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WORKING COMMISSION W18 - TIMBER STRUCTURES

A PROPOSAL FOR REVISION OF THE CURRENT TIMBER PART (SECTION 8) OF EUROCODE 8 PART 1

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Abstract

Section 8 of Eurocode 8 is very old (the first version was published in 1998) and quite short (6 pages in total). With regard to new building systems developed in Europe for the construction of multi-storey buildings, such as Cross Laminated Timber systems, there is a lack of design rules for the seismic design, and the few ones which may be applied are very conservative. Meanwhile important research projects have been completed, and the corresponding results can be used to propose new values for some important quantities for seismic design such as the behaviour factor. New detailing rules can also be suggested so as to ensure the energy dissipation corresponding to the overall target ductility is achieved. In this paper a first proposal for the revision of Section 8 of Eurocode 8 is presented. This proposal contains: (i) additional provisions for Capacity Based Design, including overstrength factors of ductile connections which are needed to avoid anticipated brittle failure mechanisms; (ii) more detailed description of the structural systems currently listed in the Eurocode 8 including other systems such as Log House buildings not currently considered; (iii) detailed verification of the current values of the behaviour factor according to the connection layout of each structural system; (iv) interstorey drift limits for performance-based design; (v) some provisions for the design of buildings with different lateral load resisting systems; and (vi) additional rules for shear walls and horizontal diaphragms.

1 Introduction

Eurocode 8 [1] deals with the design and construction of buildings and civil engineering works in seismic regions. Section 8 is the part related to the specific rules for timber buildings, which are considered as additional to those given in Eurocode 5 [2].

According to the general performance requirements and compliance criteria, all the structures should be designed to withstand the foreseen earthquake for that area. More specifically, in accordance with the so-called “no-collapse requirement”, the structure must be designed for the reference seismic action associated with a typical probability of exceedance of 10% in 50 years, corresponding to a reference return period of 475 years, so as it does not loose its structural integrity and it maintains a residual load carrying capacity after the earthquake. At the same time, the structure should also fulfil the “damage limitation requirements”, according to which the structure should survive an earthquake having a larger probability of exceedance (typically of 10% in 10 years, corresponding to a return period of 95 years) without the occurrence of damage and the associated limitations of use, the costs of which would be disproportionately high in comparison with the costs of the structure itself.

According to the performance-based design philosophy, the Limit States associated to the aforementioned conditions are the Ultimate Limit State and the Damage Limit State. In order to satisfy the Ultimate Limit State, structural systems shall be designed with an appropriate mixture of resistance and energy dissipation, which can be ensured only if ductile behaviour is achieved, and Capacity Based Design philosophy [3] is followed. In the definition given by Eurocode 8 [1], *"Capacity Based Design is the design method in which some elements of the structural system* (i.e. mechanical joints for the case of timber structures) *are chosen and suitably designed and detailed for energy dissipation under severe deformations while all other structural elements are provided with sufficient strength* (i.e. timber elements for the case of timber structures) *so that the chosen means of energy dissipation can be maintained"*.

As it is well explained in 2.2.2 2(P) of Eurocode 8 [1], "*The resistance and energy-dissipation capacity to be assigned to the structure are related to the extent to which its non-linear response is to be exploited. In operational terms such balance between resistance and energy-dissipation capacity is characterised by the values of the behaviour factor q and the associated ductility classification, which are given in the relevant Parts of EN 1998*". The behaviour factor q is defined as the "*factor used for design purposes to reduce the seismic actions in a linear static or modal analysis in order to account for the non-linear response of a structure, associated with the material, the structural system and the design procedures"* [1].

Therefore in order to ensure the achievement of the correct energy dissipation capacity assumed in the design, it should be verified that single structural elements and the structure as a whole are consistent with the chosen behaviour factor q. This condition may be regarded as fulfilled by applying the specific design rules and hierarchy of resistance criteria related to the various structural components for the different construction systems.

2.1 The current version of Section 8 of Eurocode 8

The current version of Section 8 of Eurocode 8 is divided into seven different parts, listed in the following:

General. Contains general information about this part of Eurocode 8, the specific terms related to timber structures and the design concepts.

Materials and properties of dissipative zones. In this part properties for materials and dissipative zones in seismic design are defined, particularly when using the concept of dissipative structural behaviour.

Ductility classes and behaviour factors. This is the most important part of the section, where the structural types permitted in seismic areas are listed and the relevant ductility class and behaviour factors defined in Table 8.1.

Structural analysis. In this section general information regarding the slip of joints, the Young modulus to be used in the analysis, and the detailing rules in order to consider horizontal diaphragms as rigid are given.

