

Sapphire

Design Code EN1993-1-1

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Scope of the software

Sapphire performs a general structural design of individual steel members based upon Eurocode 1993–1–1 (“EC3”). Where the Eurocode lacks clear guidance, reference is made to the BS5950, Steel Construction Institute (SCI), and other sources to make a pragmatic attempt to proceed. This software is intended to be used by appropriately qualified engineers, and it is the user’s responsibility to check and accept (or otherwise) the assumptions, limitations, calculations, and output of the software. The software is provided in good faith, and no warranty is expressed or implied as to its suitability or correctness for any particular purpose. Improvements, bug-fixes, changes in Standards and industry methods, and reinterpretation of Standards and methods in future versions may lead to a change in the outcome of the design for any given input.

Of particular note is the [handling of torsion](#) (EN1993–1–1:2005, 6.2.7). The EC3 is particularly vague about the methods required. This software refers to the SCI and makes various simplifying assumptions which ought to be conservative.

In all cases, the user must decide if the interpretations of the standards and assumptions made are justified for their particular design requirements. See the section [Assumptions and Limitations](#) for more information.

The software has the following features:

- Handles classes 1, 2, and 3.
- Handles many common hot-rolled and welded section shapes:
 - Doubly-symmetrical I/H sections.
 - Monosymmetrical Parallel Flange Channels.
 - Monosymmetrical Tees.
 - Equal and Unequal Angles.
 - Circular hollow sections.
 - Rectangular hollow sections.
- Incorporates library of many standard sections.
- Properties can be automatically generated for custom section sizes.
- Incorporates library of many standard materials.
- Generates a PDF calculation sheet which can be exported.

Assumptions and limitations

Various assumptions are made and limitations imposed due to the complexity of the standards. A non-exhaustive list is given below and is subject to change as the software is developed. Any changes could affect the output of the design, and it is the user’s responsibility to decide whether they wish to accept them.

- Does not perform class 4 design.
- Force directions are assumed to be favourable or unfavourable as appropriate for the context.
- Fastener holes are not accounted for.
- Loads are neither stabilising nor destabilising.

- Shear buckling is not considered. If shear buckling can occur then the design is aborted.
- Conditions specified within National Annexes are not considered unless there is no generic interpretation. Where a national annex decision is required, the U.K. National Annex is used.
- 6.2.3(5): Sections not connected on outstand.
- 6.2.4(4): Asymmetric Class 4 sections not considered (eccentricity moment is zero).
- 6.2.6: Shear areas and their shapes are not well defined in the standard; some assumptions are made.
- 6.2.6: The cross-sectional portions relevant to computing the first moment of area for shear stress checks are not well defined in the standard; some assumptions are made.
- 6.2.7: Torsion is accounted for with a bimoment.
- 6.2.10(2): Shear buckling is not considered for moment resistance reduction.
- 6.3.2.3: M_{cr} determined through BS5950 methods for shapes other than I/H.
- 6.3.3: Moment distribution assumed to be constant ($\psi = 1$)
- Annex B: Sway not considered.
- Computed section properties are subject to future refinement.
- All software, libraries, data, and documentation are provided in good faith, but it is the user's responsibility to check the validity of the interpretation & application of the design codes, assumptions, and of the calculations & results and their compliance with National Annexes & appropriate rules.

The properties of sections within the library are taken from multiple sources, including standard data tables and computed approximations. Computed values necessarily involve assumptions which may introduce inaccuracies (e.g. ignoring fillets) relative to the real section. They are provided in good faith, but it is the user's responsibility to check that they conform to the actual section being designed and built (e.g. by comparing against the specifications published by a steel mill). If the provided values differ from what the engineer would prefer to use for the chosen section then individual values can be overridden as desired.

Loadcases and design forces

With reference to EN1990:2002, 6.3.1(1) & 6.4.3.2(3), Sapphire computes the design forces by summing factored loadcases.

