Eurocode Portal Frame Complimentary Information Document

1. Introduction

With the publication of SCI design guide P399 Design of Steel Portal Frames Buildings to Eurocode 3 along with the additional design guides of SCI P397 - The elastic design of single span portal frames to EN 1993-1- 1, The Tekla Portal Frame program can now be upgraded to contain a "Eurocode" Code design variant.

2. Scope

Essentially the methodology, analysis and design process still adopts the original British Standard practices and has not changed, the Eurocode variant applies many changes at the "design" detailed level.

Areas of the program which are not affected by the adoption of the Eurocode variant are:

1. Hinge History - Analysis
2. Serviceability Limit State + Checks - Analysis and Limit Checks
3. Base Loads - Analysis Reporting
4. Connection Forces - Analysis Reporting
5. Foundation Loads - Analysis Reporting

3. Limitations & Assumptions

3.1 Analysis - Adoption of SCI P292

The SCI publication P292, “In-plane stability of portal frames to BS 5950-1: 2000” uses fundamental energy methods to specify an approach to second-order elastic-plastic analysis suitable for portal frame design. This is encapsulated in Tekla Portal Frame especially for the British Standard design.

Despite the title "BS 5950-1: 2000” in the aforementioned publication, this approach is code independent since it starts from first principles. As such it is asserted that this method complies with the requirements of EC3 with regard to this type of second-order analysis.

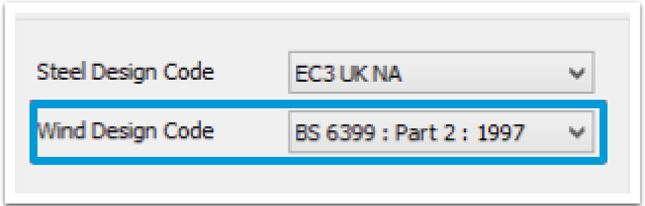
4. Design Philosophy

The methodology of modelling, loading, analysing and designing (ULS + SLS) from the British Standard variant has not changed and the same process has been adopted to design portal frames to Eurocode.

1. Analysis method take into account little and big P delta effects
2. Global imperfections are taken into account with the use of EHF's - Equivalent Horizontal Forces
3. Design checks of "Strength", In Plane Frame Stability and "Out of Plane buckling" (Member Stability) are adopted to Eurocode codes of practice.

5. Loading

When the Eurocode code of practice has been selected ("design" drop down - design code) the wind code option will still give the British Standard variant listed - this can be ignored as there is no automatic Frame Loading for Eurocode wind



5.1 Load cases

All loading and loading configuration types exist as per the British Standard variant

1. Dead
2. Imposed
3. Wind
4. Crane
5. Snow

Except for the following areas

1. Frame Wind Loading - it is disabled i.e. icon and menu option greyed out
2. Frame Snow Loading - it is disabled i.e. icon and menu option greyed out
3. Fire Base Design (Portal Wizard) Disabled - No Eurocode methodology to adopt

5.2 Combinations

Combination load factors will be defaulted appropriately to those for EN 1990. Additional information is required regarding generating combinations for crane/snow loadcases types if they are added. The defaulted load factor may require user editing.

6. Materials

Materials/Section Information If the Eurocode code variant is adopted at the start of the project - the correct Eurocode data (Materials/Section) information is applied.

If the model is already established and the code variant changed to Eurocode - model material and section information must be re-applied to establish correct data for the variant- please see section 11.

7. Analysis

7.1 Base Stiffness

No change - exactly the same as the British Standard variant.

This is covered in Section 7.3 of SCI P399 and allows the same approach to base stiffness as given in BS 5950 and as currently encapsulated in Portal Frame. One exception is the use of 'nominally fixed' bases which are not mentioned in SCI P399 although 'rigid' bases are discussed but are not recommended. The reader is directed to NCCI SN045a and this does cover nominally fixed bases used in both elastic and elastic-plastic analysis and is described with the exact words found in BS 5950.

7.2 Imperfections

The requirements of EC3 Clause 5.3.2, dealing with global imperfections (similar with 'frame imperfections') will be met again using Equivalent Horizontal Forces (EHFs) as in the BS 5950 version. The user will be able to apply these left to right (L to R) or right to left (R to L) and it is the user's responsibility to add these into design combinations in a manner appropriate to the requirements of EN 1990.

