Conceptual Design and Determination of Action Effects for Single-Storey Buildings

access steel
Eurocodes made easy

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Overview

- Client Guide
- Case Studies
- Scheme Development
- Flow Charts
- NCCI
- Examples

The client guide presents the benefits that steel construction can provide to the owners and occupiers of single storey buildings.
It offers guidance to clients on how to obtain best value from steel construction.

1. Introduction
2. The European market for single story steel buildings
3. Advantages of steel for single storey buildings
4. Achieving value from the whole: Form of contract and choice of suppliers
5. Overall design issues
6. Conclusions

Introduction

Single storey buildings contribute substantially to the built environment of Europe. They accommodate **manufacturing, warehousing, transport, sports, retail and leisure activities**.

Steel construction can offer the occupants, owners and developers for these wide ranging activities exceptional value, as evidenced by the overwhelming market shares that it achieves in some European countries.

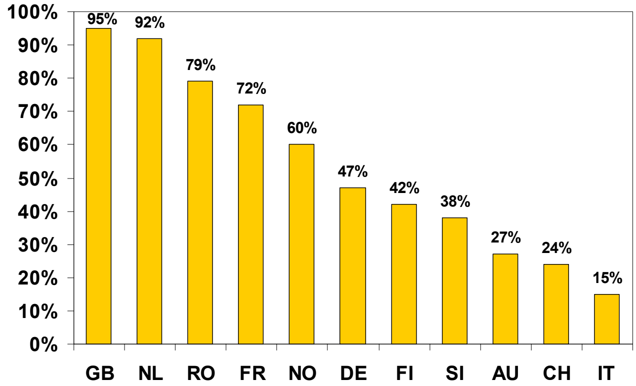
The purpose of this document is to:

- **Demonstrate the benefit** that steel construction can bring to its customers
- **Highlight the success of steel single storey construction** in major national markets
- **Illustrate the wide range of steel solutions** that are available.
- Give some **guidance on how to obtain best value from the market place.**

The European market

Market size and distribution

The European market for steel for single storey *industrial* buildings comprises approximately 100 million square metres of covered space per annum, with a value of about 6 billion euros.



Percentage market shares for steel frames in single storey industrial buildings

Factors influencing choice of material

- presence of large developers who repeatedly procure single storey buildings
- development of supply chain teams of main frame manufacturers, purlin and side rail system suppliers, cladding manufacturers and equipment (e.g. doors) suppliers who work efficiently together in long term relationships.
- wide spread use of forms of contract that suit this form of construction (e.g. Design and Build in the UK).
- strong industry infrastructures that support the supply chain, for example by ensuring that design, construction and contractual guidance is readily available and that the regulatory framework is benign for steel

Advantages

- Speed of construction
- Flexibility in use
- Maintenance
- Sustainability
- Value for money
- Examples

Kingswood Lakeside Business park, Cannock

Achieving value from the whole

In a single storey building, the contributions to the overall value of the superstructure are typically:

- Primary frames 35%
- Secondary structure, purlins and side rails 15%
- Cladding 50%

All three components are clearly important individually. As discussed in more detail below, there are also very significant structural and performance interactions between these three components. All components are supplied by specialists.

Whatever form of contract is adopted, it is therefore essential that all significant suppliers have an opportunity to contribute to the development of the design and construction specification, if client value is to be maximised.

Overall Design Issues

- **General**
- **Choice of primary frame**
- **Interdependence of frames and envelopes**
- **Energy performance**
- **Air-tightness**
- **Design Coordination**
- **Mainly architecture**
- **Mainly Engineering**
- **Influences on structural design and costs**
- **Sustainable constructions**
  - Economic considerations
  - Social aspects
  - Environmental considerations

Conclusions

For single storey buildings, steel offers:

- Cost efficiency in construction
- Low maintenance throughout a building's life
- Long spans that can accommodate changes in building occupancy and activity, thus extending a building's economic life.
- Highly sustainable contributions to Europe's Built Environment.
- Single storey steel buildings are one of the most efficient sectors in the construction industry, with optimised approaches to the primary frames, secondary structure and cladding from specialist suppliers.
- Single storey steel buildings should be provided in a way that ensures that all the specialist suppliers can make maximum contributions to overall client value.
- Clients should interact with both the design and supply teams to ensure best value for their projects.

Gazeley G-Park, Bedford

Astral Court, Baglan

Campushalle, Flensburg

Logistikzentrum, Stuttgart

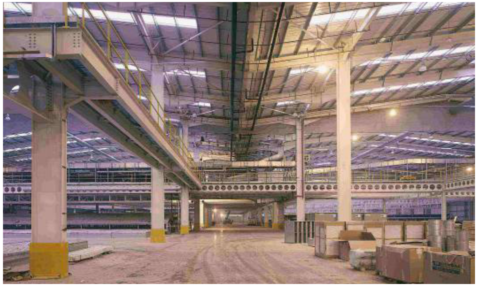
Case Studies

Access Steel highlights the benefits of steel as the primary construction material through detailed short case studies of successful buildings

- New Air Cargo Hub for DHL
  at Nottingham East Midlands Airport, UK

- ELUZ Building in Croissy-Beaubourg, France
- Airforge building, Pamiers, France

New Air Cargo Hub for DHL



New Air Cargo Hub for DHL
(45 million euro warehouse and office complex)

- 40 000 m² warehouse and truck canopy
- 9 000 m² office spans on 3 floors
- 30 truck bays and parking for 90 trucks
- 620 car parking spaces for staff and visitors
- 6 000 m² ramp equipment parking
- New, 165 000 m² apron providing 18 aircraft stands
- On-site refuelling for DHL trucks
- New roundabout to service the Hub
- Realignment of the A453
- New internal access roads
- 2 new balancing reservoirs with full pollution control system (holding 70 000 m³ of water)

ELUZ Building

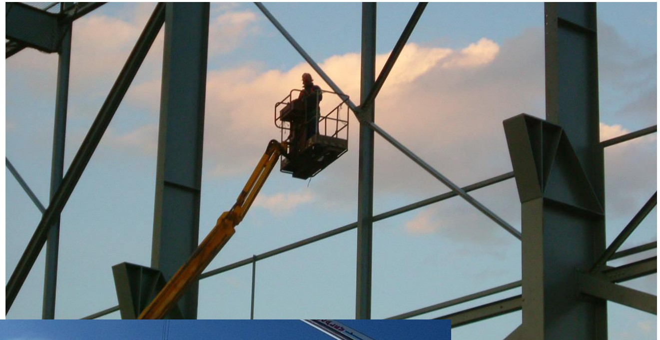
General view of the structure during erection

Tension elements

- Construction of a single storey building covering a 7000 m² area without any internal column, in order to set up racks to store the products that the ELUZ company sells.
- Span of the main frames : 84 meters
- Height of the building at the top of the roof : 15 meters

Airforge Building

Typical heavy industrial building,
with a height of 22 m and spans of up to 23 m.



- 10 500 m² of industrial building carrying cranes with a capacity up to 140 t
- 5 halls of various spans: 16 m, 23 m, 22 m and 2 × 23 m
- The total length of the building is 98 m and the main hall is 22 m high
- 1365 tons of structural steelwork completed in 8 months

15 documents

Concise information on proposal development guides the architect and engineer through all the decisions that have to be made to develop a best practice design

- Overview of structural system and form and function of mainframes
- Conceptual design (roofs, walls etc.)
- Form and function of purlins and side rails
- Conceptual design of portal frames from fabricated sections
- Conceptual design of truss and column solutions
- Eaves details / Apex (ridge) details
- Valley details for multiple bay roofs
- Overview of fire
- Movement joints / Expansion joints
- Corrosion

This document describes the range of structural systems that are commonly used for long span single storey buildings. The descriptions include the main structural frames, secondary systems such a bracing and the purlins and rails to support the cladding.

