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Frame classification according to the Spanish building code

(Based on EC3)

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1 Summary

The basic document DB SE A of the Spanish Technical Code (CTE) establishes, in the article 5.3, a frame classification into braced and unbraced and sway and non-sway steel frames in order to provide guidance on the type of analysis to be performed.

This document explains how to classify any steel frame and the consequences of the classification on the method of analysis to be used.

2 Introduction

The steel structures code establishes that the calculation model of the structure and the basic assumptions for the analysis should reflect the structural behaviour with appropriate accuracy.

When a first-order analysis is performed, internal forces and moments are determined using the initial geometry of the structure, neglecting the effects of the deformed geometry (second-order effects). However, sometimes second-order effects will increase the action effects, or modify significantly the structural behaviour.

The main objective of the frame classification into sway or non-sway frame is to determine when a first-order analysis may be used.

Frame classification into braced and not braced (or unbraced) frames is directly related with the concept of sway and non-sway frames, as bracing systems can transform a sway frame into a non-sway one.

The Basic Document DB-SE A of the Spanish Technical code, inspired on the Eurocode 3, establishes, on the first hand, the mathematical condition that a non-sway frame has to satisfy in order to be classified as a non-sway, and on the second hand, the mathematical condition that a braced frame should fulfil.

3 Objectives

After reading this document, the student will be able to classify a plane steel frame into sway or non-sway frame.

The student will also be able to evaluate when can be assumed that all the horizontal loads are resisted by the existing bracing system.

Finally, the student will be able to determine which method of structural analysis is the most appropriate to use in each particular case.

4 Frame classification

4.1 Sway and not-sway frames

Beam-and-column type plane frames in building steel structures, like the one in the figure 1, where beams are connecting each column at each storey level, may be classified as non-sway frame for a given combination of loads when equation 1 is satisfied

$$r = \frac{V_{Ed}}{H_{Ed}} \cdot \frac{\delta_{H,d}}{h} \leq 0{,}1 \qquad \textit{Equation 1}$$

Being H_{Ed} the horizontal reaction at the bottom of each storey (equal to $H_{Ed,1} + H_{Ed,2} + H_{Ed,3}$ (figure 1)

V_{Ed} Is the total vertical reaction at the bottom of the storey (Equal to the sum of every column internal axial forces at the bottom of the storey: $V_{Ed,1} + V_{Ed,2} + V_{Ed,3}$

h is the storey height

$\delta_{H,d}$ Is the horizontal displacement at the top of the storey, relative to the bottom of the storey.

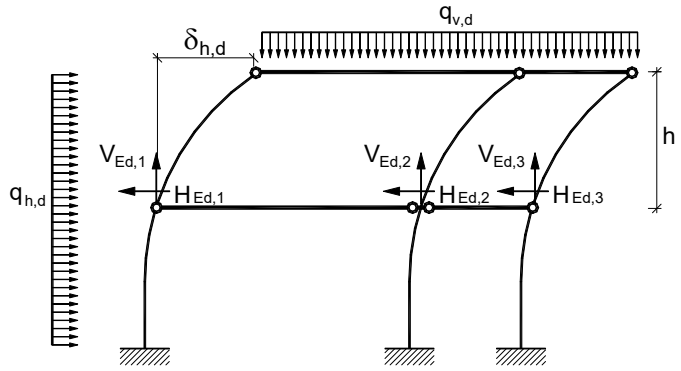

Figure 1. Geometry and loads

Therefore, when equation 1 is fulfilled for every storey, the frame can be classified, for that combination of loads, as a non-sway frame, being accurate enough to perform a first-order analysis of the structure.

On the other hand, when the equation 1 is not fulfilled for one of more storeys, the frame should be classified as a sway frame, and a second-order analysis has to be performed, being not possible to neglect second-order effects.

It must to be pointed out that one frame can be classified as sway for several combinations of actions and as non-sway for others, being possible to transform a sway frame into a non-sway frame by increasing the columns' moment inertia in order to reduce the relative horizontal displacement between storeys.

4.2 Braced and unbraced frames

A frame can be classified as a braced frame if the bracing system response to in-plane loads is sufficiently stiff.

Different bracing systems are represented in red in figure 2.

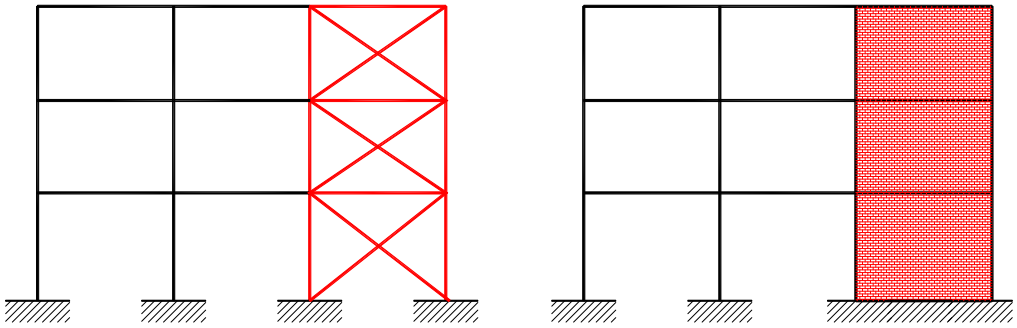

Figure 2. Bracing systems

DB SE A quantifies "*being sufficiently stiff*" as being able to reduce by at least 80%, its horizontal displacements.