Note EHF's are not automatically transferred via Tekla Structural Designer - therefore, they must be manually added to the combinations as appropriate to those for EN 1990 - please see section 10

7.3 Equivalent Horizontal Forces (EHF's)

The 'base' value of the EHFs are determined in the same way as BS 5950 i.e. 0.5% of the gravity loading in a combination. In EC3 an adjustment is allowed to the 'base' value for the height of the structure, alpha-h, and for the number of columns contributing to the lateral load resisting system, alpha-m.

With no provisions to adjust these values in portal frame program, the user must manually adjust the combination load factor to accommodate alpha values.

Considering a minimum of 5.3 m to eaves and not less than two columns contributing to the lateral stability, i.e. single span conventional portal frame. The combined value of alpha-h x alpha-m is then 0.75.

Note that the minimum and maximum reduction can lie within 0.87 and 0.51.

7.4 In-plane Sway Stability - Comparison with British Standard Options

a. Notional Sway Method - Option Removed

Covered in Clause 5.2.1 which in essence states that second-order effects may be ignored providing the alpha-critical value is less than a certain limit. The limit is different for elastic and plastic analysis. However, this approach will not be implemented in the EC3 version of Tekla Portal Frame because typical portals may fall foul of its upper limit and lower limits in its application given in EC3 (requires more information)

OPTION REMOVED

b. Formula Sway Method - Option Removed

No methodology of adopting this sway stability method in Eurocode

OPTION REMOVED

c. P292 - Option Adopted

As mentioned before The SCI publication P292 is design code independent and therefore suitable for a second order analysis procedure

OPTION ADOPTED

d. Amplified Moments Method - Option Adopted

The British Standards version uses a Merchant Rankine method of linking the second order collapse factor to the first order value and the elastic critical buckling of the frame.

If the first order collapse factor is less than Lambda_r, the load factor, the frame will fail.

The method is valid down to Lambda_cr (Elastic critical buckling factor) of 4.6. (note this value is adjustable in the design wizard of the program)

For reference the BS 5950 formula for Lambda_r is the load factor and given by;

Lambda_r = 0.9 Lambda_crit/(Lambda_crit – 1)

Where Lambda_crit - is the Elastic Critical Buckling Factor obtained by the solver.

In the EC3 variant Lambda_r becomes Alpha_r and Lambda_crit becomes Alpha_Cr

SCI P399 recommends the use of the modified Merchant Rankine approach given in the paper by Lim et al - Lim et al. Eurocode 3 and the in-plane stability of portal frames, Journal of the I Struct E, November 2005, p43-49

This approach has a number of limitations that must be respected.

1. Span over height to eaves for any span in the frame is ≤ 8.0
2. The elastic critical buckling load factor (Alpha_cr in EC3 variant) for the particular design combination, Alpha_cr > 3.0 (greater than 3.0) - can be user defined in the design wizard.
3. Portal geometry which no span contains a tie

