Specifying Steel for Seismic Lateral Resisting Frames

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Introduction

There are three common seismic frame types used in New Zealand. These are the eccentrically braced frame (EBF), concentrically braced frame (CBF) and moment resisting frame (MRF). See figure 1. All steel seismic-resisting systems are required to be classified into one of four categories for seismic design in accordance with the *Steel Structures Standard*, NZS 3404. The category of seismic frame designed will determine the displacement demand on an individual member of that seismic frame. Members of seismic frames are classified into 4 categories in the same manner as for the seismic resisting frame. Material requirements specified in NZS 3404 become more stringent for member categories associated with higher displacement demand.

The identification of the seismic member categories and the subsequent specification of appropriate steel grades in the contract documents, is the responsibility of the design engineer. This article identifies what the typical seismic member categories are for three common seismic frame types used in New Zealand and identifies complying material types for these seismic member categories.

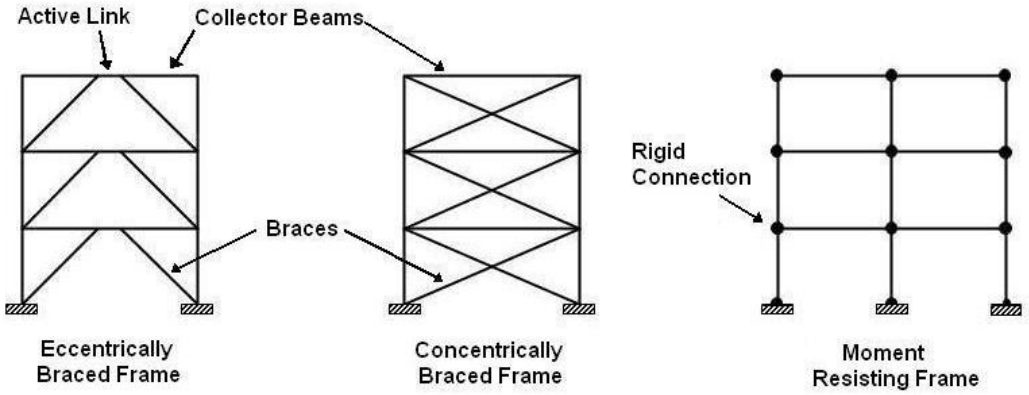

Figure 1: Common seismic frame types

NZS 3404 Seismic Frame Categories

All steel seismic-resisting systems are required to be classified into one of four categories for seismic design. These are specified in Clause 12.2.3.1 of NZS 3404 as follows:

- Category 1, Fully ductile systems.
- Category 2, Systems of limited ductility capacity or subject to limited ductility demand
- Category 3 Nominally ductile systems
- Category 4, Elastic systems

The choice of the seismic frame category is left up to the designer. Apart from having to comply with maximum height limitations for concentrically braced frames, in theory any structure category may be chosen for a structure using any one of the three main types of seismic resisting system (MRFs, EBFs, CBFs). In practice, the choice of structure category is influenced by four main factors:

1) design seismic forces and displacements
2) member category requirements

3) lateral design forces for other types of loading, e.g. wind
4) structural damage

Typical Seismic Frame Categories
The design of lightweight industrial structures is often governed by lateral wind or crane loading on the structure. In this instance a category 3 or 4 system for earthquake loading is typically chosen for seismic design to give similar design actions.

Moment frames are a flexible seismic frame. Satisfying deflection limits may limit the choice of the frame category. Auckland has a relatively low seismic hazard and there is often no benefit to design for a high level of ductility. A seismic category 3 or 4 system is typically chosen.

Eccentrically braced frames are a stiff seismic frame and are designed for a high level of ductility. To reduce structural damage for a design level earthquake the recommendation is now to design as a category 2 frame.

