Steel Design to Eurocode 3

Structural Analysis

Analysis Types

There are four types of global analysis:

Analysis Type	Initial Geometry	Deformed Geometry	Linear material behaviour	Non-linear material behaviour
First-order elastic	✓		✓	
Second-order elastic		✓	✓	
First-order plastic	✓			✓
Second-order elastic		✓		✓

Table 1: Summary of Analysis Types

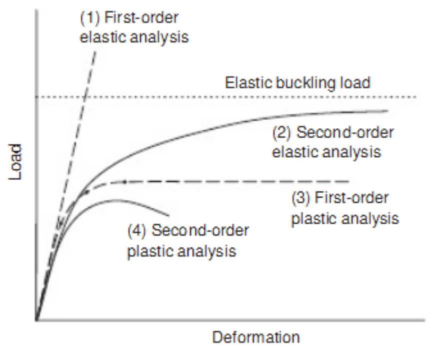

Figure 1: Load-Deformation graph for different analysis types (Source: Designer's Guide to EN 1993-1-1 Page 21)

Joints

Clause 5.1.2 deals with joint modelling

Eurocode 3 recognises the same three types of joint, in terms of their effect on the behaviour of the frame structure, as BS 5950: Part 1.

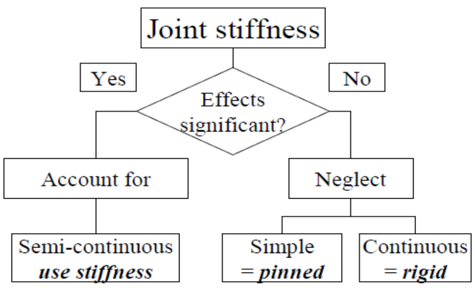

Figure 2: Joint stiffness effects (Source: SCI CPD Course Material)

The choice between a first- and second- order analysis should be based on:

- the flexibility of the structure
- in particular, the extent to which ignoring second-order effects might lead to an unsafe approach due to underestimation of some of the internal forces and moments.

Clause 5.2.1(2) states that second order effects shall be considered:

- if they increase the action effects significantly
- or modify significantly the structural behaviour

First-Order Analysis

A **first-order analysis** may be used if the following criteria is satisfied:

$$\alpha_{cr} \geq 10 \text{ for elastic analysis}$$

$$\alpha_{cr} \geq 15 \text{ for plastic analysis}$$

$$\alpha_{cr} = F_{cr}/F_{Ed}$$

α_{cr} is the factor by which the design loading would have to increased to cause elastic instability in a global mode (λ_{cr} in BS 5950-1)

F_{Ed} is the design loading on the structure

F_{cr} is the elastic critical buckling load for global instability based on initial elastic stiffness.

For **portal frames** (with shallow roof slopes less than 26°) and **beam and column plane frames**:

$$\alpha_{cr} = \left(\frac{H_{Ed}}{V_{Ed}}\right)\left(\frac{h}{\delta_{H,Ed}}\right)$$

H_{Ed} is the horizontal reaction at the bottom of the storey

V_{Ed} is the total vertical load at the bottom of the storey

$\delta_{H,Ed}$ is the horizontal deflection at the top of the storey under consideration relative to the bottom of the storey, with all horizontal loads applied to the structure.

h is the storey height.

Amplifier

If $10 > \alpha_{cr} \geq 3.0$

Increase all lateral loads by the amplifie..

$$\frac{1}{\left(1-\frac{1}{\alpha_{cr}}\right)}$$

Limits on α_{cr}	Action
α_{cr} >10	First order Analysis
10>α_{cr} >3	First order analysis plus amplification or effective length method
$\alpha_{cr} \leq 3$	Second order analysis

Table 2: Actions to be taken once α_{cr} has been calculated

Imperfections

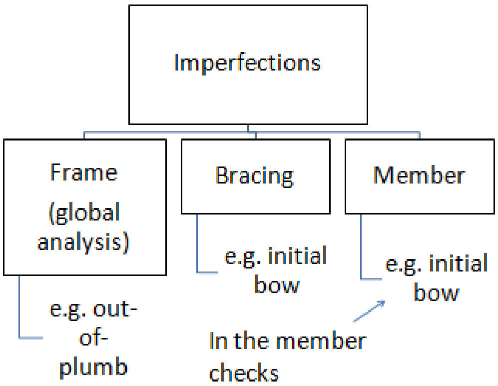

Figure 2: Typical Imperfections that will be present when designing a structure

Frame imperfections appear in (almost) <u>every</u> load case. We can represent initial sway imperfections by using Equivalent Horizontal Forces (EHFs) which are based on 1/200 of the <u>factored</u> vertical load, with reduction factors.

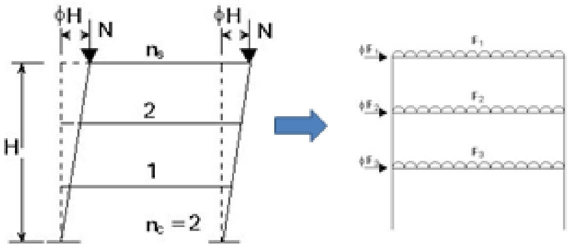

Figure3:Replacing initial sway imperfections with equivalent horizontal forces

EHF = φ x Vertical Forces

φ = $\varphi_0 \alpha_h \alpha_m$

φ_0 = 1/200 = 0.005

α_h is the reduction factor for height:

$$\alpha_h = \frac{2}{\sqrt{h}} \text{ but } \frac{2}{3} \leq \alpha_h \leq 1{,}0$$

(h is the height of the structure in metres)

α_m is the reduction factor for columns

$$\alpha_m = \sqrt{0{,}5\left(1+\frac{1}{m}\right)}$$

(m is the number of columns contributing to the effect on the bracing system)

Summary

1) Model the Frame
2) Put all the loads on the frame

   (Including the EHFs)
3) Calculate α_{cr}
4) Check to see if second-order effects are significant
5) If necessary use the ampl...: $\frac{1}{\left(1-\frac{1}{\alpha_{cr}}\right)}$