
European Commission
Research Programme of the Research Fund for Coal and Steel
Technical Group: TGS8 Steel products and applications for buildings, construction
and industry

Steel cladding systems for stabilization of steel buildings in fire
STABFI

Project Coordinator: Kristo Mela, Assistant Professor of Metal Structures
TUT, Tampere University of Technology, TTY-SAATIO
Korkeakoulunkatu 10, TAMPERE 33720, Finland, FI22861063

Other beneficiaries:

- CVUT, CESKE VYSOKE UCNI TECHNICKE V PRAZE, Czech Republic
- CITY, CITY UNIVERSITY OF LONDON, United Kingdom
- BME, BUDAPESTI MUSZAKI ES GAZDASAGTUDOMANYI EGYETEM, Hungary
- BTU, BRANDENBURGISCHE TECHNISCHE UNIVERSITAT COTTBUS-SENFTENBERG, Germany
- RUUKKI, RUUKKI CONSTRUCTION OY, Finland
- KINGSPAN, KINGSPAN A.S., Czech Republic
- HAMK, HAMEEN AMMATTIKORKEAKOULU OY, Finland
- SFS, SFS INTEC OY, Finland

Grant Agreement Number: 751583 – STABFI – RFCS-2016

STABFIsoft User Guide

Authors: Zixiao Wang and Kuldeep S. Virdi
City, University of London

Reporting period: 01.07.2017 – 31.03.2020

Table of Contents

INSTALLATION	3
1. Introduction	4
2. Basic input required	4
3. Output	4
4. Input Modules pertinent to Column Design.....	5
Module 1 : Material of Main Member and Temperatures.....	5
Module 2. Section of Steel Member.....	6
Module 3. Sandwich Panels	7
Module 4. Fasteners for Sandwich Panels.....	8
Module 5. Trapezoidal sheets	9
Module 6. End conditions of main member being stabilized	10
Module 7. Design of Columns.....	12
Module 9. Printout of results	13
5. Worked Example.....	15
Column stabilised with sandwich panel at elevated temperatures.....	15
6. Example of Output from STABFIsoft	16
References	18
Appendix 1 - List of symbols and variables	19
Appendix 2 - Module 8. Design of Beams	21

INSTALLATION

The program STABFIsoft runs under MS Windows. It has been tested to run only under Windows 10. The program is distributed as a single zipped file. It is necessary to unzip the file in a folder as specified below.

Create a folder C:\Temp if it does not already exist. Unzip the file STABFIsoft.7zip using any suitable software (7-Zip, Winrar, etc.) and direct the output to the folder (C:\Temp). It is important all the unzipped files to be in the program folder (C:\Temp).

EXECUTING THE PROGRAM

Clicking on the file STABFIv01.exe starts the program.

Please note that there is a delay of about half a minute before the first screen shows. Please follow the steps described in the main document.

SUPPORT

The program is designed expecting the user to use the menu items from left to right. If a step is missed and calculations are attempted for a later screen, some errors may appear in a background dark window. These may be ignored – please simply return to the step which was missed and continue. The program is robust and will not crash.

If help is needed please contact (by e-mail only): k.s.virdi@city.ac.uk

DATA ARCHIVING

Once the data has been entered, the user may save the data in a file with a suitable filename. This file can be re-opened for later use. When running a number of cases, a previously saved file may be opened, edited, and saved with a new name.

RESULTS

Apart from showing the results on the screen, a text file of the calculations is available under the last menu item. This file is always labelled 'Results.txt'. It is recommended that after each case is run, the file is renamed manually, perhaps linking the name with the name of the input file.

1. Introduction

The STABFIsoft application has been developed using Python 3 language with Python's standard GUI (graphical user interface) package Tkinter for integrated design of a single column stabilised with sandwich panels or trapezoidal sheets. The software does include the design of a single beam stabilised with sandwich panels or cladding, but in the absence of validation, the procedure has been described in an appendix.

This user manual is organized in nine separate sections corresponding to the nine modules of the software, namely, Material, Section, Sandwich Panels, Fasteners for Sandwich Panels, Trapezoidal sheeting with fasteners, End Conditions of main members, Column Design to EC3 Part 1-2, Beam Design to EC3 Part 1-2, and Output.

Specifically, the proposed design rules cover the following:

- Columns stabilised with sandwich panels
- Columns stabilised with trapezoidal sheeting

As stated above, the modules on Beam design are presented in Appendix 2.

It is imperative that the user reads the Design Guide and understands the assumptions and procedures described therein before attempting to use the software for design.

A worked example is included in Section x as an illustration of using the software.

2. Basic input required

The user should have the following information available:

- Main member – this can be a standard rolled section or a rectangular hollow section
- The sandwich panel or trapezoidal sheeting
- Fasteners
- Temperatures in the main member, panel steel and the fastener
- End condition of main member

Once all the data has been entered in the program, it is possible to save the input using the File | Save option. The user can give the file a meaningful name. Any saved file can be opened subsequently using the File | Open option.

3. Output

Results are displayed on screen as the analysis progresses. A text file of results can also be generated using the step described in Module 9 of the program.

4. Input Modules pertinent to Column Design

Module 1 : Material of Main Member and Temperatures

In the first module, for the main member (column or beam), mechanical properties of steel such as yield strength f_y and Young's modulus E_s are to be entered. The user may select standard grades or may specify a value. The latter option is useful when checking for experimental results.

Materials for panels and fasteners are defined later in the program.