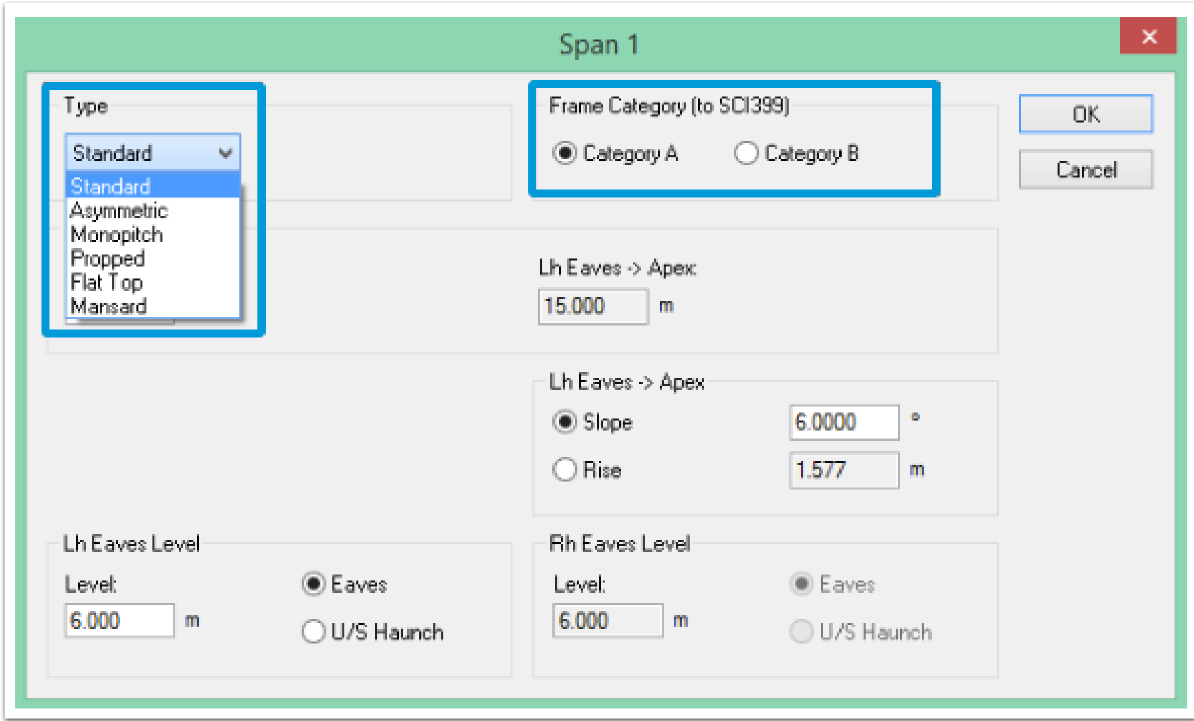
Calculation of Amplifier

The portal frame model must be categorised as there are 2 equations for the amplifier

- Category A, regular symmetric and asymmetric, pitched and mono-pitched portals which can be either single span or multi-span providing the height and span of each span in the frame varies little (10% is suggested).
- Category B, all other frames.

In the context of Tekla it is clear that frame types 'Propped', 'Flat topped' and 'Mansard' would be Category B.

It is up to the user to define the frame on the Edit Span page, where defining the type will set the category, But for a multispan portal user engineering decisions is required



For Frame Types, Standard, Asymmetric and Monopitch, default Category A and for the remainder default Category B.

The formulae for Alpha_r are,

Alpha_r = Alpha_cr /(Alpha_cr – 1) for Category A frames

Alpha_r = 1.1 Alpha_cr /(Alpha_cr – 1) for Category B frames

OPTION ADOPTED

8. Member Strength Design Checks (Strength)

8.1 Classification

Class 4 sections are not allowed

Plastic hinge formed under the load factor of 1.0 - section must be class 1 or 2

If frame is purely elastic - class 1, 2 or 3 sections can be used

8.2 Shear Resistance

EC standard shear and shear buckling checks on the haunch and uniform section

8.3 Moment Resistance

EC standard moment checks on the haunch and uniform section including provisions for high shear

8.4 Axial Resistance

EC standard axial checks on the haunch and uniform section including provisions for both axial tension and compression

8.5 Combined Axial and Bending

EC combined axial and bending checks are performed on the haunch, uniform section of the column and rafter

9. Member Stability in Comparison with British Standards

9.1 Restraints type summary

Type	Comment
O\S Flange	Used as an end restraint for the elastic checks when the outside flange is in compression and as an intermediate restraint for Annex G Elastic and Plastic.
I\S Flange	Used as an end restraint for the elastic checks when the inside flange is in compression and as an intermediate restraint for Annex G Elastic and Plastic.
Torsional	Used as an end restraint for all checks and as an intermediate restraint for Annex G Elastic and Plastic.
Contra-flexure	The point of contra-flexure can be used in the same way as a torsional restraint. Note point of contra-flexure will alter position per combination