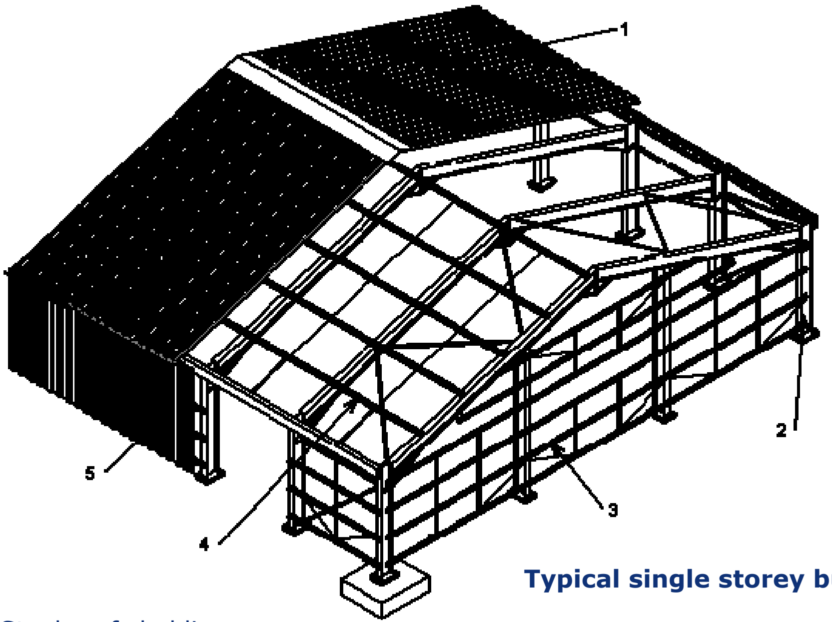
1. Overview of applications for single storey buildings
2. Basics for design
3. Typical structural frame solutions
4. Connections
5. Acknowledgement

Overview of applications

- wide range of buildings, from small homes to the largest covered spaces, such as exhibition halls and stadia.
- Large buildings will use multi-span structures and may, on occasion, cover 100 000 m².
- origin of building form in industrial building and this description is still often applied but it is misleading
- uses are many and varied with considerable usage by the general public.
- Typical end uses
  - retail,
  - distribution centres,
  - call centres,
  - leisure facilities
  - indoor sports facilities.
- greater focus on the envelope in terms of aesthetics, insulation, airtightness etc.
- title of **industrial buildings** has therefore been **replaced by** the broader term, **single storey buildings**.

While there has been considerable change in the appearance the basic structural forms have changed little other than to evolve in the details needed to support more varied cladding forms as described in later sections.

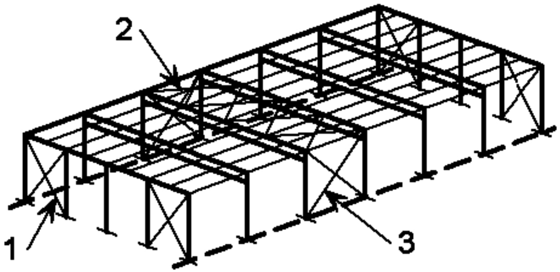
Overview of components



Typical single storey building

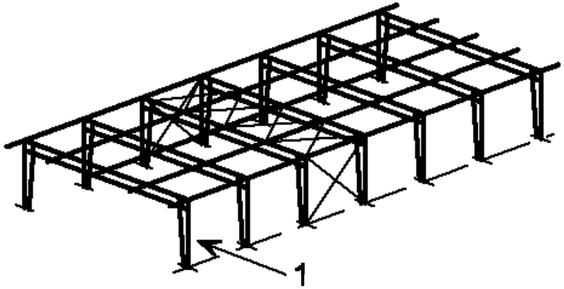
1. Steel roof cladding
2. Primary steel frame
3. Side rails
4. Purlins
5. Wall cladding