This means that an initial first order analysis of the steel frame without the bracing system has to be performed in order to obtain the initial horizontal displacements, δ_i.

Then, the real steel frame including the bracing system is analysed again, comparing the real horizontal displacements δ_r, with the initial ones δ_i.

If the reduction of the horizontal displacements is at least 80%, the steel frame can be classified as a braced frame.

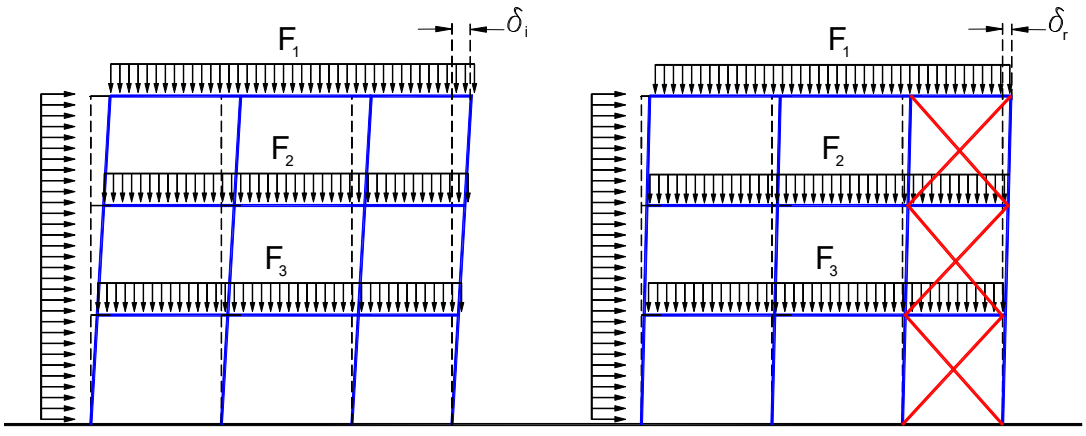

Figure 3. Initial and real displacements

Being classified as a braced frame implies that:

1. The steel frame is considered a non-sway frame, and has to be designed to resist just the applied vertical loads.
2. The bracing system should be designed to resist any horizontal loads applied to the frame which it braces and any horizontal or vertical loads applied directly to the bracing system.
3. The bracing system may be a sway or a non-sway frame. It has to be checked according to equation 1.

If the reduction of the horizontal displacements does not reach the 80% limit, the steel frame should be classified as an unbraced frame.

Being classified as an unbraced frame means that the whole steel frame, including the bracing system, can be a sway or a non-sway frame, depending on the value of the *r* coefficient in equation 1.

4.3 Summary

Along this document, the conditions established by the Basic Document DB SE A for frame classification into sway or non-sway and braced or unbraced steel frames, have been analysed.

Being both concepts related, it is important to differentiate each one and understand the consequences that the classification of the frame as a sway or non-sway frame implies, and what means that the steel frame can be considered a braced one.

4.4 Proposed question

In order to guarantee the comprehension of the former concepts, it is proposed the following question:

Can an unbraced steel frame be classified as a non-sway frame?

You will find the response at the end of the document.

5 Conclusion

- Being classified as a sway or non-sway frame depends on the value of the *r* coefficient established in the DB SE-A article 5.3.1
- The value of the *r* coefficient depends on the ratio between vertical and horizontal loads, the height of the storey and the horizontal displacement at the top of the storey relative to the bottom of the storey.
- If the frame is classified as a non-sway frame, a first order analysis can be performed; on the other hand, when it is classified as a sway frame, a second order analysis should be performed.

- Being classified as a braced frame depends on the stiffness of the bracing system.

- If the bracing system is stiff enough, which means that reduces the initial horizontal displacements of the structure without the bracing system by at least 80%, the frame can be considered as a braced frame.

- Being classified as a braced frame implies:

    - The structure is considered a non-sway frame and it has to be designed to resist the applied vertical loads.
    - The bracing system has to be designed to resist all the horizontal loads applied to the braced frame and any horizontal or vertical loads applied directly to the bracing system.
    - The bracing system may be classified as a sway or non-sway frame according to equation 1

- If the frame is classified as an unbraced frame, it has to be checked if it is a sway or non-sway frame in order to choose the appropriate method of analysis.

- It has to be pointed out that although non-sway and braced frames are related concepts, the meaning is not the same, being possible to be a non-sway unbraced frame.

6 Bibliography

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7 Solution

Being classified as a non-sway steel frame depends on the value of the *r* coefficient, independently of the existence of a bracing system.

Therefore, it is possible to be classified as a non-sway steel frame being and unbraced frame.