In addition, the user specifies the temperatures at which the mechanical properties of steel are to be evaluated. These temperatures are required for the main member, the panels and the fasteners. Guidance has been given in the Design Guide for obtaining the temperatures in the structural components – the main member, the panel and the fastener. It should be noted that the temperature range for all steels is between 20°C and 1200°C in accordance with Eurocode 3 Part 1.2 (EN 1991-1-2:2002).

The user is presented with the form shown in Figure 1.

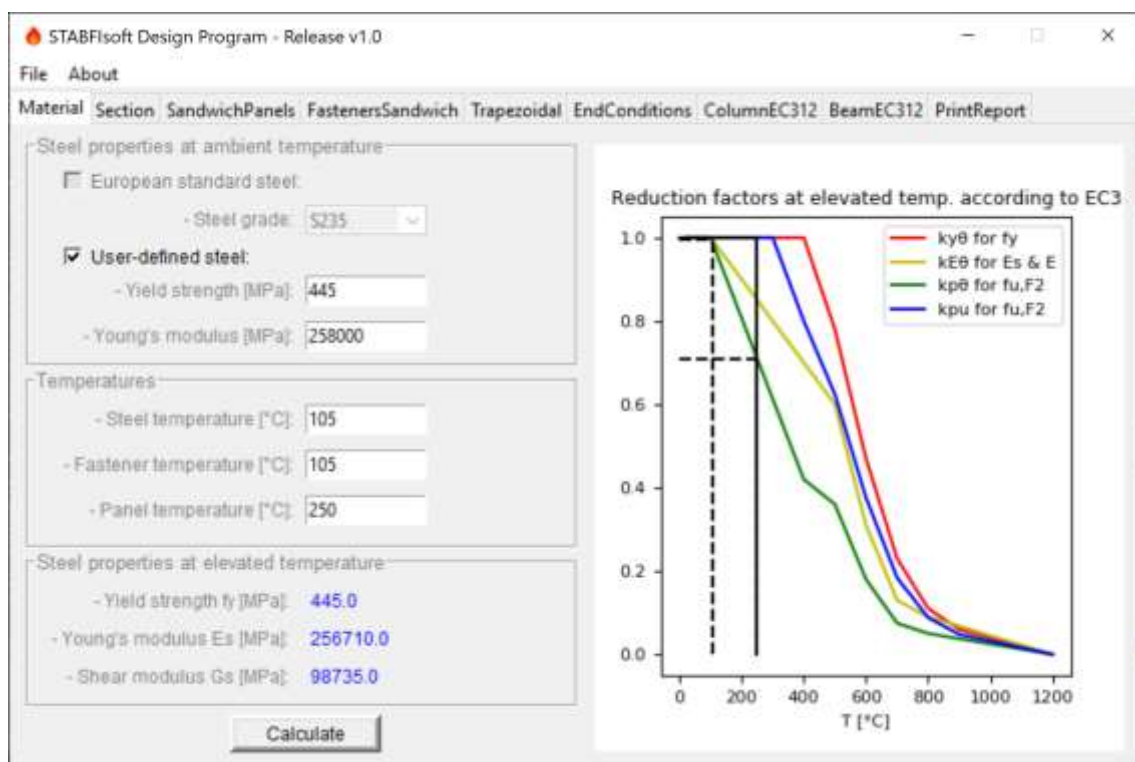


Figure 1 - Form for Main member steel grade and temperatures of main steel, panel and fastener

The reduction factors for the steel of the main member at temperature applicable to f_y or E_s of the main member at 20°C are calculated using k_y or k_E , respectively, as listed in

Table 3.1 of (EN 1993-1-2, 2005). For intermediate value of temperatures, the software uses linear interpolation to obtain the reduction factors. The reduction factors for the fastener at its temperature are calculated using k_p as determined in the project, also from Table 3.1 of (EN 1993-1-2, 2005).

On pressing the button, the values of yield stress, elastic modulus and the shear modulus for the main member at the specified temperature are displayed. As supplementary information the interpolation is also displayed in the graph. For the cladding steel and the fastener, relevant values are displayed in later modules.

It should be noted that the program requires the button to be pressed even when using a previously saved data which has been read using File | Open.

Module 2. Section of Steel Member

In this module, shown in Figure 2, section properties of the main steel member are defined. The software provides two options for entering a section. Standard sections can be selected from a drop-down list. Alternatively, a user defined section may be entered by manually entering each and every property that is required for the design.

The screenshot shows the 'Section' module of the STABFIsoft Design Program. The 'Euro standard section' is selected, and 'HEA120' is chosen from the drop-down list. The 'User-defined sections' area is also visible with various input fields for H, W, T, Tw, A, Iyy, Izz, Jt, Wyy, Wzz, Iw, and Buckling curve. The 'Section properties of specified section' are displayed at the bottom.

Section properties of specified section	
- Sectional area A [mm ²]:	2534
- Moment of inertia Iyy [mm ⁴]:	6062000
- Elastic modulus Wel,y [mm ³]:	106300
- Elastic modulus Wel,z [mm ³]:	38480
- Warping constant Iw [mm ⁶]:	6285000000
- Moment of inertia Izz [mm ⁴]:	2309000
- Torsional constant Jt [mm ⁴]:	59570
- Plastic modulus Wpl,y [mm ³]:	119500
- Plastic modulus Wpl,z [mm ³]:	58850

Figure 2 - Selection of main steel member

To define a standard section, user first ticks the checkbox within the “Euro-standard-sections” frame to activate a drop-down list, that has built-in standard sections for the user to choose from. Various types of standard sections, e.g., IPE, IPN, HEA, HEB, HEM, HD, UB, UC, UBP, HFSHS, HFRHS, CFSHS, CFRHS, are included in the program. Based on the selection, sectional properties are automatically retrieved by the software and displayed within the “Sectional properties of specified section” frame as shown in the **Error! Reference source not found.** above for the selected section.