Detailing rules. Detailing rules for connections and horizontal diaphragms are given. Provisions for both carpentry and mechanical joints are also provided. However for horizontal diaphragms only light-frame floors are considered.

Table 8.1: Design concept, structural types and upper limit values of the behaviour factors for the three ductility classes.

Design concept and ductility class	**q**	**Examples of structures**
Low capacity to dissipate energy - DCL	1.5	Cantilevers; Beams; Arches with two or three pinned joints; Trusses joined with connectors.
Medium capacity to dissipate energy - DCM	2.0	Glued wall panels with glued diaphragms, connected with nails and bolts; Trusses with doweled and bolted joints; Mixed structures consisting of timber framing (resisting the horizontal forces) and non-load bearing infill.
	2.5	Hyperstatic portal frames with doweled and bolted joints (see **8.1.3(3)**P).
High capacity to dissipate energy - DCH	3.0	Nailed wall panels with glued diaphragms, connected with nails and bolts; Trusses with nailed joints.
	4.0	Hyperstatic portal frames with doweled and bolted joints (see **8.1.3(3)**P).
	5.0	Nailed wall panels with nailed diaphragms, connected with nails and bolts.

Safety verifications. In this part provisions for the k_{mod} and γ_M values to be used in the safety verifications are given for structures designed in accordance respectively with the concept of low dissipative and dissipative structural behaviour. In addition provisions are also given for the structural elements to which overstrength requirement applies in order to ensure the development of cyclic yielding in the dissipative zones, even though no value of the overstrength factor is given. Also detailing rules for carpentry joints to avoid brittle failure are given.

Control of design and construction. This latter section gives provisions on how the structural elements should be clearly detailed and identified in the design drawings and how they should be checked during the construction process.

2.2 What can be improved in Section 8 of Eurocode 8

The heading of Section 8 of Eurocode 8 is "Specific rules for timber buildings", which should imply a clear definition and identification of the different structural systems for timber buildings. However, particularly for widely used structural systems such as cross-laminated (Xlam) and log house systems, it is sometimes hard to find the proper description in Table 8.1. This aspect is not irrelevant if we consider the importance of the correct choice of the ductility class and the relevant behaviour factor q according to the Capacity Based Design, which can be satisfied only by applying the specific design rules and hierarchy of resistance criteria provided for the specific construction system analysed. Moreover, for each structural system, it should be clearly stated the capacity design criteria and the specific design rules, as well as the overstrength factors.

Analysing the structural types listed in Table 8.1, it can be noticed that some of them are structural components of buildings, such as large span glulam roofs or timber buildings roofs (e.g. trusses with nailed, doweled or bolted joints); some other refer to structural systems used for old buildings (e.g. mixed structures consisting of timber framing and non-load bearing infill) but no longer used for new buildings; and only few of them clearly refer to residential buildings, which are the nowadays most commonly used type of construction.

Furthermore, some sentences should be corrected in order to avoid confusion or misunderstanding. For example in Table 8.1 the structural system "*Hyperstatic portal frames with doweled and bolted joints*" is mentioned twice, as a High Ductility Class with a q factor of 4.0 and as a Medium Ductility Class with a q factor of 2.5, depending on whether the specific requirements regarding the ductility capacity of connections given in 8.3.3(P) are or not satisfied, as specified in the subsequent Table 8.2. However, the structural system "*Nailed wall panels with nailed diaphragms*" is mentioned only once in Table 8.1 with the higher behaviour factor q, although the same ductility rule applies also for this system, thus generating possible confusion.

Also the ductility provisions given for the dissipative zones which limit the diameter of dowel type fasteners to 12 mm and the thickness of connected member to 8 times the fastener diameter in order to attain a ductile failure mechanism [4], appear to the Authors a limitation which could be superseded by requiring a failure mode characterized by the formation of one or two plastic hinges in the mechanical fastener, which can be easily checked using the Johanssen equations prescribed by the Eurocode 5 Part 1-1.

Finally some values of the behaviour factor q are considered by the Authors too high, especially in the lack of detailing rules and of Capacity Based Design criteria, such as the value of 4.0 for the behaviour factor q for "*Hyperstatic portal frames with doweled and bolted joints*".

3 A proposal for a new Section 8 of Eurocode 8

The proposal consists of the following changes to the current version of Eurocode 8:

- Addition of a new section before the "Ductility classes and behaviour factors" entitled "Structural systems and capacity design rules" including detailed description of the main structural systems also using graphical sketches and definition of the overstrength factors for different types of connections.
- Correction of Table 8.1 and of some sentences in the "Ductility classes and behaviour factors" section.
- Some changes in the Detailing rules section including rules on structural systems with different lateral load resisting systems.
- Some changes in the Safety verification section including overstrength factors for Capacity Based Design and inter-storey drift limits for Performance based Design.

