does not exceed $f_{y,max}$ noted on drawings for dissipative zones by more than 10 per cent.

The material overstrength factor γ_{ov} mentioned above under the paragraph 1 is a provision newly introduced into the 2003 version of Eurocode 8. The value of γ_{ov} gives a substantial influence on the overstrength factor for joints and connections. For example, the overstrength factor for fillet-welded or bolted connections is equal to $1.1\gamma_{ov}$ according to the paragraph 3a) of

the above rules. This value turns out to be very stringent as compared with the overstrength factor used in common design practice, if a recommended value of γ_{ov} =1.25 is adopted. A fixed value of the overstrength factor of 1.2 specified in the 1994 version of Eurocode 8 is simpler and more commonly used in practice.

It has been shown after the Northridge and Kobe Earthquakes that the detailing rule on butt-welded joints mentioned above under the paragraph 2 is not always correct. Further detailing rules to fulfil the sufficient overstrength criterion are discussed in Section 7.6.

Eurocode 8 allows connections that are designed to contribute significantly to the energy dissipation capability inherent in the chosen q-factor. The overstrength conditions need not apply for these connections. But these connections have to use experimentally verified special devices and, therefore, are not suitable to ordinary design office work. The only exception to these difficult connections is the column web panel, which is described in Section 7.7.

References

AISC, 2005: Seismic provisions for structural steel buildings, American Institute of Steel Construction, Chicago, Ill., USA.

CEN, 2003: Eurocode 3: Design of steel structures: Part 1.1 General rules and rules for buildings, EN 1993-1-1, Part 1.8 Design of joints, EN 1993-1-8, Comité Européen de Normalisation.

CEN, 2003a: Eurocode 8-Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings, prEN 1998-1, Comité Européen de Normalisation, Brussels, Belgium.