Structural principles for frames



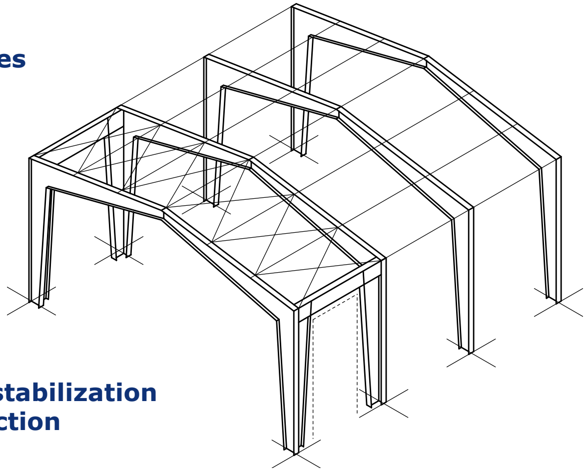
Layout with braced gable frames

1 Gable bracing
2 Roof bracing
3 Longitudinal bracing



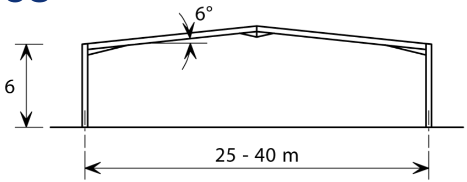
Layout with portalised gable frames

1 Portalised end frame

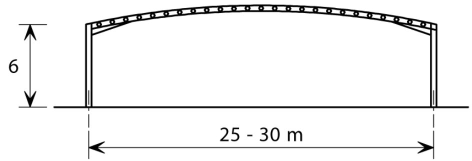


Moment frame for stabilization in longitudinal direction

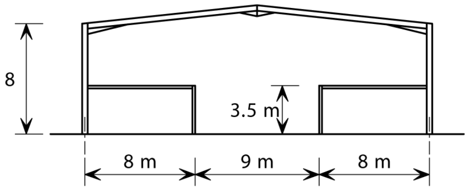
Portal Frames



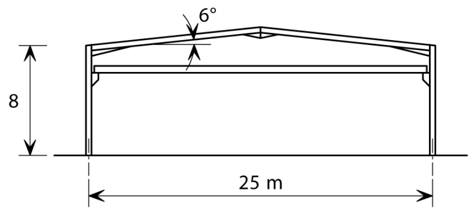
(a) Portal frame – medium span



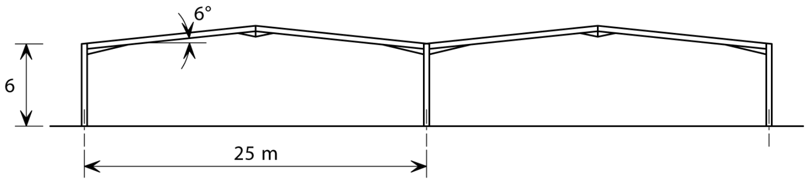
(b) Curved portal frame



(c) Portal frame with mezzanine floor

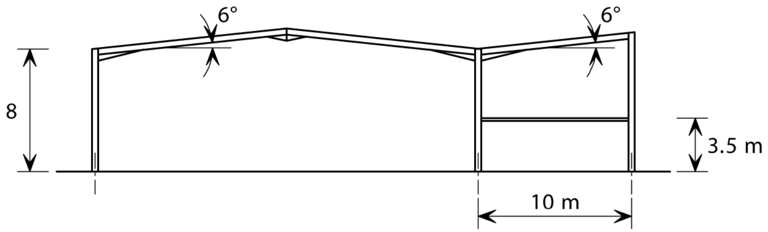


(d) Portal frame with overhead crane

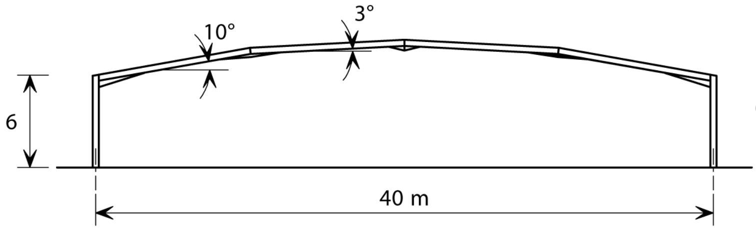


(e) Two bay portal frame

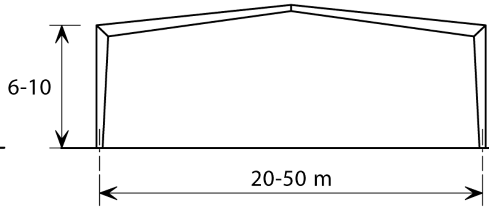
Portal Frames



(f) Portal frame with integral office



(g) Mansard portal frame



(h) Portal frame from welded plates

Typical structural frame solutions

Innovative moment-resisting connections in an industrial building

Valley beam details for “hit” and “miss” frame

Installation process for modern portal frames

Typical structural frame solutions

Secondary members

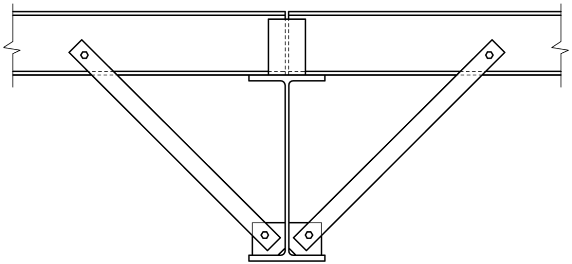
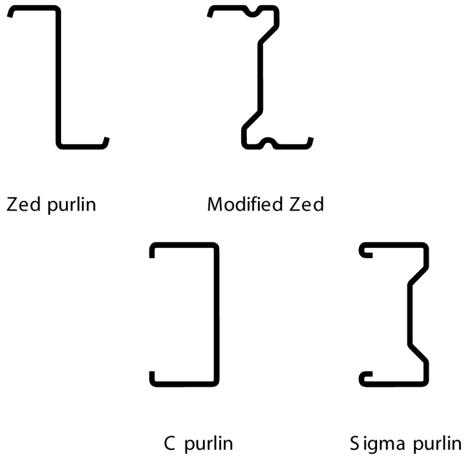
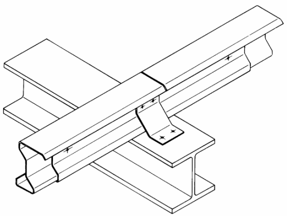


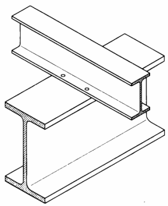
Figure 3.15 Restraints system at hinge positions

Typical purlin/rail solutions

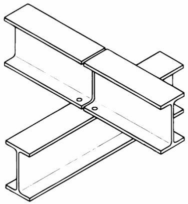




Support for continuous cold-formed Z-shaped purlin



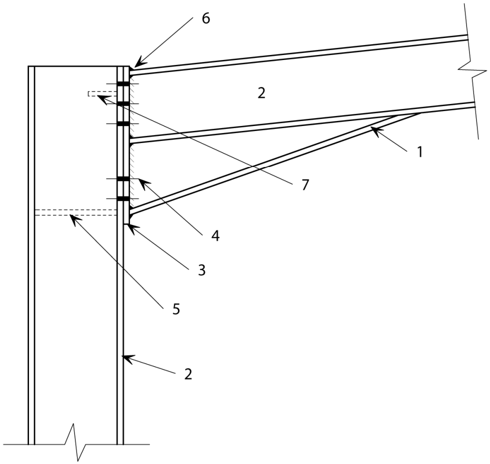
Support for continuous hot-rolled purlin



Support for single-span hot-rolled purlin

Possible solutions for purlin to rafter connections

Connections



Key:

1. Eaves haunch
2. Hot rolled section
3. End plate
4. Bolts grade 8.8 or 10.9
5. Compression stiffener when required
6. Tension flange welds
7. Tension stiffener when required

Figure 4.1 Typical eaves connections in a portal frame

Key:

1. End plates
2. Hot rolled section
3. Apex haunch when required
4. Bolt Grade 8.8 or 10.9

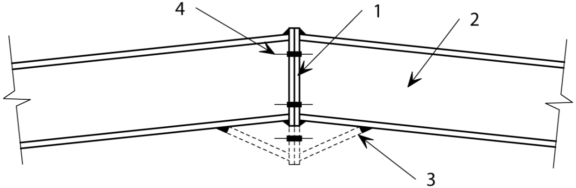
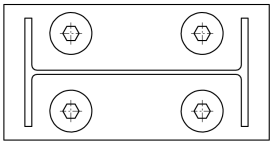


Figure 4.2 Typical apex connections in a portal frame



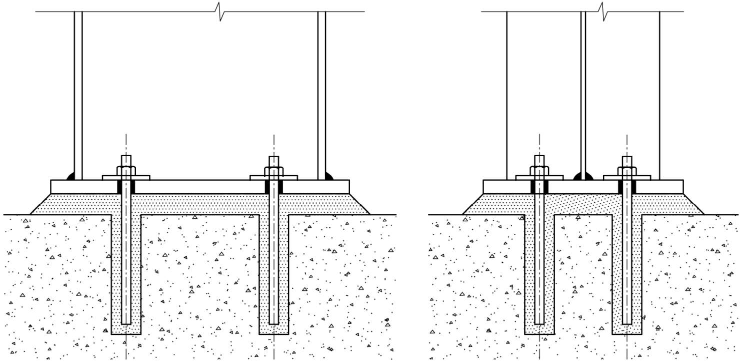


Figure 4.3 Typical examples of pin base connections in a portal frame

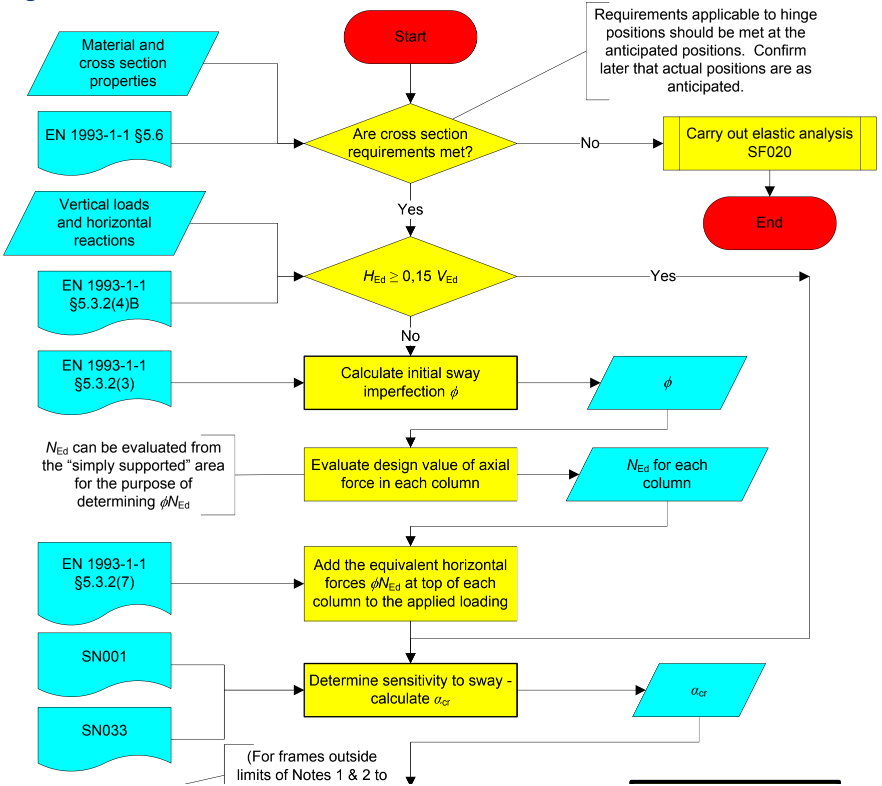
21 documents

Each design activity is described separately by a flow chart:

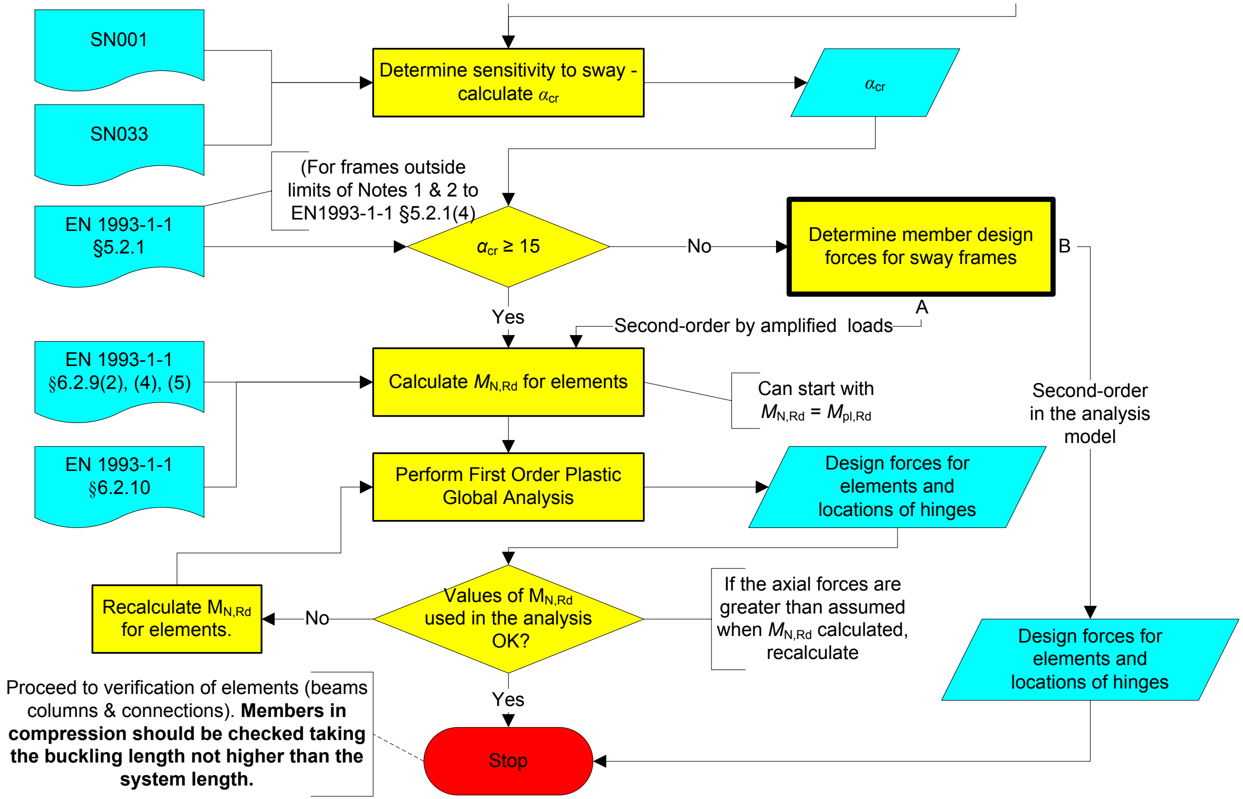
- **Plastic analysis of a portal frame**
- Evaluation of wind loads
- Global analysis and overall cross-section checks
- Global analysis (elastic) of class 2,3 or 4 sections
- Verifying out of plane stability
- **Elastic design, uniform sections (rafter or column)**
- Design of eaves / apex connections
- Design of fixed / pinned base connections
- **Design model for welded joints in trusses using structural hollow sections**
- Design of compression chord splices
- Purlin / side rail design

Flow Charts – Plastic Analysis

This flowchart illustrates the process of plastic analysis for portal frames. The output of the analysis is the design forces and moments in members and connections.