To enter a user-defined section, the user first needs to uncheck the “Standard section” checkbox and tick the “User defined” checkbox to activate the related entry widgets. The user then needs to select from one of the two section types (by left-clicking the corresponding button) to tell the software whether the section to be defined is a welded flange section or a hollow box . The user only needs to enter section dimensions such as height H , width W , flange thickness t_f , and web thickness t_w , and all sectional properties are automatically computed by the software.

Module 3. Sandwich Panels

If using sandwich panels, Module 3 and Module 4 are used to enter input data for the panel and fastener respectively. If using trapezoidal panels, these two modules should be skipped.

Figure 3 - Form for defining sandwich panels

In the “Sandwich Panel” module (**Error! Reference source not found.**), user defines the properties and dimensions of sandwich panels that are used to restrain/brace the steel member within the plane of panels.

The software provides two options for defining the sandwich panel. A drop-down list enables commercially available sandwich panels to be selected as well as user-defined panels. To select a pre-manufactured sandwich panel, user first ticks the <commercially available panels> checkbox. Currently, sandwich panels manufactured by Ruukki and Kingspan are available. The user will then need to select the panel width B in the <panel width> drop-down list. In addition, three coating options are provided for all panel systems. The grade of the steel sheet is selected using another drop-down list. At present, if the user wishes the steel strength to be different from the manufacturer’s specified steel grade, for example when using experimentally obtained values, the user-defined option must be chosen and the steel strength entered as shown.

To manually define a sandwich panel, user needs to uncheck the “commercially available panels” checkbox, and then tick the “User-defined panels” checkbox to activate the related entry widgets. The four parameters needed to be entered in this case are panel thickness D , panel width B , internal sheet thickness t_{F2} , and coating thickness t_{Zinc} as shown in **Error! Reference source not found.** Note the entered value of panel thickness D must not be smaller than 40mm, whereas the value of core/net thickness of internal sheet $t_{cor,F2}$ must be within the range from 0.4mm to 1.0mm. Should the entered values of these two parameters fall outside the limits, the software will display a warning message. These limits arise from ECCS Recommendations (ECCS, 2014).

Module 4. Fasteners for Sandwich Panels

In this module shown in Figure 4, the user defines parameters of the primary/main fasteners that are used to connect the sandwich panels to the supporting steel member. The two most important geometric parameters to be entered are the threaded diameter d_1 and the shank diameter d_s . The latter must be within the range of 5.5mm to 8.0mm to accord with ECCS Recommendations (ECCS, 2014).

Even though it would be rare to use more than 2 pairs of fasteners, the software allows up to 4 pairs of fasteners per panel, (by selecting from the <number of pairs of fasteners> drop-down list. The user also needs to specify the vertical distances between *each* symmetrical connector pairs by entering the values of distance in the ck_1 , ck_2 , ck_3 , and ck_4 entry boxes accordingly. Note the values of ck_1 , ck_2 , ck_3 , and ck_4 must satisfy following condition: $B > ck_1 > ck_2 > ck_3 > ck_4$, otherwise the software will display a warning message.

Once the above parameters are provided correctly, the user needs to specify the flange thickness of supporting steel member $t_{cor,sup}$ in the corresponding entry box. Note the value of thickness must be within the range of 1.5mm to 10.0mm, outside which the calculation will not continue. For larger thicknesses, the software will proceed using the upper limit of thickness, i.e., $t_{cor,sup} = 10.0\text{mm}$, for design. For standard sections, this value is automatically retrieved from the section properties database.

Using the temperature for the panel, specified in the first form, the form also displays the reduction factor k_p from Table 3.1 of (EN 1993-1-2, 2005) that would be applied to the strength of the panel. The background to this is explained in Part 1 of this deliverable (Virdi & Ma, 2020).