9.2 Stability check summary

a. Elastic Checks - Equivalent EC checks below

	Check	Restraints	Comment	Formula
BS Check ↓	BS 4.8.3.3.1	comp. flange (or torsional)	Tapered & uniform sections	$F_c/P_c + m_{LT}.M_{LT}/M_b \leq 1$
EC Check	Elastic Tapered	comp. flange (or torsional)	Tapered and uniform sections	$N_{Ed}/N_{b,z,Rd} + M_{y}/M_{b,Rd,i} \leq 1.0$
BS Check ↓	BS 4.8.3.3.2	comp. flange (or torsional)	Uniform sections	$F_c/P_c + m_{LT}.M_{LT}/M_b \leq 1$
EC Check	Elastic Equ.6.62	comp. flange (or torsional	Uniform sections	$N_{Ed}/N_{b,z,Rd} + M_{y}/M_{b,Rd,i} \leq 1.0$
BS Check ↓	BS Annex I1	comp. flange (or torsional)	Uniform sections without axial tension. Not Class 3 (semi-compact) sections. Generally longer stable lengths than 4.8.3.3.1 or 2.	$m_{LT}.M_{LT}/M_{ab} \leq 1$
EC Check	No Equivalent EC Check	N/A	N/A	N/A
BS Check ↓	BS Annex G Elastic	Torsional with 1 intermediate comp restraint	Requires at least 1 intermediate restraint. Intermediate length checks to 4.8.3.3.1/2, or Annex I1 Elastic zone only.	$F_c/P_c + m_t.M_x/M_b \leq 1$
EC Check	Elastic App. C SCI P399	Torsional with 1 intermediate restraint	Requires at least 1 intermediate restraint. Can be used for tapered sections Elastic zone only	NEd/ Nb,z,Rd + Myi/ Mb,Rd,i ≤1.0
	No Check Req'd	any	no restrictions - rarely used!	

b. Plastic Checks - Equivalent EC check below

	Check	Restraints	Comment	Formula
BS Check ↓	BS 5.3.3	comp. flange (or torsional)	Generally short stable lengths. Stable length enhanced if moment drops by 50% - does not apply in haunches. Allowed in both elastic and plastic zones..	Length ≤ Lm
EC Check	Plastic, Ann. BB.3 Lm	Between torsional, compression and intermediate restraints	$L_m = 38 \times i_z / [(N_{Ed}/(A \times 57.4)) + 1/(756 \times C_1^2) \times (W_{pl,y}^2/(A \times I_t)) \times (f_y/235)^2]^{0.5}$	Length ≤ Lm
BS Check ↓	Annex G Plastic	Torsional with 1 intermediate restraint	Requires at least 1 intermediate restraint. Intermediate length checks to 4.8.3.3.1/2 or Annex I1. Intermediate length next to a hinge checked to 5.3.3 - except if the length is an elastic haunch. Allowed in both elastic and plastic zones.	Length ≤ L_s
EC Check	Plastic, Ann. BB.3 Ls	Between torsional, compression and intermediate restraints	$L_s \le \sqrt{(C_m)} \times L_k \times (M_{pl,y,Rk}/(M_{N,y,Rk} + a \times N_{Ed}))^{0.5}$	Length ≤ L_s

10. Integration with Tekla Structural Designer

10.1 Use with Tekla Structural Designer

Tekla Structural Designer with the use of the combination generator will create combinations with EHF's and wind as per the requirement of EC 0. All combinations will be exported across, along with the combinations titles. But please note the EHF loadcases will be stripped out of the included selection.

Loadcases

All loadcases will be exported to the portal frame program where the user can establish his own combinations.

EHF's loadcases are not generated in the gable direction - therefore the only directions applicable are L>R and R>L

10.2 Imported Combinations

All combinations are exported - but no EHF values from Tekla Structural Designer are retained

10.3 EHF's

The 'base' value of the EHFs are determined in the same way as BS 5950 i.e. 0.5% of the gravity loading in a combination. EC 0 allows for an adjustment for the height of the structure and the contributing columns in the load resisting system. Please see section 7.3

The adjustment factors of alpha-h x alpha-m are not automatically included in the EHF calculation therefore the user must adjust the combination factor of safety manually if alpha values are to be included.

11. Considerations when changing Codes of Practice (within Portal Frame)

11.1 Material properties

When Changing from a BS to an EC design with already confirmed geometry, the material grade needs to be changed and re-applied

11.2 Sectional Properties

When changing from a BS to an EC design with already confirmed geometry, the sectional sizes in the frame need to be changed and re-applied or the frame set into "Auto Design" mode

11.3 Load cases

All loadcases are retained but the "type" may to change regarding the EC variant

11.4 Combinations

All combinations are retained but the safety factors will still relate to the previous BS code and will have to be changed manually

11.5 EHF's

EHF's once applied to the BS code will be retained when the code changes to EC (but new EHF's values applied)

11.6 Wind

Any previous generated wind loading from the BS modules will be retained when changing to EC - the user must manually delete this wind load from the loadcases and combinations and manually applied them.

Note that the BS wind loading is a valid "loadcase" within the program and can be analysed and designed, but will be generated to the wrong design code and cannot be edited.

12. Connection Export

12.1 Moment Connections To Eurocode

Connections are Exported

12.2 Base Plate Connections To Eurocode

Connections are Exported