# QUANTIFIRE

**FIRE PROTECTION ESTIMATION SOFTWARE**

User Manual

PFP Specialists

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**CONTENTS**

# 1 QUANTIFIRE SOFTWARE

Quantifire is developed and maintained by PFP Specialists Limited. Use of the software constitutes acceptance of the terms of the license agreement.

The software should always be used by a professional capable of exercising sound estimation judgement. PFP Specialists Ltd. takes no responsibility for the accuracy or use of the software.

# 2 SOFTWARE ARCHITECTURE AND SYSTEM COMPATIBILITY REQUIREMENTS

Quantifire uses a combination of cloud-based databases and local executable files. Users require a PC with Windows 7, 10 or 11 installed, and a locally installed version of Microsoft Excel version 15 or higher. Users also require an internet connection and the ability for the system to communicate with Microsoft SQL Server over port 1433 and to https://pfpspecialists.co.uk/ without error.

# 3 INSTALLATION

First installation and ongoing updates are handled by the user, via download of the .exe from the PFP Specialists' website. No installation routine is necessary, the software runs on execution of the file, however, before Quantifire can be used it must be activated.

# 4 ACTIVATION

On first execution of Quantifire, the user will be asked for an activation token. Tokens will be provided by PFP Specialists, to users identified by the client's nominated user administrator via email to an email address ending in the client's domain.

Activation codes are tied to specific PCs and are non-transferable. If users change their PC they must ask PFP Specialists to deactivate the software on the previous machine and provide a new activation code.

# 5 LICENCE AGREEMENT

The license agreement is presented after activation. Users must accept the license agreement before the software can be used. A copy of the license agreement is saved as a text file (ending .lic) in the same folder as the .exe file.

# 6 USER ACCOUNT

Each user will be provided with a username and password. These are personal and should not be shared. Passwords must contain a minimum of 8 characters, including at least one letter, one number, and one special character. User accounts may apply to Quantifire desktop application only, to the Quantifire Web Service only, or to both. This document is concerned with only the desktop application version of Quantifire.

# 7 SOFTWARE DEVELOPMENT REQUESTS AND FEEDBACK

While under license, Quantifire will be subject to regular updates. Users are requested to send suggestions or bug reports to PFP Specialists via an email to quantifire@pfpspecialsts.co.uk.

# 8 GLOSSARY

The passive fire protection and structural fire engineering industry use a multitude of acronyms and abbreviations. A non-exhaustive list is provided below to aid the user.

| | |
|---|---|
| ALS-Fire | Accidental limit state of fire |
| $A_m/V$ | Section factor. Exposed area/volume. Sometimes given as A/V. See $H_p/A$ also. |
| A/P | A section factor terminology used in North America for hollow sections |
| Bd. ft | Board foot, a unit of volume used commonly for SFRMs in North America. |
| BOQ | Bill of Quantity |
| BS | British Standards |
| CB | Cellular beam or beam with large web openings |
| CFT | Concrete filled tube |
| CCT | Critical core temperature of steelwork – see $T_{crit}$ |
| DFT | Dry film thickness |
| EMTA | Elemental multi-temperature analysis (for beams with large web-openings) |
| EN | European norm |
| FR | Fire rating. Referred to in Quantifire as the total fire duration. |
| $H_p/A$ | Section factor. Heated perimeter / cross-sectional area. See A/V also. |
| HHF | High heat flux |
| ISO | International Organization for Standardization |
| JF | Jet fire |
| MTA | Multi-temperature analysis |
| MTO | Material take-off |
| PG | Plate girder |
| PFP | Passive fire protection |
| SF | Section factor. See $A_m/V$ |
| SFRM | Spray applied fire resistant material, a commonly used term for lightweight cementitious material |
| $T_{crit}$ | Critical temperature of steelwork, often referred to as Limiting Temperature in the hydrocarbon industry |
| ULS | Ultimate limit state |
| WFT | Wet film thickness |
| WPF | Web post factor |
| W/D | A section factor terminology used in North America for I-sections |

# 9 INTRODUCTION

Quantifire is a comprehensive and efficient software tool for estimating the amount of passive or reactive fire protection material required to achieve the fire resistance of steel-framed structures.

## 9.1 Background to the developers

The developers of the Quantifire at PFP Specialists Ltd. have significant experience in passive fire protection estimation, including direct collaborative working with main contractors, Structural engineers, fire engineers, steelwork fabricators, applicators, installers and passive fire protection product manufacturers on a global scale in both the cellulosic and hydrocarbon markets. They also have vast experience in fire testing, product assessment and certification.

The developers also participate in trade associations and multiple standards development bodies to contribute to the drafting of existing and new guidance in the fire testing and assessment realm and the structural fire engineering industry at UK, CEN (European) and ISO (Global) levels.

## 9.2 Key features of Quantifire

The software has been designed to operate on a global scale and as such, it includes a multitude of features to capture region, country and market-specific approaches commonly adopted. Some key licence-specific aspects include: -

- Cellulosic and hydrocarbon capabilities
- Tailored for intumescent coatings
- Public and private product databases
- Extensive global steel section library
- Ability to import bulk datasets for rapid estimation
- Product comparison
- Section size optimisation
- Structural fire engineering capabilities
- Capability to analyse cellular beams (web-openings)
- Primers and topcoats
- Pricing
- Project database
- Assign user permissions and access rights
- Compatibility with data analytics and reporting platforms
- Multi-language
- Metric and imperial units
- Support

# 10 QUANTIFIRE VERSIONS

To allow all aspects of potential estimators to use Quantifire, the software is available in several different licence types as shown in Table 1. Please contact PFP Specialists Ltd. to discuss options.

*Table 1: Different Quantifire licence versions*

| **Quantifire Licence Version** | **Comments** |
|---|---|
| Quantifire | Unlimited licences for a single company<br>This is the base version of the software and includes all capabilities other than use of the advanced critical temperature calculators structural for structural sections and cell beams. |
| Quantifire + | Unlimited licences for a single company<br>Has all the abilities of **Quantifire** but also permits users to access the advanced critical temperature calculators. |
| Quantifire $+^{CB}$ | Unlimited licences for a single company<br>Has all the abilities of **Quantifire +** but also permits users to access the advanced beam with web-opening (cellular beam) calculator. |
| Quantifire LT | Single licence per user<br>This is a 'light' version of the base **Quantifire** licence. It has the standard capabilities but does not include support, multiple users, and access to the analytical tools. |
| Quantifire XLT<br>Quantifire X+<br>Quantifire X CB<br>Quantifire X +CB | Single licence per user<br>These are 'external' versions of the **Quantifire LT** licence. Only a single manufacturer's products can be viewed. This licence is typically applied for by a manufacturer for a client to permit collaborative working.<br>The + and CB suffix denote access to the advanced temperature calculators for structural and cell beam sections respectively. |

# 11 STARTING THE SOFTWARE

Double-click on the Quantifire program icon or right-click on the icon and select ‘Open’.

## 11.1 Entering user credentials

The user should enter the username and password provided and then click ‘Proceed’. An incorrect username or login will prompt an error message. After three incorrect tries, Quantifire will close.

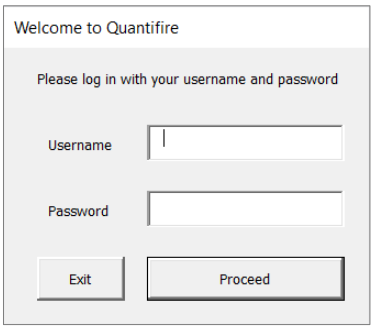



*Figure 1: Login window*

## 11.2 Permissions

Following a successful login, Quantifire loads the permissions available to the user as shown in Figure 2. Permissions are determined by the client's nominated user administrator, within the options available for a given license version. If users wish to extend permissions to additional functionality, they should contact their nominated user administrator.

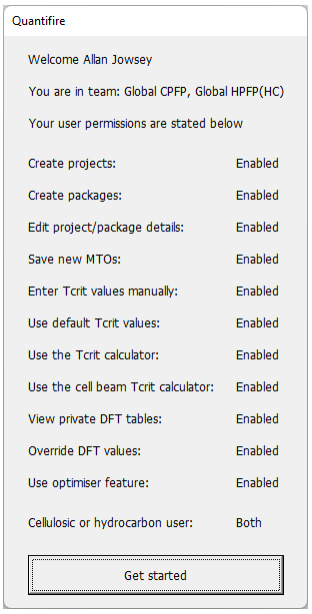



*Figure 2: Permissions*

## 11.3 Updates

From time to time, Quantifire is updated. On opening, it will check to ensure it is the most up to date version. If not, after logging in, the user will be prompted to download any updates via a link See Figure 3.

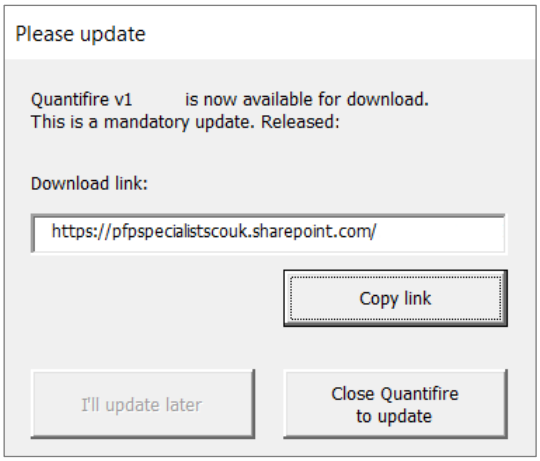



*Figure 3: Update prompt*

To install the update, copy and paste the download link to a web browser address bar and download the new version. The new version is intended to replace the previous version. Close the older version before running the newer. Note that older versions can be deleted safely – there is no data stored in the local Quantifire .exe files.

Some updates are mandatory, and the user will be required to complete the update before proceeding. When this is the case the 'I'll update later' option will be disabled as shown in Figure 3.

# 12 GETTING STARTED

The following section of the user guide is intended for the first-time user and begins by first guiding the user through the most direct route to producing an estimation report, also known as a Bill-of-Quantity (or BOQ) report. It provides a brief overview of the basic, core features of Quantifire.

Chapters following this cover additional features of the program in more detail. Directions to relevant sections are included so that the user can jump ahead to a more detailed explanation of the features of any stage, should this be useful.

Directions given in green walk the user through a simple creation of a project, inputting a list of sections, and creation of a BOQ report.

## 12.1 Quantifire flow chart

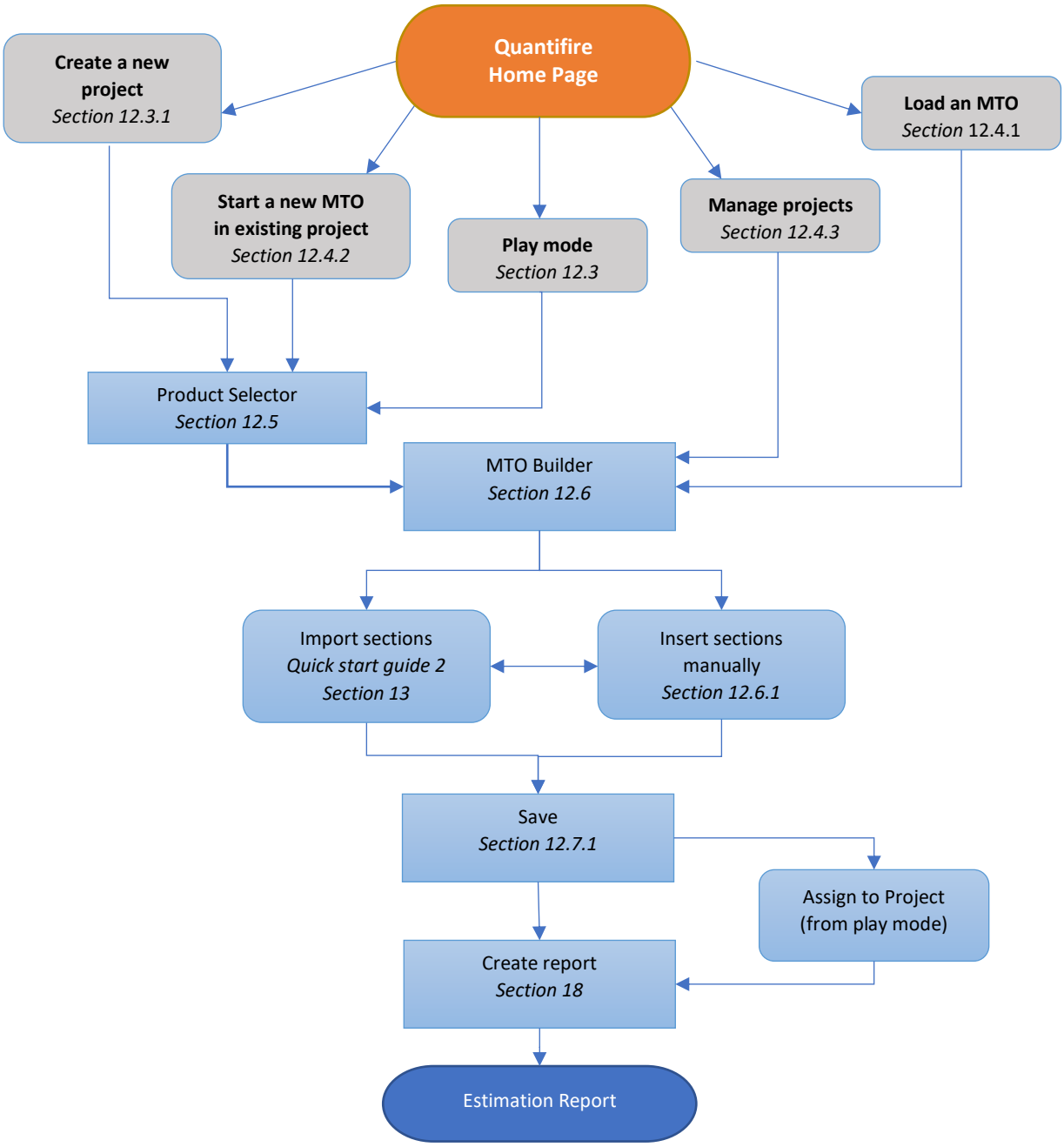



*Figure 4: High-level flowchart of use of Quantifire*

## 12.2 Projects, Packages, Jobs and Revisions

### *12.2.1 Quantifire use of terminology*

Quantifire implements the above terms in the following way (illustrated in Figure 5):

- ***Project***
  The primary (high-level) construction project. For example, the specific building or offshore platform being built.

- ***Package***
  A part of the overall project bid separately to other parts of the project (i.e., a sub-project). For example, a specific building within a larger development, or a liquefaction train within an LNG plant. Not all projects are divided into packages.

- ***Job***
  Any saved MTO within Quantifire. It may be complete or incomplete, but each save is given a unique Job ID for traceability and future loading.

- ***Report revision***
  Each report generated within a project and package (if relevant) is given a unique revision identification (ID) number.

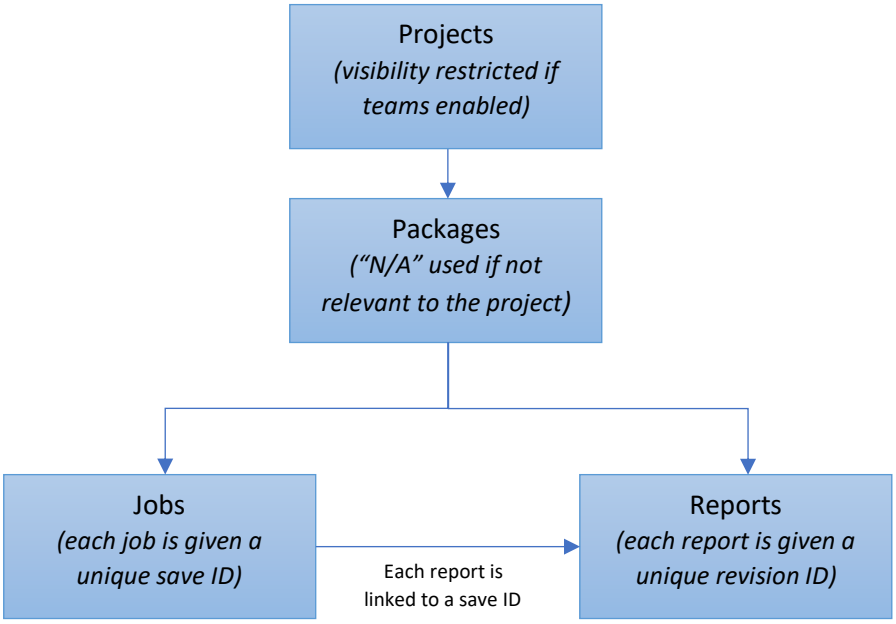



*Figure 5: Terminology and hierarchy of projects, packages, jobs and revisions*

### *12.2.2 Note on handling multiple options during bid stage*

Most bids undergo multiple revisions to a BOQ, and some may even have BOQs provided for a range of options (e.g., different products or different fire ratings), even though only one will ultimately end up being used. PFPS recommends these are handled as multiple jobs (not multiple projects or packages) as this permits use of filtering functions within analytical tools to ensure multiple MTOs from single projects do not inflate values in analytics reports.

## 12.3 Home page

The Home page can be reached at any point in the Quantifire process by selecting the Home Tab at the bottom of the Screen. The Quantifire Home page offers five function options, see Figure 6.

Click on **Create a new Project** to start a new job.


*Figure 6: Home screen. Note Home tab in bottom left*

For first time users or a new project, the buttons **Create a new Project** or **Play mode** are the most relevant options.

**Create a new Project**, is the first step towards building a BOQ report. **Play mode** is the quickest route to generating DFT and weight/Vol values, skipping straight to the product Selector (Section 12.5) and bypassing the process of setting up a project.

Both options allow the user to produce MTOs but **Play mode** is intended as a shortcut when the user does not intend to save the results. **Create a new project** should be selected when the user wants to save the output and create a report. This route, not the Play mode, should be the primary method of working when the intent is to save results or generate a BOQ report. (Note, it is possible for jobs created in **Play mode** to be assigned to projects when they are saved).

### *12.3.1 Setting up a new project*

Clicking **Create a New Project** will display the New Project window as shown in Figure 7. Fields marked with a star (*) are essential fields, necessary to create a new project. Failure to complete these fields will result in an error prompt when 'Create project' is clicked.

The user should note that the Project name must be unique. When 'Create project' is clicked the entered project name is checked against the database and the user is warned if the name is a duplicate. The name must then be changed before the user can create the project. The exception to the above is the project name "N/A". It is recognised that sometimes the project name is unknown. In these cases, "N/A" may be entered, and there is no limit in the number of projects that can have this name.

The 'Region (of final operation)' and 'Country' fields are linked. If one is selected, then the other is automatically populated to reflect this choice.

All additional fields are optional and to be used as necessary. Note that good practice is to enter as much information as possible to make use of the compatibility of Quantifire with analytics tools.

Complete the starred fields and any others that are useful then Click 'Create Project'

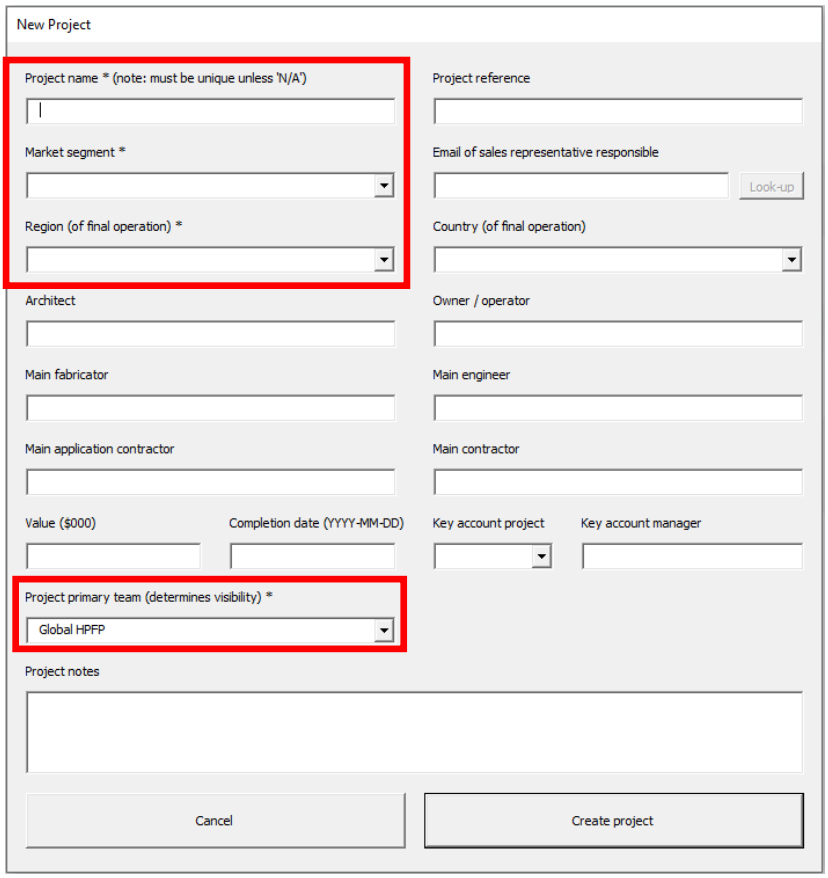



*Figure 7: New Project – required fields*

If your company has implemented a Teams structure then you will be given a list of teams that you can assign the project to on creation. Note that the highest level team (most restricted visibility) is shown first. To increase visibility select a lower level team. To use the example on the previous page, if an EMEA team member wants to create a project visible to UK & Eire and Scotland users they should assign it to Scotland on creation.

Note that the team can be edited after creation like any other property on the 'Edit project' page via the **Manage Projects** button on the Home page.

If your company has not implemented a Teams structure then the Primary project team will be set to "N/A". For further notes on the use of Teams structures see (Section 12.4.4)

### *12.3.2 Packages*

After creating the project, the user will be asked whether the new project will have packages. Packages allow a project to be divided into multiple, separate parts. If the user is looking to create a report of estimations for a number of sections that comprise only a certain part of the full project, this could be set as a package. Further packages may be added to a project at a later date if required.

If the packages feature is of use, click 'Create a package now', otherwise, click 'No Packages.'

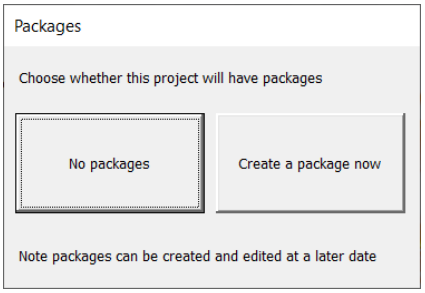



*Figure 8: Packages*

Opting to create a new package opens the 'New package' window (Figure 9). When creating a new package, there are certain mandatory fields, marked again with a star (*).

Complete starred fields and click 'Create package'

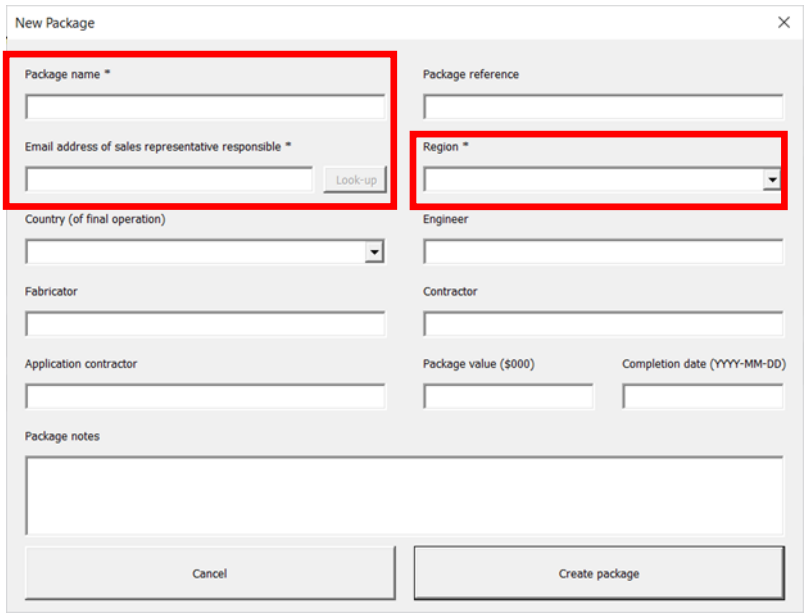



*Figure 9: New package*

Choosing the 'No packages' option will enter package as "N/A" into the database. Jobs saved within the created project will be found within package "N/A" if the user intends to load them by navigating through the project and package windows.

After choosing 'No packages' or after creating a new package, the user will progress straight to the Product selector (Section 12.5).

Skip to Product Selector 12.5 to continue quick start

## 12.4 Home Page - Returning to an existing project

If the user has previously created a Project, they are offered the option to return to a saved MTO within a project by clicking **Load an MTO,** to add a new MTO to a previously created Project by clicking **Start a new MTO in existing project,** or to amend or edit existing project details with **Manage projects.**

### *12.4.1 Load an MTO*

Clicking this button on the Home screen provides the user with 3 options for locating the chosen Project (Figure 10). Note that the projects visible may depend on whether your company has implemented a Teams structure in Quantifire. If not, all projects will be visible; if implemented then only projects your team has visibility of will be shown by default. If the Teams feature is enabled, users can click 'Show other teams' to clear the projects list and display only those from other teams. More information on Teams can be found in Section 12.4.4.

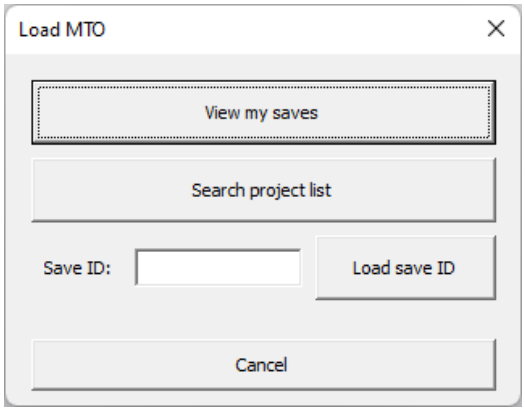



*Figure 10: Locate an existing Project*

**Load a save ID** - The quickest way to load an MTO is to enter the save ID number into the search box shown above and clicking 'Load a save ID'. Providing that the user has access to this MTO, the MTO will be opened.

**View my saves** - If the user does not have the save ID number, they can click 'View my saves' to see a list of all existing MTO's they have access to. Then simply select the chosen MTO and click 'Load Job'.

**Search Project list** - To narrow the list, the user can opt for 'Search Project list' which will display to the user the projects available to them, and the option to sort that list by various categories or search by entering the project name (Figure 11). The list of projects is automatically sorted by most recently created. It can be filtered by Market Segment and Region or reordered, using the drop-down menus at the top of the window.

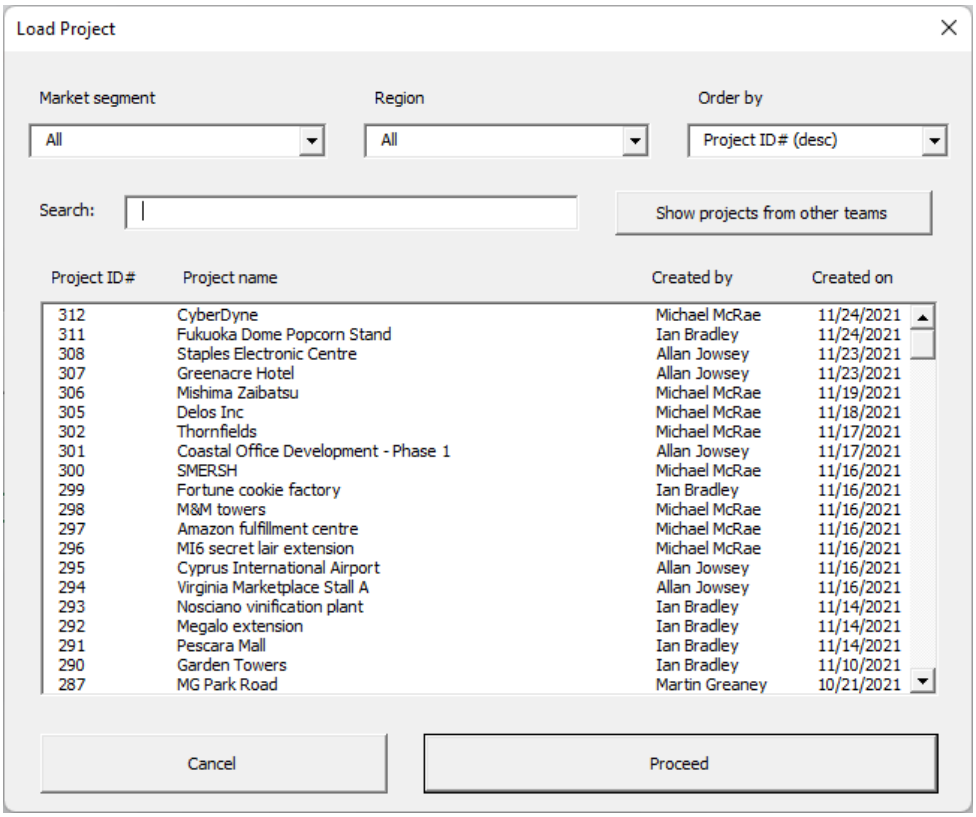



*Figure 11: Load project*

Select a Project and Click 'Proceed'. In the next window select the estimate and click 'Load selected MTO'. Note that, when loading a job, Quantifire will automatically load the products used within the save, taking the user straight to MTO Builder (Section 12.6).

At this point, the user can create a new MTO to the project rather than loading an Existing MTO. There is a quicker way to do this, however, from the Home screen, clicking **Start a new MTO in existing project.**

### *12.4.2 Start a new MTO in existing project*

Where a project has previously been created by the user, a new or additional MTO can be added to the Project using this feature. From the Home screen, click **Start a new MTO in existing project**. In the Load Project window, see Figure 11**,** the user can sort the list of projects by type or search by name for a specific Project. Select the Project and click **'Proceed'.** If an MTO is open with sections added in the MTO builder tab, the user is prompted to choose whether or not to retain and add these sections to the new MTO that is being created. When starting a new job, the user will be shown the Product Selector window (Section 12.5)

### *12.4.3 Manage projects*

This button on the Home screen brings up the Manage projects window as seen below in Figure 12.

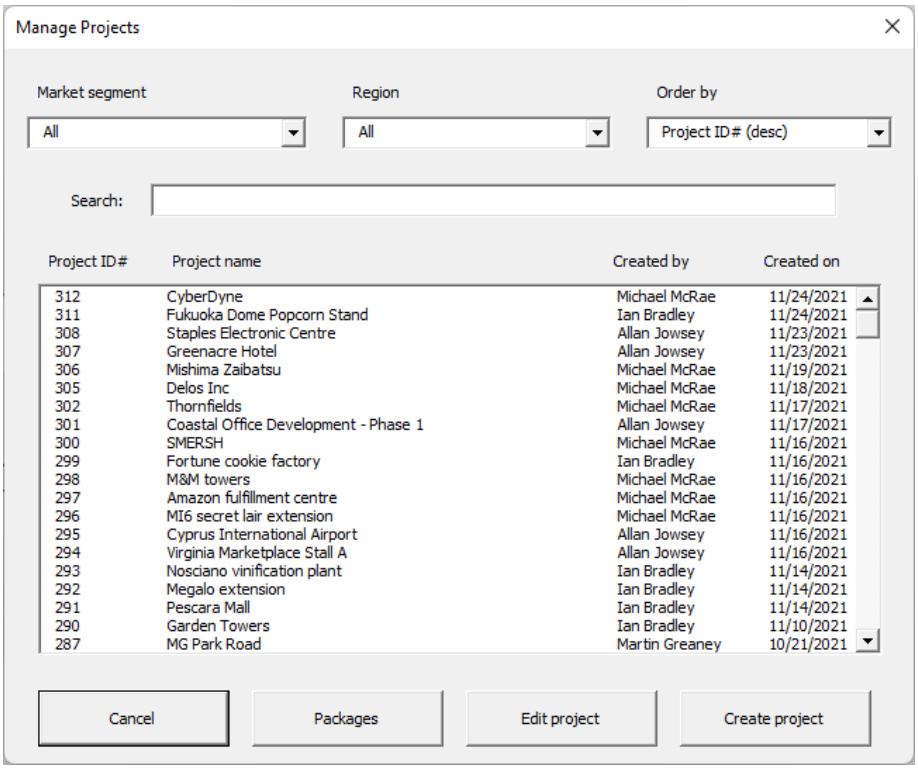



*Figure 12: Manage Projects Menu*

Here the user can select a Project from the list or using the sort/ search features and click 'Edit Project'. This brings to the screen the Edit Project window, where the user can amend the information relating to this project as required.

'Create Project' allows the user to create a new Project here but this is not the fastest way to perform this action. Instead, use **Create a new Project** from the home screen**.**

The 'Packages' button allows you to add new packages or edit package information, as shown in Figure 14.

Users can then select a previously saved job to load or start a new job within that project.

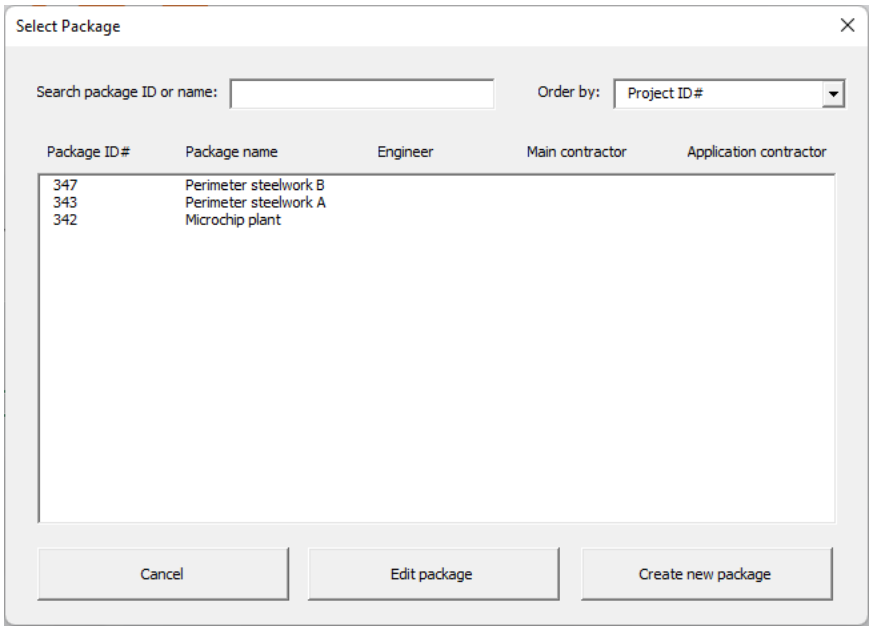



*Figure 13: Select Package/ Job*

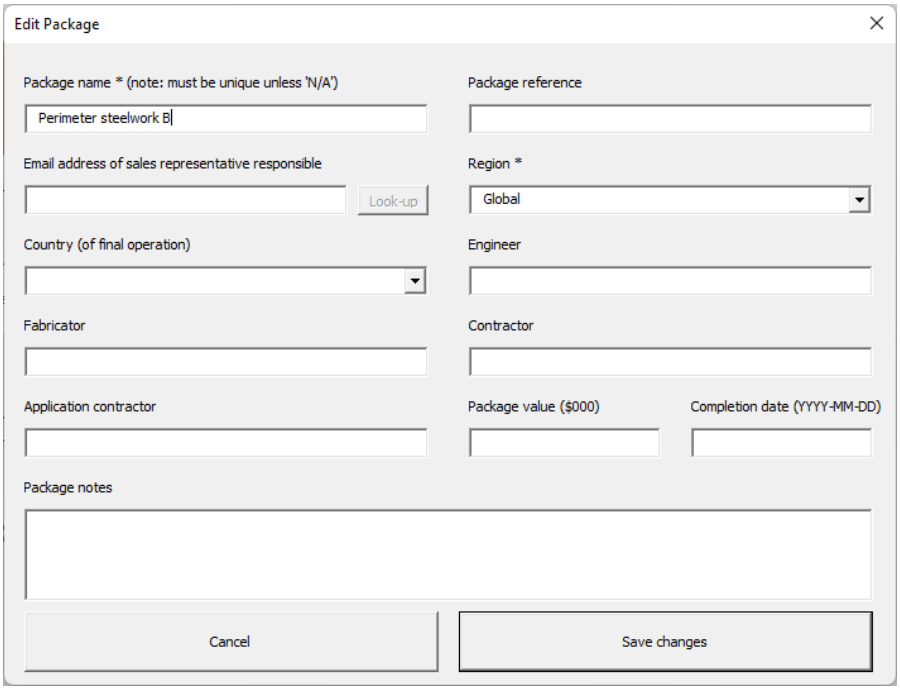



*Figure 14: Editing package details*

### *12.4.4 Working with Teams*

Companies may implement a Teams structure to restrict visibility of projects. An unlimited number of teams can be created, in a hierarchical structure of up to 5 levels. Users will have automatic visibility of any project created by a member of their team, or a member of a team that reports to their team. Note that cellulosic and hydrocarbon teams have separate structures, and a user can be in different cellulosic and hydrocarbon teams, at different levels. An example structure is shown in Figure 15.