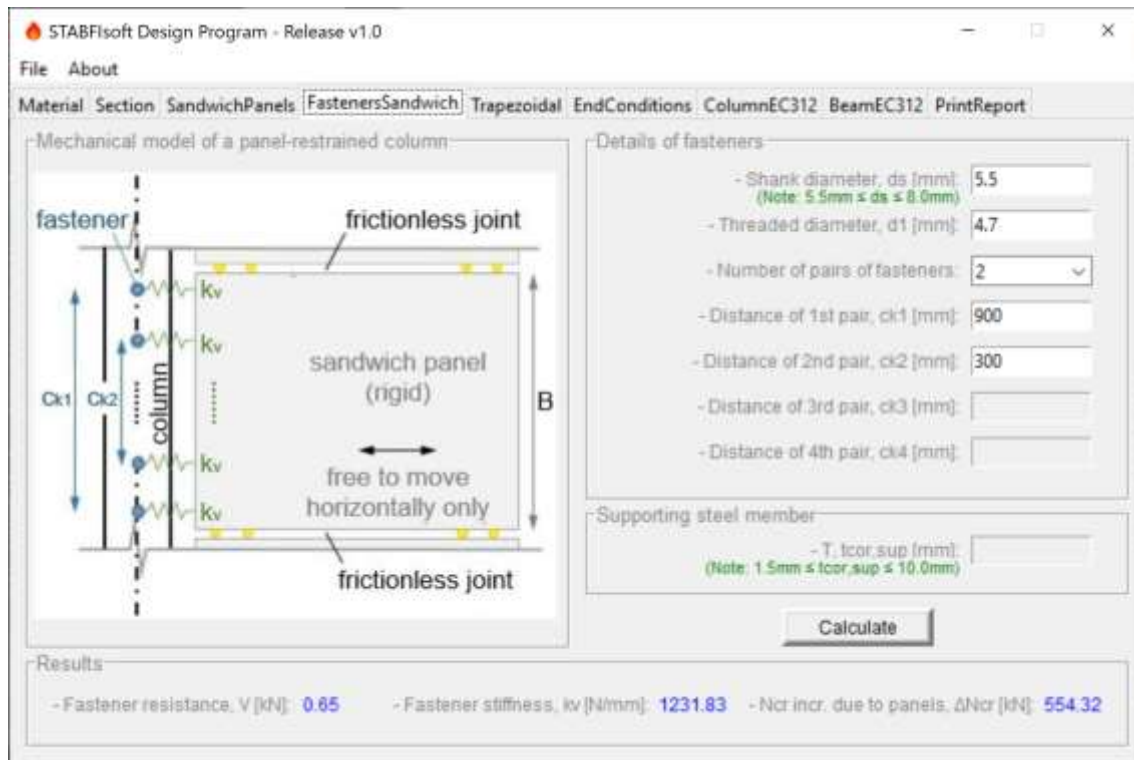


Figure 4 - Graphical user interface of <fastener> module

Once all entries are completed, the user clicks the **Calculate** button, and the software will compute and return fastener shear resistance, the shear stiffness per fastener k_v in [N/mm] as well as the increase in the *increase* in critical buckling load of the steel column due to the restraining effect of sandwich panels ΔN_{cr} [kN] using the formulae described in the Design Guide (Virdi & Ma, 2020). These formulae are the same as in ECCS Recommendations (ECCS, 2014), modified for the effect of temperature.

Module 5. Trapezoidal sheets

If trapezoidal sheets are used to stabilise the structure, instead of Module 3 and Module 4, data are entered in Module 5. Data for both the trapezoidal sheet and related fasteners are entered in a single module shown in Figure 5.

A drop-down list enables commercially available trapezoidal sheets to be selected. Only two profiles, from the manufacturer Ruukki, with various options in terms of thickness and sheet width are available.

Figure 5 - Trapezoidal sheet and fastener data

The form also requires data for the fasteners to be entered. As for sandwich panel, the two most important geometric parameters to be entered are the threaded diameter d_1 and the shank diameter d_s . The latter must be within the practical range of 5.5mm to 8.0mm.

Module 6. End conditions of main member being stabilized

In this module, the end conditions of steel member are specified. In the case of columns, different end conditions may be specified in different planes (in plane of the cladding and out-of-plane).

For beams, the software can only accept pin-ended conditions at both ends. As stated earlier, the design approach for beams has not been validated.

Six boundary conditions are provided in the software:

- I. free cantilever,
- II. pinned at the bottom end and restrained from rotation at the upper end,
- III. simply supported both ends,
- IV. fixed at the bottom end and restrained from rotation at the upper end,
- V. fixed at the bottom end and pinned at the upper end,
- VI. fixed at both ends

To specify the boundary conditions in the weak plane (about z-z), the user first needs to enter the member length L in the entry box, and then tick the checkbox “About z-z”. Next, the boundary conditions within the weak plane is selected by choosing from one of the six radio buttons (also called option buttons) as shown in Figure 6.

By left-clicking the <Calculate> button, the software will calculate and return the results such as the critical buckling load N_{cr} , and the effective length L_{cr} of member. For the in-plane case (About z-z) the results are presented with and without the restraining effect of sandwich panels as shown in Figure 6.