3.1 Structural systems for timber buildings and Capacity Based Design rules (New)

Timber buildings shall be classified into one of the following structural types according to their construction method:

- Cross laminated timber buildings
- Light-frame buildings
- Log House buildings

Other constructive systems used for the construction of timber buildings are:

- Mixed structures consisting of timber framing (resisting the horizontal forces) and non-load bearing infill

- Moment resisting frames
- Vertical cantilevers made of solid timber panels

Post and beam timber systems with vertical bracings made of timber or different materials (e.g. steel and reinforced concrete) can also be used, provided that the appropriate q factor associated with the reference type of bracing is assumed.

Mixed combinations of the above listed structural systems should be avoided in the same direction, however they are allowed in perpendicular directions. If different systems are used in the same direction, e.g. Light-frame buildings with XLam walls, non-linear static (push-over) or dynamic (time-history) analyses must be carried out to design the building.

Other structural systems used in seismic areas mostly for roof systems are:

- Arches with two or three pinned joints
- Beams and horizontal cantilevers
- Trusses with nailed joints
- Trusses with screwed, doweled and bolted joints

Different structural systems not listed above may be used provided that the properties of dissipative zones should be determined by tests either on single joints, on whole structures or on parts thereof in accordance with EN 12512 [5].

Cross laminated timber buildings

General Description

Cross laminated (Xlam) timber buildings are structures in which walls and floors are composed of cross laminated timber panels, i.e. panels made of an odd number (greater than 3) of layers of timber boards disposed alternatively at right angles and glued together.

The connection of the walls to the foundation should be made by means of mechanical fasteners (hold-down anchors, steel brackets, anchoring bolts, nails and screws) and should adequately restrain the wall against uplift and sliding. Uplift connections should be placed at wall ends and at opening ends, while sliding connections should be distributed uniformly along the wall length (Figure 1).

Walls shall have heights equal to the inter-storey height and may be made of a unique element up to the maximum transportable length or may be composed of more than one panel, of widths not greater than 2.6m, connected together by means of vertical joints made with mechanical fasteners (screws or nails). Perpendicular walls are connected by means of joints made with mechanical fasteners (usually screws).

Horizontal diaphragms are made of Xlam timber panels connected together by means of horizontal joints made with mechanical fasteners (screws or nails). The floor panels bear on the wall panels and are connected with mechanical fasteners (usually screws).

Other types of horizontal diaphragms may be used, provided that their in-plane rigidity is assured by means of sheathing material such as wood-based panels. Timber-concrete composite floors may be used provided that they are adequately connected to the lower and upper walls by means of mechanical fasteners. The concrete topping, in particular, shall be connected to the vertical panels to ensure the in-plane shear due to the diaphragm action is transferred to the walls and down to the foundations.

The upper walls will bear on the floor panels, and will be connected to the lower walls using mechanical fasteners similar to those used for the wall-foundation connection.