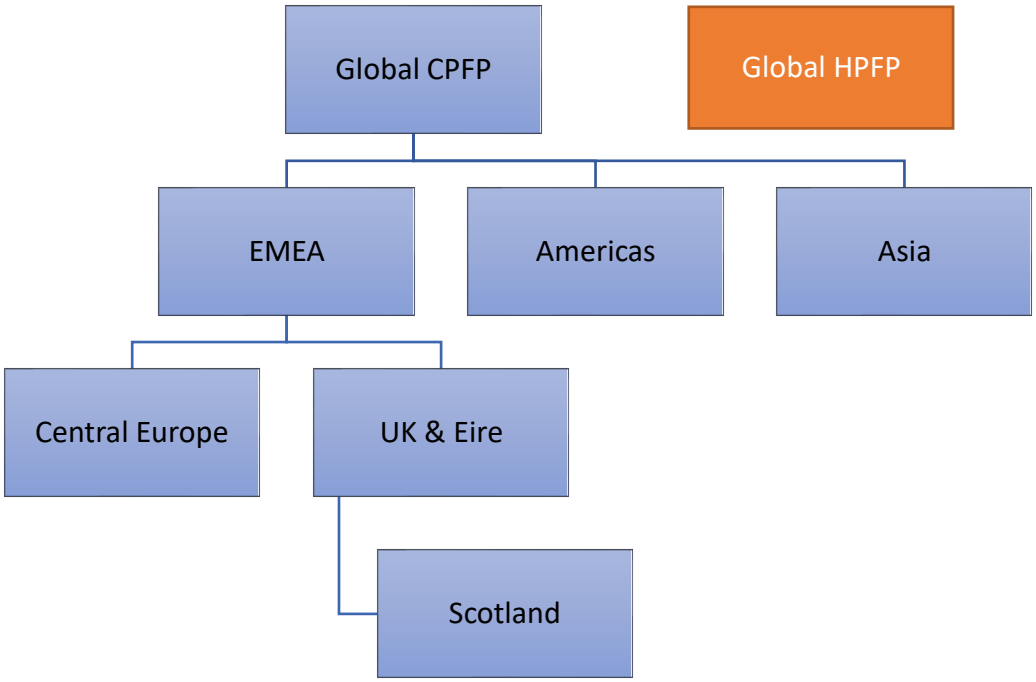



*Figure 15: Example Teams structure*

In the example above a member of the EMEA Team will have visibility of projects created by members of EMEA, Central Europe, UK & Eire, and Scotland. A member of Scotland would only have visibility of projects created by members of Scotland. If the latter user was also a member of Global HPFP they would be able to see all HPFP projects, along with the Scotland CPFP projects.

Users at higher levels can choose to create projects at a lower level to permit wider visibility as standard (see 12.3.1).

Users can also grant (or remove) special access to a project to any user, via the use of the '*Edit project*' button. Note that users granted special access cannot edit the details of a project, or grant/remove special access to that project.

## 12.5 Product Selector

Quantifire allows users to generate estimates for a wide range of PFP products. This window allows the user to locate and select the product(s) required for the estimation, as depicted in Figure 16. The user can select multiple products to allow for direct comparisons, up to 5.

View available options by clicking the + to expand the list of manufacturers and products.

Select up to 5 products by checking the box to the left of the name.

Click 'Load products'.

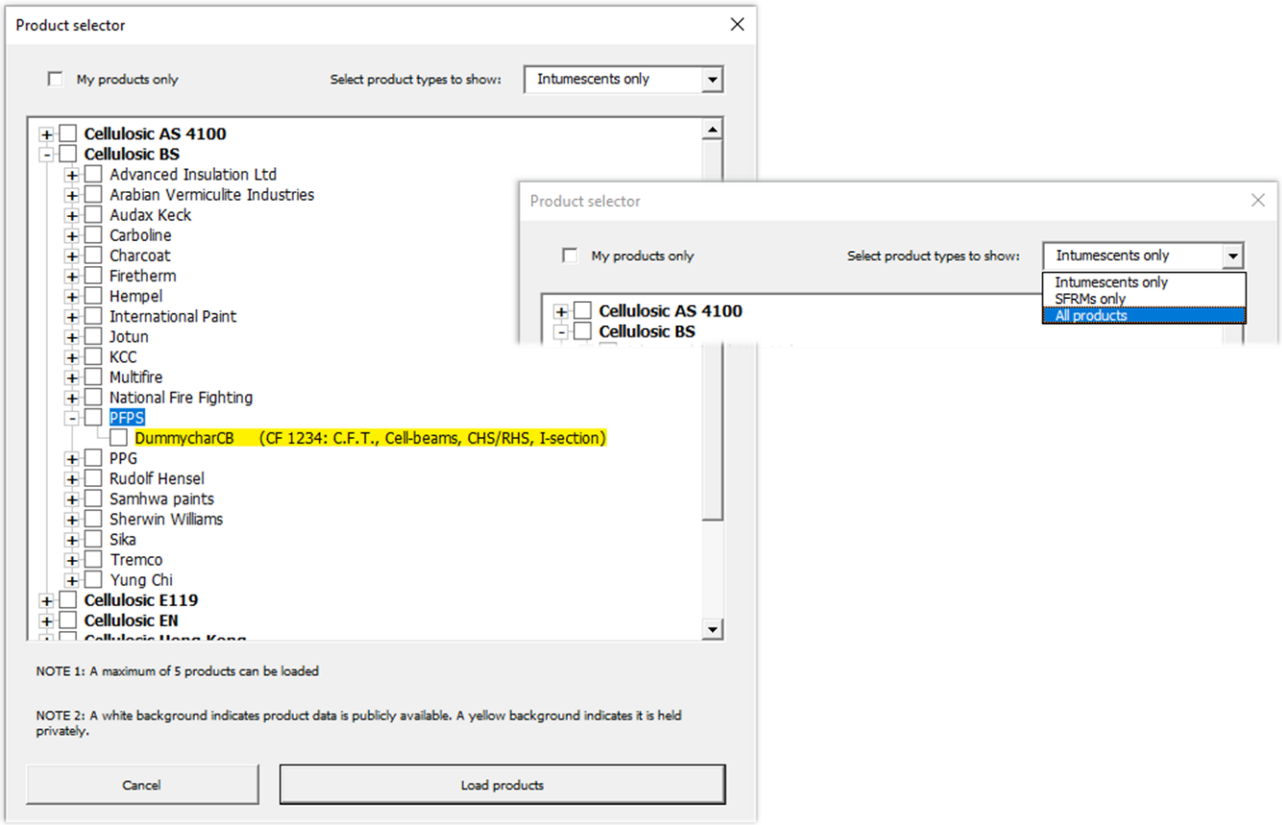



*Figure 16: Product selector window, with the dropdown showing different product type filer*

Products are organised across three levels as follows:

*+ Fire test standard*

*+ Manufacturer*

*+ Product name and certificate reference*

Begin by clicking on the + to the left of the standard that applies to the project, as in Figure 16. An expanded view is shown listing all the manufacturers who produce products with fire testing certification to these standards (within the Quantifire databases). Clicking the + to the left of the manufacturer name, expands a list of their relevant products, as in Figure 16.

Above the selection window, the user can choose whether to filter to products of their own company or those of all companies (note that 'X' license types are tied to products of a specific company and this box is not available). By default, intumescent coatings are displayed, however, the user can also select whether to display cementitious products (SFRMs) or both intumescents and SFRMs.

Click on a product to select it; a tick will indicate that it has been selected. Note that selecting the manufacturer by checking their box will automatically select all the products available from that manufacturer.

The user may select up to 5 products from one or more manufacturers. Note that if a selection is made that includes more than 5 products, the program will load only the first 5 products from the selection.

Product names with a white background are products that have made their product data publicly available. A product with a yellow background indicates that the product data is held in the private database of the user's company (and is therefore available only to that company).

### *12.5.1 The combined product summary column*

Products loaded using the steps described in the previous section are shown side-by-side in the Quantifire main window. It is also possible to see a single summary column that selects the most appropriate product on a line-by-line basis: the combined product summary column. If more than one product is selected, the user is prompted to choose a combined product summary column as shown in Figure 17.

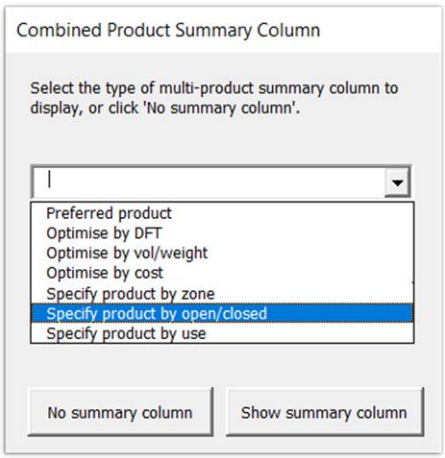



*Figure 17: Setting the combined product summary column*

After selecting a summary column type the user will be prompted to select the products that will be included in this column. The types of summary column, and the function of the subsequent window whereby the user selects the products, are explained in Table 2.

*Table 2: Report type options*

| Option | Purpose | 'Select products' window |
|---|---|---|
| Preferred Product | Provides estimate for 1st chosen product, unless DFT unavailable in which case 2nd chosen product is used. | Allows the user to select a preferred product and a secondary product |
| Optimise by DFT | Provides the best estimate for each section using the product that has the lowest DFT reading. | The user can select some or all products. |
| Optimise by vol/ weight | Provides the best estimate for each section using the product that has the lowest Weight/ Volume estimation. | The user can select some or all products. |
| Optimise by cost | Provides the estimation for each section using the product that has the lowest estimated cost (requires product costs to be entered) | The user can select some or all products. |
| Specify product by zone | Select single product to use per zone | The user selects a single product, cycling through each zone in turn. |
| Specify product by open/closed | Provides estimation using one product for open sections and another for closed sections | The user selects a product for open and a product for closed sections |
| Specify product by use | Provides estimation using one product for Beams and another for Columns | The user selects a product for beams and a product for columns/other uses. |

### *12.5.2 Updates and expiration of products*

Product data will change with time as new assessments become available or expire. Quantifire handles these situations as follows:

Expired products will be removed from the product selector and will not be available for new projects.

To accommodate the need to permit review and modification of past reports, expired products will be loaded as part of loading a job that used them. In this case, the user will be notified that product(s) have expired.

When product data is updated, new product data will always be loaded (for both new projects and when loading past jobs). However, the DFT and quantity information of past jobs will not be automatically recalculated. Recalculation will only occur if changes are made to the MTO after loading. Users should be aware that recalculation may result in changes to DFT and quantity information in these circumstances.

## 12.6 The MTO builder

This is the main workspace for building section estimates. There are many features available to the user which are covered fully in sections 0 and onwards.

This *Getting Started* section of the manual aims to explain:

1. How to enter sections to the builder on a line-by-line basis
2. The main MTO list of sections
3. Edit features
4. The Quantifire main menu
5. How to save jobs and generate reports

### *12.6.1 Entering sections line-by-line*

The red box in Figure 18 is used to filter and select specific steel sections to be inserted into the MTO list. Once inserted, the builder will then generate the associated thickness and volume or weight for each PFP product selected.

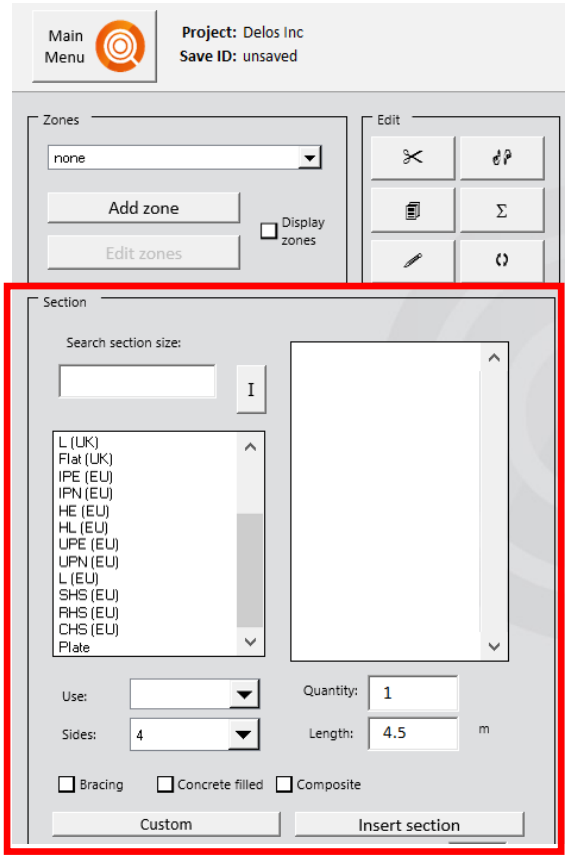



*Figure 18: Loading sections menu in the MTO builder workspace.*

Sections are grouped by section category and then by serial size. Selecting one of the options in the menu will make available a list of all the most commonly used sections in that category. As an example, in Figure 19, the option UB(UK) has been selected, bringing to view all standard dimensions of Universal Beam for the UK market.

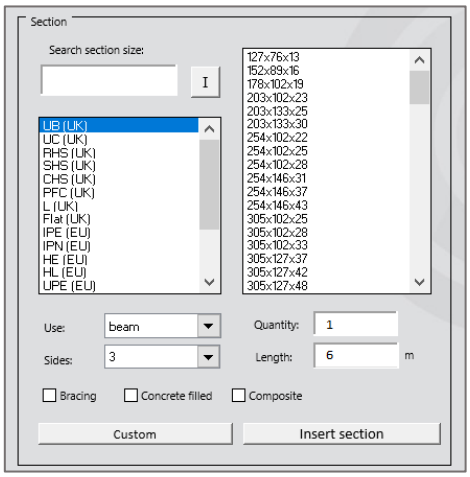



*Figure 19: Selecting section size*

Scroll through the list on the right to find the required section. Select the appropriate use (e.g., beam or column), number of sides exposed to fire, and enter the quantity and length. Note the *use* and *sides* fields default to the most common per section category, whenever a new item is clicked in the left-hand list.

The 'Search section size' feature allows the user to search for specific section sizes within all sizes possible in the right-hand list. The search does not look within categories from the left-hand list. (e.g., when searching for an IPE 300, typing *IPE* will return no results, however typing *300* will).

Find and select the section size required and then click 'Insert section'.

Ensure the correct $T_{crit}$ value and Fire Duration is entered and then click 'Insert section'. The section will appear in the main schedule to the right as the last section in the zone selected. Note that if it is the first section within a zone then the zone name will be displayed above it. Add as many different sections as required for the Project.

### *12.6.2 The MTO list of sections*

When a section is selected and 'Insert section' is clicked, Quantifire displays the entered data in the right-hand area, see Figure 20. At the far-right side, the schedule displays the required PFP thickness for each section and the required application volume/weight for each of the PFP products selected.

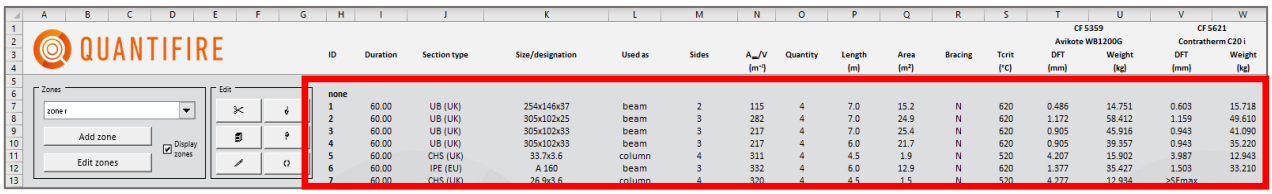



*Figure 20: The MTO list of sections*

### *12.6.3 Notification messages when sections cannot be protected*

If Quantifire cannot calculate a PFP thickness, the user may see a notification message as described in Table 3.

*Table 3: MTO notifications when sections cannot be protected*

| Notification | Cause |
|---|---|
| No cert | No certification available |
| >Dur | Duration greater than maximum certified |
| <Tcrit | Tcrit lower than minimum certified |
| >SFmax | Section factor greater than maximum certified |
| <SF min | Section factor below minimum certified |
| >max | Maximum DFT exceed (typically due to 4-sided beam limit or JF addition) |
| No 4sb | Four-sided beam certification not available |
| No EMTA | No elemental MTA data available for cell beams |
| <>WPF | No web post factor data available for cell beams |
| <WPmin | Web post width is below the minimum available |
| No box | The certificate is specific to contour/profile application only |
| Box only | The certificate is specific to box-design only |

### *12.6.4 Edit features*

There are a number of features available to the user to modify the estimate, many of which are accessible via the edit buttons, see Figure 21.


*Figure 21: Edit features*

The edit buttons have the following functions:

- Scissors
  Delete a range of sections, written using commas to separate lines and hyphens to denote ranges (e.g., 1,2,4-6). Enter “x” to delete all sections, but to keep all user-entered zone names (note they will no longer appear on screen as no sections will be present, but they can be selected from the zones drop-down menu). Enter “xx” to delete all sections and clear all user-entered zone names.

- Point up /down
  Move a range of sections (in the format: 1,2,4-6). The sections will be moved to the same zone of the target specimen number, either preceding or following the target specimen depending on the option selected.

- Copy
  Duplicates a range of sections (in the format: 1,2,4-6). The sections will be duplicated the number of times specified. For example, to add the same section 10 times the user can add it once and use the copy button to duplicate it 9 further times. Duplicates are always added to the end of the selected zone.

- Sum totals
  Shows a quick summary of the following for each product loaded: the total quantity of product required, the number of sections that cannot be protected, the number of kits/bags required, and the cost. Note that the cost is based on the number of kits/bags required and will not be available if this information is not entered.

- Pen
  Enters the manual edit mode, allowing you to type (or copy and paste) values into the MTO builder window directly. Activating the manual edit mode will highlight the columns that can be changed in green. Note that only the input dimension selected in the main menu (length, area, or weight) will be editable, and this feature has limited compatibility with cell beams.

  Certain users may have permission to manually change DFT values. Those users will have all DFT columns unlocked. Any change to a DFT value will result in a ‘freeze’ of all DFT values for that row (i.e., for all products, even if only one product is changed). These DFTs will not be recalculated regardless of other changes to the section.
  Users can check which DFTs are ‘frozen’ by entering the manual edit mode. Frozen DFTs will be shown in yellow. A ‘freeze’ can be removed by clicking the pen button to enter manual edit mode and deleting any DFT of a section and turn off the manual edit mode. The DFTs for that section will be recalculated.

- Change
  The change section wizard is one of the most powerful features in Quantifire, and users are recommended to become familiar with it. It can be used to rapidly modify part or all of the MTO.
  First select the sections to change, by choosing 'All', 'Specific sections', or 'Within zone'. Note that to enter specific sections enter the ID numbers (in the format 1,2,4-6). The sections to be changed can be further filtered using the options under 'Restrict changes to sections with'.
  It is important to note that some changes can affect the Tcrit when methods default from industry guidance or advance calculation have been used. For example, changing a beam from non-composite to composite would change the Tcrit. If the user has changed fields that can affect the Tcrit and has not selected to modify the Tcrit specifically, then the user will be asked if they want to recalculate Tcrit values. If they select Yes, then the values will be updated without changing the method of calculation. If they select No the Tcrit values will remain unchanged. Note that if the 'Modify Tcrit' button is clicked and the method of recalculation is selected then all specified sections will be changed to that method.
  Users also have the option to retain existing section factors and areas/weights, for use when user-specified values have been used and should not be overwritten.

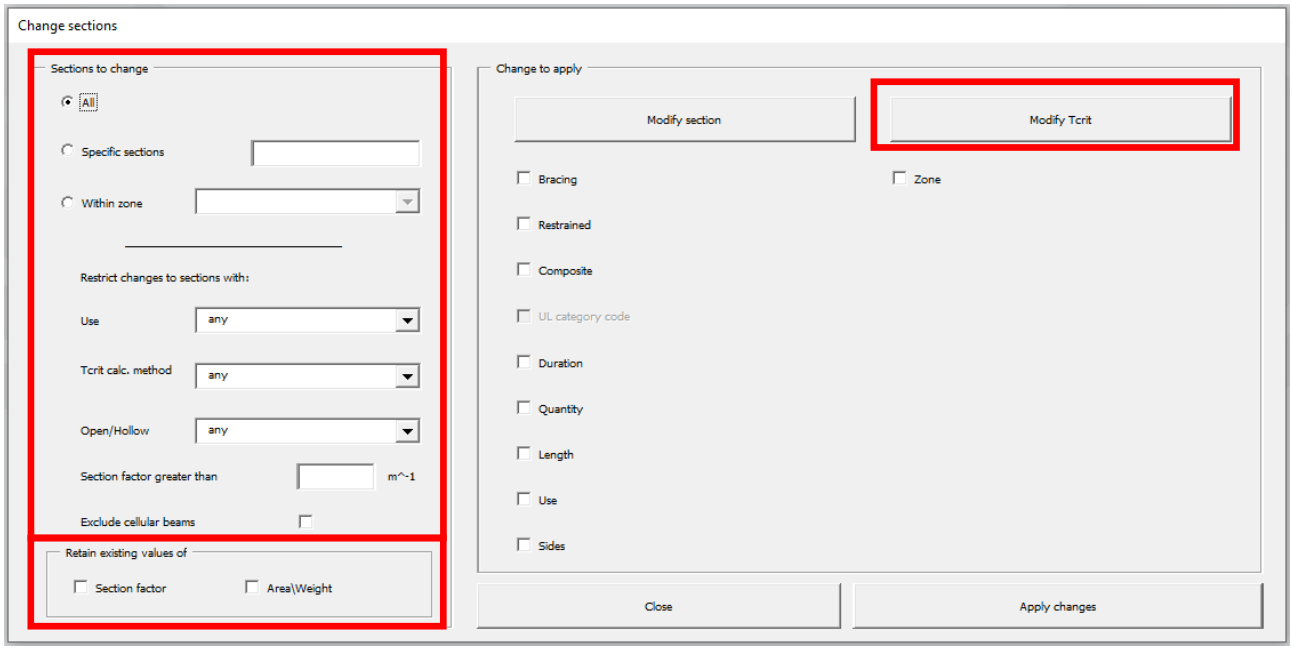



*Figure 22: The Change Sections window*

### *12.6.5 Zones*

This feature allows the user to subdivide the list of estimates into different zones. For example, a job may include sections that require different coatings or a different type of report to the others. Zones allow the user to separate parts of the sections list. Sections entered always take the last position of the selected zone, renumbering other sections as appropriate.

Zones can be added and edited using the buttons as shown in Figure 23.

It is recommended for best practice to sub-divide a material estimate into zones for clarity in reading a report output. However, they can also be useful when changing entries as it is possible to change aspects of the material estimate in a number of ways, including all entries within a zone.

'Edit Zones' includes the option to move zones up or down in the MTO order or to delete the entire zone.

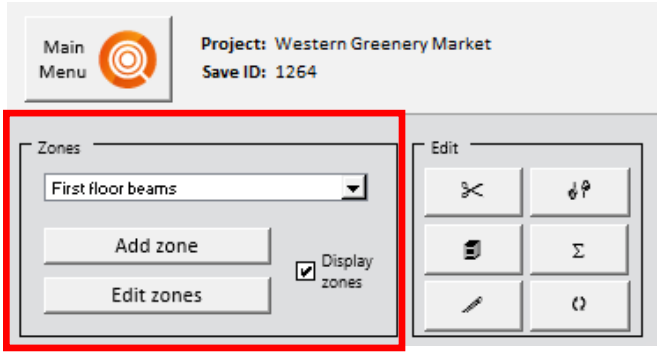



*Figure 23: Zones*

## 12.7 Main Quantifire menu

Clicking on the Main Menu button at the top left of the screen brings up the Quantifire menu, see Figure 24. This allows the user to change the columns displayed, the units, and the dimensions used for input. It also allows further settings to be changed, as discussed elsewhere in this document.

Click on the Quantifire Logo to bring up the Quantifire Menu

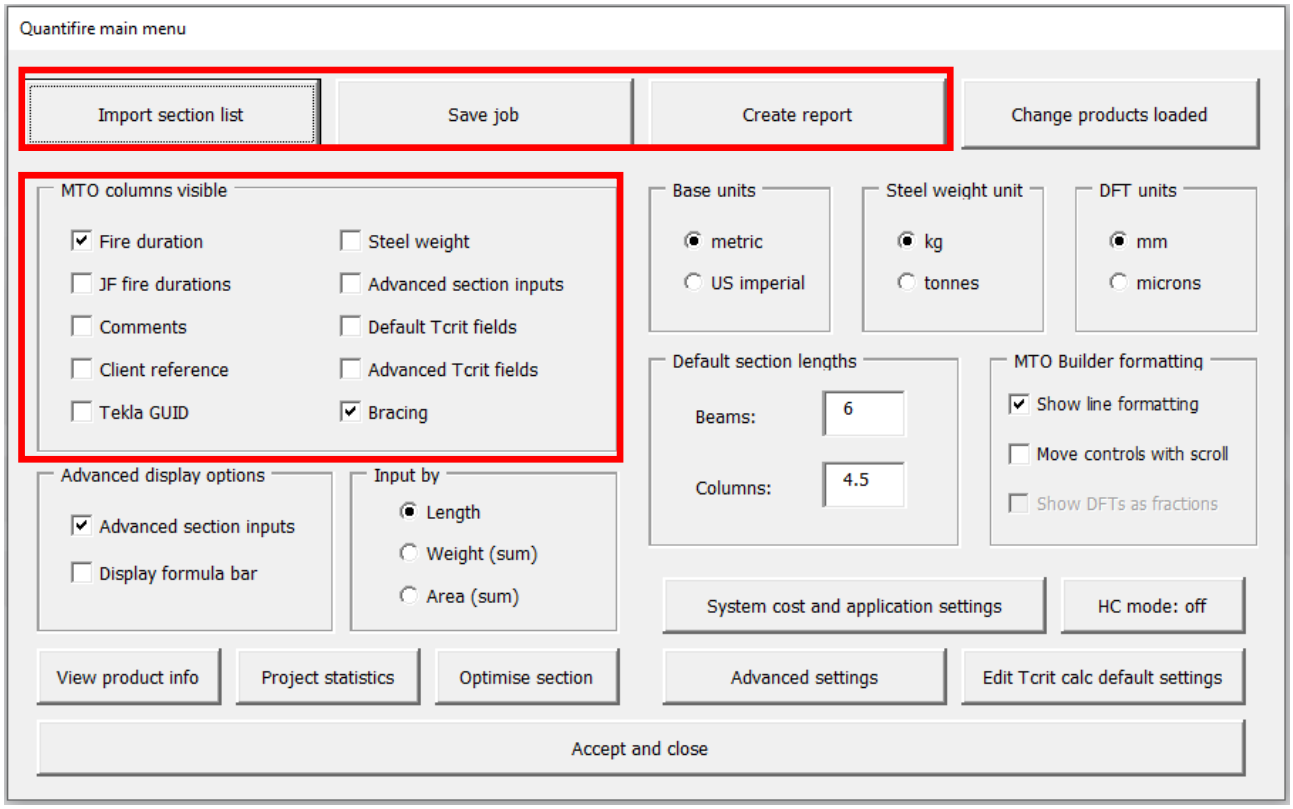



*Figure 24: Quantifire main menu options*

### *12.7.1 Saving*

'Save Job' allows the user to save the estimate progress and return to the project at a later point. Saving the Job generates a Job ID number. The user can search for a saved project by Job ID, so it may be useful to make a note of this number.

*Note that to create a report or save estimates in Play mode, the estimates must be assigned to an existing Project or a new project created.*

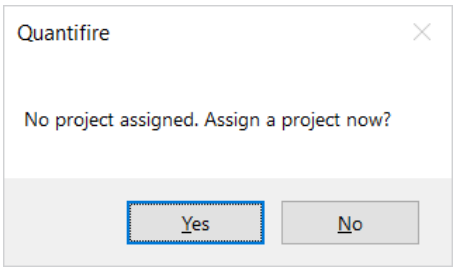



*Figure 25: Assign to project*

### *12.7.2 Generating reports*

Clicking ‘Create report’ allows the user to produce a formatted BOQ report. Each report is tied to a specific save (for traceability) and so clicking ‘Create report’ will automatically save the existing MTO as a new job. For this reason, there is no need to click ‘Save project’ before ‘Create report’.

Click ‘Create report’.

Click 'Yes’ to proceed and select or create a project and package accordingly.

After clicking ‘Create report’, the user is offered three revision options. See Figure 24.

A new report is created by selecting ‘Create new revision’; if the user is returning to edit an existing job for which a report has already been generated, the Overwrite revision option becomes available. Selecting this button allows the user to Overwrite existing reports with the current one. ‘Recreate an old revision’ allows the user to create a copy of a report prepared at an earlier date.

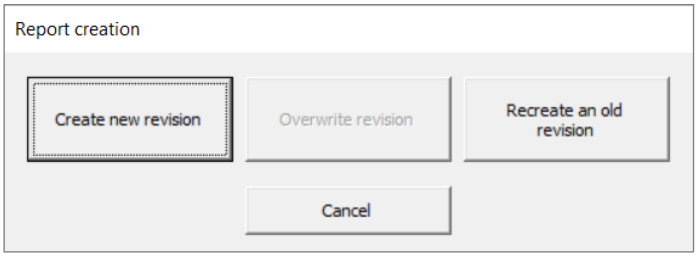



*Figure 26: Revision options*

Following this step, the report Window is displayed as in Figure 27.

The Report window allows the user to set the type of reports produced and the contents of the report. A BOQ report is the standard report, whereas a Technical Basis Schedule is intended as a supplementary report if the user needs to give further information, such as the basis for $T_{crit}$ values or further assumptions.

Users should modify the project details as necessary, select the columns they wish to display, the calculation notes they wish to include, the standard disclaimer they wish to include, and the report language.

Select Preferences, Click 'Create report'.

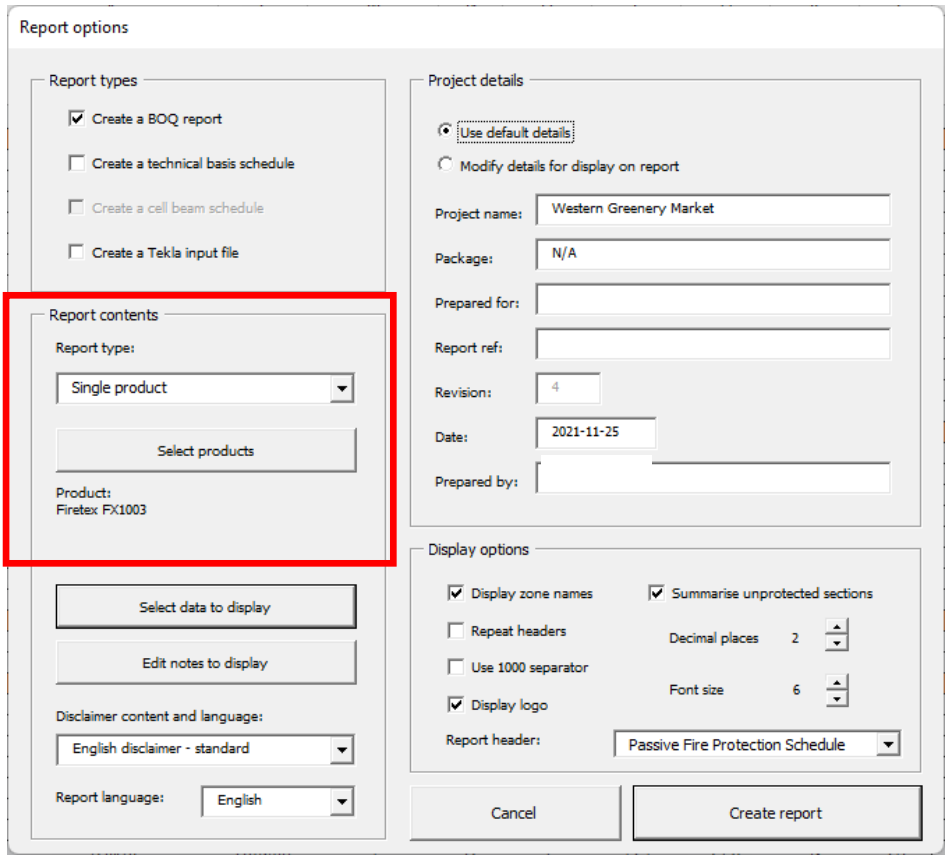
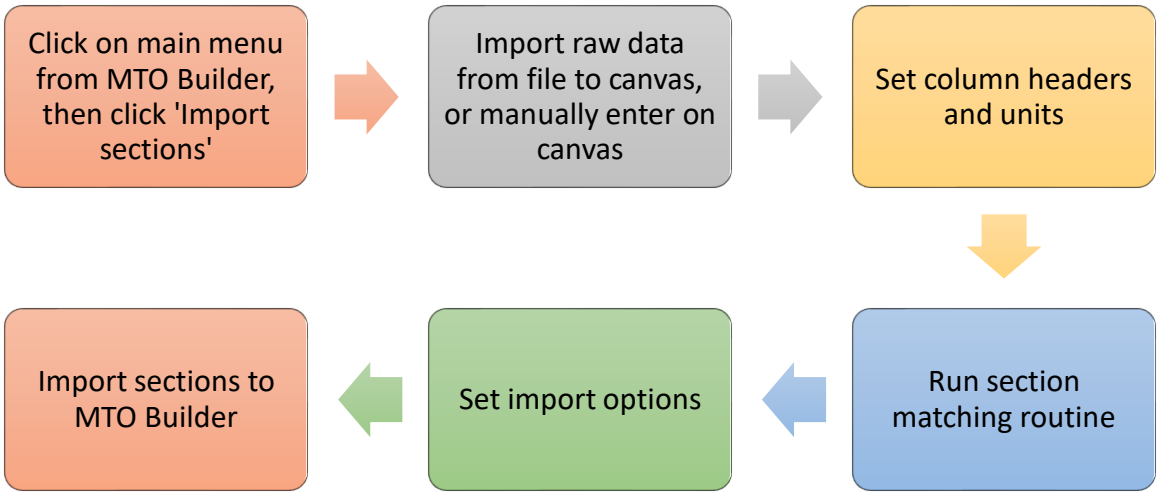



*Figure 27: Report options*

Reports can only give one product, DFT and Quantity per line. If the MTO builder includes more than one product, the user can mix and match products on the report. First by using the drop-down menu to select the methodology (such as selecting specific products under certain conditions, or using Quantifire to optimise the report) and then by clicking on 'Select products' to choose the products to include - highlighted in red.