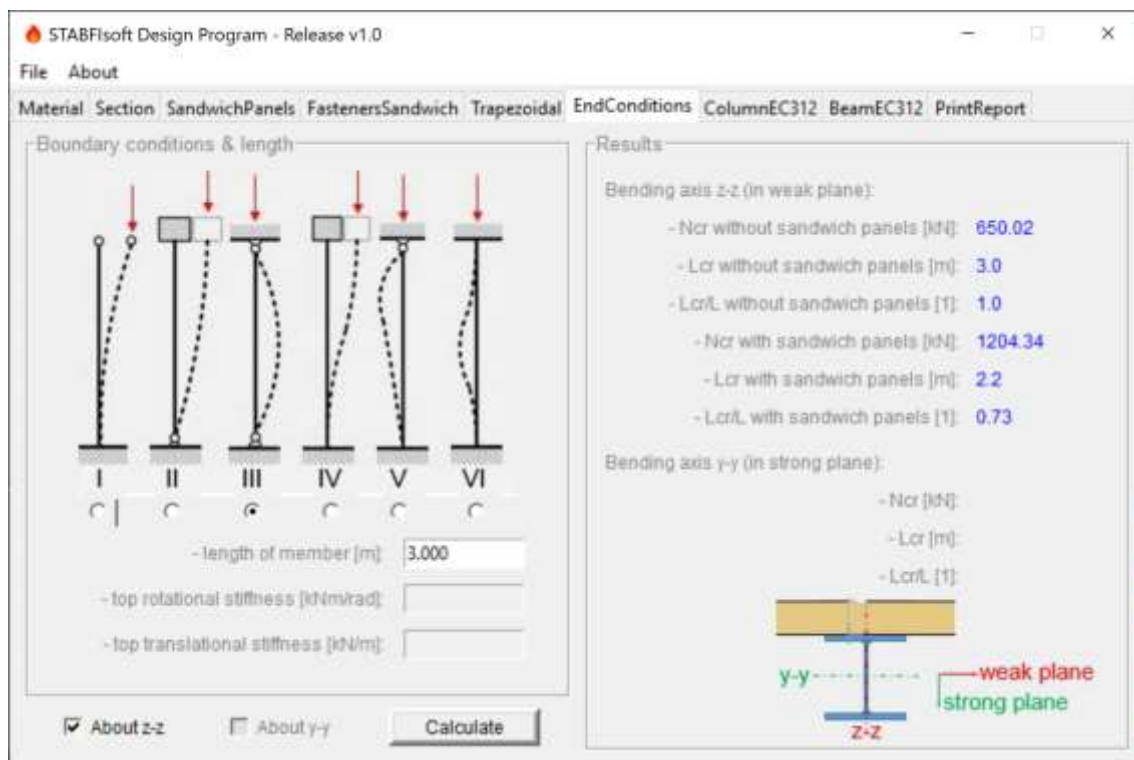


Figure 6 - End conditions form – bending about the z-z axis

The above procedure needs to be repeated for the strong axis, that is buckling about bending axis y-y. Since it is realistic to assume that the sandwich panels only stabilize the steel column within the plane of panels, the critical buckling load N_{cr} and the effective length L_{cr} of the column in the strong plane, that is, about the bending axis y-y, are not influenced by the sandwich panels. Accordingly, the software does not calculate N_{cr} and L_{cr} with sandwich panels in the strong plane.

The results for bending about y-y axis are shown in Figure 7.

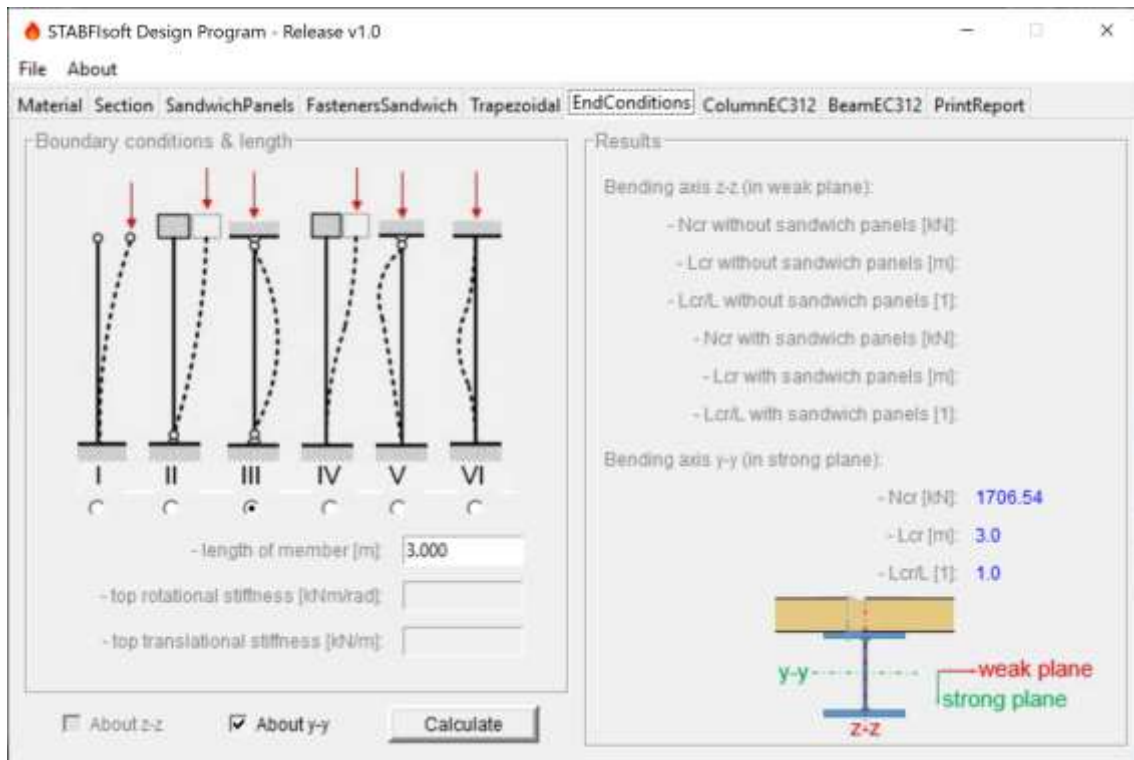


Figure 7 - End conditions form – bending about the y-y axis

Analysis for bending about both axes enables the program to determine which of the two cases gives the lower axial capacity for design using (EN 1993-1-2, 2005).

Depending upon the bending axis selected, the software will only show results either for bending about the z-z axis or bending upon the y-y axis, as selected by the user. Nevertheless, once the results for the two planes are calculated, in any order, they are stored by the software for further calculations.

Module 7. Design of Columns

The input thus far is sufficient to calculate the buckling strength resistance of the steel member in uniform compression taking into account the stabilising effect of sandwich panels using the fire part of Eurocode 3 (EN 1993-1-2, 2005). No further input is required.