Concentrically braced frames with buckling braces are not commonly designed in New Zealand. Tension only CBF systems are commonly used for a single storey construction and designed for elastic loads (category 4) to permit the use of proprietary connections or category 3 when the connections possess some degree of ductility. Buckling restrained braces are becoming increasingly common for seismic load resisting system in New Zealand. To take advantage of the good inelastic performance of these systems, BRBs are typically designed as category 1 or 2 systems.

NZS 3404 Seismic Member Categories
The category of seismic frame assumed in design will determine the displacement demand on an individual member of that seismic frame. Members of a seismic frame are classified into primary, secondary and column members. The primary member of a seismic frame is the member designed to be part of the main energy dissipating mechanism of the seismic frame and is subject to the highest displacement demand. The secondary member is a member chosen not to be part of the main energy dissipating mechanism. Table 12.2.6 of NZS 3404 provides the relationship between seismic frame category and individual member category. The member categories are:

- Category 1, Members subject to high ductility demand
- Category 2, Members subject to limited ductility demand
- Category 3, Members subject to nominal ductility demand
- Category 4, Members subject to no ductility demand

Typical Seismic Member Categories
Based on the typical seismic frame categories discussed above, the corresponding seismic member categories are provided in table 1. Refer to figure 1 for location of member types.

Table 1: Summary table

Seismic Frame	Typical Seismic Frame Category	Typical Category 1 or 2 members	Typical Category 3 members	Typical Category 4 Members
Single level portal frame	3	-	All	-
	4	-	-	All
Multi-level Moment Frames	3	-	All	-
	4	-	Columns	Beams
Eccentrically Braced Frames	2	Active Links, Collector Beams, Columns immediately above the base	All other columns	-
Concentrically Braced Frames (tension only)	3	-	All	-
	4	-	-	All
Concentrically Braced Frames (BRB)	1 & 2	Buckling restrained braces, Columns immediately above the base	Collector beams, All other columns	-

NZS 3404 Steel Types for Seismic Member Categories

Table 12.4 of NZS 3404 sets outs the material requirement for the four seismic member categories. The new *Steel Structures Standard Part 1: Materials, fabrication and construction*, NZS 3404:Part 1:2009, has relaxed some of the material requirements and now provides a useful table identifying which steel types are suitable for each seismic member category and this is replicated in table 2 below. The material requirements for category 1 and 2 members are more stringent than those for category 3 members, which in turn are more stringent than those required for category 4 members. Therefore steel types suitable for category 1 and 2 members may also be suited for category 3 and 4 members. Similar, steel types for suitable for category 3 members may also be used for category 4 members.

Category 1, 2 and 3 seismic members are all required to be impact tested. There are more stringent impact toughness requirements for categories 1 and 2 seismic members.

Table 2: Steel types for seismic members

Seismic member category	Conforming steel types	Conforming Steel Impact Grades		
		AS/NZS	BS EN	JIS
1 and 2	2S, 3, 5S, 6	S0[1], L15	J2[2]	C[3]
3	2, 5	L0	J0	B
4	1, 4, 7A, 7B, 7C	No requirements for impact testing		

Examples: 1) AS/NZS 3679.1 G300S0
2) BS EN 10025 S275J2G3
3) JIS G 3106 SM 400C

Conclusion

For seismic frames the steel types are selected to meet the seismic member category material requirements in *Steel Structures Standard*. The typical seismic member category for the three common seismic frame types is provided. However the identification of the seismic member categories is the responsibility of the design engineer and must be provided in the contract documents. If engineers are correctly applying the NZS 3404 seismic provisions they should be specifying seismic grade steel (S0) for the yielding elements of category 1 and 2 seismic frames and L0 steel for all the primary and secondary elements of category 3 seismic load resisting systems.

References

SNZ, Steel Structures Standard (Incorporating Amendments 1 and 2), NZS 3404:1997 Part 1 and 2, Standards New Zealand, Wellington, 2007

SNZ, Steel Structures Standard Part 1: Materials, fabrication, and construction, NZS 3404 Part 1:2009, Standards New Zealand, Wellington, 2007