# 13 IMPORT SECTIONS FROM A FILE OR LIST

The process followed when importing data is as follows:




Before Quantifire can import sections to MTO Builder, it must match sections/profiles on the canvas with built-in section designations. This is explained further below.

## 13.1 Accessing the import feature

From the MTO Builder page click the Main Menu button to open the main menu window. The import feature is accessed via the top-left button. The user then has the choice of selecting a raw-data file to import, or they can start with a blank canvas. Compatible raw-data file types include .xlsx, .xls, .xlsm, .csv, and .txt files, see Figure 28

Use a blank canvas if the raw data is in a format not compatible with Quantifire's built-in recognition routines. When writing or copying & pasting sections, note that column A is reserved for the Quantifire matched section. Do not enter information into this column manually.

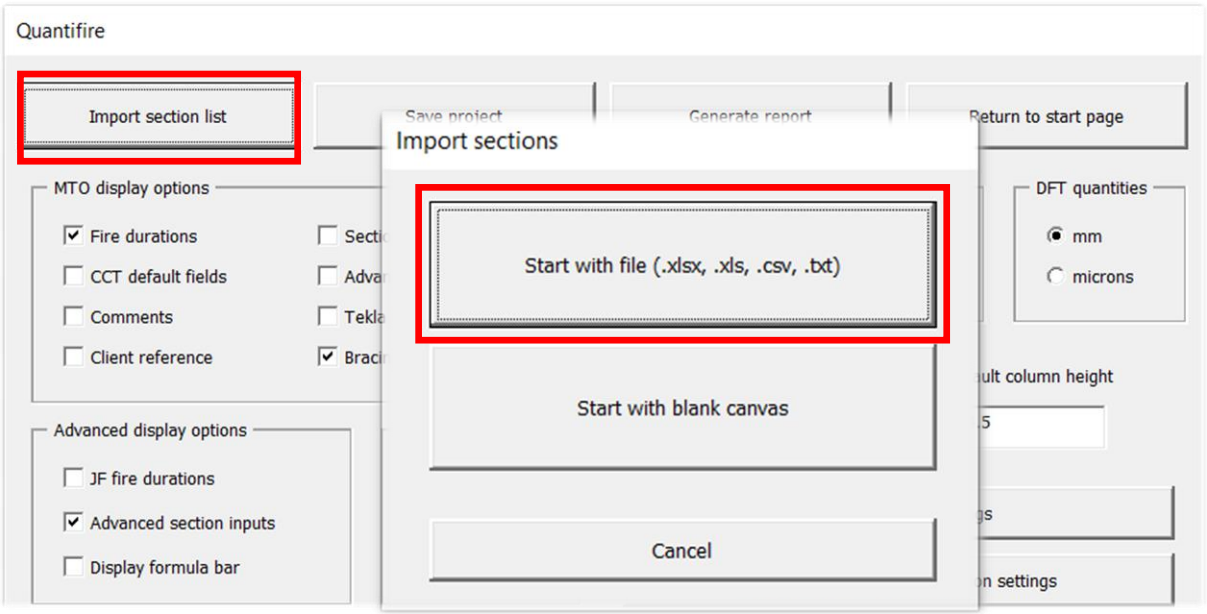



*Figure 28: Import sections*

Whether starting from a file or with a blank canvas, the various parts of the canvas are shown in Figure 29.

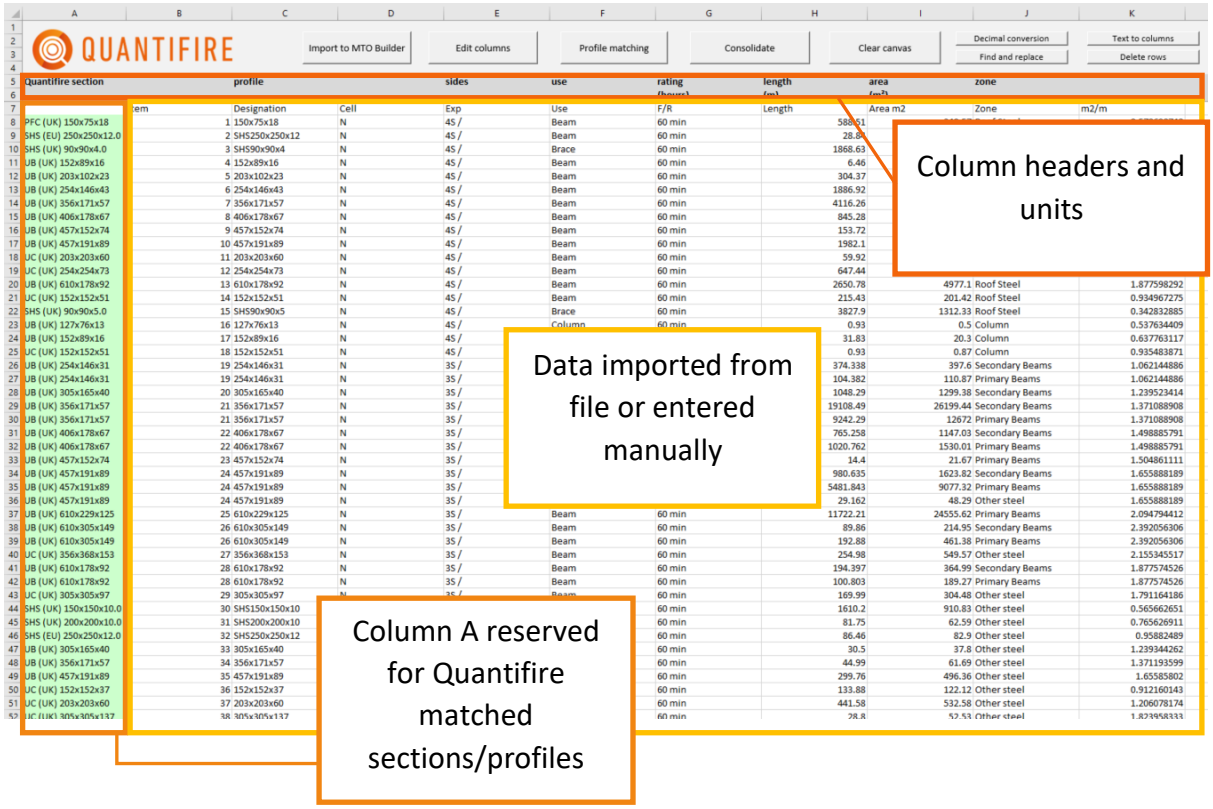



*Figure 29: Import canvas*

## 13.2 Setting column headers and units

Correct setting of the column headers is critical for the import function to work. After importing a raw data file or manually entering the section list, the column headers are set by clicking 'Edit columns' as shown in Figure 30. A menu will open where the user can select the columns that are present and set the corresponding canvas column.

Note that Quantifire will automatically attempt to detect the columns present when a raw data file is imported. This process can be manually initiated by clicking the 'Edit columns' button.

Click 'Accept' and the import canvas will update, showing the headers in rows 5 to 7. Up to three headers can be assigned to the same column.

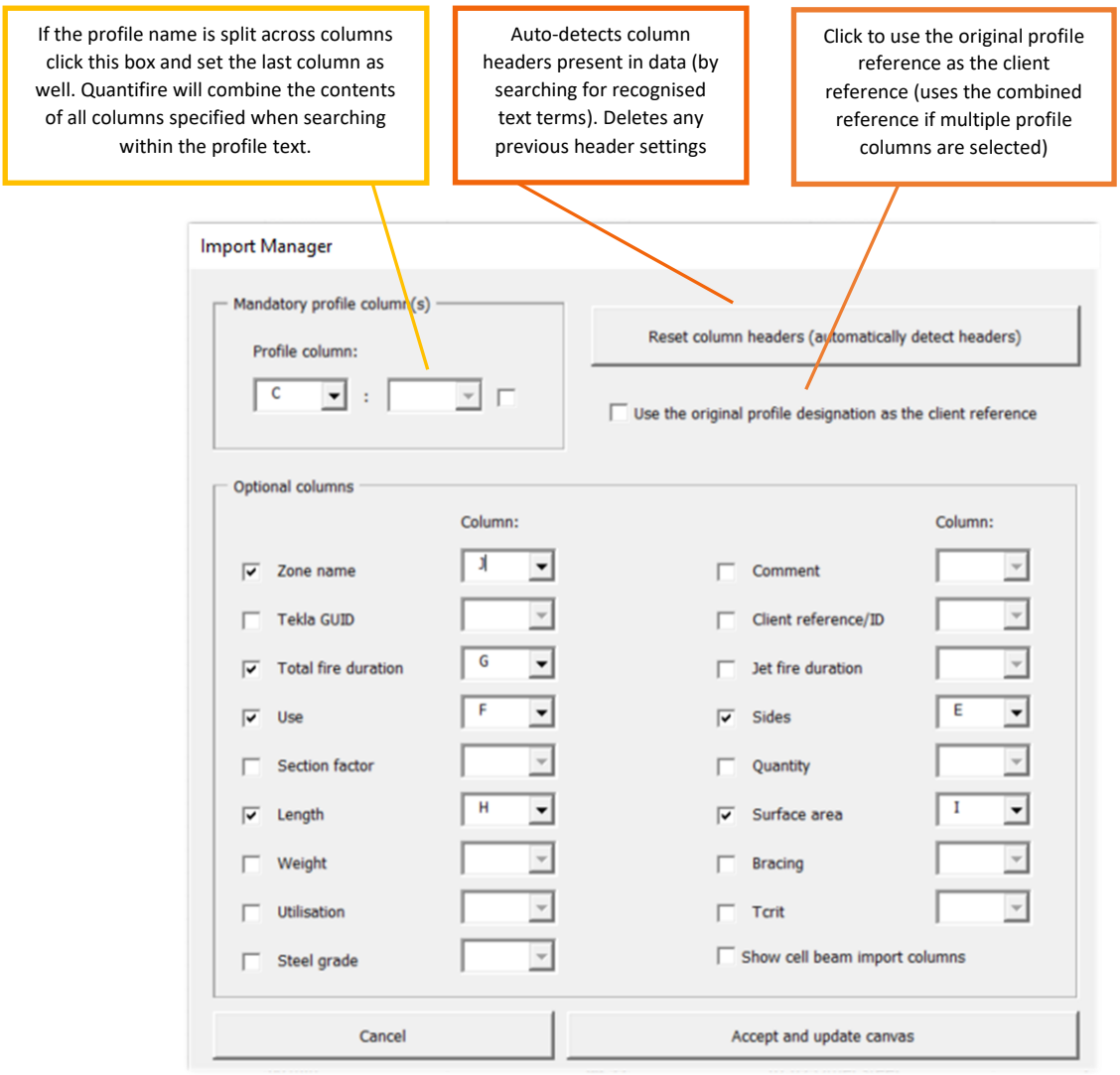



*Figure 30: Import manager settings*

Cellular beam column headers can be defined. The designation text for the cellular beam must still be entered in the *Profile* column. Attributes associated with the beam's geometry and failure criteria

can be set by the user in their respective columns. Where these are not provided by the user, the conservative defaults in the settings will be adopted.

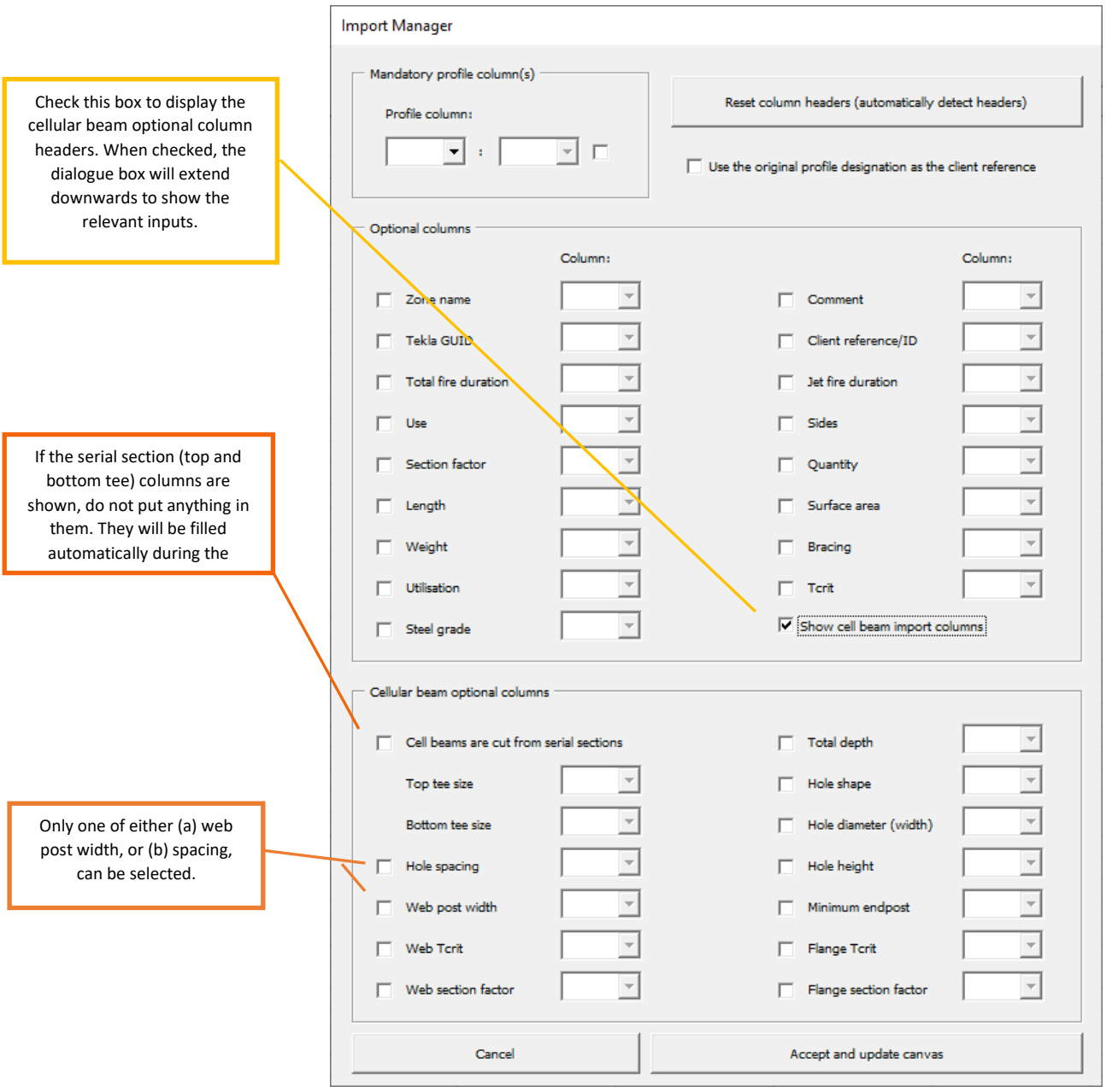



*Figure 31: Import manager settings showing cellular beam inputs*

## 13.3 Quantifire section matching

Before sections/profiles can be imported into Quantifire, they must be matched with the equivalent section in the Quantifire database or entered as Quantifire custom sections. Quantifire will attempt to match the sections automatically when a raw data file is imported. If working from a blank canvas this must be initiated manually via the *Profile matching* button. This opens the options as shown below.

The section matching routine will attempt to match or build sections in the following order:

1) Custom section builder for non-serial types (plate girders, cell beams, concrete filled tubes, built up boxes)
2) Serial section match for the types selected
3) Serial section match without a category code text match, if enabled
4) Custom section builder for serial types when an ideal match is not found (CHS, SHS, RHS, T, L, Channel and Flat sections). Note: serials sections typically have better properties and so are prioritised.

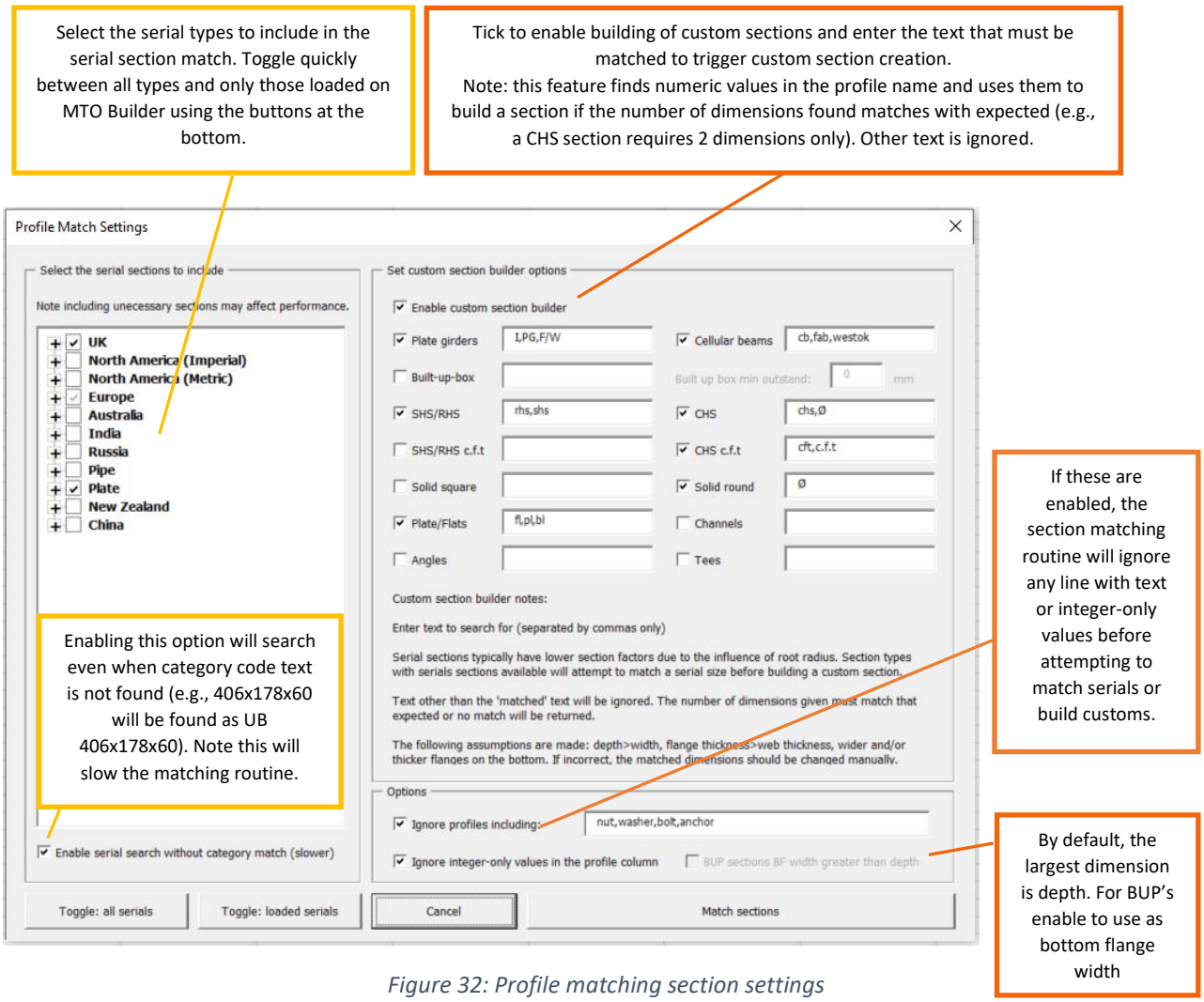



*Figure 32: Profile matching section settings*

## 13.4 Manually matching sections

Before sections/profiles can be imported into Quantifire, they must be matched with the equivalent section in the Quantifire database or entered as Quantifire custom sections. If the raw data includes a list of profiles, then Quantifire can attempt to match these. This is performed automatically when a raw data file is imported and can also be initiated manually from the 'Edit columns' window.

The matching routines may give incorrect results or *'false positive'* results. To correct the matching routine output, click on any row in column A. The resulting menu allows the user to select an alternative section, enter a custom section, or remove the section entirely. This is depicted in Figure 33.

Custom sections can be added via the section selector. If a sides column has been set (see section 13.2) then sides options will be visible, and the one selected will automatically be populated into the sides column when the user clicks OK. If no sides column is set, the sides options will be disabled.

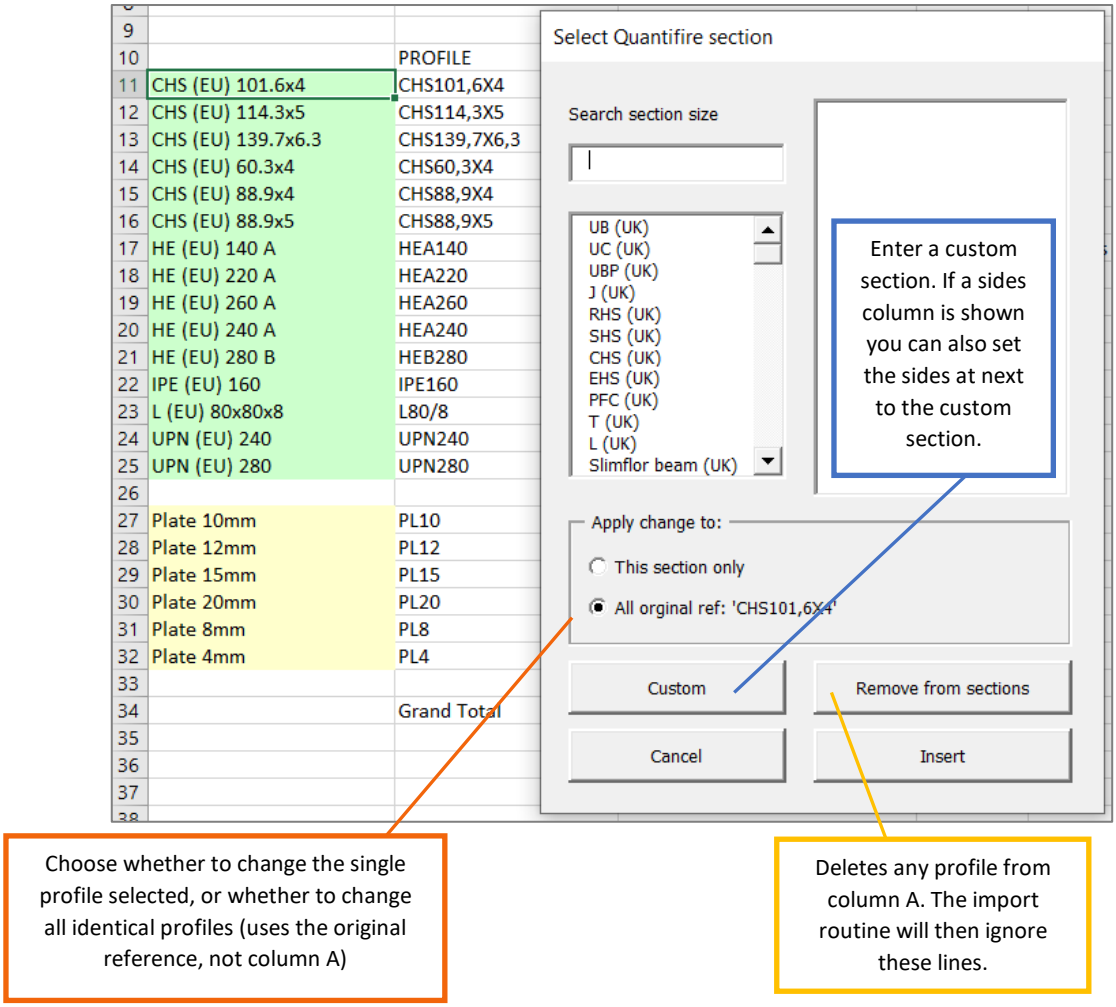



*Figure 33: Section matching*

### *13.4.1 Plate girder, CHS, RHS/SHS, Flat builder*

Section descriptions that include “I” or “PG” will be checked to see if they can be converted into custom plate girders. This requires there to be 4 or 6 numerical dimensions in the profile size.
These will be matched in the following descending order: depth (largest), bottom flange width, top flange width, bottom flange thickness, top flange thickness, web (smallest). Note that if there are only four dimensions present the top and bottom flange will be assumed to be identical.
The section description in the Quantifire Import Canvas will be in a slightly different order, to reflect industry convention, and given as: “I depth x width x web thickness x flange thickness” (or “I depth x top flange width x bottom flange width x web thickness x top flange thickness x bottom flange thickness”).

Section descriptions that include “CHS”, “RHS” or “SHS” will be checked to see if they can be converted into hollow sections. Circular hollow sections require two dimensions, rectangular hollow sections require three dimensions, while square hollow sections can be based on two or three dimensions (or three is the one is given twice).

Section descriptions that include “Flat,”, “Fl,” or “Pl” will be checked to see if they can be created as flats. This requires 2 dimensions.

## 13.5 Canvas features

Length, area and weight columns have units displayed underneath. Click on the units directly to change them as appropriate, as shown in Figure 34.

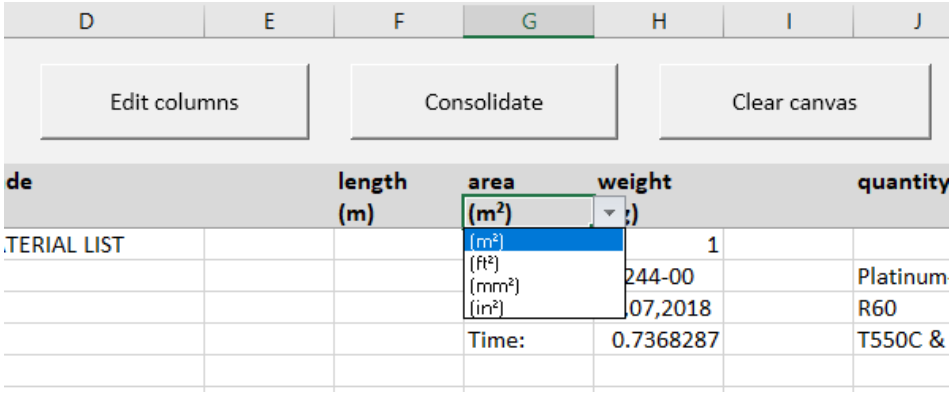



*Figure 34: Changing units on the canvas*

There are further features to help the user manipulate data they load or copy/paste onto the canvas, as described below and shown in Figure 35.

- Text to columns allows users to break text across columns
- Find and replace allows the user to swap unrecognised text for text understood by Quantifire (e.g., "Compression member" for "Column")
- Decimal conversion will swap all points for commas and vice-versa (note that regional setting may automatically alter what is displayed on-screen, however this does not matter if the number is correct).

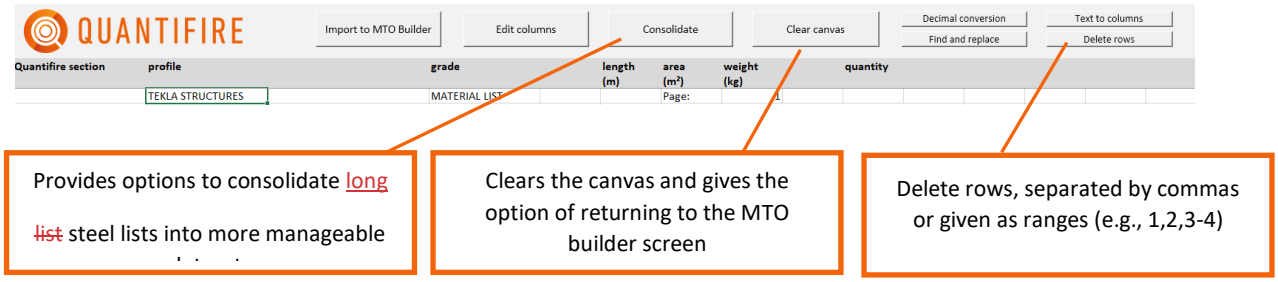



*Figure 35: Additional features to help manipulate data on the canvas*

If the canvas area contains a long list of steel sections with multiple occurrences of a steel member, each with varying quantities and/or lengths, then the consolidation options (see Figure 36) can be used to combine similar sections to simple steel lists before import to the MTO Builder. This is a useful feature and Quantifire provides the user with different options depending on preference.

- As an example: -

UB 406x178x60 QTY = 4 Length = 6m

UB 406x178x60 QTY = 8 Length = 12m

UB 406x178x60 QTY = 2 Length = 6m

Can be consolidated to: -

UB 406x178x60 QTY = 1 Length = 132m

Or to the following, if the length is to be retained for Tcrit calculation: -

UB 406x178x60 QTY = 8 Length = 12m

UB 406x178x60 QTY = 6 Length = 6m

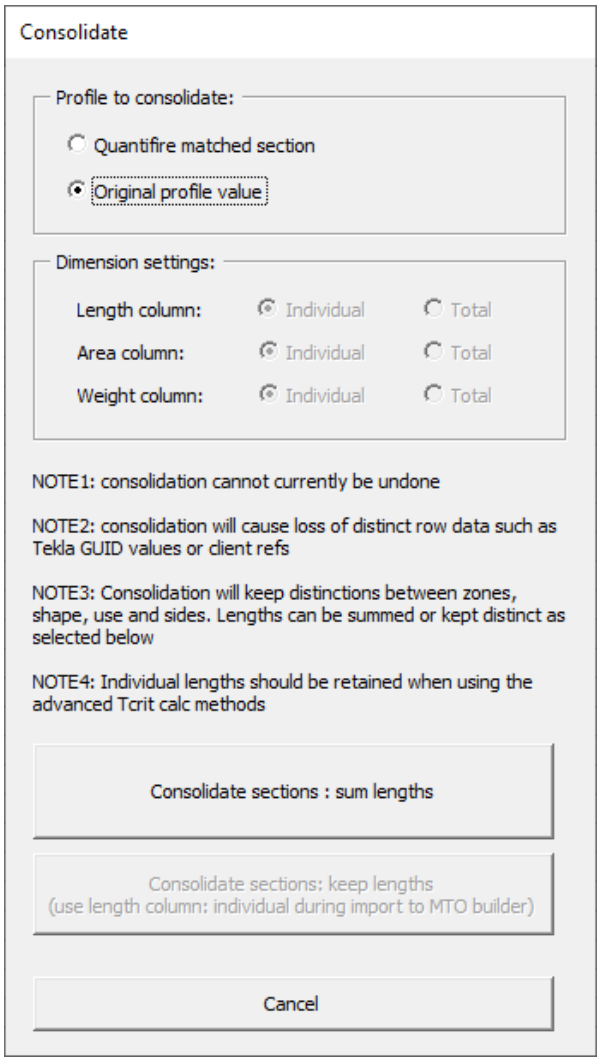



*Figure 36: Consolidation options*

Note that version 1.7.0.0 introduces TCrit and duration (including jet fire duration) into the consolidation routine as fields that must remain distinct. If the user does not wish to keep these distinct they should de-select these columns before consolidating.

- As a further example (using the sum lengths option): -

| | | | |
|---|---|---|---|
| UB 406x178x60 | QTY = 4 | Duration = 30 | Length = 6m |
| UB 406x178x60 | QTY = 8 | Duration = 60 | Length = 12m |
| UB 406x178x60 | QTY = 2 | Duration = 30 | Length = 6m |

Can be consolidated to: -

| | | | |
|---|---|---|---|
| UB 406x178x60 | QTY = 1 | Duration = 30 | Length = 36m |
| UB 406x178x60 | QTY = 1 | Duration = 60 | Length = 96m |

## 13.6 Importing to MTO Builder

Once the canvas is complete, click 'Import to MTO Builder'. Only rows with a profile in column A are considered, regardless of whether there is text present in other columns.

The main import options are shown in Figure 37. The length, area and weight columns must be set to either total or individual. Note that when multiple dimensioning columns are present (e.g. length and area) Quantifire considers length dominant and calculates the surface area and weight per metre of the sections based on the imported length from in-built section dimensions. When multiple quantity columns are present (e.g., weight and area) this can lead to small discrepancies between the import and the original data. To force Quantifire to use the values on the canvas click the appropriate boxes, see Figure 37.

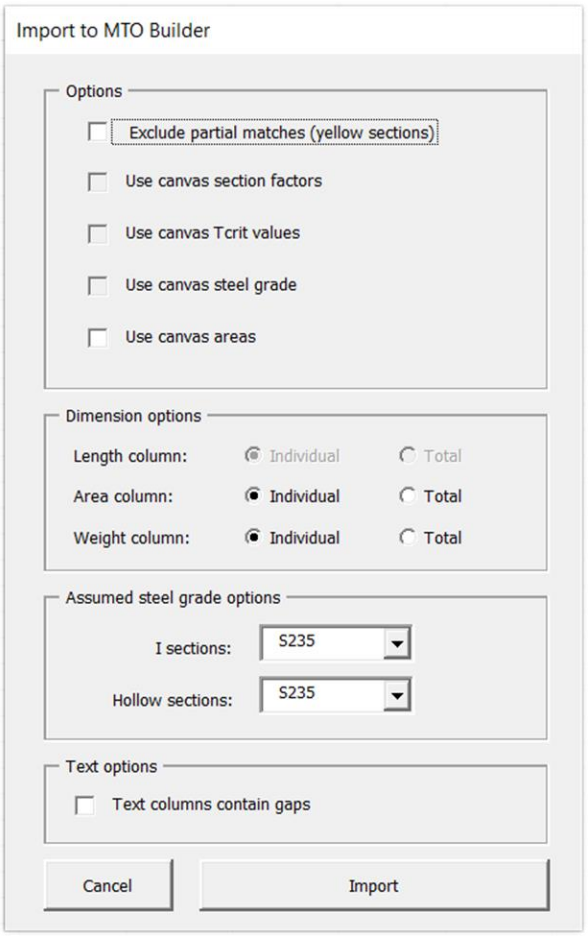



*Figure 37: Import options*

It is common for areas to be reported as total surface areas, ignoring the reduction in fireproofed areas for beams due to the concrete slab. To convert areas of beams to account for a reduction from 4 sides to 3 sides click to use the canvas area values and then click the additional box that appears.

Some text columns (use, bracing) may be present as headers, not as entries for every section. Clicking 'Gaps in data' will retain the last detected value during import until an alternative value is found. Leaving this unchecked will cause Quantifire to revert to the default for that section type unless a specific value is found on every row. Note that the values must be in the same row as Quantifire profiles in column A, otherwise they will be ignored.

If not using $T_{crit}$ values from the canvas the user will be prompted which method to use, and then Quantifire will copy the sections to the MTO Builder.

## 13.7 Zones

By default, all sections are entered into whatever zone was selected on the MTO Builder page when the import feature was initialised, see Figure 38.