For each loadcase:

The forces are the “characteristic actions” (F_k), and are typically the unfactored forces obtained from analysis. These forces are signed, but the signs of shearing, bending, and torsional forces do not matter as long as they are consistent over every loadcase (e.g. unfavourable forces may be +ve and favourable forces –ve). The axial force convention is +ve for compression and –ve for tension.

Accompanying variable actions are subject to a factor ψ , giving “representative actions” $F_{rep} = \psi \cdot F_k$, where ψ is the factor for combination value (ψ_0), factor for frequent value (ψ_1), or factor for quasi-permanent value (ψ_2).

Permanent actions and leading variable actions typically have $\psi = 1.0$, thus $F_{rep} = F_k$.

The representative actions are multiplied by the partial factor γ_F , which accounts for: (i) the possibility of unfavourable deviations from the representative values, (ii) model uncertainties and dimensional variations.

The final “design actions” (F_d) are then the summation of each loadcase’s actions multiplied by its factors. Once summed, only the magnitudes are considered because they are considered to act in the worst-case directions according to the context of each part of the design, with the exception of axial force which retains its sense of compression or tension. Thus, $F_d = \left| \sum(\gamma_F \cdot \psi \cdot F_k) \right|$

If it is desired to provide only the design forces directly, then enter them as a single loadcase with partial factors $\gamma_F = 1.0$ and $\psi = 1.0$.

Actions (loadings) are described in EN1990 and EN1991, and values for γ_F and ψ can be found in EN1990 Annex A and its appropriate National Annex.

Unit systems

The formulae given in the calculation sheets implicitly relate to working with S.I. units and metric prefixes (e.g. newtons and kilonewtons). When using non-SI units (e.g. U.S. customary system), constant numbers contained within the formulae must be factored appropriately if cross-checking the calculations.

Within the app, all internal calculations are performed in S.I. units; the user’s choice of units only affects the presentation of the input data and results.

Torsion

EN1993-1-1:2005, 6.2.7 is vague about designing for torsion. With reference to other sources, such as the Steel Construction Institute (SCI), we make interpretations and simplifying assumptions for a pragmatic approach.

SCI P385 indicates that for hot-rolled and welded sections, St Venant torsion is significant for all cross-sections, whereas warping torsion is only significant for sections with two flanges (I-beam and channel). It is not straightforward to determine the relative components of St Venant and warping torsion, and so we make a simplifying conservative assumption: where St Venant torsion is considered we take it as the full design torsion, and where warping torsion is considered we also take it as the full design torsion, even when both may be considered simultaneously.

For 6.2.7(1) eq.23, there is no clear method for computing the torsional resistance, T_{Rd} . However, 6.2.6(4) eq.6.19 provides a criterion for shear stress (τ), albeit in terms of shear forces. SCI P385 defines the shear stress due to torsion as a function of the torsional section modulus (W_t). By rearranging these and inserting into eq.23, we obtain a value for the torsional resistance. This formula is seen in a worked example in SCI P385 for a rectangular section.

Warping torsion is taken into account in the form of a “bimoment” which is added to the bending moments in the flanges. The bimoment is only considered for the local bending checks (6.2.5 & 6.2.9), and not for overall stresses, classification, nor buckling.

Operating the app

Workflow

The typical process is simple:

- Open an existing document or create a new one in the document browser.
- Enter the design data in the Design tab.
- View the calculation sheet and, if desired, export or print it as PDF.
- Return to the document browser and save the document.

Document handling

This app uses the standard iOS file browser from which member design documents are created and opened as well as transferred to and from the device.

As a deviation from standard iOS practice, documents are not edited directly. Instead, they are opened as “sessions”, to which changes can be made. Multiple sessions may be open simultaneously, though only viewed one at a time. Changes made to a session are automatically preserved if the app is closed and reopened or other sessions worked upon. However, changes are not saved back to the original document file until the user requests it through the session manager within the document browser.