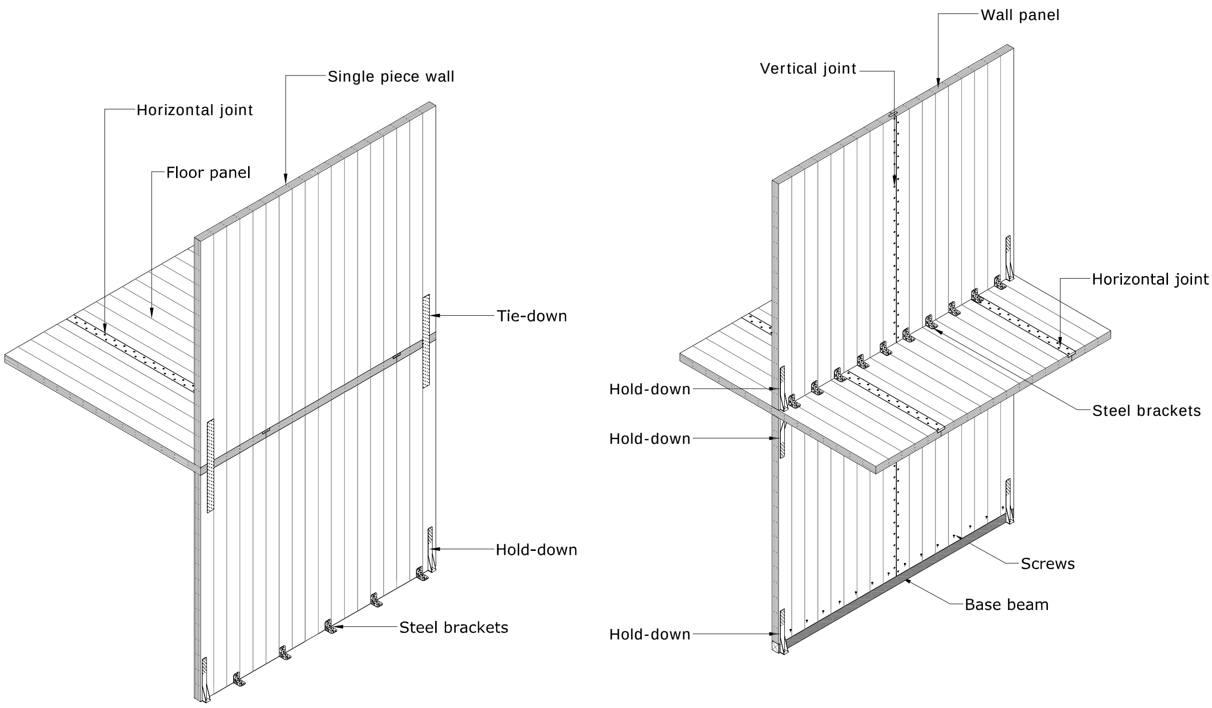

Figure 1: Walls and floors in Cross Laminated buildings

Capacity Design rules

Xlam timber buildings shall act at the greater possible extent as box-type structures. To achieve this, it is important to ensure that local failures which may compromise the box-type behaviour will not occur.

The connections devoted to the dissipative behaviour in a Xlam building are:

* vertical connection between wall panels in case of walls composed of more than one element;
* shear connection between upper and lower walls, and between walls and foundation;
* anchoring connections against uplift placed at wall ends and at wall openings.

In order to ensure the development of cyclic yielding in the dissipative zones, all other structural members and connections shall be designed with sufficient overstrength so as to avoid anticipated brittle failure. This overstrength requirement applies especially to (Fig.2):

* connections between adjacent floor panels in order to limit at the greater possible extent the relative slip and to assure a rigid in-plane behaviour;
* connection between floors and walls underneath thus assuring that at each storey there is a rigid floor to which the walls are rigidly connected;
* connection between perpendicular walls, particularly at the building corners, so that the stability of the walls itself and of the structural box is always assured;
* wall panels under in-plane vertical action due to the earthquake and floor panels under diaphragm action due to the earthquake.