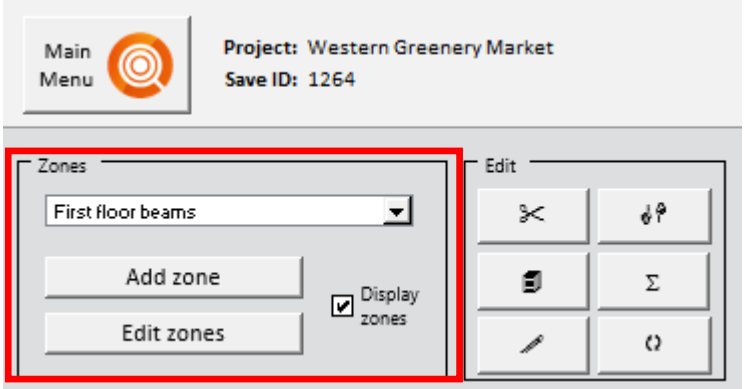
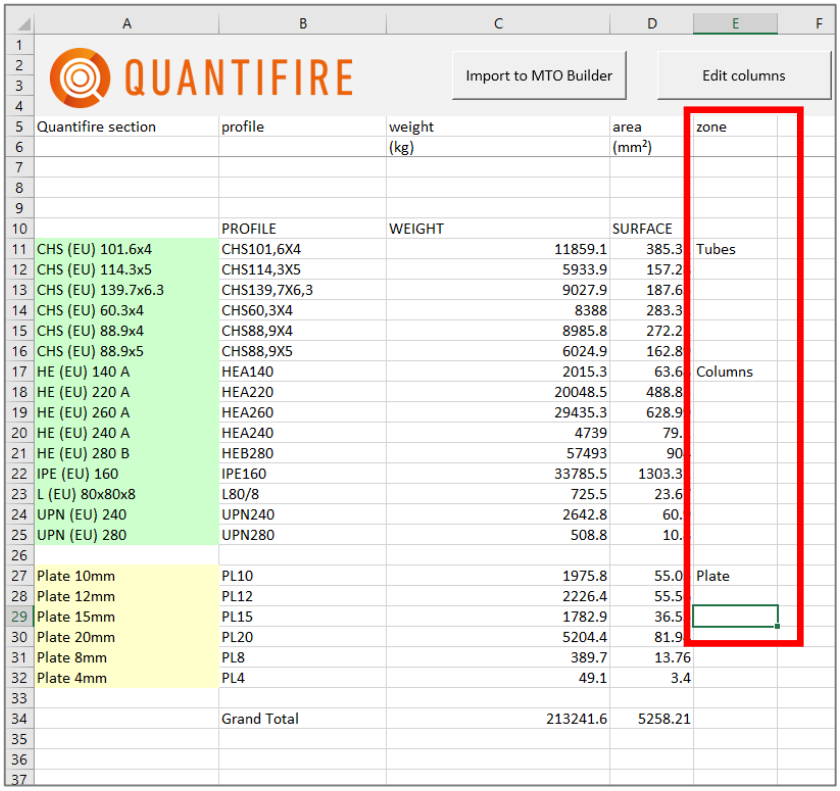



*Figure 38: Zones*

Sections can be imported directly into zones by enabling a zones column on the 'Edit columns' form, see Figure 39. This process will create the necessary zones if they do not exist.

Zone names should be entered in the 'zone' column, ensuring they are in the same row as a Quantifire matched section in column A (otherwise they will be ignored). Zones names are always retained until an alternative name is detected, hence there is no need to copy zone names across all sections as shown in Figure 39.



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | QUANTIFIRE | | | Import to MTO Builder | Edit columns | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | Quantifire section | profile | weight | area | zone | |
| 6 | | | (kg) | ($mm^2$) | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | PROFILE | WEIGHT | SURFACE | | |
| 11 | CHS (EU) 101.6x4 | CHS101,6X4 | 11859.1 | 385.3 | Tubes | |
| 12 | CHS (EU) 114.3x5 | CHS114,3X5 | 5933.9 | 157.2 | | |
| 13 | CHS (EU) 139.7x6.3 | CHS139,7X6,3 | 9027.9 | 187.6 | | |
| 14 | CHS (EU) 60.3x4 | CHS60,3X4 | 8388 | 283.3 | | |
| 15 | CHS (EU) 88.9x4 | CHS88,9X4 | 8985.8 | 272.2 | | |
| 16 | CHS (EU) 88.9x5 | CHS88,9X5 | 6024.9 | 162.8 | | |
| 17 | HE (EU) 140 A | HEA140 | 2015.3 | 63.6 | Columns | |
| 18 | HE (EU) 220 A | HEA220 | 20048.5 | 488.8 | | |
| 19 | HE (EU) 260 A | HEA260 | 29435.3 | 628.9 | | |
| 20 | HE (EU) 240 A | HEA240 | 4739 | 79. | | |
| 21 | HE (EU) 280 B | HEB280 | 57493 | 90 | | |
| 22 | IPE (EU) 160 | IPE160 | 33785.5 | 1303.3 | | |
| 23 | L (EU) 80x80x8 | L80/8 | 725.5 | 23.6 | | |
| 24 | UPN (EU) 240 | UPN240 | 2642.8 | 60. | | |
| 25 | UPN (EU) 280 | UPN280 | 508.8 | 10. | | |
| 26 | | | | | | |
| 27 | Plate 10mm | PL10 | 1975.8 | 55.0 | Plate | |
| 28 | Plate 12mm | PL12 | 2226.4 | 55.5 | | |
| 29 | Plate 15mm | PL15 | 1782.9 | 36.5 | | |
| 30 | Plate 20mm | PL20 | 5204.4 | 81.9 | | |
| 31 | Plate 8mm | PL8 | 389.7 | 13.76 | | |
| 32 | Plate 4mm | PL4 | 49.1 | 3.4 | | |
| 33 | | | | | | |
| 34 | | Grand Total | 213241.6 | 5258.21 | | |
| 35 | | | | | | |
| 36 | | | | | | |
| 37 | | | | | | |

*Figure 39: Entering zones in the import function*

# 14 FIRE DURATION

The fire duration, known as the fire resistance period, is the duration set by the project team and which is regulated by the Approving Authorities.

## 14.1 Cellulosic

Cellulosic fires are those in the typical office or domestic environment, involving furniture, textiles, wall and floor coverings, etc. Typical fire standards include EN 1363-1, BS 476-20, ASTM E-119 and UL 263. When products with cellulosic fire test certification are selected only the total fire duration will be shown. This is equivalent to the fire resistance period.

## 14.2 Hydrocarbon

Hydrocarbon fires are those fueled by oil, gas and other hydrocarbons. Typical fire standards include UL 1709 and BS 476-20 Appendix D. When a product with hydrocarbon fire test certification is loaded three duration inputs will be visible:

- Total fire duration
- Jet fire (JF) duration
- High heat flux (HHF) duration

There is often confusion in the industry about the description of fire ratings. For example, H60 is not an appropriate rating for structural steelwork as it is a divisional rating. Note that divisions within Quantifire are handled as custom sections and should be entered accordingly.

The ‘pool-fire’ rating shall be entered as the total fire duration. Jet fire durations shall be entered as the total jet fire duration including any duration of high-heat flux.

For example, 5 minutes 350 kW/m$^2$ jet fire (HHF jet) fire, followed by 10 minutes 250 kW/m$^2$ jet fire, followed by 45 minutes HC pool fire shall be entered as shown in Figure 40.

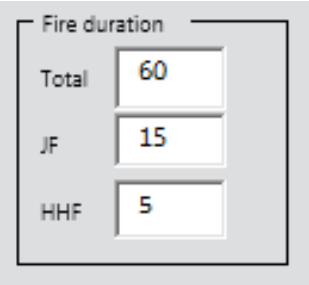



*Figure 40: Fire durations for hydrocarbon products*

Further information on hydrocarbon fires and the hydrocarbon mode is given in section 24.

# 15 STEEL SECTIONS

## 15.1 Serial section library

Quantifire has an in-built library of globally available steel serial sections. While not exhaustive, this list should accommodate the most frequent serials sections used in the industry. Where a section cannot be found in the serial library, then it must be entered as a custom section – see Section 15.2.

Figure 41 shows the serial section library input on the MTO Builder. The user can search for a specific section by typing the designation into the 'Search section size' text box. A section is selected by clicking on the relevant serial type designation in the left box, e.g. UB(UK) and then the required section size in the right box, e.g. 127x76x13.

To access the section library, click the 'I' button as highlighted in Figure 41. This will open the 'Structural section selector' as shown in Figure 42. The user can then browse the available section types, which are grouped by typical regional and country-specific use. Once the required sections are selected, clicking 'Load sections' will load them into memory and populate the 'Section' frame on the MTO Builder page.

Note that upon opening Quantifire, some default sections are loaded automatically. These are a selection of common UK, European and Plate sections.

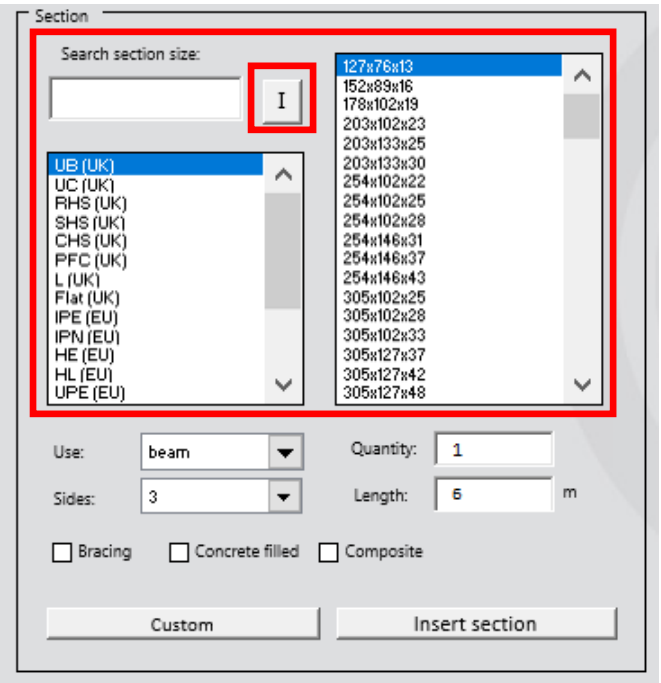



*Figure 41: Serial section library*

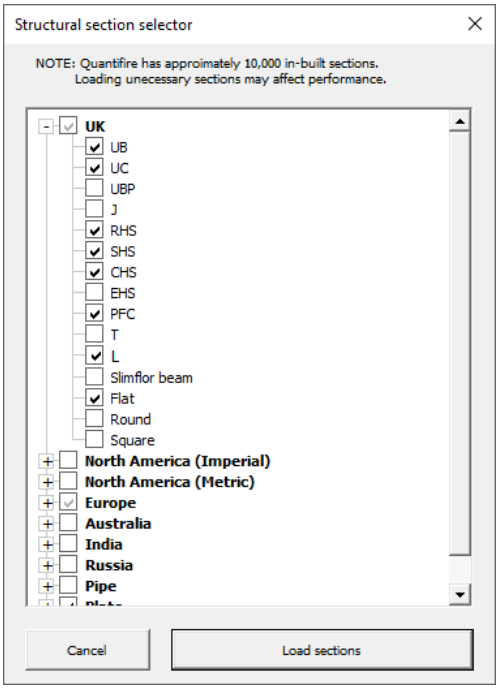



*Figure 42: Structural section selector*

At present, over 10,000 serial sections are available to choose from. However, the user is advised that loading too many sections may affect the performance of the software.

The following geographical regions are currently included together with standard pipe designations and common plate dimensions: -

- UK
- North America (Imperial)
- North America (Metric)
- Europe
- Australia
- India
- Russia
- New Zealand
- Pipe
- Plate

Flats are distinct from plates in that they have a known width. Plates are of unknown width and are given in terms of thickness only. To simplify calculations a nominal width of 1m is assumed, therefore the length in meters is equivalent to the surface area in $m^2$ for one-sided plate or equivalent to half the surface area for a two-sided plate.

If a user is aware of additional sections that could be included, they are encouraged to contact the developers of Quantifire to enable them to update the section library accordingly.

## 15.2 Custom steel sections

Where a serial section does not exist in the library or a member is fabricated from plates, then it must be entered as a custom user-defined section. To access the input box to do this, click the 'Custom' button in the 'Section' frame on the MTO Builder page as shown in Figure 43.

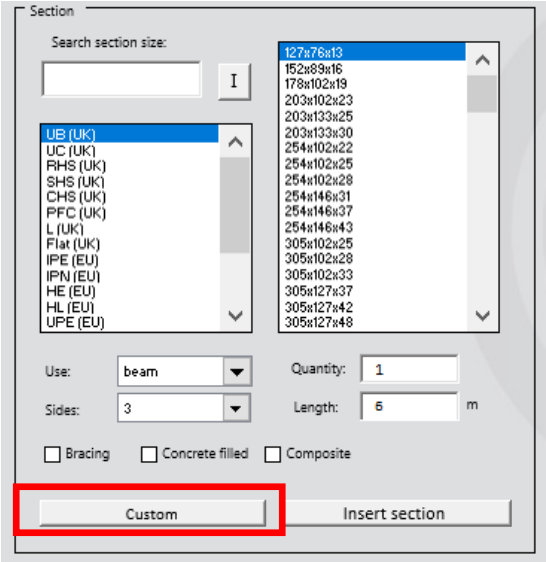



*Figure 43: Accessing the user-defined custom section generator*

### *15.2.1 Custom fabricated sections*

The user-defined section dialogue box is shown in Figure 44. The following section types can be entered using the relevant tabs in the 'Member dimensions' frame: -

- I-shape
- SHS/RHS/CHS
- Tees
- Channel
- Angle
- Flats
- Rods
- Cell beam
- Bulkhead / deck (see section 24.7)
- Custom (permits a definition directly by a section factor)

Within each tab, the relevant dimensions in the white boxes must be entered. Note that for some section types, for speed of use certain dimensions will automatically be repeated, e.g. for an I-beam, the entered top flange width is automatically shown to be the same for the bottom flange. The user can overwrite these values by ticking the checkbox to the right of the value.

Note that a 'Proposed section designation' is displayed towards the bottom of the dialogue box. This uses the section type and the member dimensions. This designation will be used by Quantifire unless a 'Custom section designation' is defined by ticking the checkbox and entering a designation name.

Once defined, click on 'OK' to modify Use, $T_{crit}$, Quantity, etc. Alternatively, click 'Quick insert' to add straight into the MTO Builder list and keep the dialogue box open to add more sections.

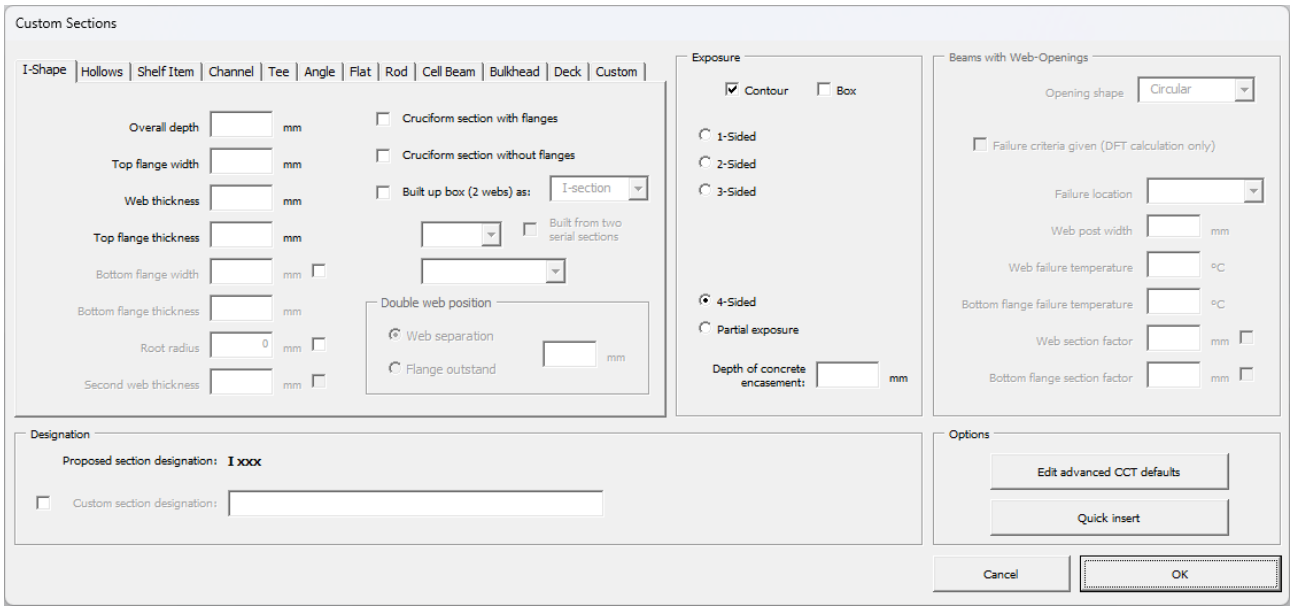



*Figure 44: The user-defined section dialogue box*

If the user selects 'OK' then they are returned to the MTO Builder page. Note that the custom section designation now shows at the bottom of the 'Section' frame alongside 'Working with:', as shown in Figure 45. The user can then modify the setting options, i.e. Use, Sides, Quantity, etc. prior to clicking 'Insert section'.

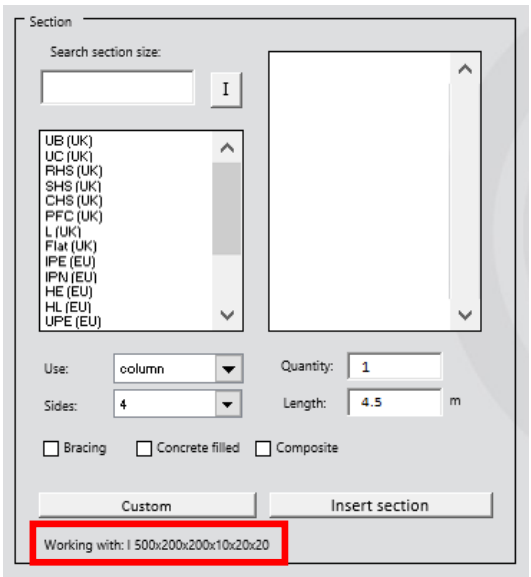



*Figure 45: Example of a custom section prior to being entered into the MTO list*

### *15.2.2 Specifying a section factor directly*

In some instances, the user may want to define a section purely by its section factor. In this case, use the Custom section dialogue box and select the 'Custom' tab. The user must select whether it is a hollow section or not, as this is used with the use and side to determine the appropriate product thickness from the certification.

### *15.2.3 Concrete filled tubes*

Some designs use concrete filling of a steel tube to either provide an enhanced structural performance and/or to achieve the required fire resistance. The heat sink of the concrete typically permits a beneficial thickness of passive fire protection with respect to an unfilled tube. Quantifire can accommodate these within an estimate. There are several aspects to be aware of when entering concrete filled tubes – these are explained further in Section 16.5.2.

Concrete filled tubes can be defined with respect to serial sections and custom sections. For serial square, rectangular and circular sections, check the 'Concrete filled' checkbox on the MTO Builder page, shown in Figure 46.

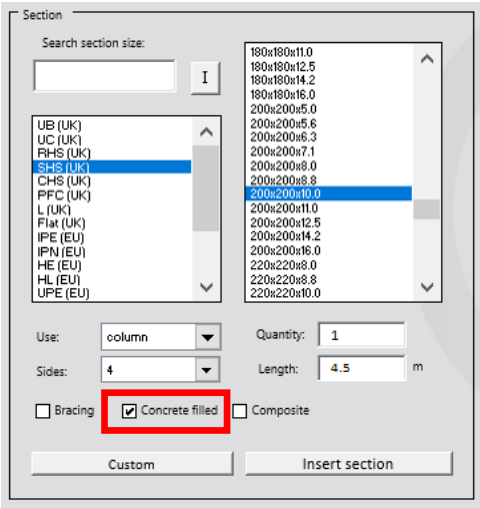



*Figure 46: Defining a concrete filled tube for a serial section*

Custom sections which are filled with concrete are entered by clicking the 'Concrete filled' checkbox on the relevant section type tab on the 'User-defined section' dialogue box as shown in Figure 47. Note that the 'Proposed section designation' at the bottom of the dialogue box will include a '(cft)' notation to confirm the concrete filling.

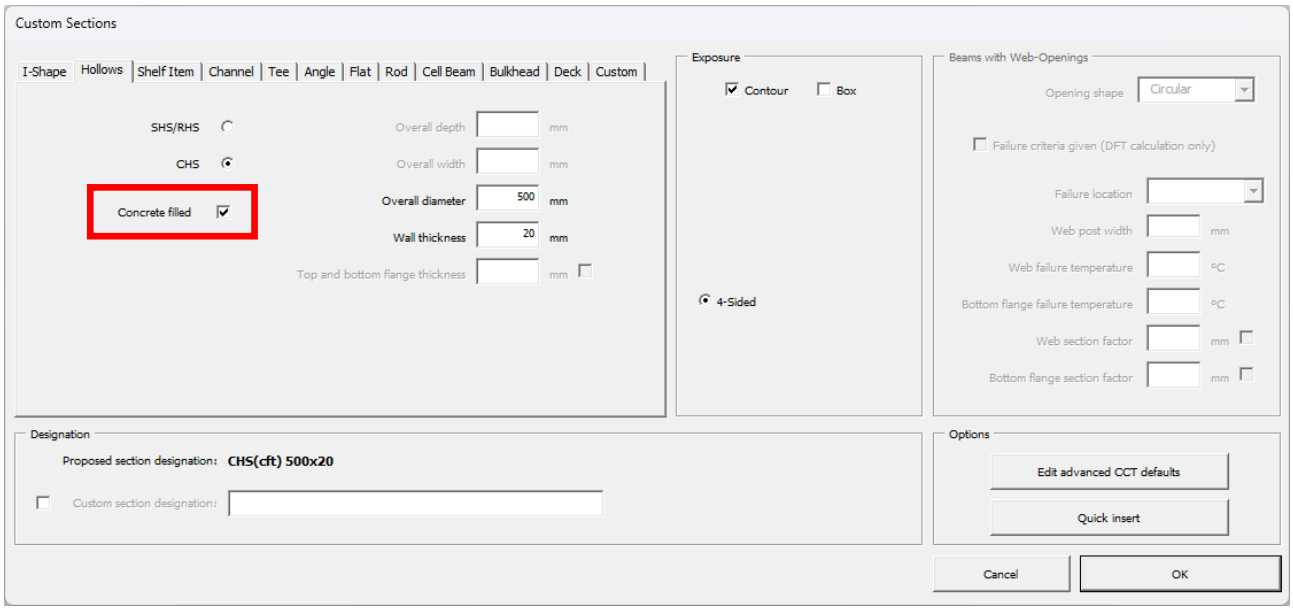



*Figure 47: Entering a concrete filled design using the custom section dialogue box*

### *15.2.4 Beams with large web openings*

Beams with large web-openings (also known as cellular beams or cell beams) require special treatment. They can only be protected with products that have the appropriate certification and their critical temperature requires a detailed structural assessment.

See Section 17.3.4 for more discussion on how cell beams are analysed.

When selecting products, ensure that at least one product is selected that has certification for cell-beams as shown in Figure 48. Only products that have been tested on cell beams to generate web-post factors and have been reassessed to generate elemental multi-temperature analysis (EMTA) thicknesses are permitted to be used to protect a beam with web-openings.

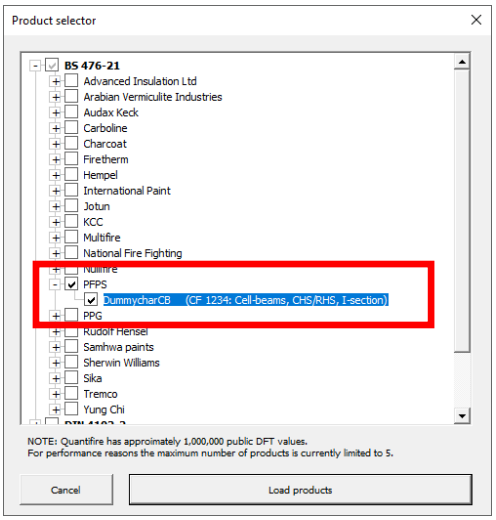



*Figure 48: Select a product that has cell beam certification. Note 'Cell-beams' in description.*

Click the 'Custom' button to enter a custom section.

Click on the 'Cell Beam' tab in the member dimensions area.

The beam's cross-section must be entered as either a series of plates or from top and bottom tee serial sections. Figure 49 shows an example using plate dimensions.

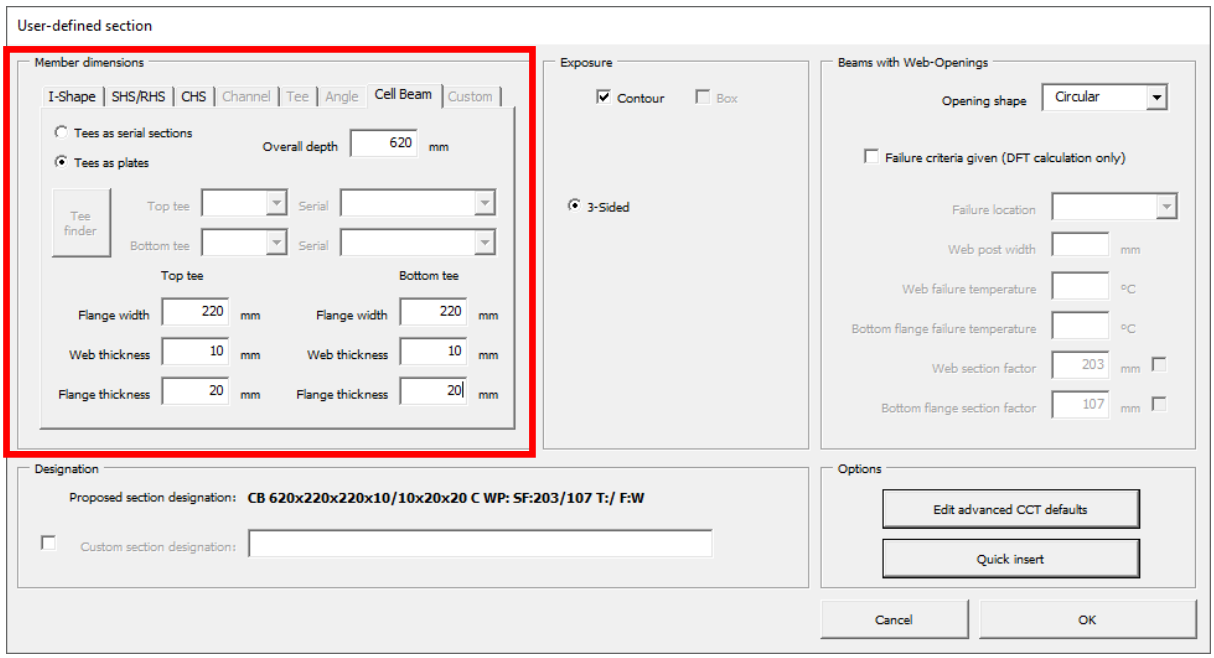



*Figure 49: Cell-beam tab on the custom section window. In the above example, a beam made from plates is shown as per the dimensions in the input boxes.*

Some UK cell beam designations are provided in the following format: -

*Depth x Top flange width / Bottom flange width x Average linear weight*

*e.g. 533x140/178x56.5*

In this case, the 'Tee finder' button can be clicked, and the section designation entered. By then clicking on 'Find top and bottom tee', the Quantifire will determine the possible combination on top and bottom tee based on serial sections, as shown in Figure 50. The user can then choose which design to adopt.

The tee finder cycles through possible combinations of UB and UC serial sections until their average weight matches that given in the input box.

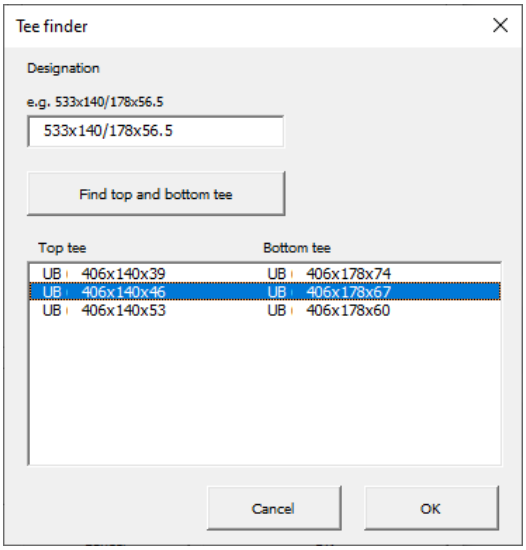



*Figure 50: Tee finder tool*

After using the tee finder tool and clicking 'OK', the serial sections and the overall depth of the beam are populated on the cell beam dimensions form, as shown in Figure 51.

Alternatively, the serial sections could be entered manually from the dropdown input boxes, together with the overall height of the beam.

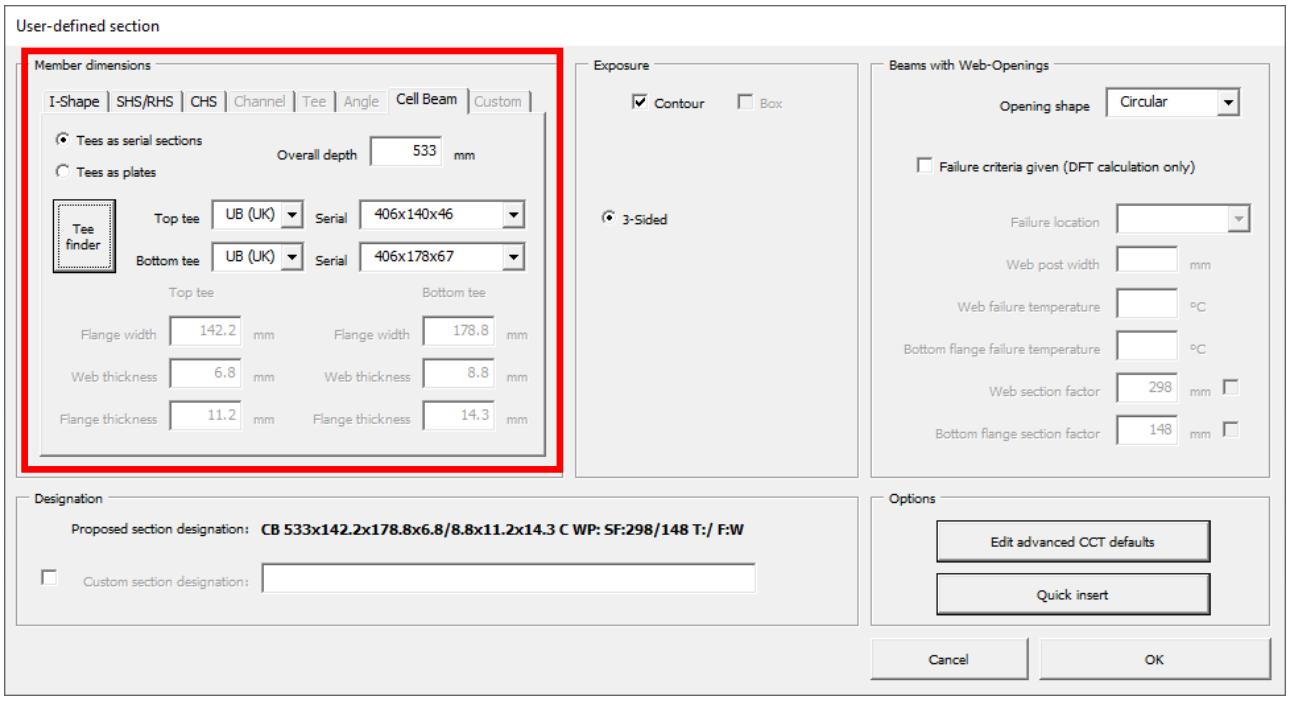



*Figure 51: Example of a beam cross-section input in terms of serial sections*

If the failure temperatures of the cellular beam are provided by a client, then they can be entered directly into the custom member window, as shown in Figure 52. Click on the tick box 'Failure criteria given' and enter the relevant data.

Note that if a single temperature is provided, enter it for both the web and the bottom flange.

Note that the web and bottom flange section factors calculated and shown in the form. These can be overwritten by checking the tick box alongside the relevant value.

The opening shape should be the shape associated with the failure of the beam, e.g. opening shape if failure is at an opening or opening shape either side of a web-post failure. A rectangular shape will typically be conservative if the shape is unknown, although circular shapes are most common in design.

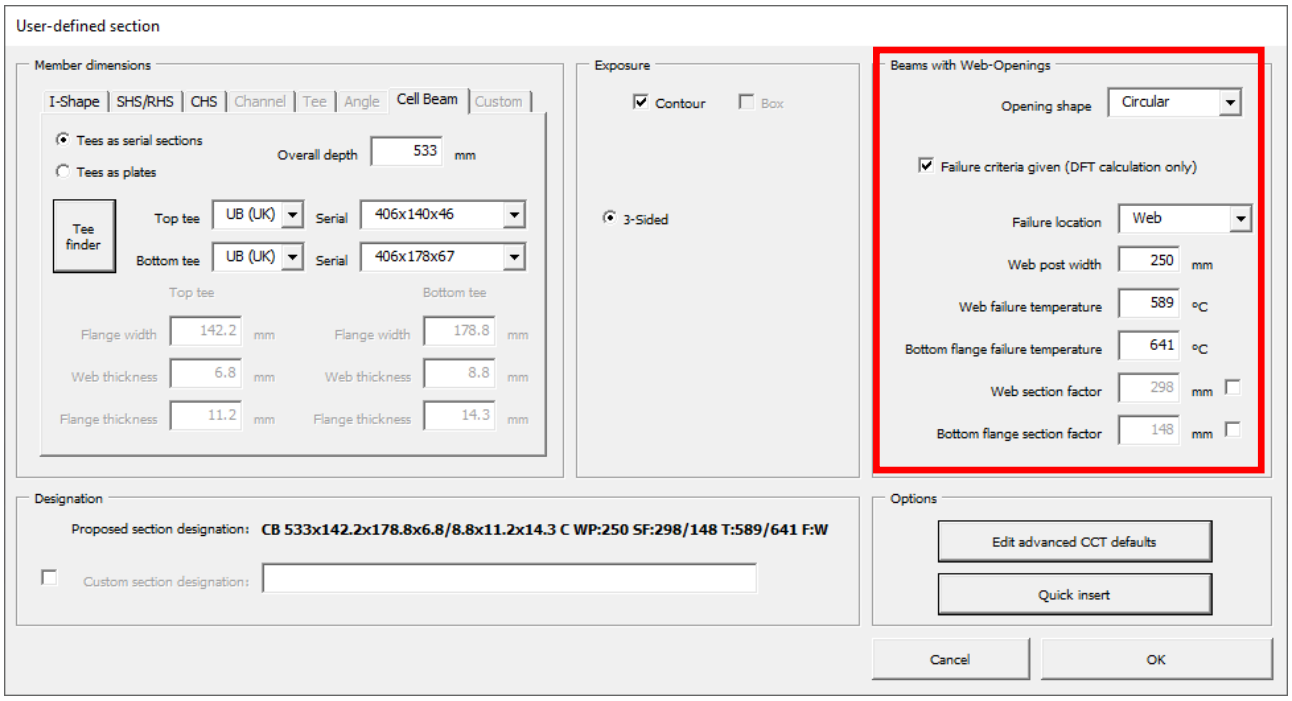



*Figure 52: Entering failure criteria when they are provided directly by a client*

In many cases, no failure criteria are provided. In this case, the only required parameter is the opening shape, as shown in Figure 53.