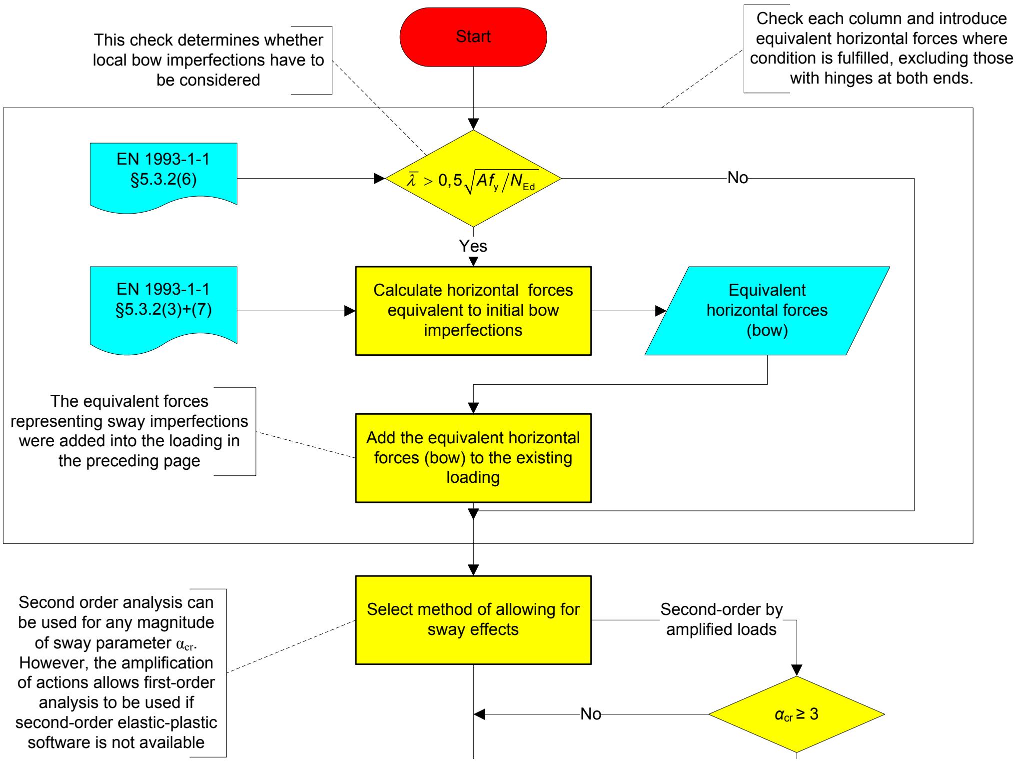


Flow Charts – Plastic Analysis

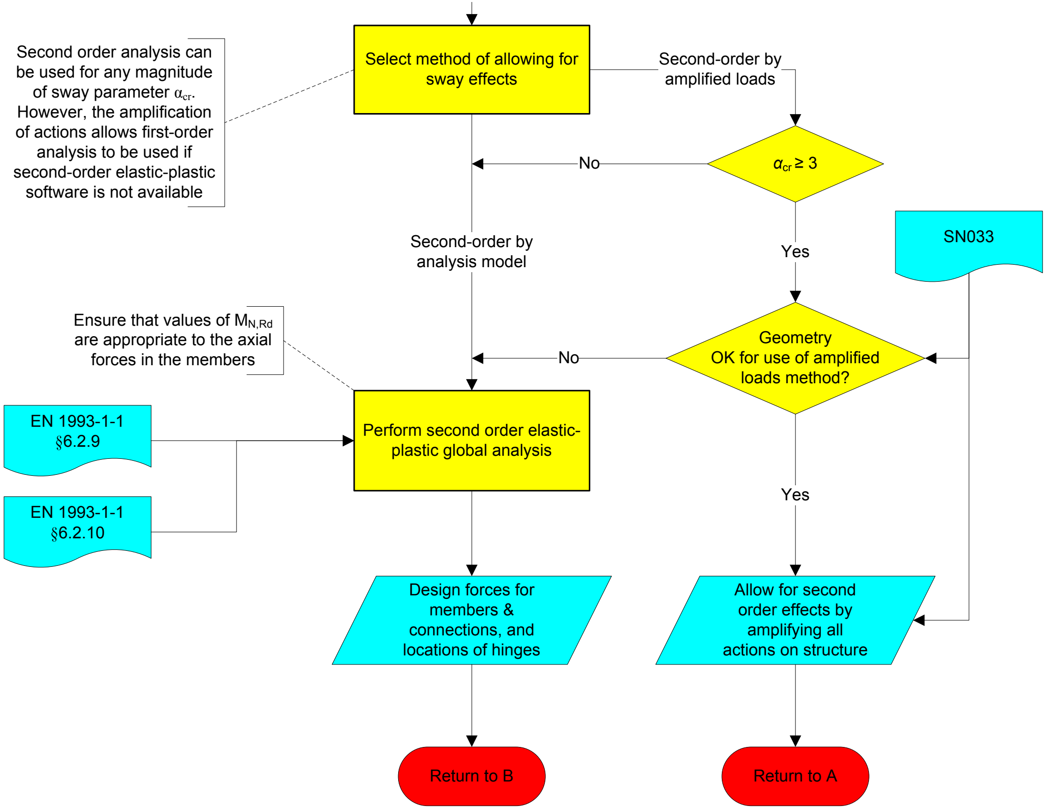


Flow Charts – Plastic Analysis

Determine member design forces for sway frames

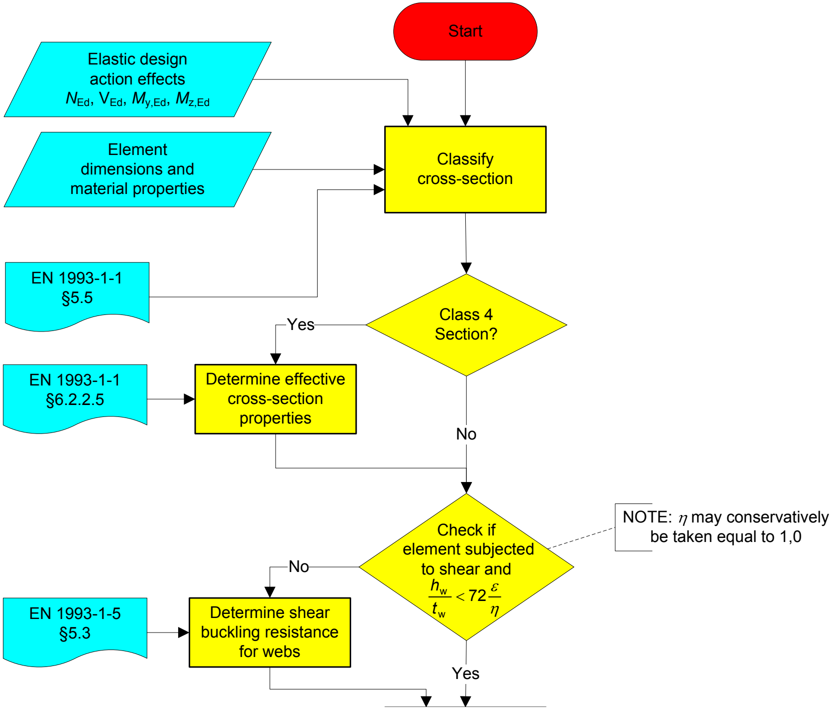


Flow Charts – Plastic Analysis

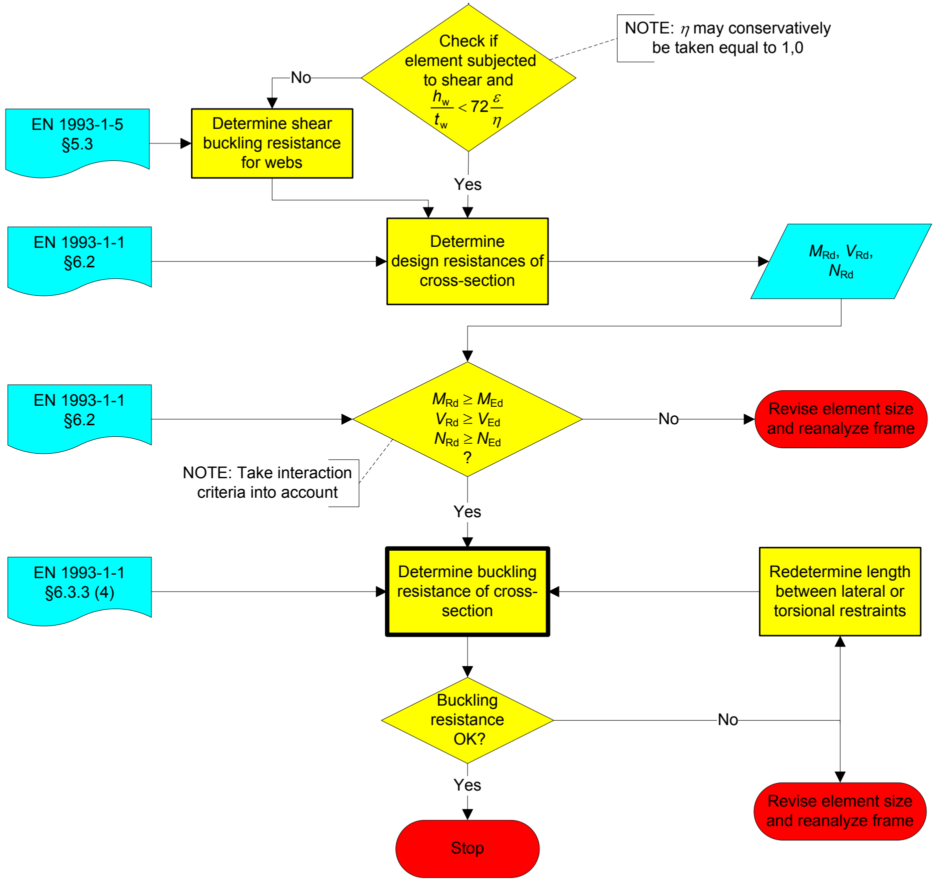


Flow Charts – Element elastic design

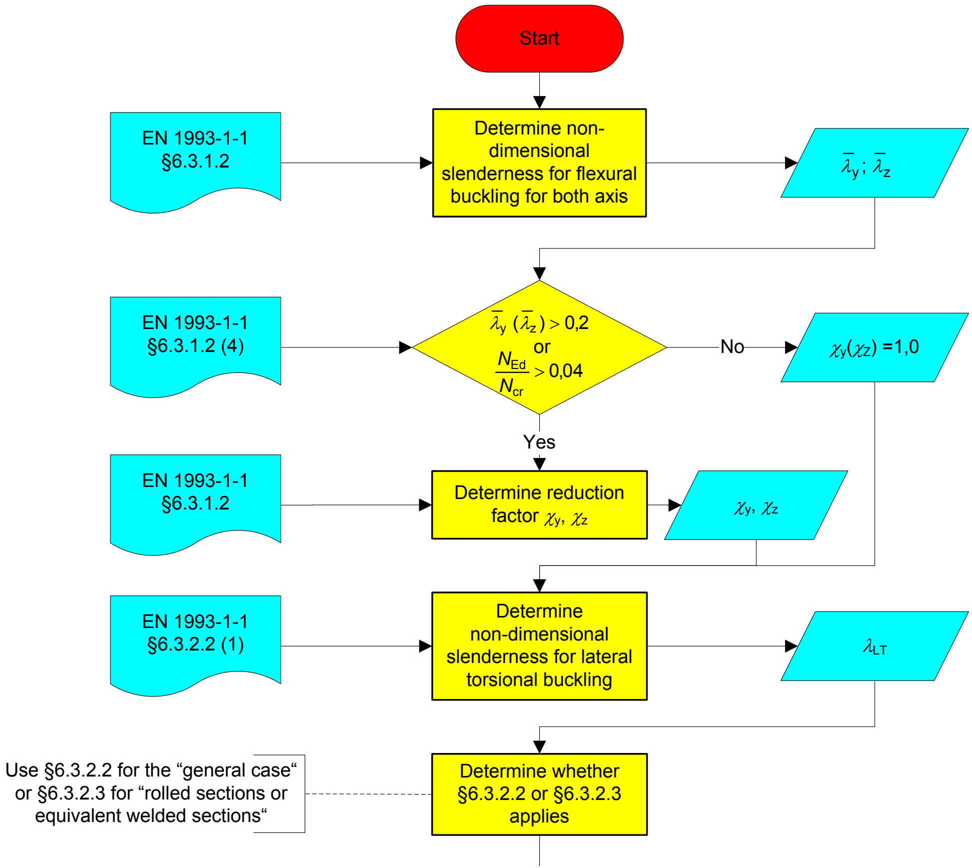
This flow chart presents the design procedure for uniform sections (rafter or column) in portal frames.