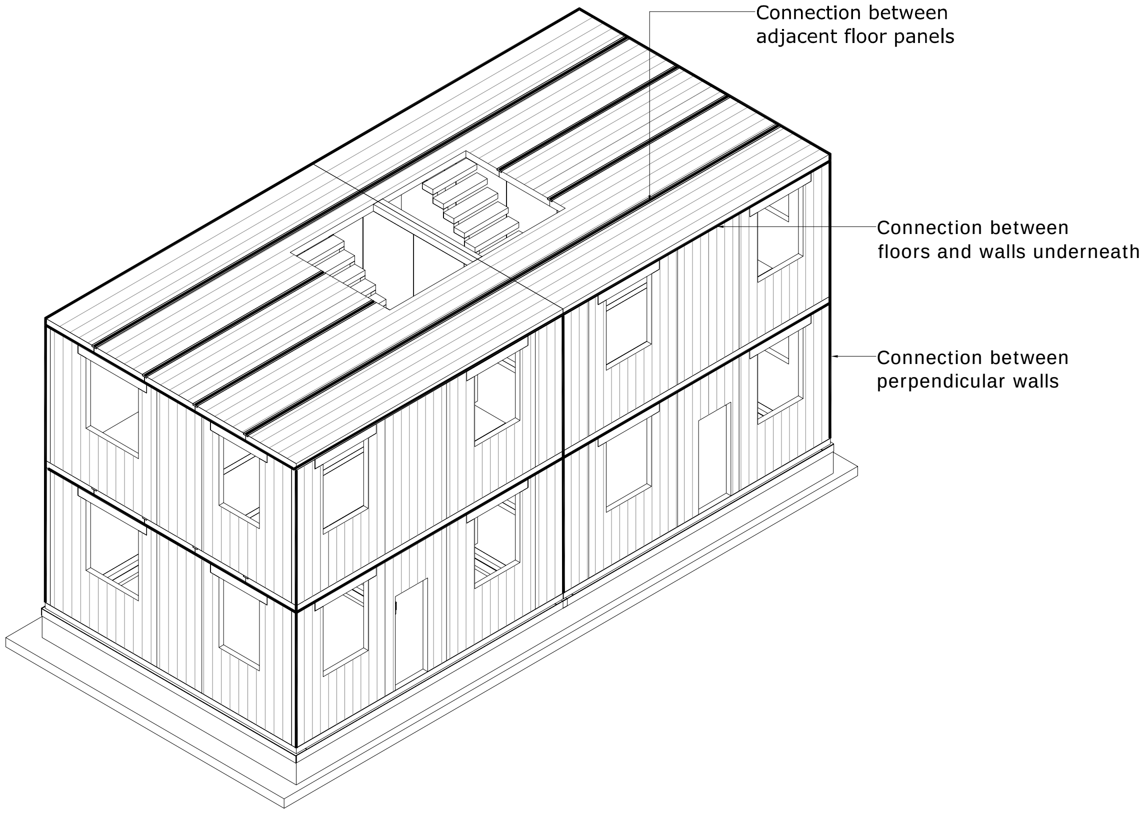

Figure 2: Connection to be designed with overstrength criteria in order to fulfil the capacity design criteria in Cross Laminated buildings [6].

The seismic resistance of shear walls should be higher at lower storeys and should decrease at higher storeys proportionally to the decrease of the storey seismic shear, thus leading to the simultaneous plasticization of the ductile connections in order to maximize the energy dissipation of the whole building.

Detailing rules

Nails other than smooth nails, as defined in EN 14592 [7], or screws should be used. Each single connection should be accurately detailed in order to avoid brittle failures. Special care should be used when designing the dissipative connections to ensure the attainment of a ductile failure mechanism characterized by the formation of one or two plastic hinges in the mechanical fastener [8]. A brittle failure mechanism in the weaker section of the steel plate should always be avoided in connections with steel brackets or hold-downs anchors connected to the wall panels by means of nails or screws.

Light-frame buildings

General Description

Light-frame buildings are structures in which walls, floors and roofs are made of timber frames to which a wood-based sheathing material (plywood or OSB) is connected by means of nails (Figure 3).

Shear walls are composed of a top and bottom plate and equally spaced vertical studs which the sheathing material is connected to on one or both sides.

Horizontal diaphragms are composed of equally spaced beams or joists and timber bridging in between, usually spaced at the same distance of wall studs, on top of which a wood-based sheathing material (plywood or OSB) is connected by means of nails. At each floor a perimeter edge beam should be provided to resist the tension forces which arise from the diaphragm action when the floor is loaded by horizontal forces acting in his plane.

The connection of the walls to the foundation should be made by means of mechanical fasteners (steel brackets, anchor bolts, nails and screws) and should adequately restrain the wall against overturning and sliding. Overturning connections should be placed at wall ends and at opening ends, while sliding connections should be distributed uniformly along the wall length.

Walls have heights equal to the inter-storey height. Perpendicular walls are connected by joining together two vertical studs with mechanical fasteners (usually nails or screws).

Other types of horizontal diaphragms may be used, such as cross laminated timber floors, provided that their in-plane rigidity is assured. Timber-concrete composite floors may be used provided that they are adequately connected to the lower and upper walls by means of mechanical fasteners. The concrete topping, in particular, shall be connected to the vertical panels to ensure the in-plane shear due to the diaphragm action is transferred to the walls and down to the foundations.