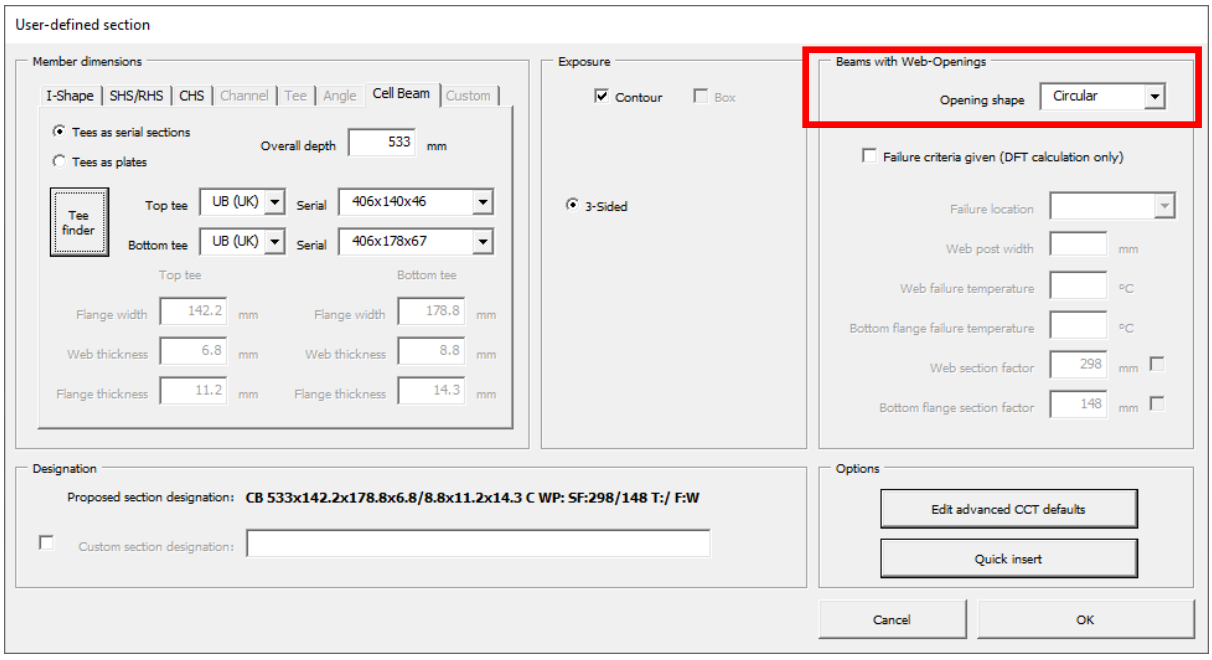



*Figure 53: When no failure criteria are provided by a client*

After clicking ‘OK’ on the custom form, the beam information is held just below the ‘Custom’ button, starting with ‘Working with:…’. If the user is happy with beam designation and fire resistance period, then click ‘Insert section’ to add it to the MTO list, see Figure 54.

Note that temperature options ‘Default’, ‘Advanced’ and ‘User set’ are not compatible with cellular beams. Failure temperatures must be specified directly, or the advanced calculator used.

If no failure temperature criteria are provided, then Quantifire will automatically use its limiting temperature calculator to determine the failure temperature.

Note that failure temperatures calculated by Quantifire will be stated as 'Q+CB' on the MTO Builder and will not be displayed. This is because the temperature is product-specific and is not fixed. To view temperature calculation outputs the user can use the Tcrit editor function.

Beams with web-openings can be entered as 4-sided, only when the failure criteria are provided. Failure temperature calculations undertaken by Quantifire are based on 3-sided published structural models only. At the time of writing there is no published explicit structural methodology to determine a failure temperature of beam with web-openings exposed on 4-sides.

In the case of 4-sided beams with web-openings, Quantifire treats the top flange in the same manner as the bottom flange. DFTs are evaluated from the EMTA datasets for the flanges and the web (following modification of the web failure temperature with respect to the web-post factor). The highest DFT is adopted for the overall section.

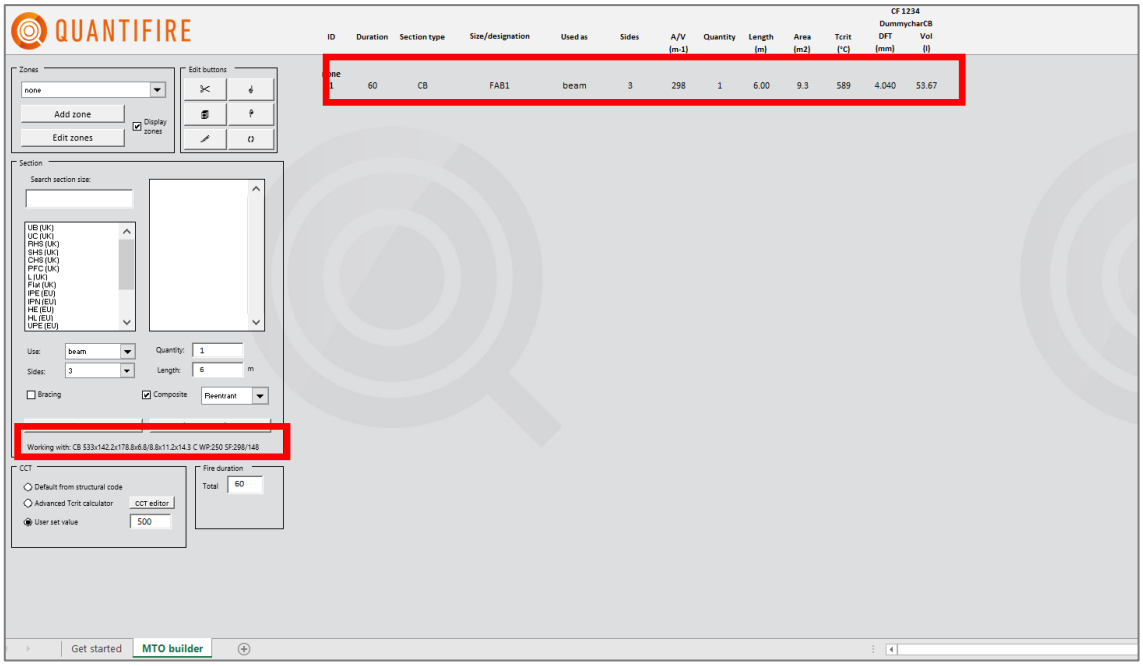



*Figure 54: Entering a cell beam into the MTO builder*

A default span of 6m is adopted by Quantifire. This can be changed by the user, however, it adopts this value to negate issues related to cumulative length (e.g. 2673 m of beam) being entered and assumed as the span of a single beam.

If no opening geometry is defined, then Quantifire will put as many openings as possible into the web of the beam as permitted in accordance with the user preferences, see Figure 55 (click on the Quantifire logo and then 'Edit default $T_{crit}$ settings'. All preferences can be changed by the user but are initially set as conservative defaults.

By default, the web-post width is set to 130mm as this correlates with the typical minimum required in fire testing.

The beam is then subject to loading as defined in Default $T_{crit}$ preferences, which by default is a conservative level of 65% at the accidental limit state of fire. This value is defined in EN 1993-1-2 to be used in the absence of actual loading being known. Note that it can be very conservative and may lead to many sections not being able to be protected.

Other default settings for cell beams are taken from those defined under the 'Partial Safety Factors & Loading' tab and the 'Beam' tab.

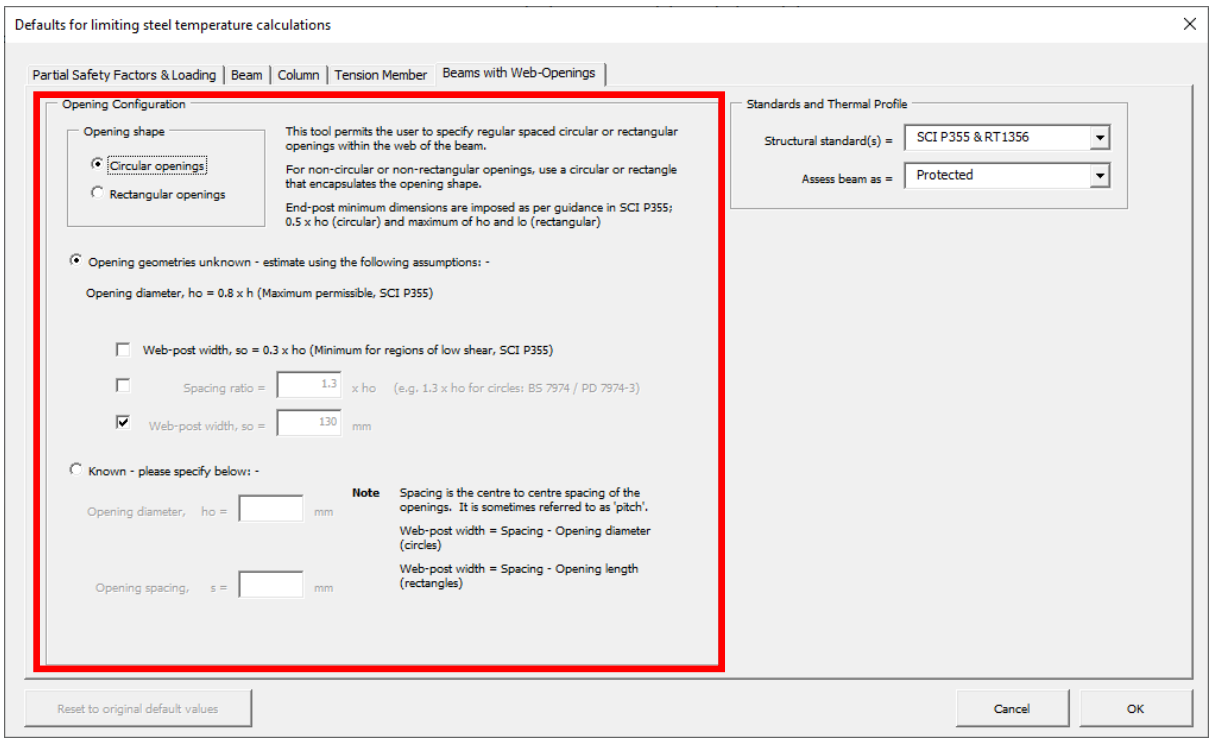



*Figure 55: User preferences for limiting temperature assessments for beams with web-openings*

The key dimensions and associated notation of a beam with web-openings are shown in Figure 56. These are applicable for circular, elongated or rectangular openings. Not shown is the length of an elongated or rectangular opening, $l_o$. Note that the end-post dimension is the distance between the end of the beam and the edge of the first opening.

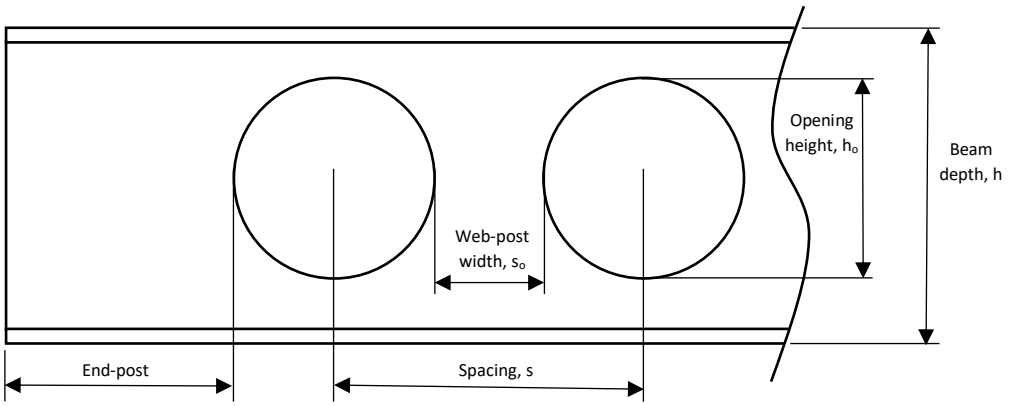



*Figure 56: Schematic of beam with web-openings, showing key dimensions and associated notation*

To see the detail related to the beam, click on '$T_{crit}$ editor' and enter the relevant section ID of the beam into the input box, see Figure 57.

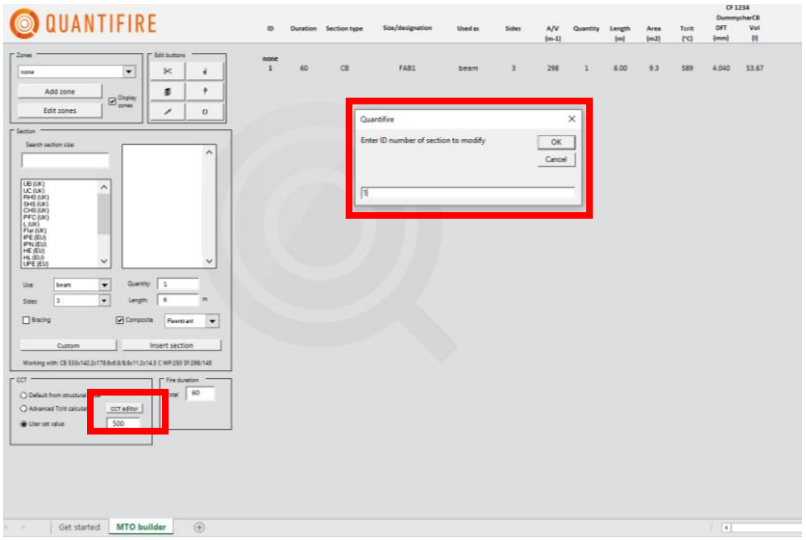



*Figure 57: Viewing more detail associated with the cell beam via the $T_{crit}$ Editor button*

After clicking on 'OK' the relevant information for the cell beam is populated onto the cell beam calculator sheet, as shown in Figure 58.

All the white boxes can be modified by the user as required. If modified, their value will be retained by Quantifire on a section by section basis.

A visual representation of the beam and its openings is provided. In Figure 58, it is shown that the default 130 mm web-post has been captured. The user may modify the opening geometries accordingly, for example, if opening information has been provided.

If openings are irregular along the length of the beam, then each opening must be entered manually.

If openings are regular, then the 'Generate regularly spaced openings' button can be used to automate opening definitions.

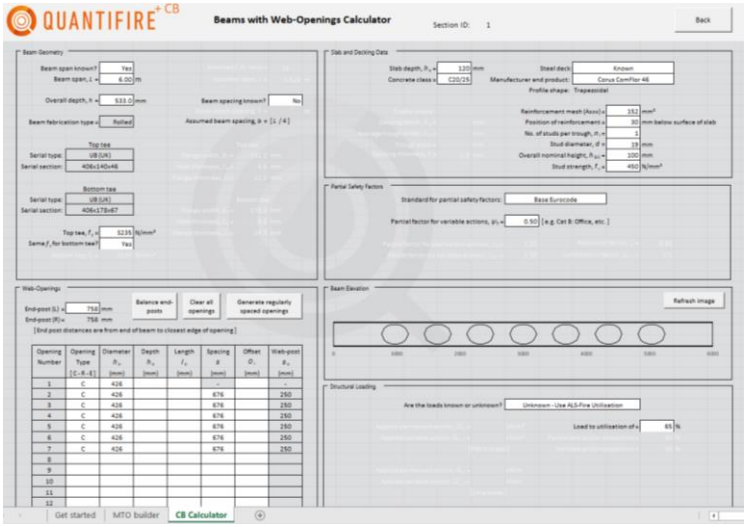



*Figure 58: Detail associated with the cell beam*

Scroll down to see the output results (including limiting temperature) associated with beam, see Figure 59.

Click on ‘Assess beam’ to find its limiting temperature

Click on ‘Generate report’ to produce an output report of calculations that can be printed

Click on ‘Accept beam and return’ to enter the beam and its DFT and failure criteria back into the MTO list.

Note that further discussion on use of the calculation of beams with large web-openings is provided in Section 17.3.4.

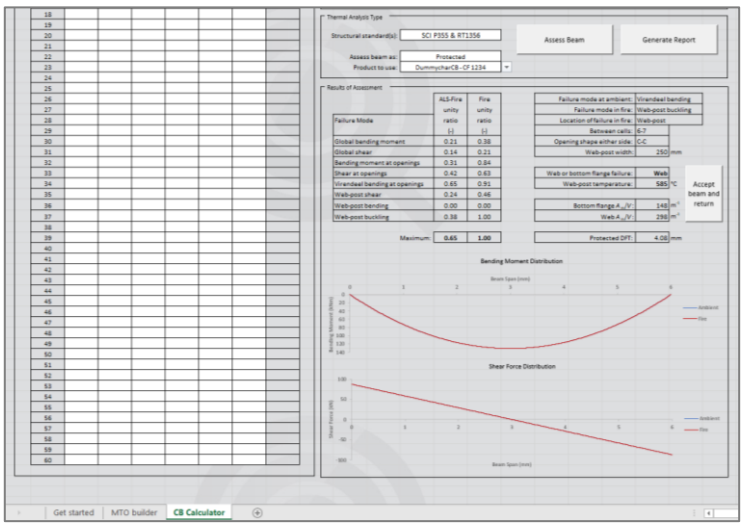



*Figure 59: Finding a failure temperature, and understanding the output results*

The user should note that the surface area of a beam within Quantifire is by default the surface area of an equivalent solid-web beam. As such, wastage calculations should take this into account. The settings (Figure 60) can be modified to use the actual area of the beam, i.e. removing the openings from the surface (ignoring the surface of the inside of the opening), however, this approach should only be used when the exact opening geometry is known and as such, wastage calculations should be modified accordingly.

In a similar sense, to the surface area, the steel weight associated with a beam with openings is reported as the weight of an equivalent solid weight beam. This is typically how cellular beam weights are described in industry.

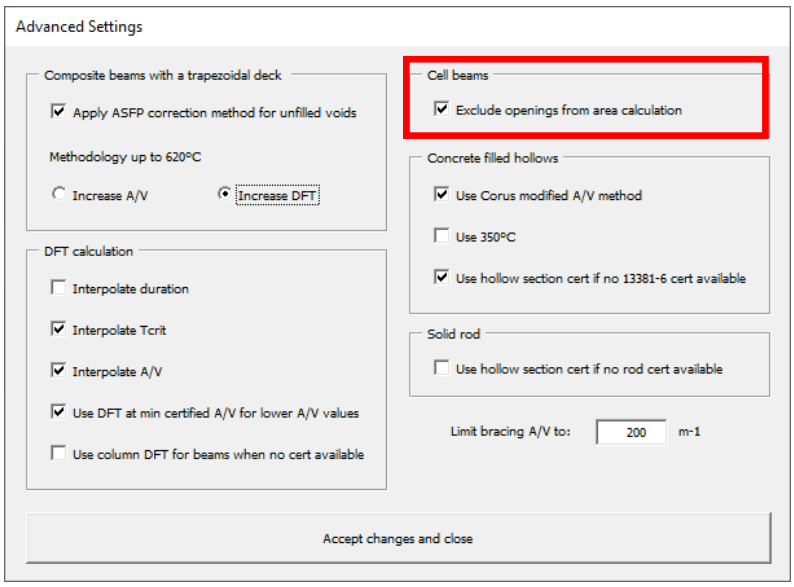



*Figure 60: Advanced setting for cellular beam area definition (showing default option within Quantifire)*

# 16 SECTION ENTRY OPTIONS

After selecting a serial or custom section, the user can define further attributes associated with the member. These are all contained within the 'Section' frame and are explained below.

## 16.1 Use

The dropdown alongside 'Use' (see Figure 61) provides the user with the following choices: -

- Beam
- Column
- Rod – this can be set for all tension members
- Truss – note that truss members comprise member subject to both compression and tension, this use is the same as column, however, it allows for a visual difference on reports if required

By default, Quantifire will attempt to automatically determine the use of the member based on the type of serial section selected, for example, UB(UK) and IPE(EU) will both default to 'beam' and UC(UK) and HE(EU) will default to 'column'.

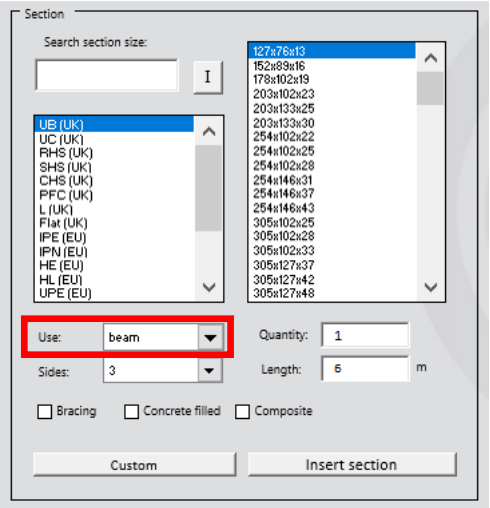



*Figure 61: Selecting the use of the member*

## 16.2 Sides

The number of sides exposed to fire determines the section factor of the section and determines the surface area for applied passive fire protection. The drop-down option highlighted in Figure 62. Quantifire will automatically try to determine the number of sides based on section type and its use. For example, a UB(UK) being used as a beam will default to 3 -sides. Alternatively, a UC(UK) being used as column will default to 4-sides.

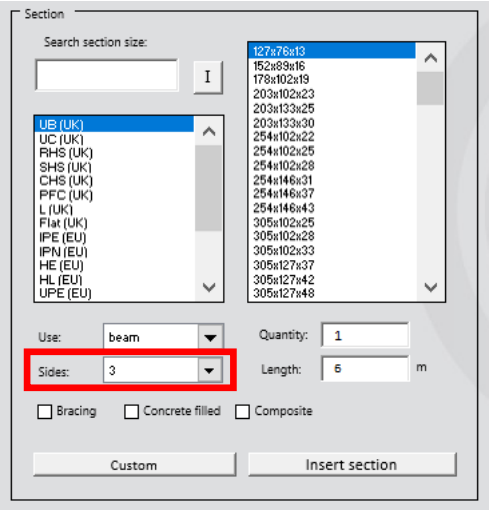



*Figure 62: Selecting the exposed sides of the member*

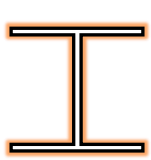
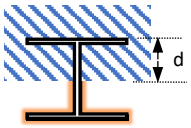
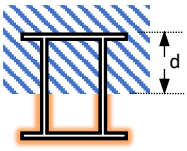
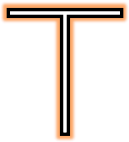
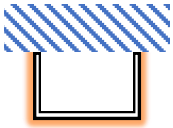
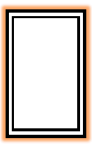
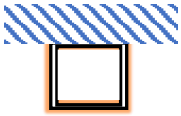
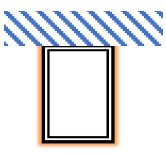
Depending on the type of passive fire protection material to be applied, either contour or box application should be considered. These two approaches will result in different section factors and surface areas. Table 5, Table 6 and Table 7 and provide a visual representation of how the members are taken to relate to the number of sides for contour protection. Table 8 provides a representation for box protection.

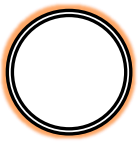
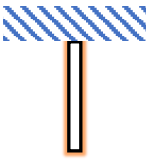
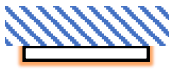
Quantifire uses the following terminology for the number of sides. The choice available in the drop-down option is linked to the section type and use and matches the choices shown in Table 5 and Table 8, they are summarised in Table 4: -

*Table 4: Side options available within Quantifire for members (not all sides are applicable to all shapes)*

| **Contour protection side options** | **Box protection side options** |
|---|---|
| 4 | 4 box |
| 3 | 3 box |
| 3 (short) | 3 box (short) |
| 3 (long) | 3 box (long) |
| 3 (end) | 2 box |
| 2 | 1 box |
| 1 | |
| Partial depth exposed | |

*Table 5: Description of sides for contour protection*

| Steel shape | Contour protection (sides) | | | | | |
|---|---|---|---|---|---|---|
| | 4 | 3 | | | 2 | 1 |
| I-sections (I) |  |  |  Partial depth, d | |  |  |
| Cruciform sections (Cruciform) |  | | | | | |
| Cruciform sections excluding flanges (Cruciform exc.fl) |  | | | | | |
| Built-up box sections (BUP Box) |  |  |  Partial depth, d | |  |  |
| T-sections (T) |  |  3 (short) |  3 (end) | | | |
| Angles (L) |  |  3 (short) |  3 (long) | |  |  |
| Channels (C) |  |  3 (short) |  3 (long) |  3 (ends) | | |
| Square or rectangular hollows sections (RHS/SHS) |  |  |  3 (short) |  3 (long) | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Circular hollow sections (CHS) |  | | | | | |
| Flat |  |  |  | | | |

Note that for building (cellulosic) applications, the term 3-sided generally means that a beam supports a concrete slab. For oil & gas (hydrocarbon) applications, the term 3-sided for beams may infer that the upper surface of the top flange is left unprotected. Quantifire does not consider the presence (or absence) of a concrete slab when looking up a 3-sided beam DFT from the product database. It is assumed that the product DFT data in the Quantifire databases is suitable for the as-built arrangement. Care should be taken when proposing a DFT for any item if part of it is unprotected yet exposed to fire. It is recommended to seek specialist guidance.

*Table 6: Description of sides for steel sections with shelf angles attached and using contour protection*

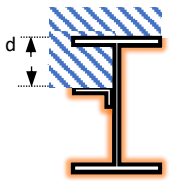
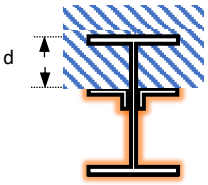
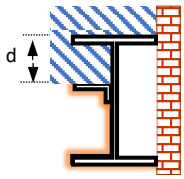
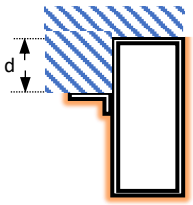
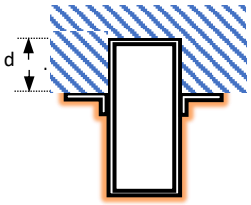
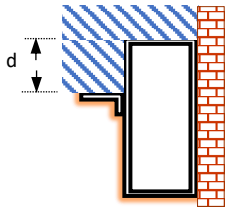
| Steel shape | Shelf angles – contour protection | | |
|---|---|---|---|
| | 1 shelf angle | 2 shelf angles | 1 shelf angle + fire resistant construction on the other side |
| I-sections (I) |  |  |  |
| | Partial depth, d | | |
| Square or rectangular hollows sections (RHS/SHS) |  |  |  |
| | Partial depth, d | | |

*Table 7: Description of sides for steel section with a plate attached to the bottom flange and using contour protection*

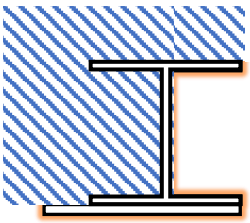
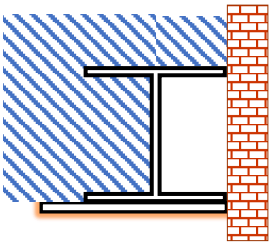
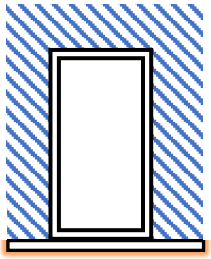
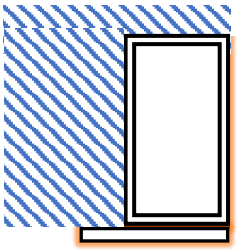
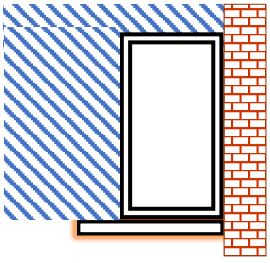
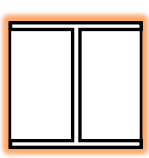
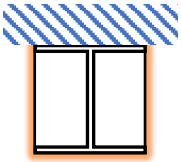
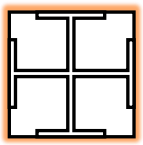
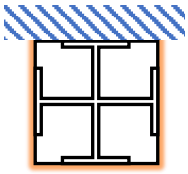
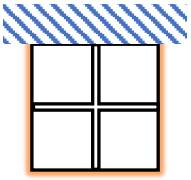
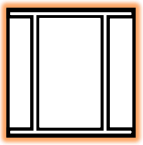
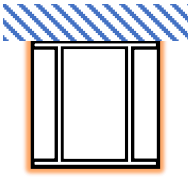
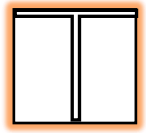
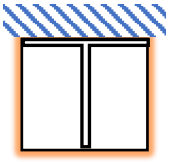
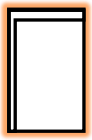
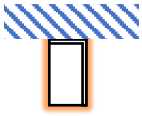
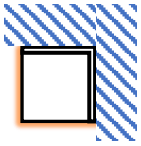
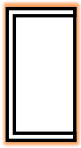
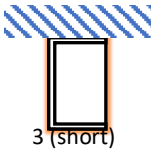
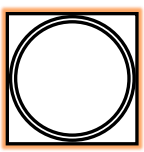
| Steel shape | Plate attached to bottom flange – contour protection | | |
|---|---|---|---|
| | 3-sided with plate + encasement | 2-sided with plate + encasement + plate extends on 1-side only | 1-sided with plate + encasement + plate extends on 1-side only + fire resistant construction on the other side |
| I-sections (I) |  |  |  |
| Square or rectangular hollows sections (RHS/SHS) |  |  |  |

*Table 8: Description of sides for box protection*

| Steel shape | Box protection (sides) | | | | | |
|---|---|---|---|---|---|---|
| | 4 | 3 | | | 2 | 1 |
| I-sections (I) |  |  | | - | | |
| Cruciform sections (Cruciform) |  |  | | | | |
| Cruciform sections excluding flanges (Cruciform exc.fl) |  |  | | | | |
| Built-up box sections (BUP Box) |  |  | | | | |
| T-sections (T) |  |  | | | | |
| Angles (L) |  |  3 (short) |  3 (long) | |  | |
| Channels (C) |  |  3 (short) |  3 (long) | | | |
| Circular hollow sections (CHS) |  |  | | | | |

Note that the air space created in boxing a CHS section improves the insulation and influences the section factor $A_m/V$. As such $A_m$ higher than that for profile protection would be anomalous. Hence, $A_m$ is taken as the circumference of the tube and not 4D, where D is the diameter. This guidance is provided within BS 5950-8 and is adopted for all CHS sections with box protection within Quantifire.

## 16.3 Quantity

The number of occurrences of a member can be input as shown in Figure 63.

By default, this value is set to 1. Members may be defined by a client as several occurrences of a set length, e.g., '7 occurrences of 6m' or a cumulative total may be defined by a client. If a cumulative total, e.g., 42m is provided, then the 'Quantity' input should be set to 1.

## 16.4 Measure

The measure associated with the member can be input as shown in Figure 64.

The measure can be either length, area or weight of steel. To change the measure input type, click on the Quantifire logo to access the main menu and change to the relevant measure under 'Input by', see Figure 65. Within this dialogue box, there is also the option to change the input base units from metric to imperial and the steel weight units. This dialogue box also allows the user to set default beam and column lengths which may be used in the absence of known lengths. These assumed lengths are required to permit calculation of critical temperature when only a cumulative length is known, e.g., 1,234m. They are also adopted for sections imported via the import feature when no known length is specified.

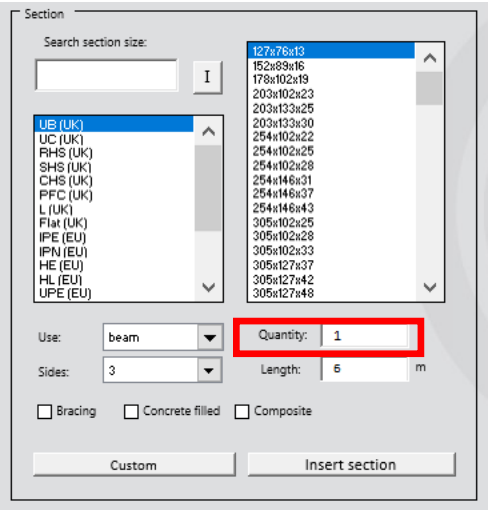



*Figure 63: Inputting the quantity of the member*

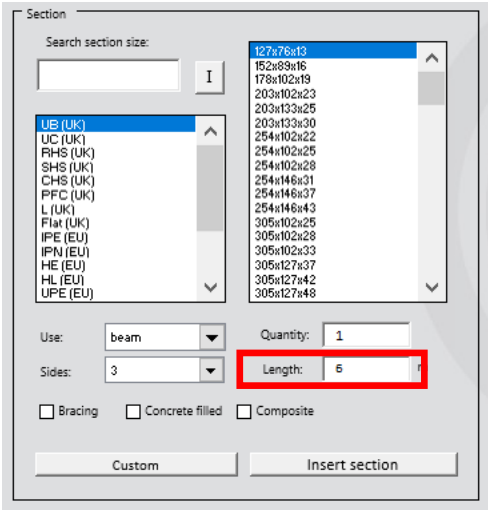



*Figure 64: Inputting the measure of the member*

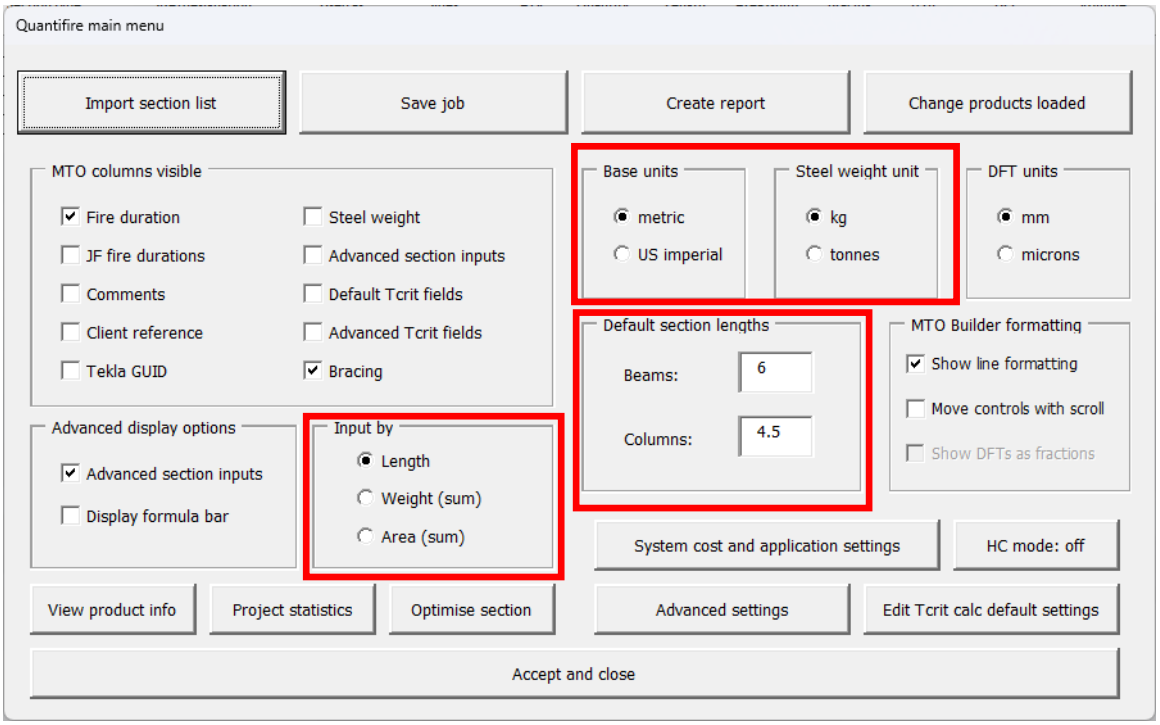



*Figure 65: Measure type, units and default length options*

Quantifire bases estimates on the length of a member. Therefore, the logic in Table 9 is adopted when different measures are used.