- To create and open a new session, simply pick a document in the document browser. The new session will be presented. If it happens that the document is already associated with an existing session, then that existing session is presented and a new one not created.
- To present an existing (i.e. an already open) session, tap on [Sessions](#) at the top of the screen. A list of open sessions will appear. Tap on the name of a document to present its associated session.
- To return to the document browser from a session, go to the [Utilities](#) tab and tap on [Documents](#) at the top of the screen.
- To save the changes made in a session, tap on [Sessions](#) and then tap on the [Save/As](#) button next to the document’s name. A choice is presented whereby the session can be saved back to its currently associated document, or a new file name can be entered and the session saved to that.
- To close a session, as when you are finished working with it, tap on [Sessions](#) and then tap on the [Close](#) button next to the document’s name. If the session contains unsaved changes then you will be alerted and given the choice to either not close the session or to discard the changes.

While there is only one member design per document, multiple documents (and thus multiple members) can be saved within project directories to keep them together.


Within the file browser, multiple documents can be selected and exported together for transferring to another device.

The design tab

This tab presents the member data sheet, calculation sheet, and PDF output, selectable via the two buttons at the top-right of the screen.

In the member data sheet, the relevant data for the member is tabulated. A green cell represents data that the user must provide, and can be tapped to edit. A red cell opens a library of standard parts from which the tables can be automatically populated. Diagrams down the right-hand margin depict the shape, dimensions, and axes of the chosen cross-section. A summary of the design for the current member data is presented continuously at the bottom of the screen.

Various sections of the calculation sheet can be viewed by tapping on the bookmarks button (top-right) and picking the appropriate section.

A PDF of the calculation sheet can be created by tapping on the  (PDF) button at the top-right of the screen.

The utilities tab


The on-line help (this) can be opened by tapping on [Help](#) in the top-right corner of the screen.

The [Open Settings](#) button gives access to Sapphire's options. This occurs within the iOS Settings App, and you can return to Sapphire by tapping on "Sapphire-EC" in the top-left of the screen.

The [Documents](#) button switches to the document browser, within which work can be saved or other sessions accessed (see [Document handling](#)).

Calculation sheets (PDF)

The current design can be reported as a PDF by tapping on  in the Design tab.

From the file browser, multiple documents can reported together in a single PDF by selecting them and tapping on .

Two PDF files are produced as reports; one being a 2-page summary, and the other being the full calculations. Either or both can then be printed (e.g. via AirPrint) or exported (e.g. by e-mail or AirDrop) if your device is suitably connected.

What is new & Version history

Current version 19.08

V.19.08

- **Enhancements**

- On-line help can be accessed from the document browser.
- Document handling has been overhauled:
 - All loading and saving is performed within the standard document browser.
 - Documents are opened in “sessions” which remain open until the user closes them.
 - Editing occurs only within the sessions.
 - Changes made within a session are only saved back to the original document when the user requests it (or the changes can be discarded).
 - Multiple sessions can be active and easily switched between, making it easier to work on more than one at once (e.g. for copy-and-paste).

V.19.05

- **Bug fixes**

- The torsional section modulus (W_t) was not being updated when editing cross-sectional dimensions of sections with automatically generated properties. For any designs that used this (i.e. had torsion), please recompute W_t by tapping on [Pick Library Section](#) → [Generated Properties](#), and check the new design. Library sections and those with entirely manually specified properties are not affected.

- **Enhancements**

- Design forces are now specified as one or more factored loadcases, with names.
- When generating PDFs, two documents are created: a summary and the full calculations.
- PDFs can be generated directly from the file browser by selecting one or more files and tapping on [PDF](#).
- Keyboards have an accessory view with additional relevant character keys.
- The [Done](#) button on the keyboard will enter data, not just close the keyboard.
- If obviously invalid data is entered then the user is alerted.

V.19.03

- **Enhancements**

- Added choice of unit system.
- Libraries open at the previously chosen item.
- Libraries display a summary of each item when browsing.
- A numeric keyboard is used for numerical data.

- Improved PDF formatting and page breaks.