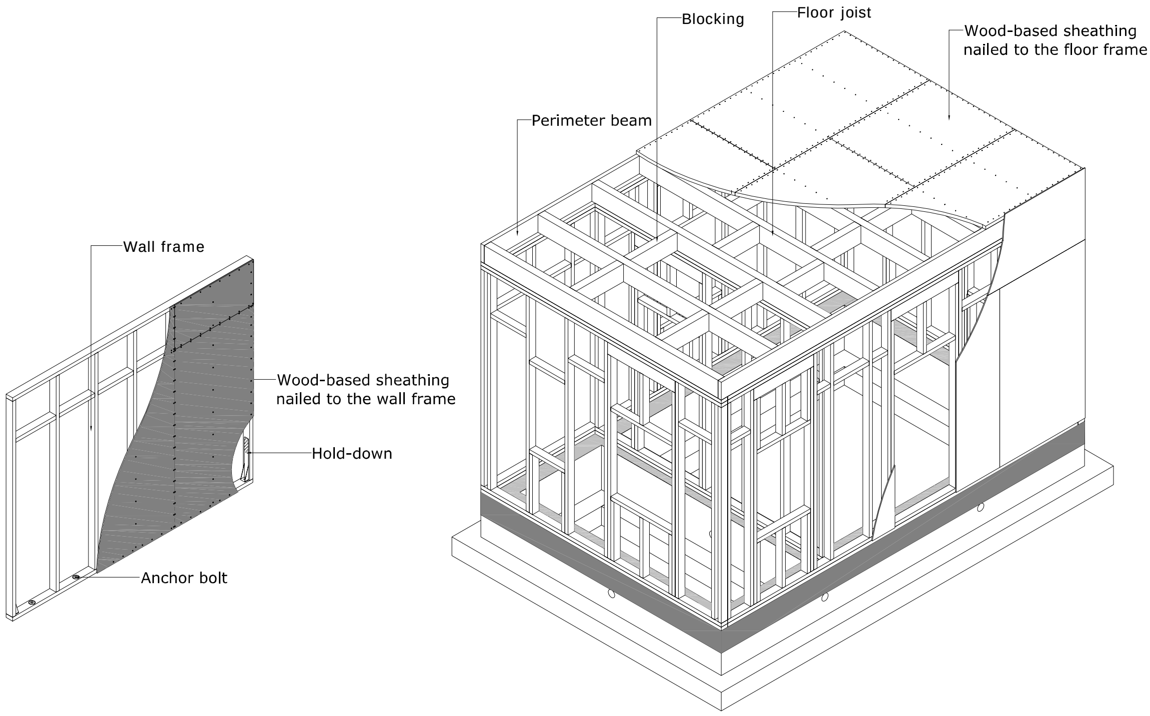

Figure 3: Walls and floors in light-frame buildings

Capacity Design rules

Light-frame buildings shall act at the greater possible extent as box-type structures. To achieve this it is important to ensure that local failures which may compromise the box-type behaviour will not occur.

The connections devoted to the dissipative behaviour in a light-frame building are nailed connection between sheathing material and timber frame in shear walls.

In order to ensure the development of cyclic yielding in the dissipative zones, all other structural members and connections shall be designed with sufficient overstrength so as to avoid anticipated brittle failure. This overstrength requirement applies especially to:

* nailed connections between sheathing and timber joists/beams at each floor;
* shear connections between upper and lower walls, and between walls and foundation;
* connections against uplift placed at wall ends and at wall openings;
* connection between floors and underneath walls thus assuring that at each storey there is a rigid floor to which the walls are rigidly connected;
* connection between perpendicular walls, particularly at the building corners, so that the stability of the walls itself and of the structural box is always assured;
* sheathing panels under in-plane shear induced by seismic actions;
* timber framing members (studs, plates, and joists) under axial forces induced by seismic actions.

The seismic resistance of shear walls should be higher at lower storeys and should decrease at higher storeys proportionally to the decrease of the storey seismic shear, thus leading to the simultaneous plasticization of the ductile connections in order to maximize the energy dissipation of the whole building.

Detailing rules

(omitted as this part will remained unchanged from the current version of EC8)

Log House buildings

General Description

Log House buildings are structures in which walls are made by the superposition of rectangular or round solid or glulam timber elements, prefabricated with upper and lower grooves in order to ease the overlapping and improve the stability of the wall, and connected together by means of steel tie-rods or screws (Figure 4).

The connection between perpendicular walls is made by means of carpentry joints obtained by notching the logs of the two walls or by means of screws.

Horizontal diaphragms are composed of equally spaced beams or joists and timber bridging in between, usually spaced at the same distance of wall studs, on top of which a wood-based sheathing made of plywood or OSB is connected with nails. At each floor a perimeter edge beam should be provided to resist the tension forces which arise from the diaphragm action when the floor is loaded by horizontal forces acting in his plane.

Other types of horizontal diaphragms may be used, such as cross laminated timber floors, provided that their in-plane rigidity is assured. Timber-concrete composite floors may be used provided that they are adequately connected to the lower and upper walls by means of mechanical fasteners. The concrete topping, in particular, shall be connected to the vertical panels to ensure the in-plane shear due to the diaphragm action is transferred to the walls and down to the foundations.

The connection of the walls to the foundation should be made by means of mechanical fasteners (tie rods, anchor bolts, nails and screws) and should adequately restrain the wall against overturning and sliding. Overturning connections should be placed at wall ends and at opening ends, while sliding connections should be distributed uniformly along the wall length.