Using the length of the member permits accurate assessments of surface area to be determined for passive fire protection needs. Two examples are shown below: -

- A specified area of 1,000m² for beams may not have accounted for the fact the top flange supports concrete and doesn't need fire protection. Quantifire will determine the equivalent linear length of beam for the given section to then allow the user to select its use and sides as 'beam' and '3-sides' respectively. The result will be a reduced and more accurate surface area. Of course, the initial assumption of the 1,000m² being 4-sided should be verified with the client.

- The requirement of a steel member to have fire protection may be specified as 3,000 tonnes of a specific member. Quantifire will determine the equivalent linear length of beam for the given section to then allow the user to select its use and sides as 'beam' and '3-sides' respectively. The result will be an accurate surface area.

*Table 9: Logic to determine length of member in Quantifire*

| Measure | Logic comments |
|---|---|
| Length | Length is used as specified |
| Area | The heated perimeter ($A_m$) is used to determine the equivalent length of the member |
| Weight | The linear weight, e.g. kg/m is used to determine the equivalent length of the member |

## 16.5 Advanced input options

In addition to the standard inputs to define a member to determine passive fire protection requirements, there are some additional optional features that the user should be aware of. These are contained towards the bottom of the 'Section' dialogue box, as shown in Figure 66 and explained in the following sections.

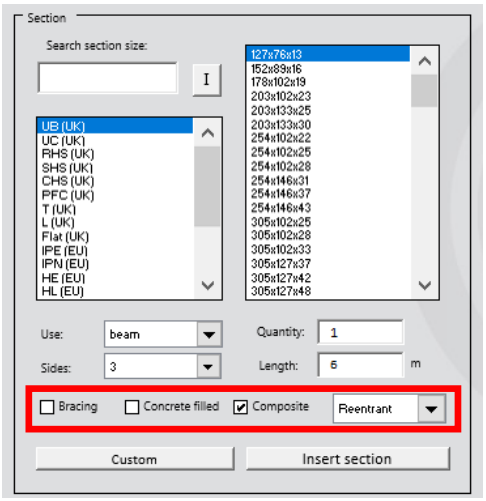



*Figure 66: Optional features when defining the requirements of a member*

### *16.5.1 Bracing*

Some geographical regions and markets permit bracing elements to be treated as a special case. **Users are encouraged to verify the acceptance of this approach on the project. For example, parts of Europe and the oil and gas (hydrocarbon) industry may not accept this modification.**

Bracing members are typically very thin and have high section factors which are not possible to protect as they fall outside the limits of certified product thicknesses.

Quantifire allows the user to set a maximum section factor (A/V) to be defined for members designated as bracing elements. This is set on the 'Advanced Settings' dialogue box via the main menu (Quantifire logo), see Figure 67. By default, this is set to 200$m^{-1}$. If the bracing setting is used then the maximum Tcrit possible is also limited to the value set, as stated in the ASFP Yellow Book.

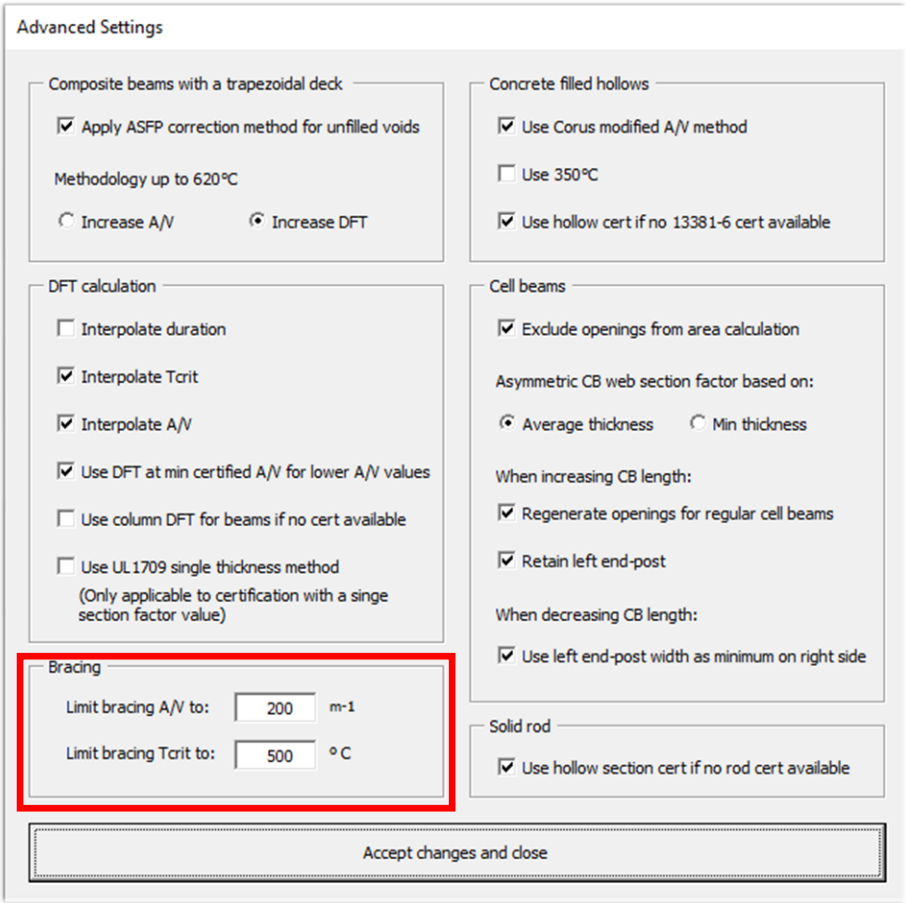



*Figure 67: Advanced setting for setting a maximum section factor (A/V)*

The following explanatory text is taken from BS 5950-8 (similar text is given in the ASFP Yellow Book): -

> *"Steel bracing members required to provide stability to the structure at the fire limit state should have adequate fire resistance unless alternative load paths can be identified.*
>
> *Where fire protection to bracing members is necessary, the protection thickness should be based on the section factor of the member or a value of 200 $m^{-1}$, whichever is the smaller value.*
>
> *In some cases, it might not be necessary to apply fire protection to bracing members and consideration should be given to:*

*— shielding bracing members from fire by placing them in vertical shafts or within walls;*

*— the use of infill masonry walls which, although they are typically ignored in terms of overall stability at ambient temperature, can provide the sufficient shear capacity during a fire instead of relying on the steel bracing systems;*

*— the possibility that only bracing systems within a fire compartment might be subjected to elevated temperatures and the other unaffected bracing systems might be sufficient to provide the required stability at the fire limit state;*

*— the possibility that the steel beam to column connections might have sufficient stiffness to ensure stability at the fire limit state."*

### *16.5.2 Concrete filled tubes*

There are different methods for the user to consider for a concrete filled steel tube. The 'Advanced settings' dialogue box (Quantifire logo -> Advanced settings) provides options for these, as shown in Figure 68. These settings can be turned on or off at the user's discretion and for clarity are discussed in Table 10.

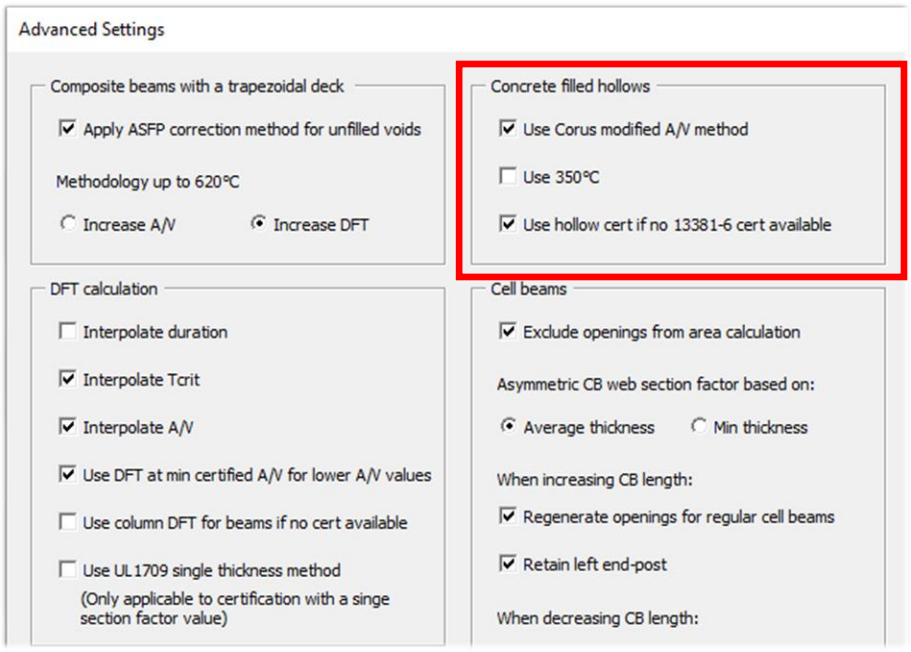



*Figure 68: Advanced setting for concrete filled tubes (showing default options within Quantifire)*

*Table 10: Advanced settings associated with concrete filled tubes*

| Setting | Comments |
|---|---|
| Use Corus modified A/V method | The publication "*Design Guide for SHS concrete filled columns, Corus Tubes, The Steel Construction Institute, 2002*", includes a calculation methodology to evaluate a modified section factor of a steel tube to account for concrete filling. **Note that acceptance of this approach may vary across the globe and therefore users should verify its permitted use.** |
| Use 350°C | EN 1994-1-2 states that the critical temperature of a steel tube filled with concrete may be taken as 350°C. Although not explicitly stated, this is understood to be based on the possibility of localised buckling of Class 4 sections which could occur as the steel tube expands at a faster rate than the concrete infill. Setting this option will force the critical temperature to be 350°C. |
| Use hollow section cert if no 13381-6 cert available | For projects where the required fire test standard is EN 13381, a specific standard exists for concrete filled tubes: EN 13381-6. This standard together with its output thicknesses should be adopted for concrete filled tubes. However, the user can allow Quantifire to use hollow section thicknesses in the absence of product specific certification to EN 13381-6. Note this options is automatically disabled when any product with EN 13381-6 certification data is loaded. **Users should verify this approach with the project design team.** |

### *16.5.3 Composite beams*

3-sided beams in the building (cellulosic) market support concrete slabs. However, these can be classified as one of two options: -

1. Non-composite: The slab rests of the upper surface of the top flange of the beam
2. Composite: The slab is connected to the top flange using shear studs

It is important to understand if a beam is composite or non-composite since it influences the critical temperature of the beam and may need consideration of how to treat protection of the top flange.

By default, Quantifire assumes beams to be non-composite. The user should verify whether beams are composite or not with the project team. For example, in UK buildings, most beams in multi-storey construction are composite.

Composite beams will typically have a lower critical temperature than a non-composite beam, see Section 17.2 and its associated references.

If the beam is composite, then the user must define the shape of the metal deck that supports the concrete. The inputs for this are given in the drop-down box to the right of the 'Composite' option button – see Figure 66. These input options are illustrated and briefly described in Table 11, with further discussion below.

3-sided beams protection thicknesses are derived based on fire testing of non-composite beams with a solid concrete slab on the top flange. Composite beams use steel decking profiles which may form voids between the top flange and the deck itself, see Figure 70 and Figure 71. In the case of trapezoidal decking, there is a risk that the exposed surface of the top flange at the void location could heat and cause failure of the beam.

Guidance in the Association for Specialist Fire Protection (ASFP) in the UK outlines the possibilities of when these voids must be filled (Figure 72) or when they can be left unfilled (Figure 73). In some instances, the guidance provides a method to increase the passive fire protection thickness on the beam to compensate for not filling a void.

Where filling is required, Quantifire will not determine the amount of pre-formed fillers however, it does determine the increased passive fire protection thickness in accordance with the ASFP guidance. The settings related to this are found in the 'Advanced Settings' dialogue box, which is accessed via the Quantifire logo main menu, as shown in Figure 69.

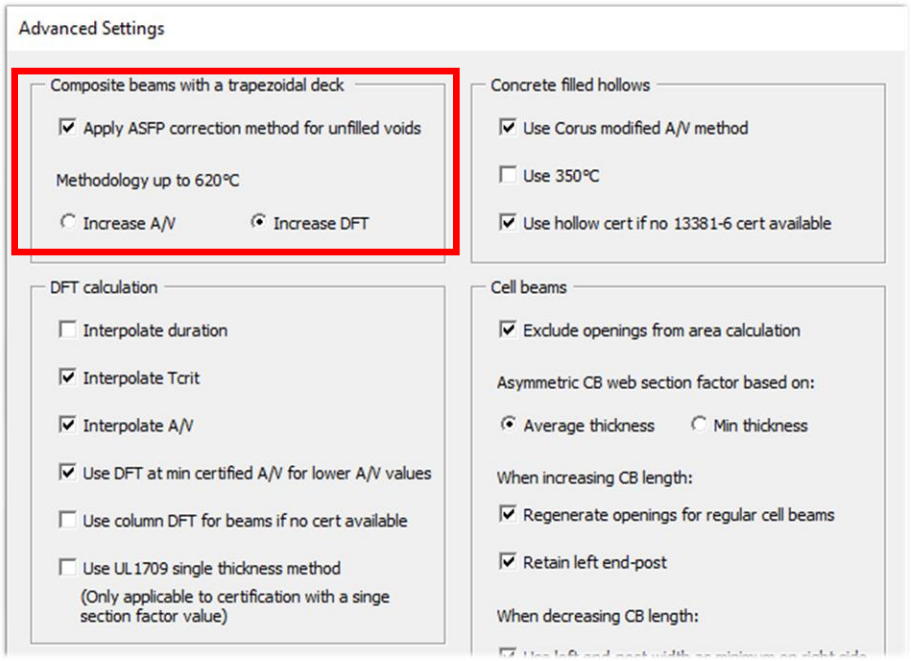
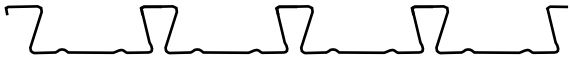
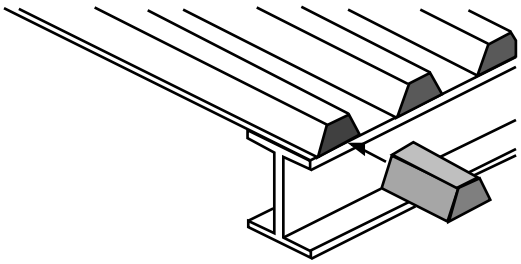
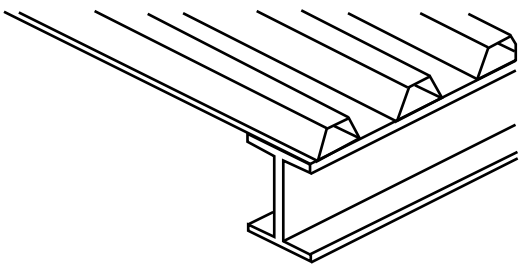



*Figure 69: Advanced setting for composite beams with a trapezoidal deck (showing default options within Quantifire)*

**Note the ASFP guidance is UK centric. Its use may not be permitted in other geographical regions. Users are advised to verify acceptance of this approach with the design team.**

*Table 11: Different composite decking types and their treatment*

| Decking input | Comments |
|---|---|
| Re-entrant | Voids under decking with re-entrant profiles (sometimes called dovetail profiles) can remain unfilled for all fire resistance periods.<br>  <br>*Figure 70: Re-entrant or dovetail decking profile example* |
| Trap. filled | Voids which occur under trapezoidal decking profiles may need to be filled with a suitable fire stopping material.<br>  <br>*Figure 71: Trapezoidal decking profile example*<br>  <br>*Figure 72: Example of a pre-formed filler used to fill the voids of a trapezoidal deck* |
| Trap. unfilled | Voids which occur under trapezoidal decking profiles can be left unprotected in some instances, but the passive fire protection thickness may need to be increased on the beam to compensate.<br>  <br>*Figure 73: Unfilled voids of a trapezoidal deck* |

### *16.5.4 Rods/Rounds*

Rods (round and square) are typically small in diameter and are commonly used in structural applications as tension elements.

Historically, passive fire protection thicknesses for these members have been based on CHS or SHS/RHS thicknesses. However, it is known that their small dimensions and high curvature for circular rods, may adversely affect the performance of fire protection materials, e.g. intumescents.

Users should be aware that some BS 476 products have been subject to separate rod tests to verify performance. These have produced their own thickness certificate, which is different to CHS or SHS/RHS thickness tables.

Similarly, for projects specifying EN 13381, users should be aware that a separate test standard exists for rods in EN 13381-10.

Quantifire provides the option for users to use product-specific hollow section thicknesses in the absence of a specific rod thickness certificate.

**Use of this option is at the user's discretion and its use should be communicated to the project's design team to verify its acceptance.**

# 17 CRITICAL TEMPERATURES

There are three different ways to define a critical temperature of steelwork within Quantifire, as discussed in the following section. Note that the user must have the correct access privileges to access certain features.

## 17.1 User set value

With this option selected, the user can enter any critical temperature. For instance, when a client has evaluated their own temperatures.

Note that the use of non-justified high critical temperatures may not be safe. As such this approach is not advised.

## 17.2 Default from industry guidance

When no critical temperature evaluation has been undertaken, this option enables the user to let Quantifire determine the appropriate temperature relative to specific industry guidance. In some instances, the industry guidance reference will consist of different critical temperatures based on use of the member, e.g., beam or column. Quantifire automatically determines the relevant temperature to use using the process shown in Figure 74.

Note that industry guidance temperatures are typically deemed to be conservative in the absence of critical temperatures being correctly evaluated. The following points should be noted: -

1. Default temperatures are typically considered to be conservative, however, they may not always be safe. It may be possible to derive lower failure temperatures for members subject to extreme loads in certain design scenarios.

2. Use of default temperatures may result in low temperatures such that members cannot be protected. A calculated temperature pertinent to the member and the design project may be higher and yield a protection thickness.

The industry guidance documents for default critical temperature included within Quantifire are outlined in Table 12.

Users are advised to familiarise themselves with these documents and their associated temperatures and background where given. The list provided is not exhaustive across the globe and others may exist. Where a required default temperature reference is not included within Quantifire, the user is recommended to enter temperatures as user-set values and provide a clarification note on the output report detailing the basis of the temperature for the end-client.

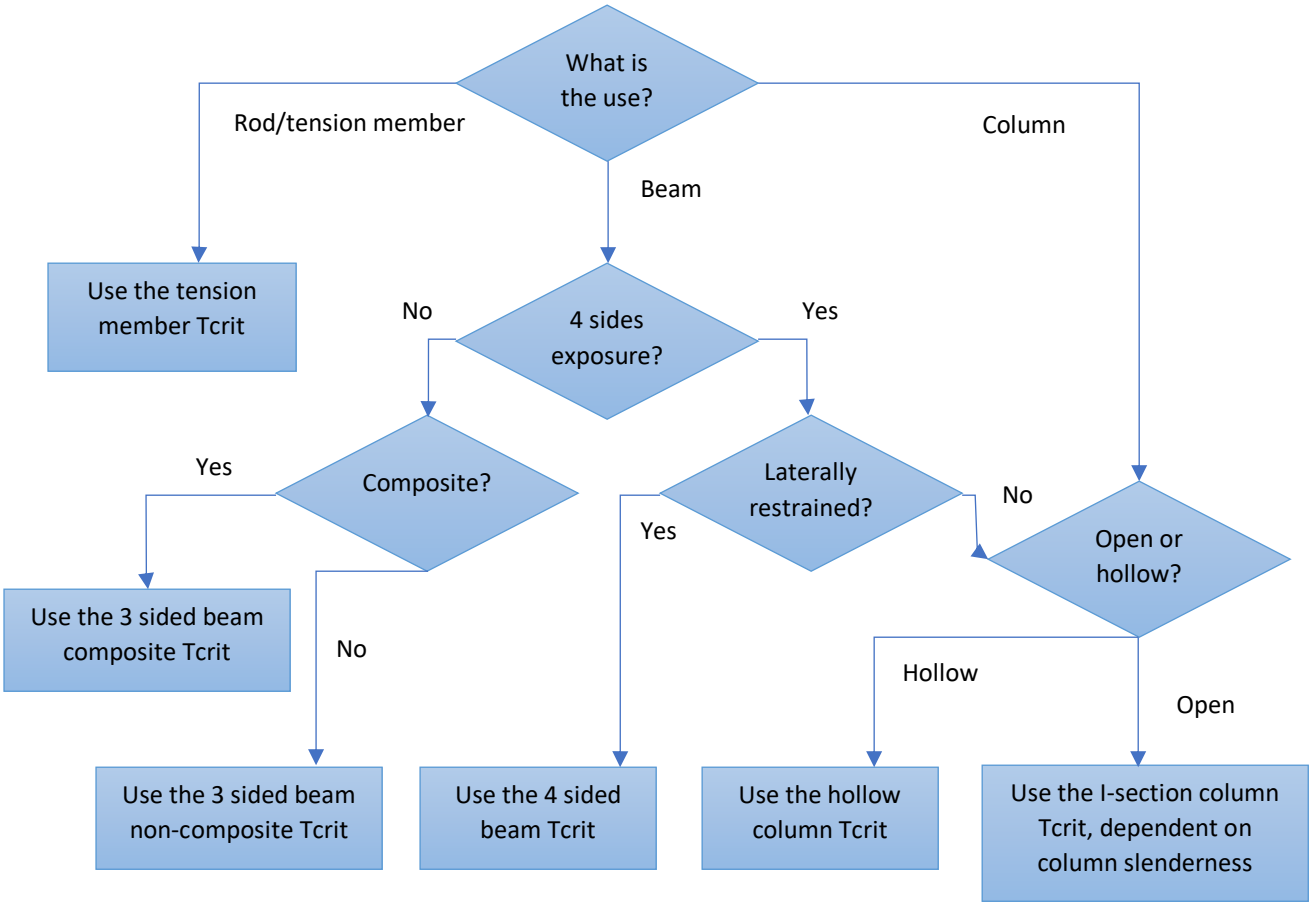



*Figure 74: Default Tcrit process chart*

*Table 12: Industry guidance references for default temperatures within Quantifire*

| Industry Guidance | Comment |
|---|---|
| BS5950: ASFP Yellow Book | The Yellow Book presents a table of critical temperatures for designs of beams and columns subject to BS 5950 design guidance. |
| Eurocode: ASFP Yellow Book | The Yellow Book presents a table of critical temperatures for designs of beams and columns subject to Eurocode (UK National Annex) design guidance for varying occupancy loading types. |
| 620/550/520 | These are commonly used critical temperatures for beams supporting a concrete slab, open profile columns and hollow columns respectively. They are derived from permissible stress design methods in BS 449 and historical testing. |
| 593/538 | These temperatures are used in ASTM E-119 and are typically associated with UL 263. They represent Celsius conversions of temperature for beams supporting a concrete slab (1100°F/593°C) and columns (1000°F/538°C) |

By clicking on 'Set Tcrits' along side Default Tcrit, see Figure 75, the user can see the critical temperatures associated with each basis of temperature. It is important to ensure that the basis of temperature is set correctly.

The user can modify the associated values displayed, however within the estimate, any modified value will be shown as 'User set' for the basis of temperature.

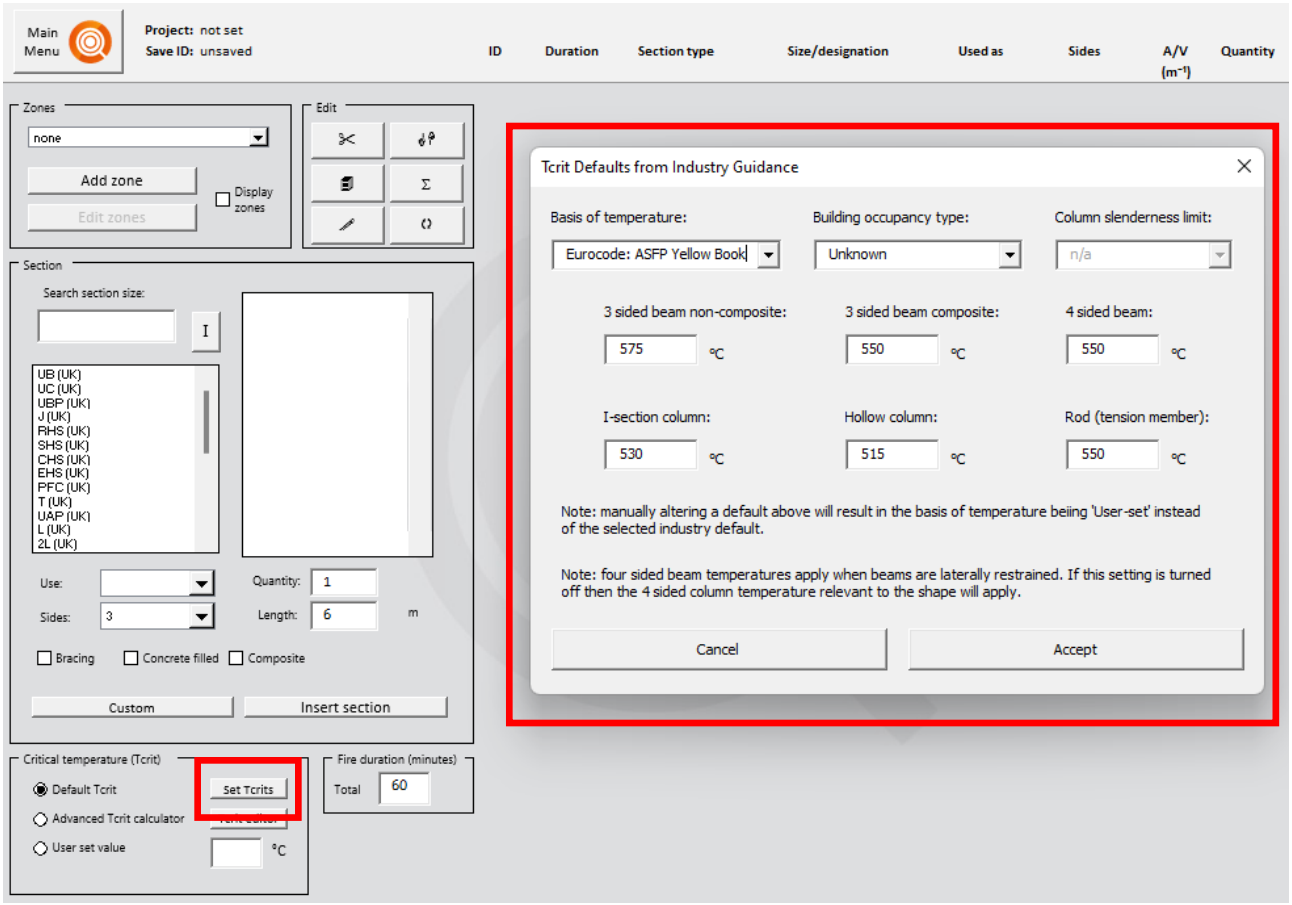



*Figure 75: Tcrit defaults*

## 17.3 Advanced $T_{crit}$ calculator

This method permits the user to calculate a critical temperature of steelwork in accordance with the Eurocodes or for beams with web-openings, RT 1356.

**Only users with relevant competency and familiarisation with structural fire engineering methodologies should use this feature. For this reason, it is possible to disable access to this approach. Users should note that any deviation from default or 'expected' critical temperatures should be verified with the end-client together with the basis for any deviation. Certain global requirements may only permit a professional engineer or equivalent to effectively sign-off on use of a calculated critical temperature, e.g. in the UK, guidance states that it should be a Chartered Engineer. The project's Structural Engineer will typically assume responsibility for the stability of the steel frame at both 'ambient' and in fire unless it is taken by another party.**

**Where a project does not accept the use of Eurocodes to determine critical temperatures, then this approach may not be used unless agreed with the client. Users are advised to check in advance before undertaking calculations.**

Only I-shape profiles, hollows and solid rods can be assessed using the advanced calculator. All other profile shapes, e.g., angles, channels, etc. must have their temperature defined using either the default calculator or be specified by a user-set value.

Members are considered as being subject to forces relevant to their use as defined in Table 13.

*Table 13: Structural calculation and standard with respect to member use*

| **Member use** | **Structural calculation** | **Standard** |
|---|---|---|
| Beam | Members subject to bending | EN 1993-1-2 / EN 1994-1-2 |
| Column / Truss | Members subject to compression | EN 1993-1-2 |
| Rod | Members subject to tension | EN 1993-1-2 |
| Beam with web-openings | Beams with large web-openings | RT 1356 |

Members can be assessed individually or as a bulk process for multiple members.

Where members are assessed individually, the user has control over each input parameter and can generate calculation reports for use and review by the project team.

Where multiple members are assessed or where a member is added using the Advanced $T_{crit}$ option on the MTO Builder page, the software will use the critical temperature input parameter defined in the default settings. For more information on this, see Section 17.3.5.

To edit a single section, click the $T_{crit}$ button in the Critical Temperature dialogue box on the MTO Builder page, see Figure 76. Then enter the ID number of the section to analyse. A calculation page relevant to the member will open.

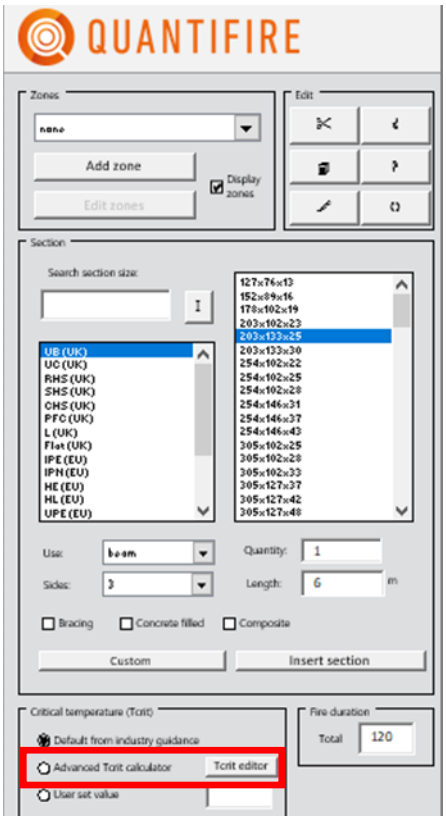



*Figure 76: Advanced critical temperature options*

All calculation pages adopt a similar format. Information relating to the member ID is displayed at the top as shown in Figure 77 – note that beams with web-openings are displayed slightly different, see Section 17.3.4. Information relating to the section profile is displayed in the Section Profile frame. Note that the section cannot be edited from this page, it can only be edited from the MTO Builder input screen. The steel strength, however, can be edited from this frame together with the fabrication method for hollow sections (hot-rolled or cold-formed).

Partial safety factors are also displayed in their own frame on the right. Note that if the member is being loaded to a utilisation at the accidental limit state of fire (ALS-Fire) then the partial safety factor inputs will be greyed out as they are not required for the temperature calculation. The user can specify the partial safety factors in accordance with those in Table 14. When ambient (ULS) utilisation or actual loads are known, the user must also specify the partial factor for variable actions (live loading) which is specific to the occupancy type.

*Table 14: Options for partial safety factors to adopt*

| Standard | Comment |
|---|---|
| Base Eurocode | Adopts recommended values in the Eurocode |
| UK National Annex | Adopts the recommended values as given in the UK National Annex |
| User-specified | Allows the user full control on what values to use |

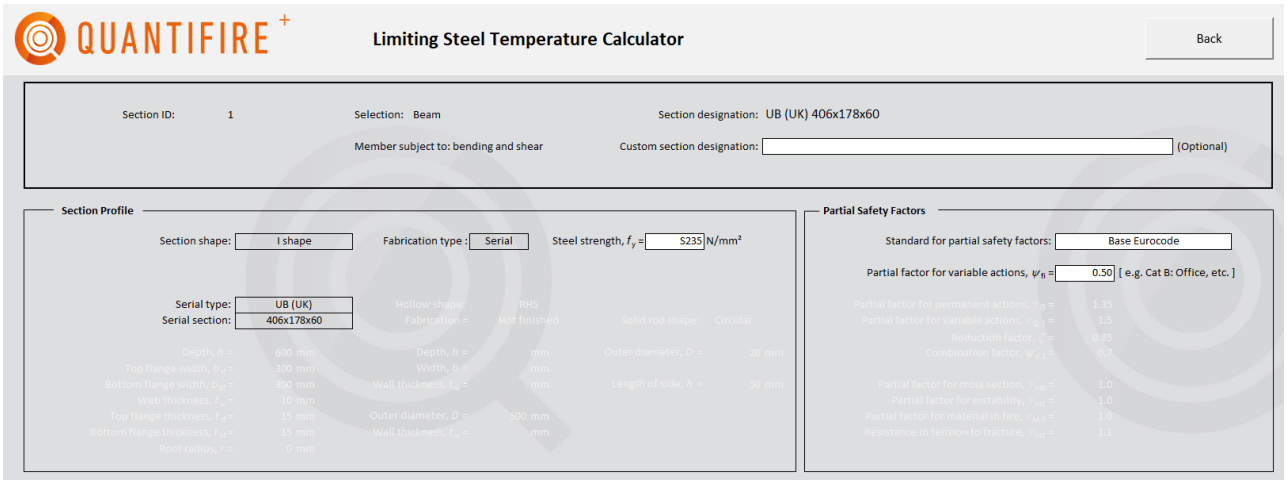



*Figure 77: Format of top of calculation page for advanced critical temperature calculations*

### *17.3.1 Members subject to bending*

The relevant input parameters for members subject to bending are shown in Figure 78. Only the white boxes are to be completed to assess a critical temperature. The greyed-out boxes represent parameters which could be used if certain options are selected.

Beams are considered as simply supported at their ends.

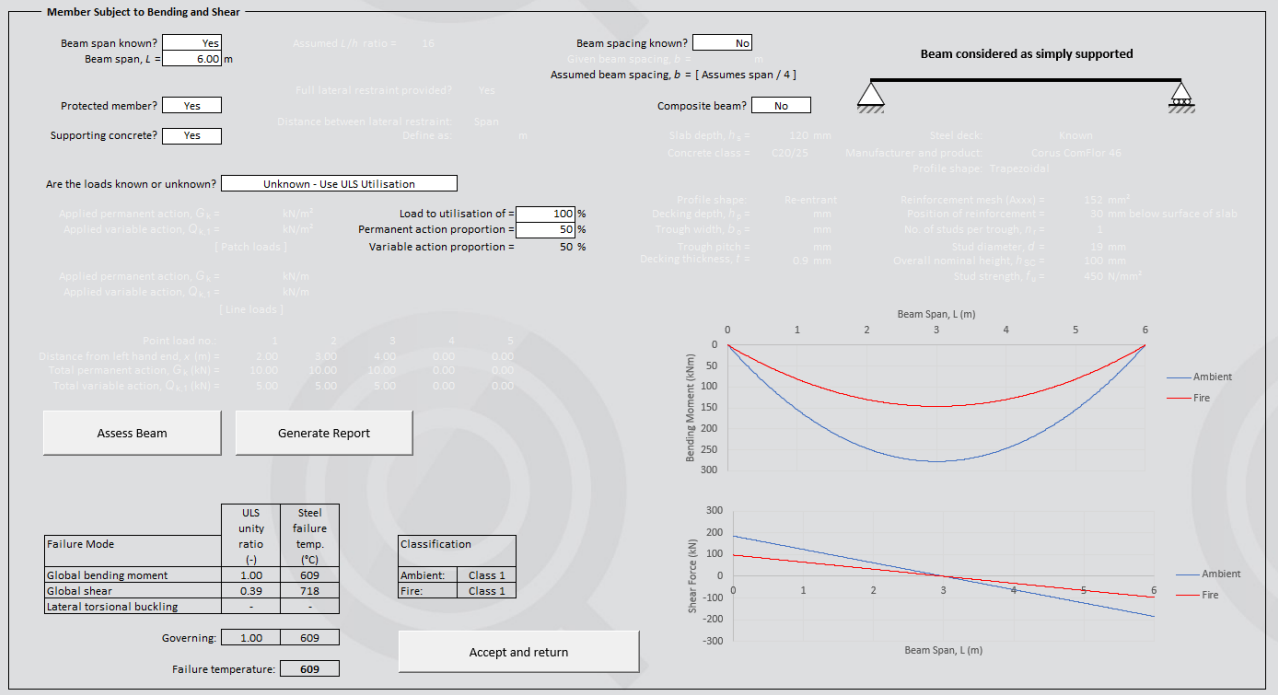



*Figure 78: Input options for members subject to bending*

The following bullet points and associated text explain the various input parameters: -

- **Beam span**

  The beam span is shown in the top left. This information is inherited from the MTO Builder page but can be changed here if required. Note that if the total length of beam in the MTO Builder page is total cumulative length, i.e., 1,234 m then Quantifire will adopt a 'generic' beam length, i.e., 6m in the case of Figure 78. This is to ensure that sensible lengths of beam are adopted for the purposes of calculation. The 'default' beam length can be changed by the user in the settings.