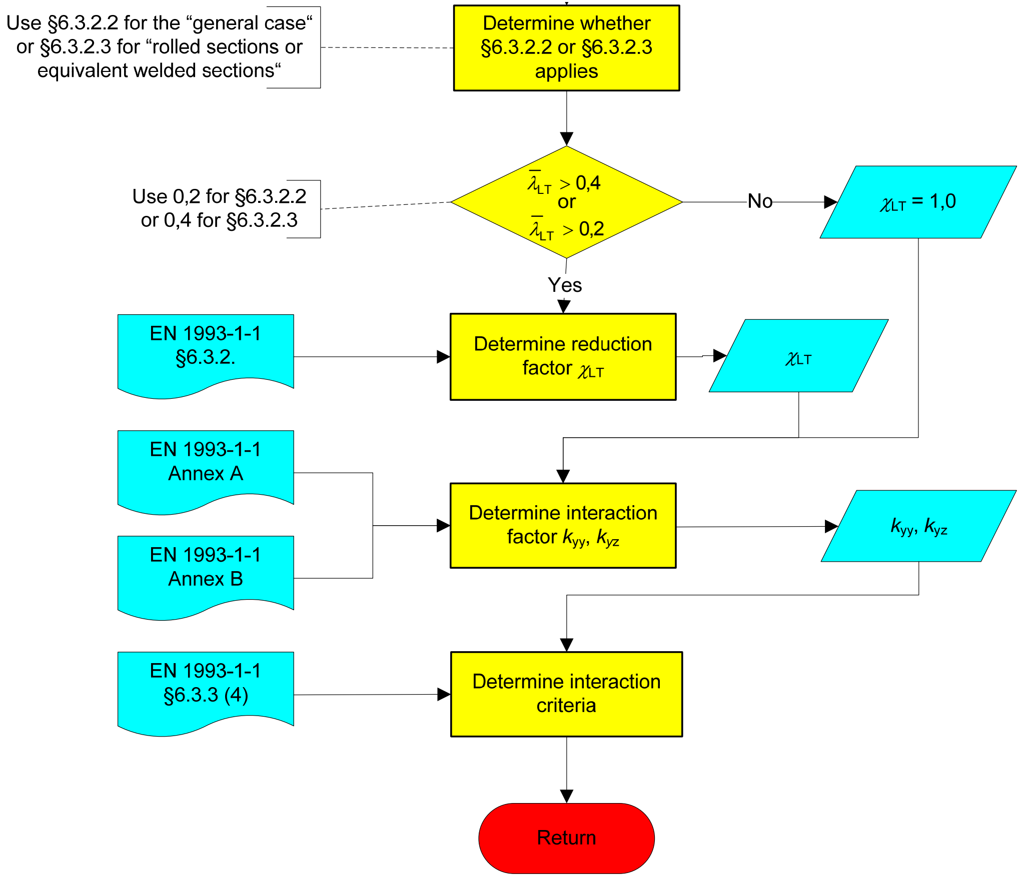
Flow Charts – Element elastic design



Flow Charts – Element elastic design

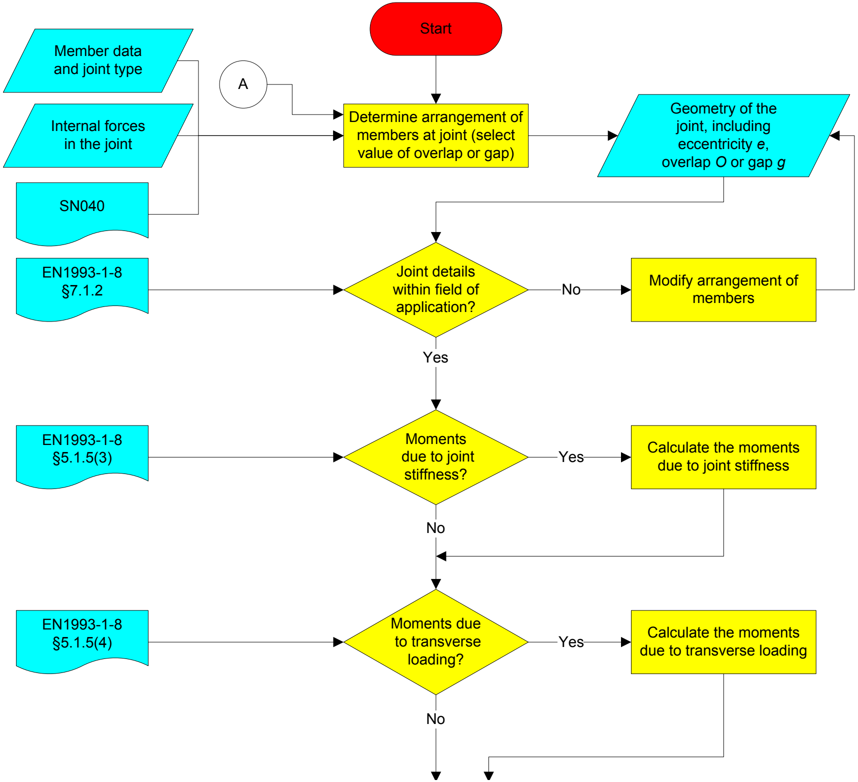


Flow Charts – Element elastic design

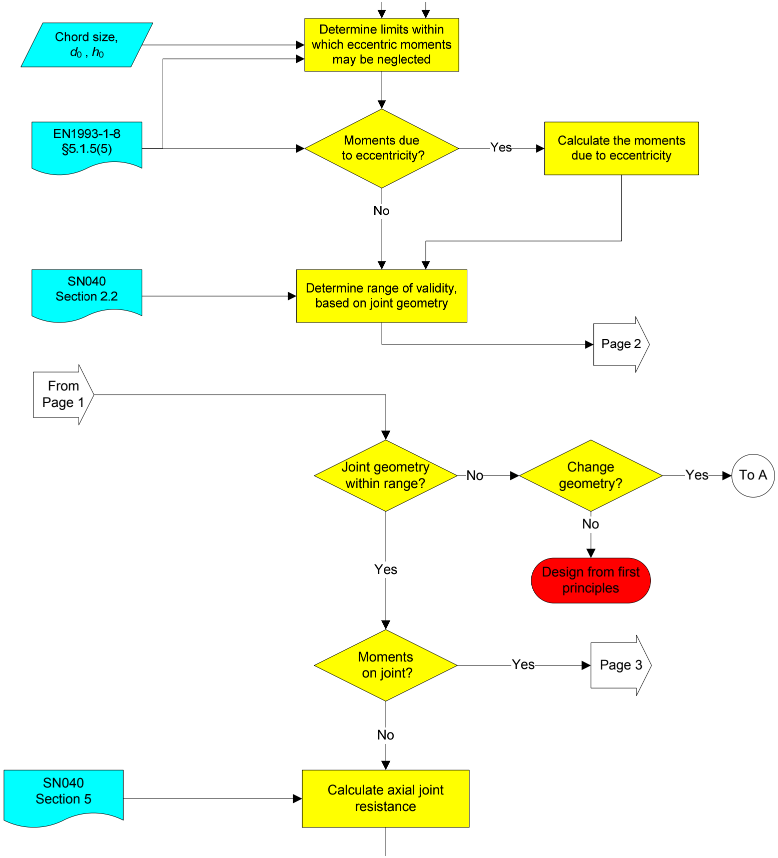


Flow Chart – Design model for welded joints

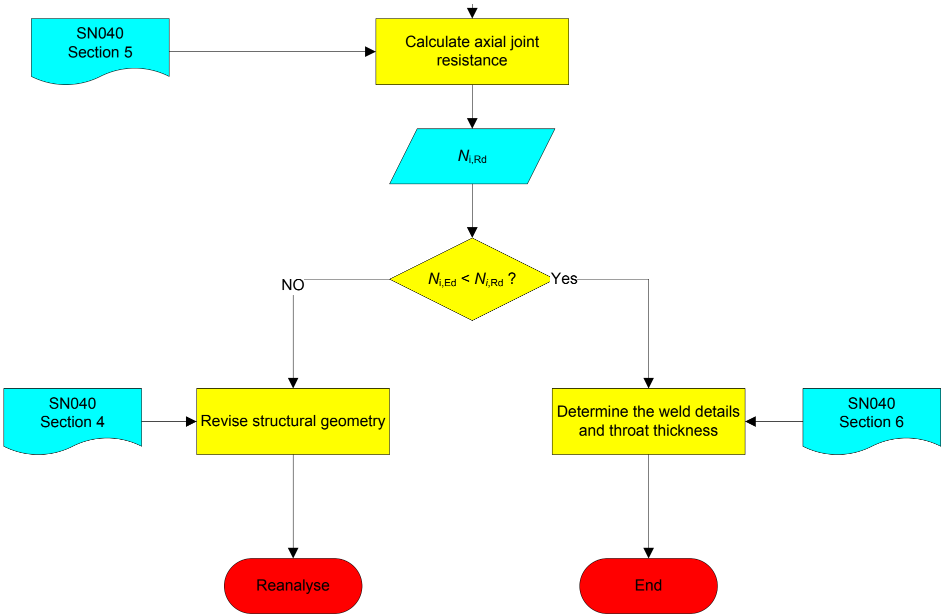
This flow chart outlines the verification procedure for welded, uniplanar unreinforced joints in trusses using structural hollow section alone or in combination with open sections



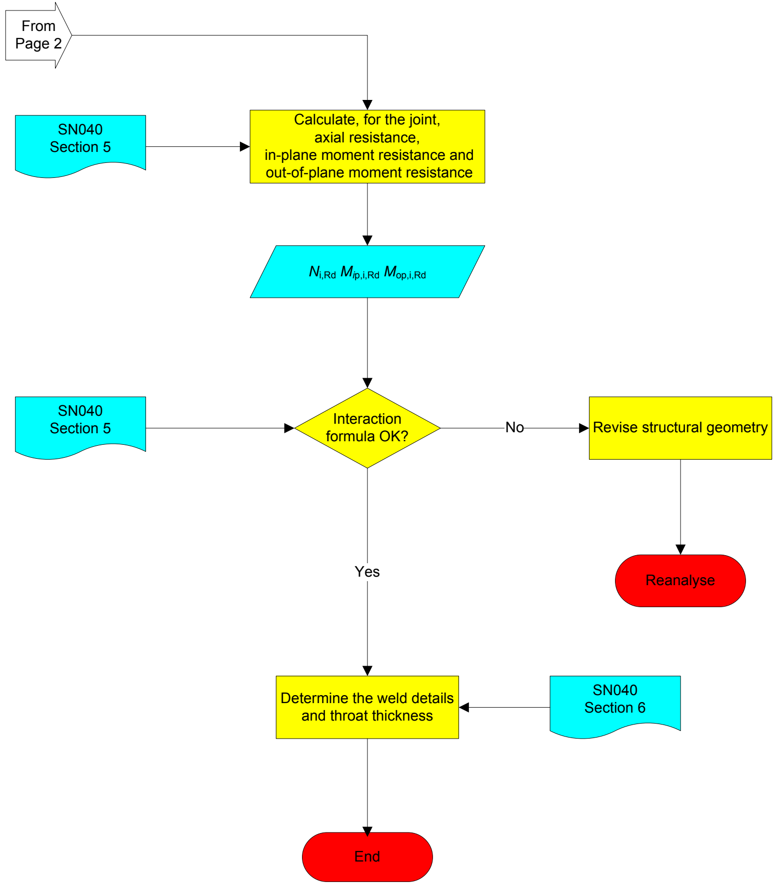
Flow Chart – Design model for welded joints



Flow Chart – Design model for welded joints



Flow Chart – Design model for welded joints



19 documents

Non-contradictory, complementary information (NCCI) is presented that addresses all the information that the Eurocodes do not cover that is essential for design

- Analytical models for trusses
- Design of asymmetric members under M&N
- Foundation stiffness for global analysis
- Practical analytical models for portal frames
- Design model for eaves / apex connections
- Design model for fixed / pinned base connections
- **Deflection limits for single storey buildings**
- Simple methods for second order effects
- Classification tables for rolled profiles
- General method for out of plane buckling
- Benefits of cladding
- Effective lengths of columns

Deflection limits for single storey buildings

This NCCI provides recommendations and guidelines for horizontal and vertical deflection for single storey buildings.

1. Introduction

No specific deflection limits are set in Eurocode 1993-1-1 [1]. According to EN 1993-1-1, § 7.2 and EN 1990 – Annex A1.4 [2], deflection limits should be specified for each project and agreed with the client. The National Annex to EN 1993-1-1 may specify limits for application in individual countries. Where limits are specified they have to be satisfied. Where limits are not specified, the following might be helpful when deciding relevant deflection limits.