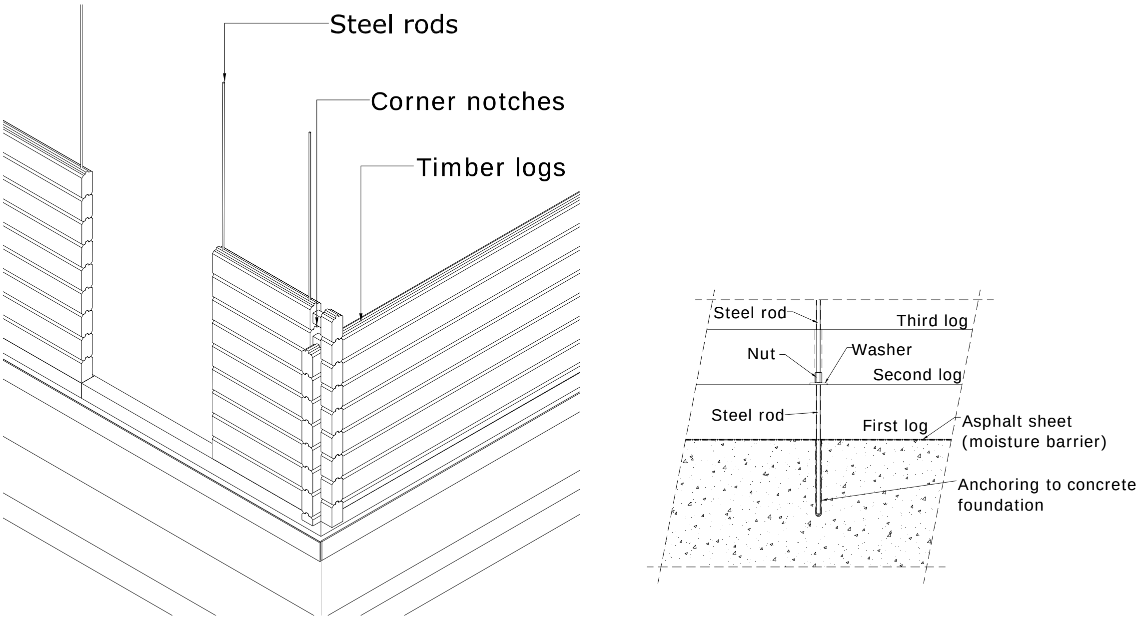

Figure 4: Perpendicular walls (left) and anchorage to foundation (right) details in Log House buildings

Capacity Design rules

Log house buildings shall act at the greater possible extent as box-type structures. To achieve this it is important to ensure that local failures which may compromise the box-type behaviour will not occur.

In order to ensure the development of the energy dissipation in the dissipative zones, all the connections to the foundation or between any massive sub-element should be designed with sufficient overstrength. To this regard also carpentry notching joints between perpendicular walls should be designed with sufficient overstrength.

The energy dissipation will be obtained due to friction between the logs.

Detailing rules

Carpentry joints between perpendicular logs which may fail due to deformations caused by load reversals, shall be designed in such a way that they are prevented from separating and remain in their original position.

Special care should be given to the design of wall openings in order to take into account shrinkage deformation due to moisture variations.

3.2 Ductility classes and behaviour factors (substituting the existing section)

Based on the previous capacity design criteria and design rules, the structural systems allowed in seismic areas are listed in Table 8.1, and the relevant ductility class and upper limit of the behaviour factors are given.

((2)and(3)P omitted as this part will remained unchanged from the current version of EC8)

(4) (*New*) The provisions of (3)P of this subclause and of 8.2(2) a) and 8.2(5) b) may be regarded as satisfied in the dissipative zones of all structural types except moment-resisting frames with high ductility joints and log house buildings if a ductile failure mechanism characterized by the formation of one or two plastic hinges in the mechanical fasteners is

attained [8]. Referring to 8.2.2 of EN 1995-1-1 for timber-to-timber and panel-to-timber connections, failure modes *a*, *b* and *c* for fasteners in single shear, and *g* and *h* for fasteners in double shear should be avoided. Referring to 8.2.3 of EN 1995-1-1 for steel-to-timber connections, failure modes *a*, *c* for fasteners in single shear, and *f*, *j* and *l* for fasteners in double shear should be avoided.

Table 8.1(New): Design concept, structural types and upper limit values of the behaviour factors for the three ductility classes.

Design concept and ductility class	**q**	**Examples of structures**
Low capacity to dissipate energy - DCL	1.5	Vertical cantilever walls. Beams and horizontal cantilevers. Arches with two or three pinned joints. Trusses joined with connectors (e.g. toothed metal plates). Moment resisting frames with glued joints
Medium capacity to dissipate energy - DCM	2.0	Cross laminated buildings with walls composed of a unique element without vertical joints. Log House Buildings. Trusses with screwed, doweled and bolted joints. Mixed structures consisting of timber framing (resisting the horizontal forces) and non-load bearing infill.
	2.5	Moment resisting frames with dowel-type fastener joints
High capacity to dissipate energy - DCH	3.0	Cross laminated buildings with walls composed of several panels connected with vertical joints made with mechanical fasteners (nails or screws) [6]. Trusses with nailed joints.
	4.0	Moment resisting frames with high ductility joints (e.g. densified veneer wood reinforced joints with expanded tube fasteners) [9]
	5.0	Light-frame buildings with nailed walls.