  If the beam span is set as unknown, the user can use a span/depth ratio to determine an estimate of beam length.

  NOTE: for the purposes of calculation, the maximum beam span is set to be 18m. For any beam length greater than this, the advanced calculator will use the default beam length in the settings. This is to mitigate against non-sensical calculations for extremely long beams as defined as a total cumulative length in the MTO Builder.

- **Beam spacing**

  The beam spacing (distance between adjacent beams) may be either known or unknown. If set to unknown, Quantifire will adopt a spacing of span/4. If actual loads are being entered, then be sure to set to the correct beam spacing.

- **Protected member?**

  The user can state if the beam's critical temperature is to be considered as a protected beam or an unprotected beam. The reason for this difference is that due to cross-sectional heating gradients, an unprotected beam can fail at a different temperature in comparison to a protected beam. In most cases, it is anticipated that beams will be protected.

- **Supporting concrete?**

  If a beam supports concrete, then it will have a gradient of temperature between its top flange and its bottom flange. This is taken into consideration by Quantifire.

  Additionally, if a beam supports concrete, it can be considered as being laterally restrained. In other words, no lateral torsional buckling checks are undertaken by Quantifire.

  - If the beam is not supporting concrete (i.e., 4-sided beam) then the user can define whether lateral restraint is provided or not. If full lateral restraint is not provided, then lateral torsional buckling (LTB) checks are undertaken by Quantifire.

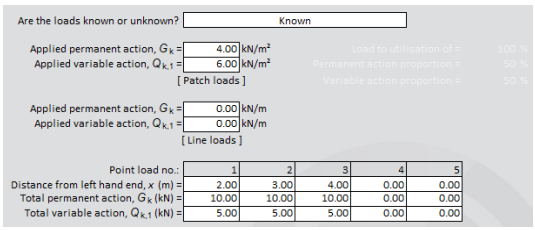
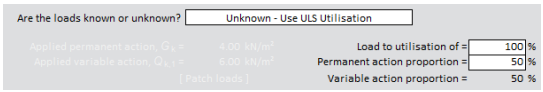
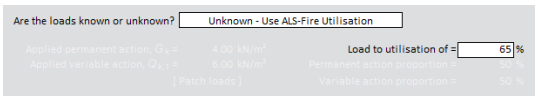
  A beam supporting concrete can also be either non-composite or be connected to the concrete slab via the use shear-studs.

  - If the beam is defined as being composite then the user can define characteristics including the slab depth, the concrete class, the decking shape and geometry, the reinforcement, the number of studs per trough, stud diameter, stud height and stud strength. These may all have an influence on the critical temperature.

- **Loading**

  Beam loading can be defined in one of three ways as shown in Table 15 with examples in Figure 79, Figure 80 and Figure 81 respectively.

*Table 15: Types of loading available when assessing beams*

| Loading type | Comment |
|---|---|
| Known | The exact loading is known by the user (including self-weight)<br>Loads can be entered by surface area (patch loads), by linear load (line loads), or as point loads (maximum 5 along the beam length).<br>All loads can be defined as permanent (dead) and variable (live).<br>  <br>*Figure 79: Example when beam loading is known* |
| Unknown – Use ULS Utilisation | Loading is unknown but is specified at a utilisation at ultimate limit state (ULS). A conservative approach is to use 100%.<br>The proportion of permanent (dead) to variable (live) load must also be specified.<br>  <br>*Figure 80: Example when loading is unknown but defined as 'ambient' utilisation* |
| Unknown – Use ALS-Fire Utilisation | Loading is unknown but is specified at a utilisation at the accidental limit state of fire (ALS-Fire). The Eurocodes recommend 65% in the absence of any other information.<br>  <br>*Figure 81: Example when loading is unknown but defined as 'fire' utilisation* |

The optimum basis for a critical temperature calculation is an ALS-Fire utilisation from the Structural Engineer. Such an assessment should remove any unprotected members.

Click on the 'Assess Beam' button to undertake the calculation.

The result of the calculation is displayed at the bottom of the frame – see Figure 82. The relevant checked failure modes are summarised with respect to their utilisation and corresponding failure temperature. The critical temperature is taken as the lowest failure temperature and reported accordingly. Also shown are the corresponding section classifications at ambient and fire. Note that

if a section is determined to be Class 4 (i.e., susceptible to local buckling), then it is given a critical temperature of 350°C in accordance with the Eurocodes.

To the right of the calculation summary are two charts, see Figure 83. These depict the bending moment and shear force diagrams respectively.

| Failure Mode | ULS unity ratio (-) | Steel failure temp. (°C) |
|---|---|---|
| Global bending moment | 0.61 | 679 |
| Global shear | 0.21 | 805 |
| Lateral torsional buckling | - | - |
| Governing: | 0.61 | 679 |
| Failure temperature: | | 679 |

| Classification | |
|---|---|
| Ambient: | Class 1 |
| Fire: | Class 1 |

Accept and return

*Figure 82: Example output following a beam calculation*

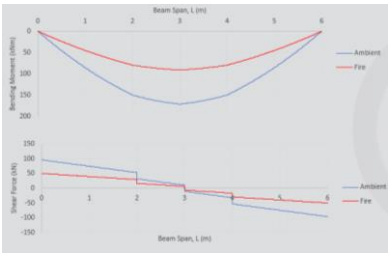
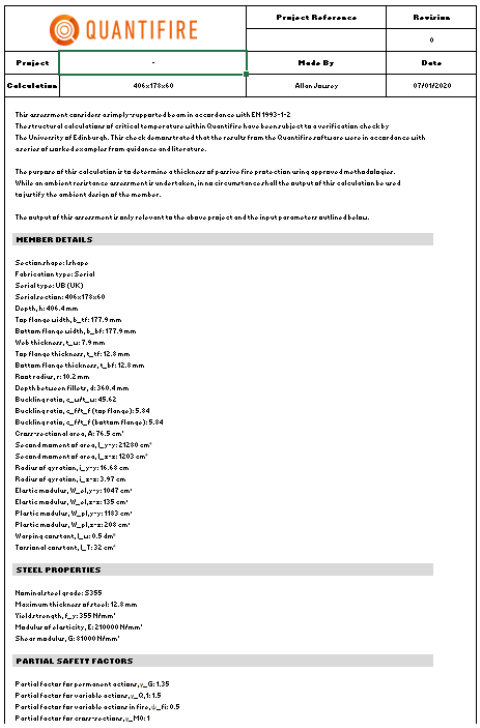



*Figure 83: Example bending moment and shear force diagrams*

Click on the 'Generate report' button to create a printable report of the entire calculation, as shown in Figure 84.


QUANTIFIRE

| Project Reference | Revision |
|---|---|
| | 0 |

| Project | - | Made By | Date |
|---|---|---|---|
| Calculation | 406x178x60 | Allan Jaurey | 07/01/2020 |

This assessment considers a simply-supported beam in accordance with EN 1993-1-2
The structural calculations of critical temperature within Quantifire have been subject to a verification check by The University of Edinburgh. This check demonstrated that the results from the Quantifire software were in accordance with a series of worked examples from guidance and literature.

The purpose of this calculation is to determine a thickness of passive fire protection using approved methodologies. While an ambient resistance assessment is undertaken, in no circumstance shall the output of this calculation be used to justify the ambient design of the member.

The output of this assessment is only relevant to the above project and the input parameters outlined below.

**MEMBER DETAILS**

Section shape: I-shape
Fabrication type: Serial
Serial type: UB (UK)
Serial section: 406x178x60
Depth, h: 406.4 mm
Top flange width, b_tf: 177.9 mm
Bottom flange width, b_bf: 177.9 mm
Web thickness, t_w: 7.9 mm
Top flange thickness, t_tf: 12.8 mm
Bottom flange thickness, t_bf: 12.8 mm
Root radius, r: 10.2 mm
Depth between fillets, d: 360.4 mm
Buckling ratio, c_w/t_w: 45.62
Buckling ratio, c_f/t_f (top flange): 5.84
Buckling ratio, c_f/t_f (bottom flange): 5.84
Cross-sectional area, A: 76.5 cm²
Second moment of area, I_y-y: 21280 cm⁴
Second moment of area, I_z-z: 1203 cm⁴
Radius of gyration, i_y-y: 16.68 cm
Radius of gyration, i_z-z: 3.97 cm
Elastic modulus, W_el,y-y: 1047 cm³
Elastic modulus, W_el,z-z: 135 cm³
Plastic modulus, W_pl,y-y: 1163 cm³
Plastic modulus, W_pl,z-z: 208 cm³
Warping constant, I_w: 0.5 dm⁶
Torsional constant, I_T: 32 cm⁴

**STEEL PROPERTIES**

Nominal steel grade: S355
Maximum thickness of steel: 12.8 mm
Yield strength, f_y: 355 N/mm²
Modulus of elasticity, E: 210000 N/mm²
Shear modulus, G: 81000 N/mm²

**PARTIAL SAFETY FACTORS**

Partial factor for permanent actions, γ_G: 1.35
Partial factor for variable actions, γ_Q: 1.5
Partial factor for variable actions in fire, γ_fi: 0.5
Partial factor for cross-sections, γ_M0: 1

*Figure 84: Example calculation report output for a beam critical temperature (first page only shown)*

When complete with the calculation, click the 'Accept and return' button to save the member information and update the MTO Builder page with the revised critical temperature.

### *17.3.2 Member subject to compression*

The relevant input parameters for members subject to compression are shown in Figure 85. Only the white boxes are to be completed to assess a critical temperature. The greyed-out boxes represent parameters which could be used if certain options are selected.

Columns are considered as being subject to pure axial loading only, i.e. no eccentric loads are considered.

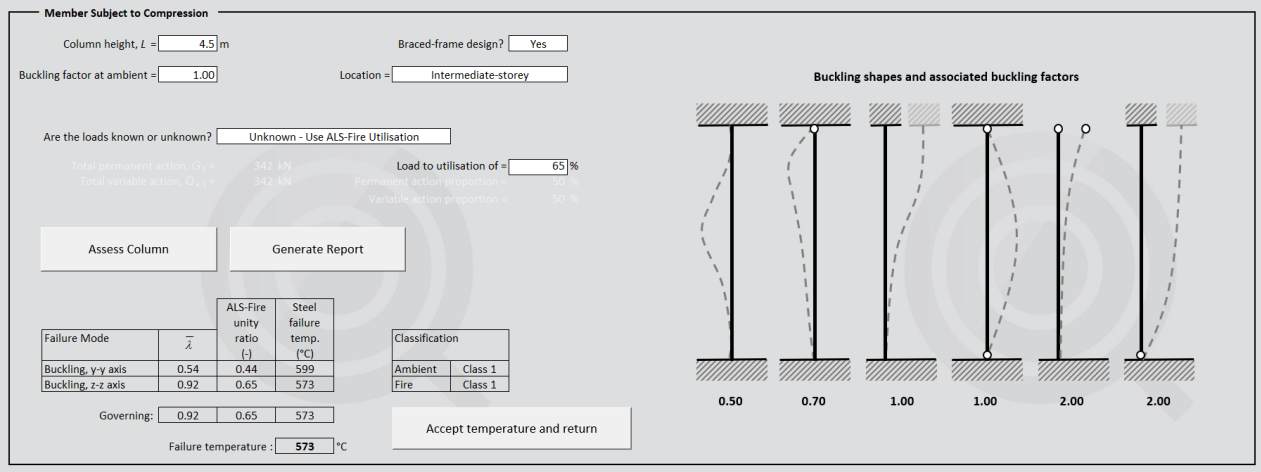



*Figure 85: Input options for members subject to compression*

The following bullet points and associated text explain the various input parameters: -

- **Column height**

  The column height is shown in the top left. This information is inherited from the MTO Builder page but can be changed here if required. Note that the maximum column height is set to be 8m in Quantifire. For heights greater than this, i.e. cumulative length, e.g. 1,234m then Quantifire will use the default column height, i.e. 4.5m in the case of Figure 85. This is to ensure that sensible lengths of column are adopted for the purposes of calculation. The 'default' column height can be changed by the user in the settings.

- **Buckling factor at ambient**

  The buckling factor at 'ambient' is used to define the effective length. By default, the value is taken as 1.00, although it can be modified by the user as required. The representative buckling shapes and associated buckling factors are displayed to the right of the input screen to provide guidance to the user.

- **Braced-frame design?**

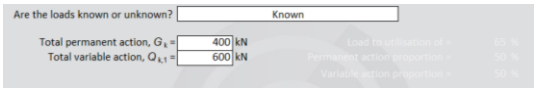
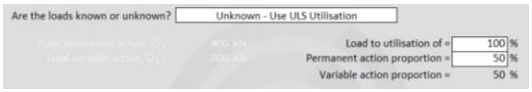
  A buckling factor is required for 'fire' also. If the column is not part of a braced-frame design, then the 'ambient' buckling factor is adopted. This is conservative. Alternatively, if it is

known that the column is part of a braced frame, then the user can select if it is at a top-storey or intermediate storey location. These will influence the buckling shape, the buckling factor in fire and ultimately the critical temperature of the member.

- **Loading**

  Compression member loading can be defined in one of three ways as shown in Table 16 with examples in Figure 86, Figure 87 and Figure 88 respectively.

  *Table 16: Types of loading available when assessing columns*

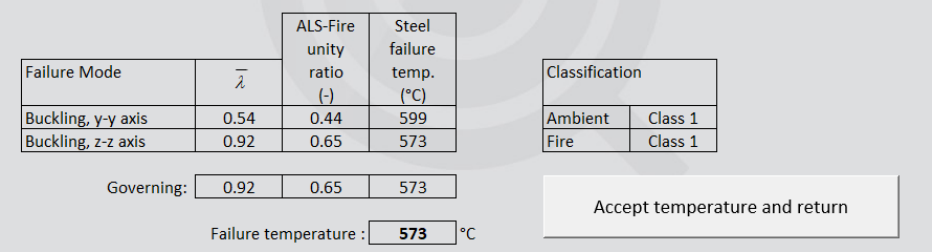
| Loading type | Comment |
|---|---|
| Known | The exact loading is known by the user (including self-weight)<br>Loads are entered as a permanent (dead) point load a variable (live) point load.<br>  <br>*Figure 86: Example when column loading is known* |
| Unknown – Use ULS Utilisation | Loading is unknown but is specified at a utilisation at ultimate limit state (ULS). A conservative approach is to use 100%.<br>The proportion of permanent (dead) to variable (live) load must also be specified.<br>  <br>*Figure 87: Example when loading is unknown but defined as 'ambient' utilisation* |
| Unknown – Use ALS-Fire Utilisation | Loading is unknown but is specified at a utilisation at the accidental limit state of fire (ALS-Fire). The Eurocodes recommend 65% in the absence of any other information.<br>  <br>*Figure 88: Example when loading is unknown but defined as 'fire' utilisation* |

  The optimum basis for a critical temperature calculation is an ALS-Fire utilisation from the Structural Engineer. Such an assessment should remove any unprotected members.

Click on the 'Assess Beam' button to undertake the calculation.

The column is checked against both the strong and weak axis of the member. The result of the calculation is displayed at the bottom of the frame – see Figure 89. The relevant checked failure modes are summarised with respect to their non-dimensional slenderness ratio, utilisation and corresponding failure temperature. The critical temperature is taken as the lowest failure temperature and reported accordingly.

Also shown are the corresponding section classifications at ambient and fire. Note that if a section is determined to be Class 4 (i.e. susceptible to local buckling), then it is given a critical temperature of 350°C in accordance with the Eurocodes.



| Failure Mode | $\bar{\lambda}$ | ALS-Fire unity ratio (-) | Steel failure temp. (°C) |
|---|---|---|---|
| Buckling, y-y axis | 0.54 | 0.44 | 599 |
| Buckling, z-z axis | 0.92 | 0.65 | 573 |
| Governing: | 0.92 | 0.65 | 573 |

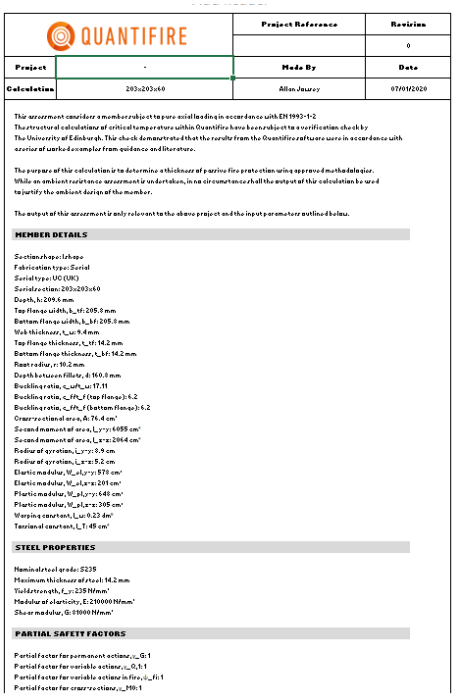
Failure temperature : **573** °C

| Classification | |
|---|---|
| Ambient | Class 1 |
| Fire | Class 1 |

Accept temperature and return

*Figure 89: Example output following a column calculation*

Click on the 'Generate report' button to create a printable report of the entire calculation, as shown in Figure 90.



QUANTIFIRE

| Project Reference | Revision |
|---|---|
| | 0 |

| Project | - | Made By | Date |
|---|---|---|---|
| Calculation | 203x203x60 | Allan Jowsey | 07/01/2020 |

This assessment considers a member subject to pure axial loading in accordance with EN 1993-1-2.
The structural calculations of critical temperature within Quantifire have been subject to a verification check by The University of Edinburgh. This check demonstrated that the results from the Quantifire software were in accordance with a series of worked examples from guidance and literature.

The purpose of this calculation is to determine a thickness of passive fire protection using approved methodologies. While an ambient resistance assessment is undertaken, in no circumstances shall the output of this calculation be used to justify the ambient design of the member.

The output of this assessment is only relevant to the above project and the input parameters outlined below.

**MEMBER DETAILS**

Section shape: I-shape
Fabrication type: Serial
Serial type: UC (UK)
Serial section: 203x203x60
Depth, h: 209.6 mm
Top flange width, b_tf: 205.8 mm
Bottom flange width, b_bf: 205.8 mm
Web thickness, t_w: 9.4 mm
Top flange thickness, t_tf: 14.2 mm
Bottom flange thickness, t_bf: 14.2 mm
Root radius, r: 10.2 mm
Depth between fillets, d: 160.8 mm
Buckling ratio, c_w/t_w: 17.11
Buckling ratio, c_f/t_f (top flange): 6.2
Buckling ratio, c_f/t_f (bottom flange): 6.2
Cross-sectional area, A: 76.4 cm²
Second moment of area, I_y-y: 6099 cm⁴
Second moment of area, I_z-z: 2064 cm⁴
Radius of gyration, i_y-y: 8.9 cm
Radius of gyration, i_z-z: 5.2 cm
Elastic modulus, W_el,y-y: 570 cm³
Elastic modulus, W_el,z-z: 201 cm³
Plastic modulus, W_pl,y-y: 648 cm³
Plastic modulus, W_pl,z-z: 305 cm³
Warping constant, I_w: 0.23 dm⁶
Torsional constant, I_T: 45 cm⁴

**STEEL PROPERTIES**

Nominal steel grade: S235
Maximum thickness of steel: 14.2 mm
Yield strength, f_y: 235 N/mm²
Modulus of elasticity, E: 210000 N/mm²
Shear modulus, G: 81000 N/mm²

**PARTIAL SAFETY FACTORS**

Partial factor for permanent actions, γ_G: 1
Partial factor for variable actions, γ_Q: 1.1
Partial factor for variable actions in fire, γ_Q,fi: 1
Partial factor for cross-section, γ_M0: 1

*Figure 90: Example calculation report output for a column critical temperature (first page only shown)*

When complete with the calculation, click the 'Accept and return' button to save the member information and update the MTO Builder page with the revised critical temperature.

### *17.3.3 Members subject to tension*

The relevant input parameters for members subject to tension are shown in Figure 91. Only the white boxes are to be completed to assess a critical temperature. The greyed-out boxes represent parameters which could be used if certain options are selected.

Tension members are considered as being subject to pure axial tension only.

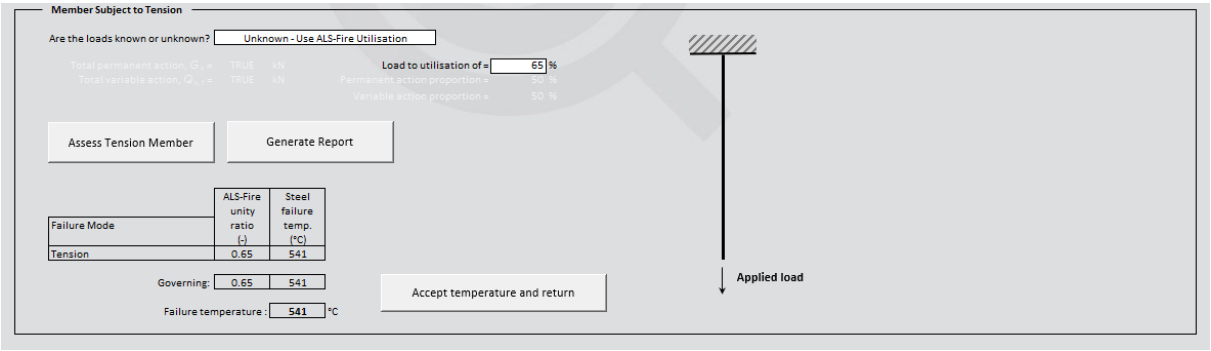


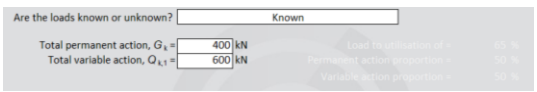

*Figure 91: Input options for members subject to tension*

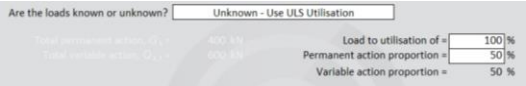
The following bullet points and associated text explain the various input parameters: -

- **Loading**

  Tension member loading can be defined in one of three ways as shown in Table 17 with examples in Figure 92, Figure 93 and Figure 94 respectively.

  *Table 17: Types of loading available when assessing tension members*

| Loading type | Comment |
|---|---|
| Known | The exact loading is known by the user (including self-weight)<br>Loads are entered as a permanent (dead) point load a variable (live) point load.<br>  <br>*Figure 92: Example when column loading is known* |

| | |
|---|---|
| Unknown – Use ULS Utilisation | Loading is unknown but is specified at a utilisation at ultimate limit state (ULS). A conservative approach is to use 100%.<br>The proportion of permanent (dead) to variable (live) load must also be specified.<br>  <br>*Figure 93: Example when loading is unknown but defined as 'ambient' utilisation* |
| Unknown – Use ALS-Fire Utilisation | Loading is unknown but is specified at a utilisation at the accidental limit state of fire (ALS-Fire). The Eurocodes recommend 65% in the absence of any other information.<br>  <br>*Figure 94: Example when loading is unknown but defined as 'fire' utilisation* |

The optimum basis for a critical temperature calculation is an ALS-Fire utilisation from the Structural Engineer. Such an assessment should remove any unprotected members.

Click on the 'Assess Beam' button to undertake the calculation.

The tension member is checked with respect to the tensile capacity of the member. The result of the calculation is displayed at the bottom of the frame – see Figure 95. The failure mode is summarised with respect to utilisation its corresponding failure temperature.

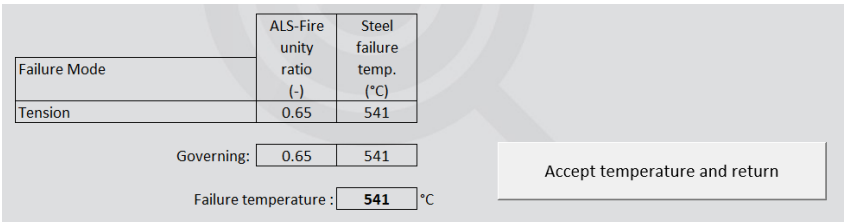
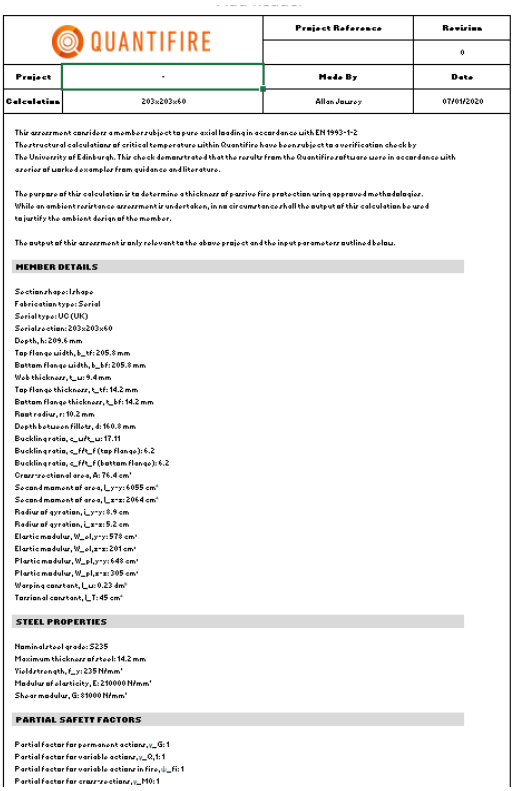



*Figure 95: Example output following a tension calculation*

Click on the 'Generate report' button to create a printable report of the entire calculation, as shown in Figure 96.



| QUANTIFIRE | Project Reference | Revision |
|---|---|---|
| | | 0 |
| Project | - | Made By | Date |
| Calculation | 203x203x60 | Allan Jaurey | 07/01/2020 |

This assessment considers a member subject to pure axial loading in accordance with EN 1993-1-2
The structural calculations of critical temperature within Quantifire have been subject to a verification check by
The University of Edinburgh. This check demonstrated that the results from the Quantifire software were in accordance with
a series of worked examples from guidance and literature.

The purpose of this calculation is to determine a thickness of passive fire protection using approved methodologies.
While an ambient restrained assessment is undertaken, in no circumstances shall the output of this calculation be used
to justify the ambient design of the member.

The output of this assessment is only relevant to the above project and the input parameters outlined below.

**MEMBER DETAILS**

Section shape: I shape
Fabrication type: Serial
Serial type: UC (UK)
Serial section: 203x203x60
Depth, h: 209.6 mm
Top flange width, b_tf: 205.8 mm
Bottom flange width, b_bf: 205.8 mm
Web thickness, t_w: 9.4 mm
Top flange thickness, t_tf: 14.2 mm
Bottom flange thickness, t_bf: 14.2 mm
Root radius, r: 10.2 mm
Depth between fillets, d: 160.8 mm
Buckling ratio, c_uft_w: 17.11
Buckling ratio, c_fft_f (top flange): 6.2
Buckling ratio, c_fft_f (bottom flange): 6.2
Cross-sectional area, A: 76.4 cm²
Second moment of area, I_y-y: 6055 cm⁴
Second moment of area, I_z-z: 2064 cm⁴
Radius of gyration, i_y-y: 8.9 cm
Radius of gyration, i_z-z: 5.2 cm
Elastic modulus, W_el,y-y: 578 cm³
Elastic modulus, W_el,z-z: 201 cm³
Plastic modulus, W_pl,y-y: 648 cm³
Plastic modulus, W_pl,z-z: 305 cm³
Warping constant, I_w: 0.23 dm⁶
Torsional constant, I_T: 45 cm⁴

**STEEL PROPERTIES**

Nominal steel grade: S235
Maximum thickness of steel: 14.2 mm
Yield strength, f_y: 235 N/mm²
Modulus of elasticity, E: 210000 N/mm²
Shear modulus, G: 81000 N/mm²

**PARTIAL SAFETY FACTORS**

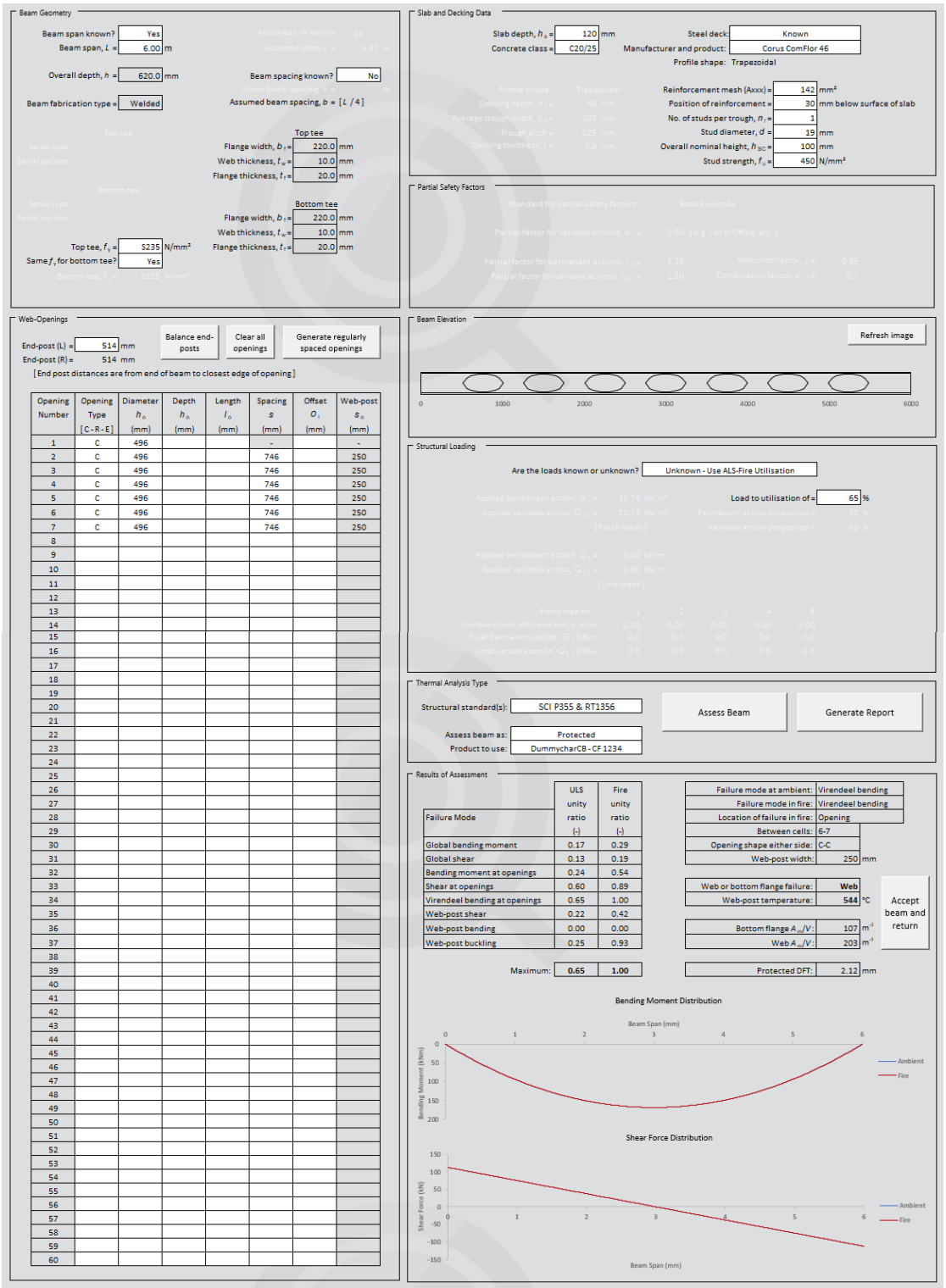
Partial factor for permanent actions, γ_G: 1
Partial factor for variable actions, γ_Q: 1.1
Partial factor for variable actions in fire, ψ_fi: 1
Partial factor for cross-sections, γ_M0: 1

*Figure 96: Example calculation report output for a tension member critical temperature (first page only shown)*

When complete with the calculation, click the ‘Accept and return’ button to save the member information and update the MTO Builder page with the revised critical temperature.

### *17.3.4 Beams with large web-openings*

The relevant input parameters for beams with large web-openings are shown in Figure 97. Only the white boxes are to be completed to assess a critical temperature. The greyed-out boxes represent parameters which could be used if certain options are selected.




| Opening Number | Opening Type [C-R-E] | Diameter $h_o$ (mm) | Depth $h_o$ (mm) | Length $l_o$ (mm) | Spacing $s$ (mm) | Offset $O_1$ (mm) | Web-post $s_o$ (mm) |
|---|---|---|---|---|---|---|---|
| 1 | C | 496 | | | - | | - |
| 2 | C | 496 | | | 746 | | 250 |
| 3 | C | 496 | | | 746 | | 250 |
| 4 | C | 496 | | | 746 | | 250 |
| 5 | C | 496 | | | 746 | | 250 |
| 6 | C | 496 | | | 746 | | 250 |
| 7 | C | 496 | | | 746 | | 250 |
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*Figure 97: Input options for beams with large web-openings*

The method to enter a beam with large web-openings is described in Section 15.2.4. This section considers the use of the advanced critical temperature tool. Some parameters relevant to the beam's geometry are inherited from the definitions provided in the MTO Builder page.

The following bullet points and associated text explain the various input parameters: -

- **Beam span**
  The beam span is shown in the top left. This information is inherited from the MTO Builder page but can be changed here if required. Note that if the total length of the beam in the MTO Builder page is total cumulative length, i.e. 1,234 m then Quantifire will adopt a 'generic' beam length, i.e. 6m in the case of Figure 97. This is to ensure that sensible lengths of beam are adopted for the purposes of calculation. The 'default' beam length can be changed by the user in the settings.

  If the beam span is set as unknown, the user can use a span/depth ratio to determine an estimate of beam length.

- **Beam spacing**

  The beam spacing (distance between adjacent beams) may be either known or unknown. If set to unknown, Quantifire will adopt a spacing of span/4. If actual loads are being entered, then be sure to set to the correct beam spacing.

- **Top tee strength**

  The top and bottom tee yield strength can be entered.

- **Slab and decking data**

  RT1356 only considers beams with web-openings acting in composite with a concrete slab via shear-studs. Therefore, the user can define characteristics including the slab depth, the concrete class, the decking shape and geometry, the reinforcement, the number of studs per trough, stud diameter, stud height and stud strength. These may all have an influence on the critical temperature.

- **Partial safety factors**

  See discussion above Table 14 in Section 17.3.