2. Horizontal deflections for portal frames

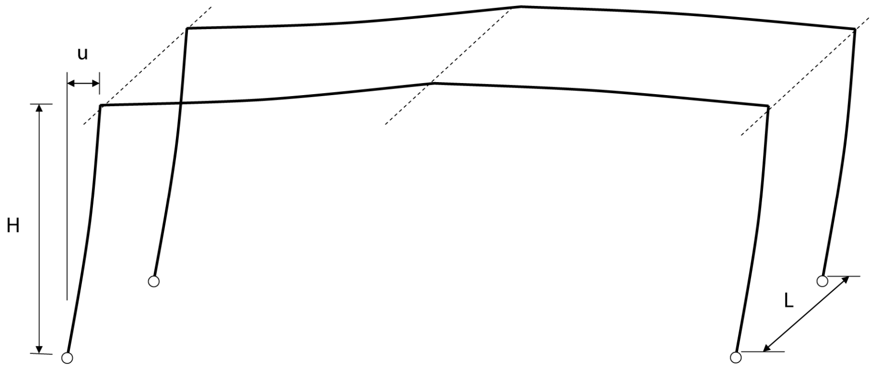


Figure 2.1 Definition of horizontal deflection

Deflection limits for single storey buildings

Table 2.1 Limiting horizontal deflection

Country	Structure	Deflection limits u	Comments
France	Portal frames without gantry cranes		The values to the left are given in the French National Annex to EN 1993-1-1 and should be used if nothing else is agreed with the client. The values of the deflections calculated from the characteristic combinations should be compared to these limits.
	Buildings with no particular requirements regarding the deflection.		
	Deflection at the top of the columns	H/150	
	Difference of deflection between two consecutive portal frames	B/150	
	Member supporting metal cladding		
	Post	H/150	
	Rail	B/150	
	Other single storey buildings		
	Buildings with particular requirements regarding the deflection (brittle walls, appearance…).		
	Deflection at the top of the columns	H/250	
	Difference of deflection between two consecutive portal frames	B/200	
Germany			There are no national deflection limits. The limits should be taken from manufacturers instructions (technical approvals) or should be agreed with the client.
Spain	Portal frames (without fragile elements susceptible to failure in the envelopes, façade and roof)	H/150	The values to the left are given in the national technical document for steel structures [3] and in the Technical Building Code [4] and should be used if nothing else is agreed with the client.
	Single storey buildings with horizontal roofs (without fragile elements susceptible to failure in the envelopes, façade and roof)	H/300	