If the above requirement is not met, reduced upper limit values for the behaviour factor q, as given in Table 8.2, should be used.

Table 8.2 (New): Structural types and reduced upper limits of behaviour factors

Structural types	**Behaviour factor q**
Cross laminated buildings with walls composed of a unique element without vertical joints.	1.5
Trusses with screwed, doweled and bolted joints.	1.5
Mixed structures consisting of timber framing and non-load bearing infill.	1.5
Cross laminated buildings with walls composed of several panels connected with vertical joints made with mechanical fasteners (nails or screws).	2.0
Moment resisting frames with dowel-type fastener joints	2.0
Trusses with nailed joints.	2.0
Light-frame buildings.	3.0

In any case, special care should be used in dissipative structures to avoid brittle failure mechanisms such as shear plug, splitting and tearing of timber in the connection regions.

(5) (*New*) Moment-resisting frames with high-ductility joints are a special system which incorporate beam-column joints specifically designed to attain high ductility behaviour. An example is the use of densified veneer wood reinforced joints with expanded tube fasteners. The upper limit value of the behaviour factor listed in Table 8.1 can be used only if provision of (3)P for ductility class H structures is satisfied for the typical joint.

((6) omitted as this part will remain unchanged from the current version of EC8)

3.3 Safety verifications (additional)

All the structural members and connections which according to the reference Capacity Design rules are to be designed with sufficient overstrength so as to avoid anticipated brittle failure shall be dimensioned using the overstrength factors provided in Table 8.3. In the absence of any specific value within Table 8.3 for the dissipative connection used in the design, a conservative value of 1.6 shall be used for the overstrength factor.

Table 8.3 (New): Overstrength factors for typical structural types

Structural type	**Overstrength factor γ_{Rd}**
Trusses with doweled joints [10]	1.6*
Cross laminated timber buildings with walls composed of a unique element without vertical joints [8,11]	1.3**
Cross laminated timber buildings with walls composed of several wall panels connected with vertical joints made with mechanical fasteners (nails or screws) [11]	1.6**

*this value refers to the analytical prediction of the connection shear strength carried out using the formulas of connections with dowel-type fastener in the Eurocode 5 Part 1-1.
** this value refers to the experimental characteristic strength of the connection.

In order to meet the requirements for the Damage Limit State under a seismic action having a larger probability of occurrence than the design seismic action corresponding to the "no-collapse requirement" in accordance with 2.1(1)P and 3.2.1(3), the following limits applies:

a) for timber buildings having non-structural elements of brittle materials attached to the structure:

$d_r \nu \leq 0.005h$;

b) for timber buildings having ductile non-structural elements:

$d_r \nu \leq 0.010h$;

where

d_r is the design interstorey drift as defined in 4.4.2.2(2);
h is the storey height;
ν is the reduction factor which takes into account the lower return period of the seismic action associated with the damage limitation requirement.

4 Conclusions

A first proposal for revision of the current timber part (Section 8) of Eurocode 8 Part 1 is presented in this paper. The objective of this proposal is to start a discussion on the update of this part which is quite old, so as to reflect the current state of the art in timber construction and research in Europe. There is still some research that is needed to complete the proposal. Based on the current state-of-the-art of the research, only three structural types have their overstrength factors listed in Table 8.3, whereas values of the overstrength factor should be provided for all structural types with medium and high capacity to dissipate energy listed in Table 8.2. More information for capacity based design should be given, as well as additional design rules for the different structural systems such as moment resisting frames and cantilevered vertical walls which are being used more and more in modern timber buildings.

The proposal presented in this paper is based both on a large and long dating experience of some of the authors in the design of timber buildings in seismic areas in Europe, and on the results of important research projects undertaken in the last decade about the seismic behaviour of multi-storey timber buildings. It is mostly intended from the designer's benefit, trying to give as many indications as possible on the construction systems, the capacity design criteria and the detailing rules, and trying to avoid misunderstanding.

The concepts and principles contained in this paper may be considered as guidelines for proper design and detailing of timber buildings in seismic areas, leaving also the possibility for the designer to find new and appropriate solutions provided that their application is consistent with the Eurocode 8 general principles and criteria, according to the performance based design philosophy.

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