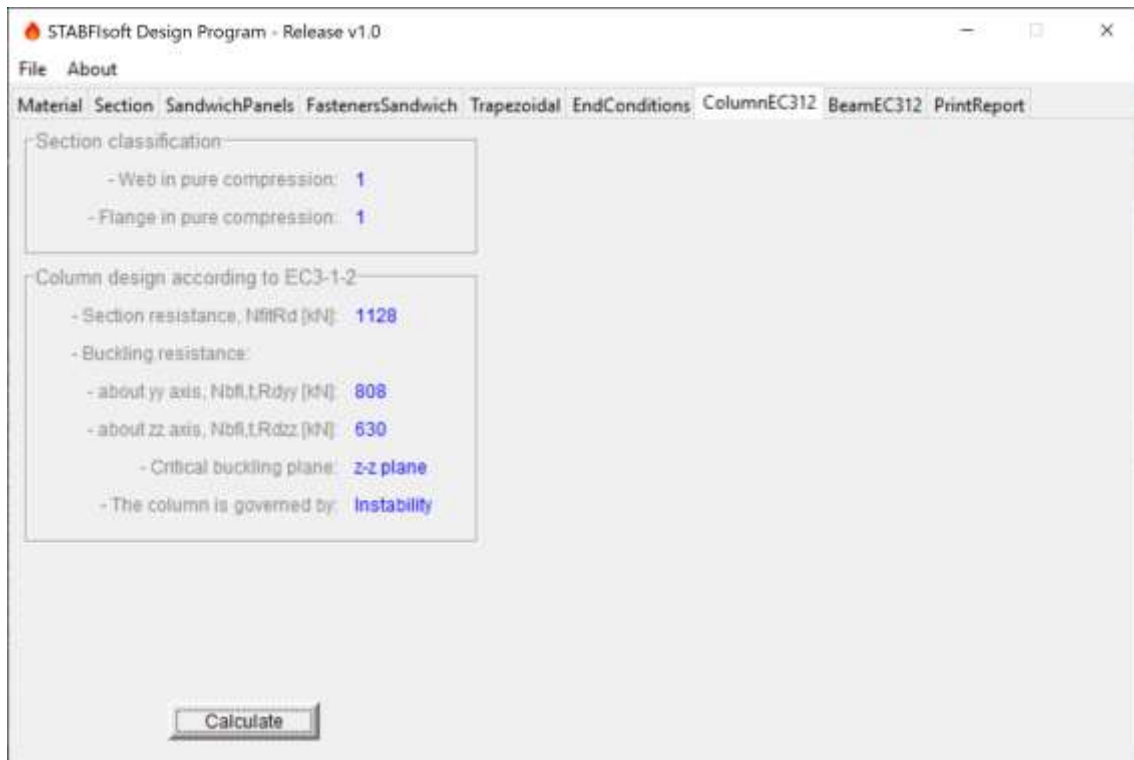


Figure 8 - Section capacity and buckling resistance of steel member in compressions

By clicking the button various results are displayed as shown in Figure 8. These include:

- Section resistance $N_c R_d$.
- Buckling resistance about y-y axis, $N_b R_{d,y}$
- Buckling resistance about z-z axis, $N_b R_{d,z}$

The output also compares the results about the two axes and displays the lower of the resistances about the two axes.

Module 9. Printout of results

A facility is available to create an annotated text file of results as shown in Figure 9. The report is created when button is clicked. The file is always called 'Results.txt'. The user can print, rename and archive the 'Results.txt' file as appropriate.

The form also has a checklist to ensure that the user has gone through all the steps before trying to print the report.

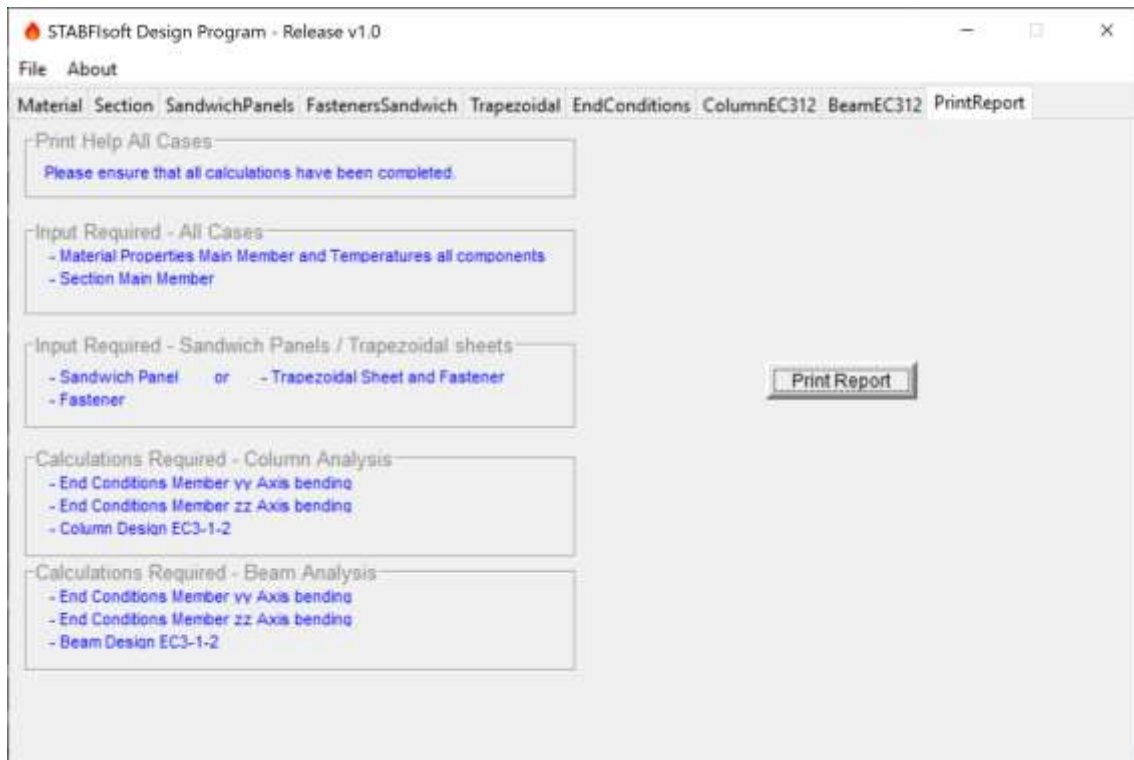


Figure 9 - Form for creating annotated text report

5. Worked Example

Column stabilised with sandwich panel at elevated temperatures

In this section, a worked example is provided to demonstrate the design procedure for evaluating the effective length of sandwich-panel-restrained columns in the plane of panels.