Deflection limits for single storey buildings

Country	Structure	Deflection limits u	Comments
UK	Portal frames without gantry cranes, with walls of :		There are no national deflection limits. The figures to the left are recommended in industry guidance [6].
	Steel sheeting - deflection at top of column	H/100	
	Fibre reinforced sheeting - deflection at top of column	H/150	
	Brickwork - deflection at top of column	H/300	
	Differential deflection between two consecutive portal frames	$\sqrt{\frac{H^2+B^2}{660}}$	
	Hollow concrete brickwork - deflection at top of column	H/200	
	Differential between two consecutive portal frames	$\sqrt{\frac{H^2+B^2}{500}}$	
	Precast concrete units - deflection at top of column	H/200	
	Differential defection between two consecutive portal frames	$\sqrt{\frac{H^2+B^2}{330}}$	

3. Vertical deflections for portal frames

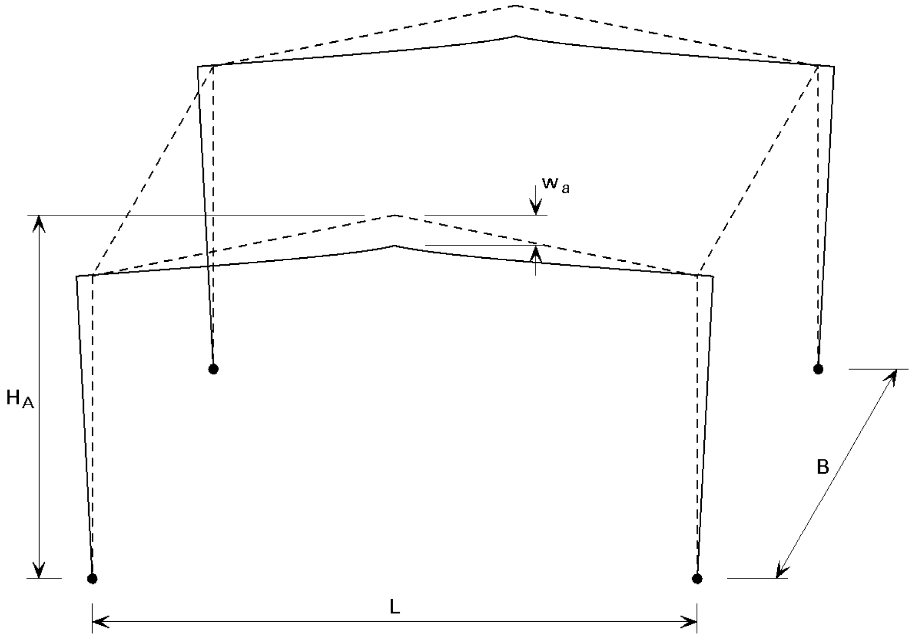


Figure 3.1 Definitions of vertical deflection of apex of portal frame

Recommended limiting values for vertical deflection are given in Table 3.1

Deflection limits for single storey buildings

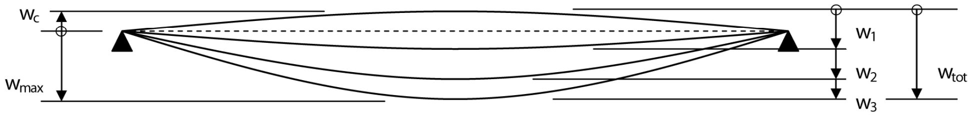
Table 3.1 Vertical deflection limits

Country	Structure	Deflection limits w_{max}	w_3	Comments
France	Roofs in general	L/200	L/250	The values to the left are given in the National Annex to EN 1993-1-1 and should be used if nothing else is agreed with the client.
	Roofs frequently carrying personnel other than for maintenance	L/200	L/300	The values of the deflections calculated from the characteristic combinations should be compared to these limits.
	Roofs supporting plaster or other brittle toppings or non-flexible parts	L/250	L/350	
Germany				There are no national deflection limits. The limits should be taken from manufacturers instructions (technical approvals) or should be agreed with the client.
Sweden				There are no national deflection limits.
UK	Portal frames without gantry cranes, with rafter slopes 3'			There are no national deflection limits. These figures are recommended in industry guidance [6].
	Differential deflection relative to adjacent frame			
	- metal sheeting and fibre reinforced sheeting	$\frac{B}{100}$		
	- felted metal decking on purlins	$\frac{B}{100}$		
	- felted metal supported on rafters	$\frac{B}{200}$		

4. Vertical deflections for horizontal roof members

4.1 Serviceability limit states

Guidance for the deflection limits are given in Table 4.1 for a selection of countries.
Definition of vertical deflection in Annex A to EN 1990 is shown in Figure 4.1



w_c : precamber in the unloaded structural member

w_1 : Initial part of the deflection under permanent loads of the relevant combination of actions

w_2 : Long-term part of the deflection under permanent loads, not to be considered for single storey steel buildings,

w_3 : Additional part of the deflection due to the variable actions of the relevant combination of actions

$w_{tot} = w_1 + w_2 + w_3$

w_{max} : Remaining total deflection taking into account the precamber

Deflection limits for single storey buildings

Table 4.1 Recommended limiting values for vertical deflections

Country	Structure	Deflection limits		Comments
		Wmax	W_3	
France	Roofs in general	L/200	L/250	The values to the left are given in the National Annex to EN 1993-1-1 and should be used if nothing else is agreed with the client.
	Roofs frequently carrying personnel other than for maintenance	L/200	L/300	The values of the deflections calculated from the characteristic combinations should be compared to these limits.
	Roofs supporting plaster or other brittle toppings or non-flexible parts	L/250	L/350	
Germany				There are no national deflection limits. The limits should be taken from manufacturers' instructions (technical approvals) or should be agreed with the client.
Spain	Roofs in general	L/300(*)	-	The values to the left are given in the national technical document for steel structures [4] and in the Technical Building Code [5] and should be used if nothing else is agreed with the client.
	Roofs with access only for maintenance	L/250(*)		
Sweden				There are no binding restrictions.
UK	Roofs with access for maintenance	-	L/200	There are no national deflection limits. The figures presented are taken from industry guidance [6].
	Roofs accessible to personnel other than for maintenance	-	L/360	

(*) This values refers to $w_2 + w_3$ but $w_2 = 0$ for steel structures.

4.2 Ultimate limit state: Ponding

Where the roof slope is less than 5%, additional calculations should be made to check that collapse cannot occur due to the weight of water :

either collected in pools which may be formed due to the deflection of structural members or roofing material,

or retained by snow.

These additional checks should be based on the combinations at the Ultimate Limit States.

Precambering of beams may reduce the likelihood of rainwater collecting in pools, provided that rainwater outlets are appropriately located.

Examples

11 documents

- **Determination of loads on building envelope**
- Plastic design of single bay portal frame – class 1 rolled sections
- Plastic design of single bay portal frame – class 2&3 rolled sections
- Elastic design of a portal frame – class 4 sections
- Truss and post single bay, low pitch roof
- Portal frame eaves connection – end plate and haunch
- Portal frame pinned base connection
- Truss/post end connection
- Bracing/wind frame connections
- Rolled section purlin
- Design of gable wind posts