As would be normal, the column is so oriented that its weak direction for bending (about z-z axis) is parallel to the panel plane and is laterally restrained by sandwich panels. The example is based one of the tests (A6) reported in (Joó, Horváth, & Lendvai, 2019). The material properties and temperatures are those measured in the experiment.

Length of the column	3000mm
Cross-section	HEA 120×200×8 mm
Elastic Modulus, E	210000MPa
Second Moment, I_{zz}	$2.309 \times 10^7 \text{mm}^4$
Support	Pinned at the base Pinned at the upper end
Sandwich panel overall thickness	160 mm-thick panel with PIR core
Panel width, B	1000mm
Thickness of inner sheet, t_{F2}	0.4mm
Yield strength of inner sheet, $f_{u,F2}$	280Mpa
Connectors hex cap steel screws	Two pairs
Spacing between the screws, c	300mm
Threaded diameter of the screw, d_1	4.7mm
Shank diameter of the screws, d_s	5.5mm

The failure load of the column as 635kN.

The computer printout for the same problem is listed in below.

6. Example of Output from STABFIsoft

StabFi Software

Printed on = 25-06-2020

MAIN MEMBER

The Section HEA120

Height of the section	D	(mm) = 114
Width of the section	B	(mm) = 120
Thickness of the flange	Tf	(mm) = 8.0
Area of Cross-Section	A	(mm ²) = 2534.0
Second Moment of Area y-y	Iyy	(cm ⁴) = 606.2
Second Moment of Area z-z	Izz	(cm ⁴) = 230.9
Temperature of the section	T	(°C) = 105
Reduced Elastic Modulus (section)	Es,th	(MPa) = 256710.0
Reduced Yield stress of the section	fy,th	(MPa) = 445.0

SANDWICH PANEL

Panel identifier		User Defined
Thickness of Sandwich Panel	d	(mm) = 160
Width of Sandwich Panel	B	(mm) = 1000
Thickness of the steel core	tF2core	(mm) = 0.4
Strength of the core steel	fuF2	(MPa) = 280
Temperature of the panel steel	Tp,th	(°C) = 105

FASTENER

Shank diameter of the Fastener	ds	(mm) = 5.5
Thread diameter of the Fastener	d1	(mm) = 4.7
Number of pairs of fasteners		= 2
Spacing of outermost pair	cK1	(mm) = 900
Spacing of second pair	cK2	(mm) = 300

FASTENER STIFFNESS CALCULATIONS

	E,thI	(Nmm ²) = 8938687.1
	Csup	= 325088.0
	xF	= 1.00552
Fastener Stiffness	kv	(N/mm) = 1231.83

COLUMN DESIGN (Clause 4.2.3.2 EN 1993-1-2)

Column height	L	(mm) = 3000.0
Bending Plane relative to the sandwich panel		: IN-PLANE
Boundary Conditions:		
Both ends pinned		
Nominal Effective Length factor		= 1.0
Critical force without panel	Ncr1	(kN) = 650.0

Increment in critical axial force Δe_{Ncr} (kN) = 554.3
 Critical force with stabilisation N_{cr2} (kN) = 1204.3
 Effective Length with stabilisation $L_{cr2,z}$ (m) = 2.2
 Effective Length factor with stabilisation = 0.73

Plane of Bending relative to the sandwich panel : OUT-OF-PLANE
 Boundary Conditions:
 Both ends pinned

Nominal Effective Length factor = 1.0
 Effective Length $L_{cr1,y}$ (m) = 3.0
 Critical axial force $N_{cr,y}$ (kN) = 1706.5

COLUMN STRENGTH CALCULATIONS

Section Classification - Web : 1
 Section Classification - Flange : 1

Axial Section Resistance $N_{c,fi,Rd}$ (kN) = 1127.6

Buckling about zz axis

Slenderness factor for fire $\lambda_{\bar{m},\bar{n},fi}$ = 0.97
 Reduction factor for buckling, fire χ_{fi} = 0.563
 Axial Buckling Resistance $N_{b,fi,Rdzz}$ (kN) = 635

Buckling about yy axis

Slenderness factor for fire $\lambda_{\bar{m},\bar{n},fi}$ = 0.815
 Reduction factor for buckling, fire χ_{fi} = 0.659
 Axial Buckling Resistance $N_{b,fi,Rdyy}$ (kN) = 743

Lower buckling axial capacity : In-Plane bending
 The column strength is governed by : Instability

END OF PRINTOUT

References

- ECCS. (2014). *European Recommendations on the Stabilisation of Steel Structures by Sandwich Panels*. ECCS, Brussels.
- EN 1991-1-2:2002. (n.d.). *Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire*. Brussels: CEN.
- EN 1993-1-2. (2005). *Eurocode 3: Design of steel structures — Part 1-2: General rules — Structural fire design*. Brussels: CEN.
- Käpplein, S., & Misiek, T. (2011). *EASIE Report No.:D3.3 – Part 2, In-plane shear resistance of sandwich panels*. Karlsruhe: Karlsruher Institut für Technologie.
- Virdi, K. S., & Ma, Z. (2020). *Deliverable 7.1 Part 1 - Design Guide*. London and Hämeenlinna: City, University of London and Hameen Ammattikorkeakoulu Oy, Hämeenlinna.

Appendix 1 - List of symbols and variables

Variables/ symbols	Description	Unit
f_y	Yield strength of steel	[MPa]
E_s	Elastic modulus of steel	[MPa]
T	Temperature of steel, note $20^\circ\text{C} \leq T \leq 1200^\circ\text{C}$	[°C]
H	Section height	[mm]
W	Section width	
T_f	Flange thickness	
T_w	Web thickness	
A	Cross-section area	[mm ²]
I_{yy}	Second moment of inertia about major bending axis y-y	[mm ⁴]
I_{zz}	Second moment of inertia about minor bending axis z-z	
W_{yy}	Appropriate section modulus about y-y	[mm ³]
W_{zz}	Appropriate section modulus about z-z	
J_t	Torsional constant	[mm ⁴]
I_w	Warping constant	[mm ⁶]
D	Sandwich panel thickness, note $D \geq 40.0\text{mm}$	[mm]
B	Sandwich panel width	
t_{F2}	Sandwich panel's internal sheet thickness	
t_{zinc}	Coating thickness of internal sheet	
t_{Tol}	Thickness tolerance of internal sheet	
$t_{F2,\text{cor}}$	Net/core thickness of internal sheet, $t_{F2,\text{cor}} = t_{F2} - t_{\text{zinc}} - t_{\text{Tol}}$, note $0.4\text{mm} \leq t_{F2,\text{cor}} \leq 1.0\text{mm}$	[MPa]
$f_{u,F2}$	Tensile strength of internal sheet	[MPa]
d_1	Threaded diameter of fastener	[mm]
d_s	Shank (unthreaded) diameter of fastener, note $5.5\text{mm} \leq d_s \leq 8.0\text{mm}$	
c_{ki}	Vertical distance between the i -th fastener pair	[mm]
$t_{\text{cor,sup}}$	Net/core thickness of supporting steel member, note $1.5\text{mm} \leq t_{\text{cor,sup}} \leq 10.0\text{mm}$	[mm]
k_v	Shear stiffness per one fastener	[N/mm]
ΔN_{cr}	Increase in the critical buckling load of member due to sandwich panels	[kN]
L	Member length	[mm]
$k_{\text{trans.}}$	Stiffness coefficient of translational/horizontal spring	[kN/m]
$k_{\text{rot.}}$	Stiffness coefficient of rotational spring	[kNm/rad]
N_{cr}	Critical buckling load of member with or without sandwich panels	[kN]
L_{cr}	Buckling length of member with or without sandwich panels	[m]
$N_{\text{c,Rd}}$	Design resistance to normal forces of the cross-section for uniform compression	[kN]
$N_{\text{b,Rd}}$	Design buckling resistance of the compression member	
k_1	Support condition coefficient at the left/upper end of member, $k_1=1.0$ for free lateral bending & warping, $k_1=0.5$ for restrained condition	[1]
k_2	Support condition coefficient at the right/lower end of member,	

	$k_2=1.0$ for free lateral bending & warping, $k_2= 0.5$ for restrained condition	
M_i ($1 \leq i \leq 5$)	Major axis bending moment along the member from the left to right end	[kNm]
M_{\max}	Maximum value of major axis bending moment along the member	[kNm]
M_{cr}	Elastic critical moment for lateral torsional buckling	[kNm]
λ_{LT}	Non-dimensional slenderness ratio	[1]
$M_{\text{c,Rd}}$	Section resistance moments about major and minor bending axis	[kNm]
$M_{\text{b,Rd}}$	Design buckling resistance moment	
α_{h}	the ratio of bending moment at the midspan M_s to that at the upper/left end M_h	[1]
ψ	the ratio of bending moment at the upper/left end to that at the lower/right end of member	[1]
N_{Ed}	Design value of compression force	[kN]
$M_{\text{y,Ed}}$	Design value of major axis bending moment about y-y	[kNm]
$M_{\text{z,Ed}}$	Design value of minor axis bending moment about z-z	

Appendix 2 - Module 8. Design of Beams


For members subjected to major axis bending and with insufficient restraint to compression flange, the user can verify the member against lateral torsional buckling (LTB) using the features provided in the “Beam EC312” module of the software. The form is shown in Figure 10.

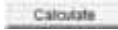
In the design of beams restrained with sandwich panels, the input data is the same as for the design of columns. The beam is assumed to be simply supported.

	y-y	z-z
- Critical M_{cr} for LTB [kNm]	N/A	N/A
- LTB slenderness ratio λ_{LT}	N/A	N/A
- Section resistance $M_{c,Rd}$ [kNm]		
- Buckling resistance $M_{b,Rd}$ [kNm]	N/A	N/A

Figure 10 – Form with computations for the moment capacity of the section

The critical moment M_{cr} enhanced by the restraining effect of the cladding and influenced by changes in material properties due to temperature is calculated using the formula given in the EASIE report (Käpplein & Misiek, 2011). This is then used to define the slenderness factor λ_{LT} which is then used to calculate the strength of the beam in accordance with fire part of Eurocode 3 (EN 1993-1-2, 2005).

Once all entries are completed, the user can click the  button to compute results.

The displayed results include, section classes of flanges and web(s), the critical bending moment for LTB M_{cr} , the slenderness factor λ_{LT} for the stabilised beam, the section resistance moments $M_{c,Rd}$ about the two bending axes, and the design buckling resistance moment $M_{b,Rd}$. As in the case of column design, an annotated text file can be created using the  button.