- **Web openings**

  A table is provided to enter the web-opening geometry. These can either be entered manually, i.e. in the case of irregular openings or automated using the 'Generate regularly spaced openings' button. The following bullet points are provided as guidance: -

  - An end-post must be specified, this is the distance between the end of the left side of the beam and the edge of the first opening.
  - Web openings can be entered as either Circular (C), Elongated circular (E) or Rectangular (R).

- Circular openings must have a diameter defined.
- Rectangular and elongated circular openings must have an overall depth and length defined.
- Spacing between openings is defined as the centre-to-centre dimension between adjacent openings.
- The offset distance allows openings to be moved vertically relative to the mid-depth of the beam. A positive value moves the opening upwards, while a negative value moves it downwards.
- The resultant web-post is displayed automatically. This is the distance between the edges of adjacent openings.
- The beam elevation image to the right of the display shows the web-opening geometry for clarity.
- A 'Balance end-posts' button is provided. This sets the left and right end-posts to be equal for the given web-opening geometry.
- The 'Generate regularly spaced openings' button provides a tool by which a series of equally-spaced identical openings can be defined for a set of given parameters – see Figure 98.

Opening definitions may be either known or unknown.

If they are known, then they may be entered directly. For example, 300mm diameter circular openings at 750mm spacings. Upon clicking 'OK' Quantifire will fit as many of the openings as possible into the web of the beam, centred such that the end-posts are equal, and the minimum end-post width dictated by design guidance is met.

If they are unknown, then Quantifire can assume certain logic to generate a series of openings. These can be one of three methods: -

1. Web-post widths are defined as a ratio of the maximum possible opening height relative to the beam's overall depth based on design guidance in SCI P355. Note that this method can be very conservative and may result in very narrow web-posts that fall below the minimum width tested for intumescent coating performance.

2. Openings can be defined based on the maximum permissible opening height relative to the beam's overall depth based on design guidance in SCI P355 and a user-specified spacing ratio, i.e. BS 7974 / PD 7974-1 references a spacing ratio of 1.3 times the opening height for circular openings.

3. The user can define the exact web-post width between adjacent openings.

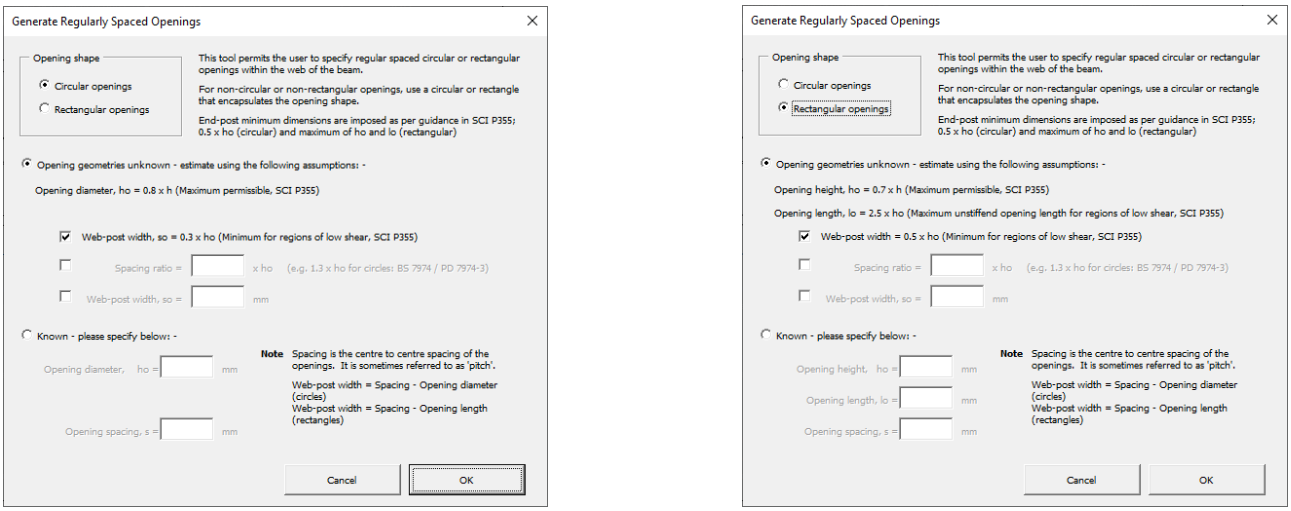
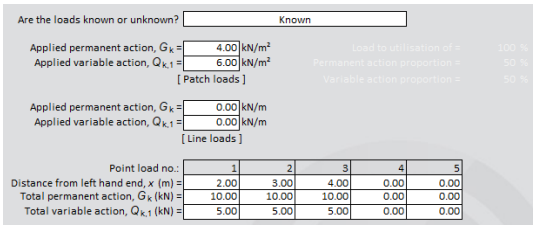


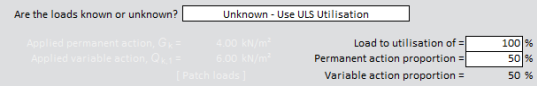
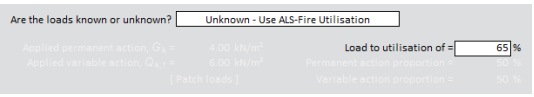

*Figure 98: Automatically generate regular (equally) spaced web-openings for circular (left) or rectangular (right) openings.*

- **Loading**

  Beam loading can be defined in one of three ways as shown in Table 18 with examples in Figure 99, Figure 100 and Figure 101 respectively.

  *Table 18: Types of loading available when assessing beams with large web-openings*

| Loading type | Comment |
|---|---|
| Known | The exact loading is known by the user (including self-weight)<br>Loads can be entered by surface area (patch loads), by linear load (line loads), or as point loads (maximum 5 along the beam length).<br>All loads can be defined as permanent (dead) and variable (live).<br>  <br>*Figure 99: Example when beam loading is known* |

| | |
|---|---|
| Unknown – Use ULS Utilisation | Loading is unknown but is specified at a utilisation at ultimate limit state (ULS). A conservative approach is to use 100%.<br>The proportion of permanent (dead) to variable (live) load must also be specified.<br>  <br>*Figure 100: Example when loading is unknown but defined as 'ambient' utilisation* |
| Unknown – Use ALS-Fire Utilisation | Loading is unknown but is specified at a utilisation at the accidental limit state of fire (ALS-Fire). The Eurocodes recommend 65% in the absence of any other information.<br>  <br>*Figure 101: Example when loading is unknown but defined as 'fire' utilisation* |

The optimum basis for a critical temperature calculation is an ALS-Fire utilisation from the Structural Engineer. Such an assessment should remove any unprotected members.

- **Structural standard**

  At present, the only structural standard to assess beams with large web-openings is SCI P355 (ambient design) and RT1356 (ambient and fire design). Until further design guidance is published and implemented into Quantifire, this shall remain the only choice.

- **Thermal analysis type**

  The beam may be assessed as either 'Unprotected' or 'Protected'. In each case, the process followed is that defined in both the ASFP Yellow Book and EN 13381-9. These are explained below. The user is encouraged to become familiar with the methods described in these references.

  In the case of 'Unprotected', the assessment considers the temperature profile of the beam heating in elemental parts such that the bottom flange, bottom tee web, top tee web and top flange are subject to a temperature development calculation for unprotected steelwork subject to a cellulosic fire temperature history relative to their respective thermal mass (section factor). The calculation methodology is taken from EN 1993-1-2.

  - The relative elemental temperatures of the beam are then iterated until structural failure occurs. The output is an overall product-independent failure temperature and associated failure criteria that can be used to define a specification for a passive fire protection thickness. Upon clicking 'Accept beam and return', the evaluation of DFTs

on the MTO Builder page will incorporate an assessment using product-specific web-post factors and elemental DFTs.

In the case of 'Protected', the assessment incorporates product-specific elemental DFTs and web-post factors to generate a thermal map over the beam.

- The DFT on the beam is then iterated within the bounds of the EMTA DFT tables. The DFT together with the elemental web and flange section factors is used to ascertain the temperature of the elemental parts of the beam. The web-post factors are then used to ascertain the steel temperature at each web-post. A structural check is then undertaken and the DFT iterated until structural failure occurs or the limits of the DFT range are met.
- It should be noted that the above step involves creating a table of temperature vs DFT for the web and flange (separately) at the fire rating and respective section factors. These tables can have differences in scope and therefore Quantifire applies the following logic:
    - Where the maximum DFT differs, the maximum of the two maximum DFTs will be used as the maximum. When the minimum DFT differs, the maximum of the two minimum DFTs will be used as the minimum.
    - Following the above point, if a table has a missing Tcrit due to use of a higher DFT within the scope of overall testing then the Tcrit of the highest tabulated DFT will be used.
    - If a table has multiple Tcrit values at the same DFT (common at high Tcrits where the minimum tested thickness is dominant) then the lowest Tcrit value at these DFTs will be used.
    - Linear interpolation is used to give Tcrit values between tabulated DFT values.
    - If one of the tables cannot be created because the section factor is out of scope, or if a DFT cannot be returned because the Tcrit is too low, then no Tcrit can be calculated for the beam.

Click on the 'Assess Beam' button to undertake the calculation.

The beam is checked with respect to the failure modes for a beam with large web-openings. The result of the calculation is displayed at the bottom of the frame – see Figure 102. The relevant checked failure modes are summarised for ULS (ambient) and ALS-Fire (fire) with respect to their utilisation. To the right of the utilisation summaries, further summaries of failure criteria are presented. These include the failure mode, location, associated web-post widths, failure temperature and elemental section factors. Where a 'Protected' assessment has been made, the resulting DFT is also shown.

Under the calculation summary are two charts, see Figure 102. These depict the bending moment and shear force diagrams respectively.

Users should note that a calculated maximum utilisation for ALS-Fire of less than 1.00 for a protected assessment is possible since the limits of the EMTA DFT tables are being met, i.e. at the thinnest DFT for the relevant section factors the temperature distribution is such that structural reserve is conservatively retained within the beam. An example of this could be a beam with a failure temperature of 857°C but protected with a product with DFTs that stop at 750°C.

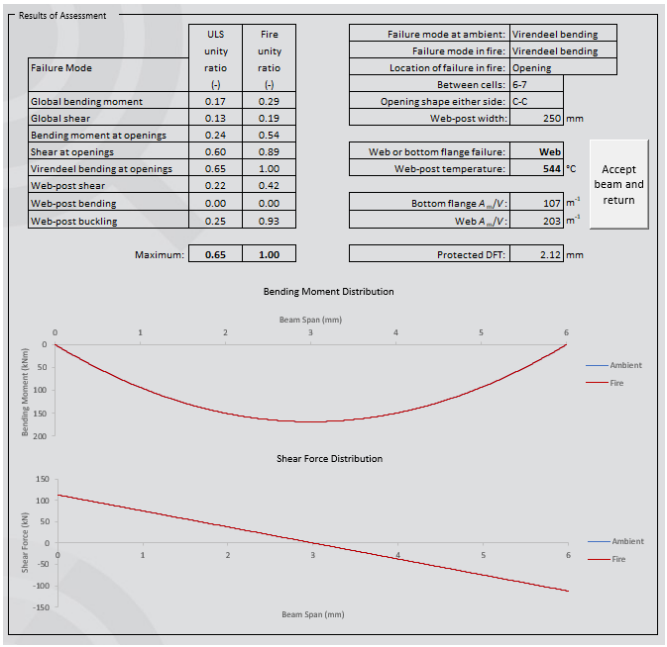



*Figure 102: Example output following a calculation of beam with large web-openings*

Click on the ‘Generate report’ button to create a printable report of the entire calculation. The user is prompted as to whether potentially confidential product-specific web-post factors and associated steel temperature distributions are to be shown or not – see Figure 103. Upon selecting ‘Yes’ or ‘No’, a report is produced as shown in Figure 104.

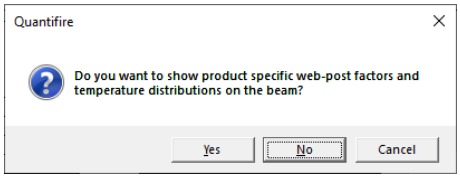
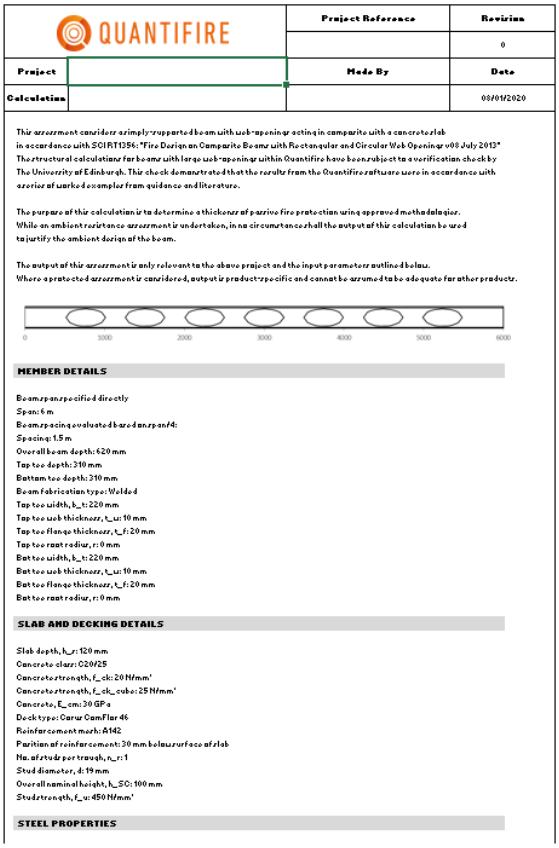



*Figure 103: Pre-reporting check on whether the user wishes to report possible confidential web-post factors and associated steel temperature distributions*



| QUANTIFIRE | Project Reference | Revision |
|---|---|---|
| | | 0 |
| Project | Made By | Date |
| Calculation | | 08/01/2020 |

This assessment considers a simply-supported beam with web-opening acting in composite with a concrete slab in accordance with SCI RT1356: "Fire Design on Composite Beams with Rectangular and Circular Web Openings v08 July 2013" The structural calculations for beams with large web-openings within Quantifire have been subject to a verification check by The University of Edinburgh. This check demonstrated that the results from the Quantifire software users in accordance with a series of worked examples from guidance and literature.

The purpose of this calculation is to determine a thickness of passive fire protection using approved methodologies. While an ambient resistance assessment is undertaken, in no circumstances shall the output of this calculation be used to justify the ambient design of the beam.

The output of this assessment is only relevant to the above project and the input parameters outlined below. Where a protected assessment is considered, output is product-specific and cannot be assumed to be adequate for other products.




**MEMBER DETAILS**

Beam span specified directly
Span: 6 m
Beam spacing evaluated based on span:
Spacing: 1.5 m
Overall beam depth: 620 mm
Top tee depth: 310 mm
Bottom tee depth: 310 mm
Beam fabrication type: Welded
Top tee width, b_t: 220 mm
Top tee web thickness, t_w: 10 mm
Top tee flange thickness, t_f: 20 mm
Top tee root radius, r: 0 mm
Bot tee width, b_t: 220 mm
Bot tee web thickness, t_w: 10 mm
Bot tee flange thickness, t_f: 20 mm
Bot tee root radius, r: 0 mm

**SLAB AND DECKING DETAILS**

Slab depth, h_r: 120 mm
Concrete class: C20/25
Concrete strength, f_ck: 20 N/mm²
Concrete strength, f_ck_cube: 25 N/mm²
Concrete, E_cm: 30 GPa
Deck type: Corus ComFlor 46
Reinforcement mesh: A142
Position of reinforcement: 30 mm below surface of slab
No. of studs per trough, n_r: 1
Stud diameter, d: 19 mm
Overall nominal height, h_SC: 100 mm
Stud strength, f_u: 450 N/mm²

**STEEL PROPERTIES**

*Figure 104: Example calculation report output for a tension member critical temperature (first page only shown)*

When complete with the calculation, click the 'Accept and return' button to save the member information and update the MTO Builder page with the revised critical temperature. Be aware that if the assessment was done as 'Unprotected', upon clicking 'Accept beam and return', the evaluation of DFTs on the MTO Builder page will incorporate an assessment using product-specific web-post factors and elemental DFTs.

### *17.3.5 Setting critical temperature defaults for advanced calculations*

Quantifire provides users with the ability to assess multiple sections simultaneously rather than having to assess members one at a time using the advanced calculation methods described above. This method uses the exact same methodology as the calculation sheets but has inputs defined as those in the 'Defaults for limiting steel temperature calculations' dialogue box.

These inputs are also used when the user selects the 'Advanced $T_{crit}$ calculator' method of defining the limiting steel temperature (see Figure 76) when entering sections on the MTO Builder page.

To access the defaults dialogue box, click the Quantifire logo to access the main menu and then click 'Edit default $T_{crit}$ settings', see Figure 105.

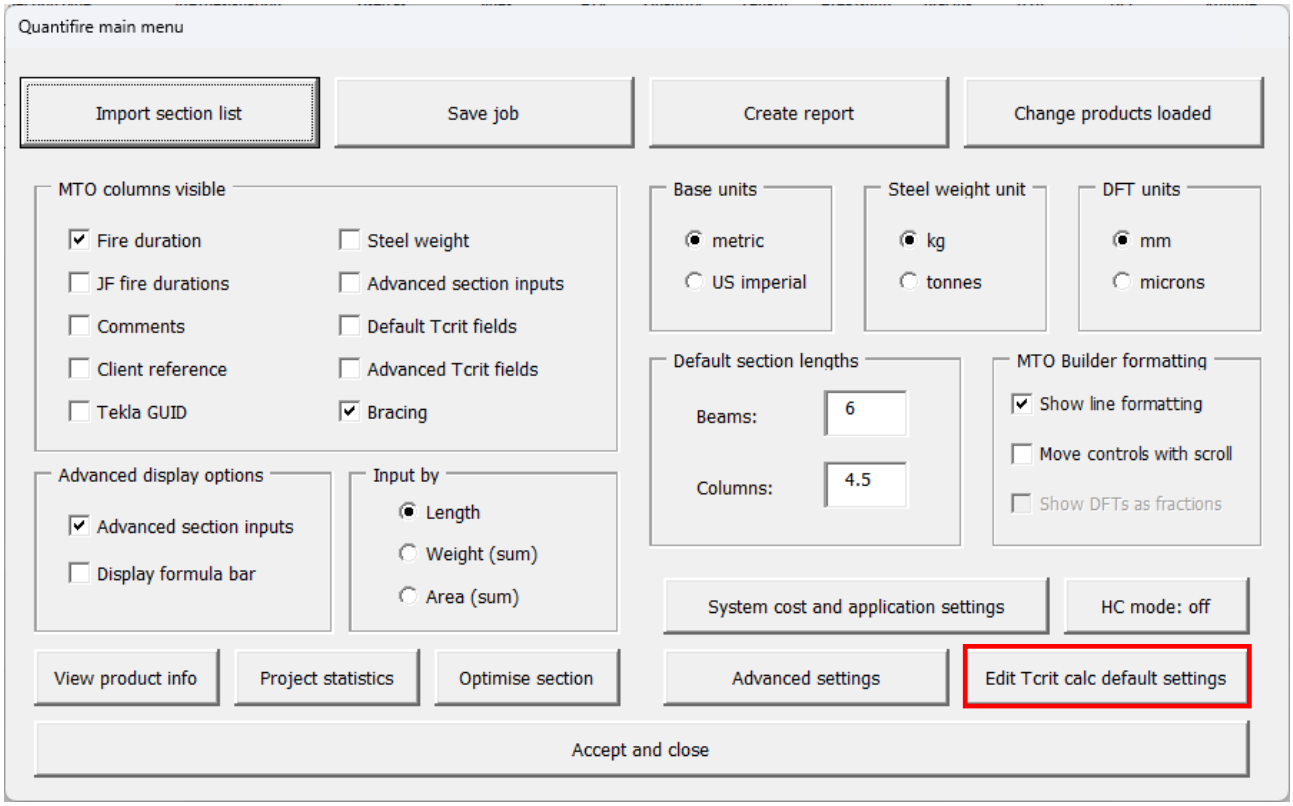



*Figure 105: Accessing the 'Defaults for limiting steel temperature' dialogue box*

The dialogue box contains five tabs which reflect the inputs on the advanced calculation pages described in the previous sections.

- Partial safety factors and loading
- Beam
- Column
- Tension member
- Beams with web-openings

Each option can be defined by the user and will be used to populate the advanced calculations unless a specific individual member has been previously edited in which case it will retain the relevant information.

Users should note that the defaults are all deliberately set to be conservative. If users are using the advanced calculation methods, then they are advised to set the defaults to the correct inputs relevant to their project. The conservative defaults if used unedited will likely result in low critical temperatures that may not be able to be protected.

To ensure optimum use, the user is advised to verify the parameters outlined in Table 19 as a minimum.

Project requirements should always be checked with the design team, but examples may include: -

- In the case of an office building in the UK, it may be beneficial to change the 'Partial safety for variable actions, $\gamma_{fi}$' to 0.50, set 'Loading type' to be 'Unknown – Use ULS Utilisation' and set the 'Load to utilisation of' to '100%'.
- Many steel yield strengths for serial I-section beams and columns in the UK are 355 N/mm². This will be beneficial for members subject to buckling, i.e. columns.
- Most buildings will be considered as a braced-frame design. By selecting yes to this input parameter will allow beneficial critical temperatures for columns.
- In a braced-frame multi-storey building, most columns will be in a 'Column location' that can be defined as 'Intermediate-storey'. This option will typically yield higher critical temperatures than a top-storey column location.

*Table 19: Notable parameters to verify within the 'Defaults for limiting steel temperature' dialogue box*

| Tab | Default parameter to verify |
|---|---|
| Partial safety factors and loading | Partial safety for variable actions, $\gamma_{fi}$ |
| Partial safety factors and loading | Loading type |
| Partial safety factors and loading | Steel grade |
| Column | Braced frame design |
| Column | Column location |

The inputs for each tab are shown in Figure 106 through to Figure 110. For each input parameter, the user should reference the relevant section within this User Manual as outlined in Table 20.

*Table 20: Notable parameters to verify within the 'Defaults for limiting steel temperature' dialogue box*

| Tab | Figure | Parameter description |
|---|---|---|
| Partial safety factors and loading | Figure 106 | Table 14 in Section 17.3 |
| Beam | Figure 107 | Section 17.3.1 |
| Column | Figure 108 | Section 17.3.2 |
| Tension member | Figure 109 | Section 17.3.3 |
| Beam with web-openings | Figure 110 | Section 17.3.4 |

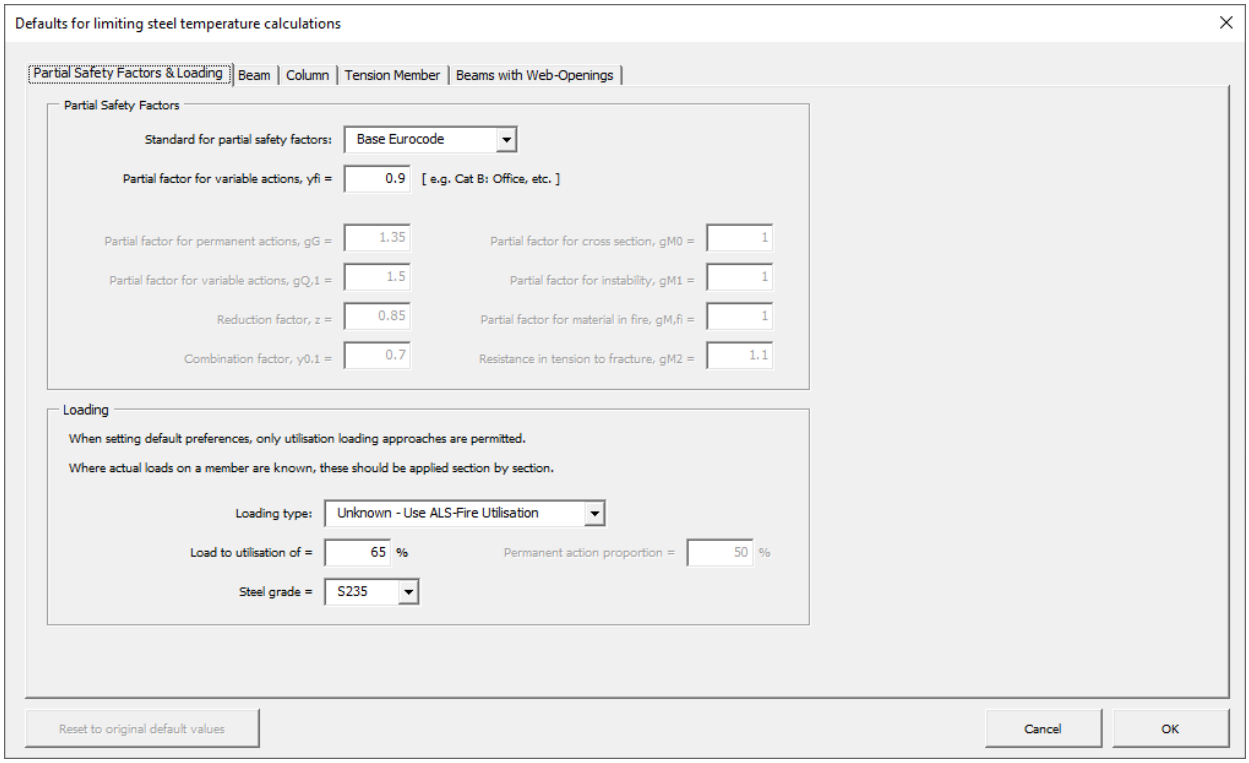



*Figure 106: Default inputs for partial safety factors and loading for advanced $T_{crit}$ calculations*

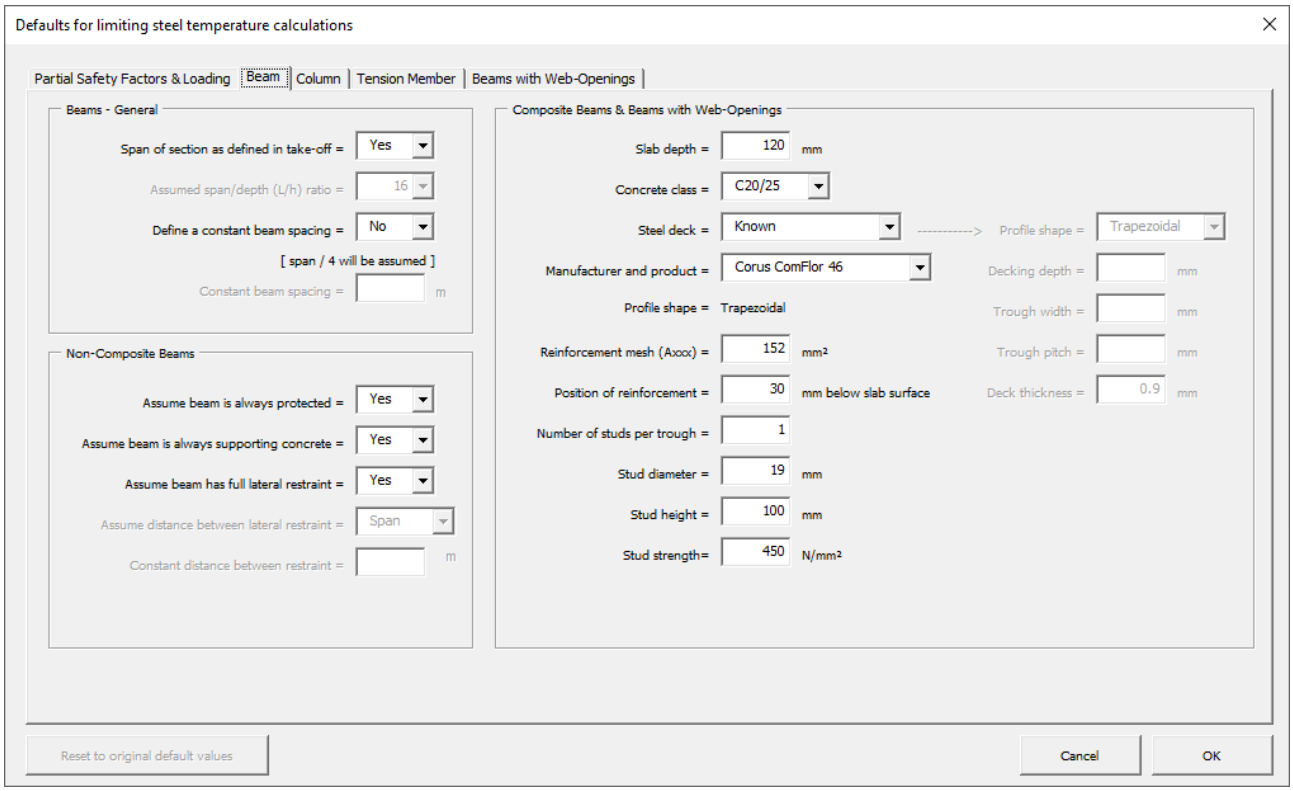



*Figure 107: Default inputs for beams for advanced $T_{crit}$ calculations*

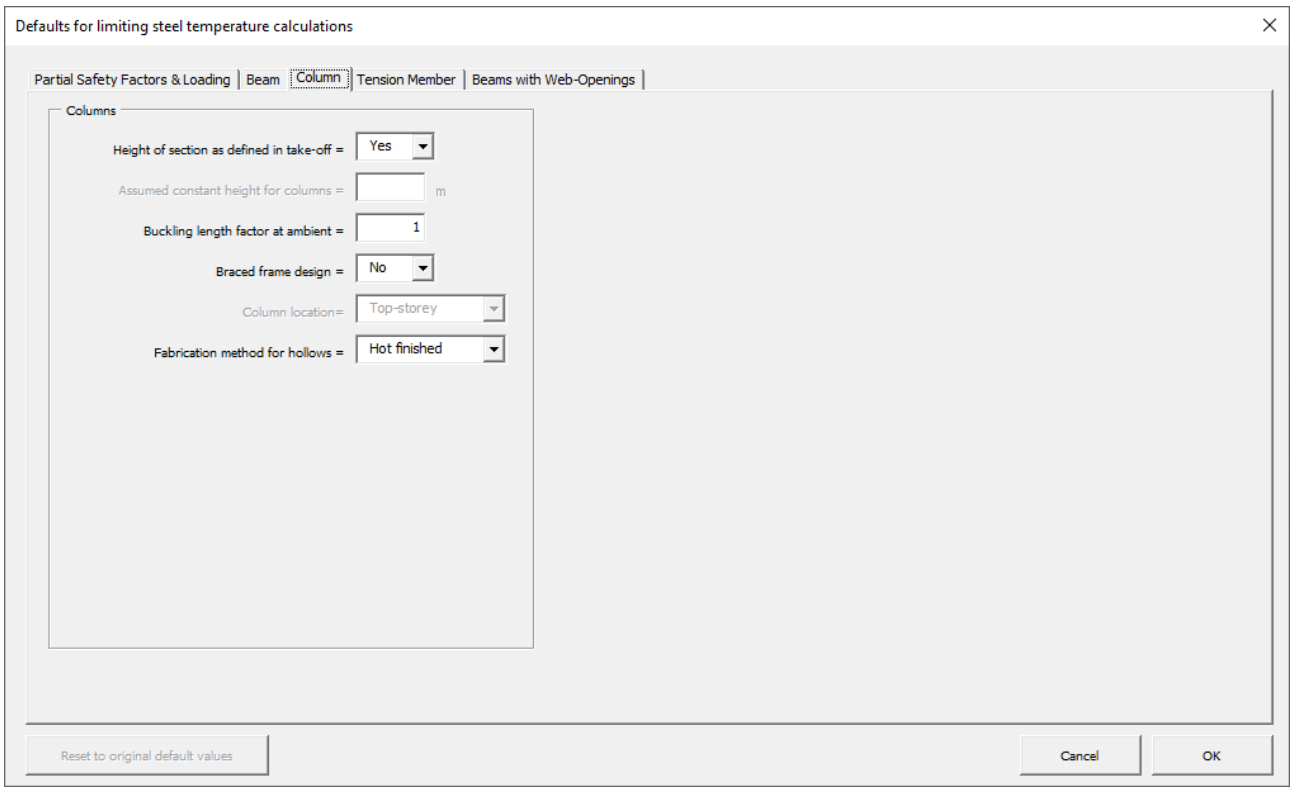



*Figure 108: Default inputs for columns for advanced $T_{crit}$ calculations*

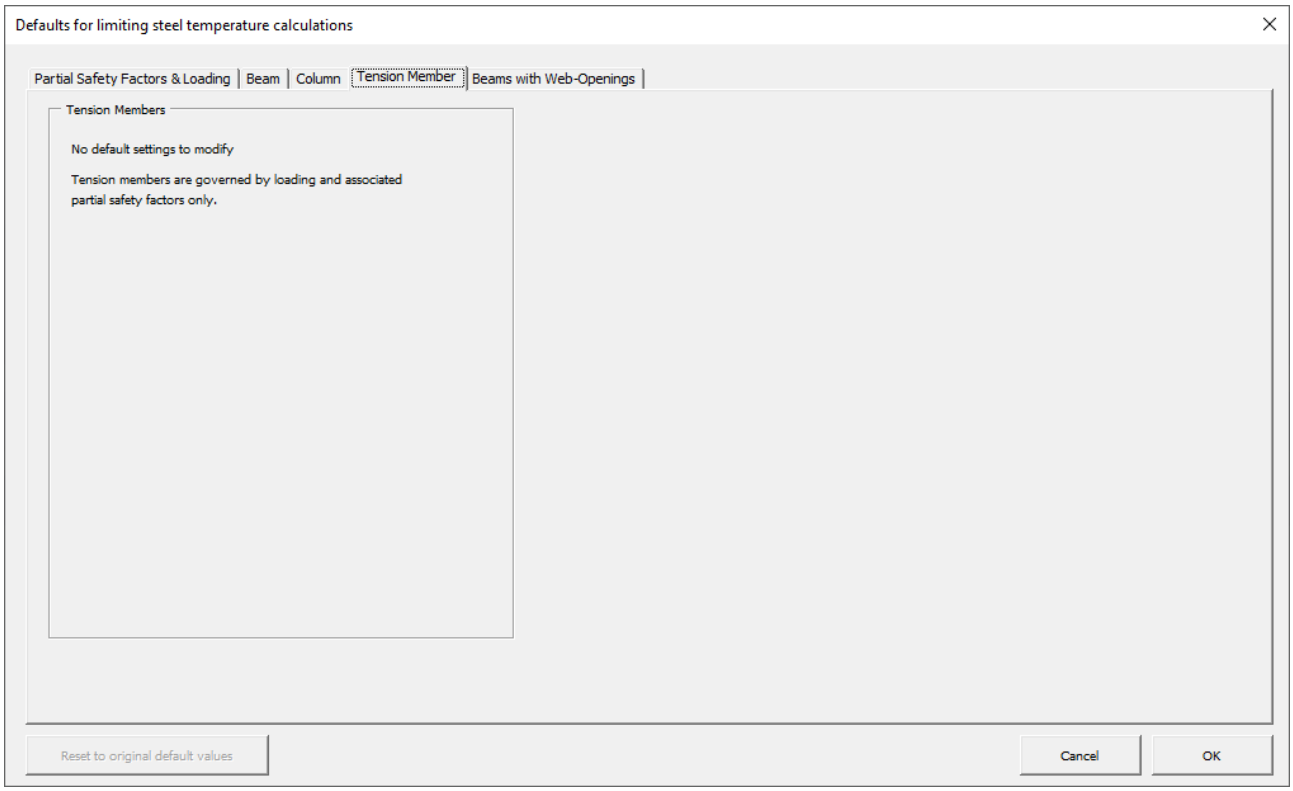



*Figure 109: Default inputs for tension members for advanced $T_{crit}$ calculations*

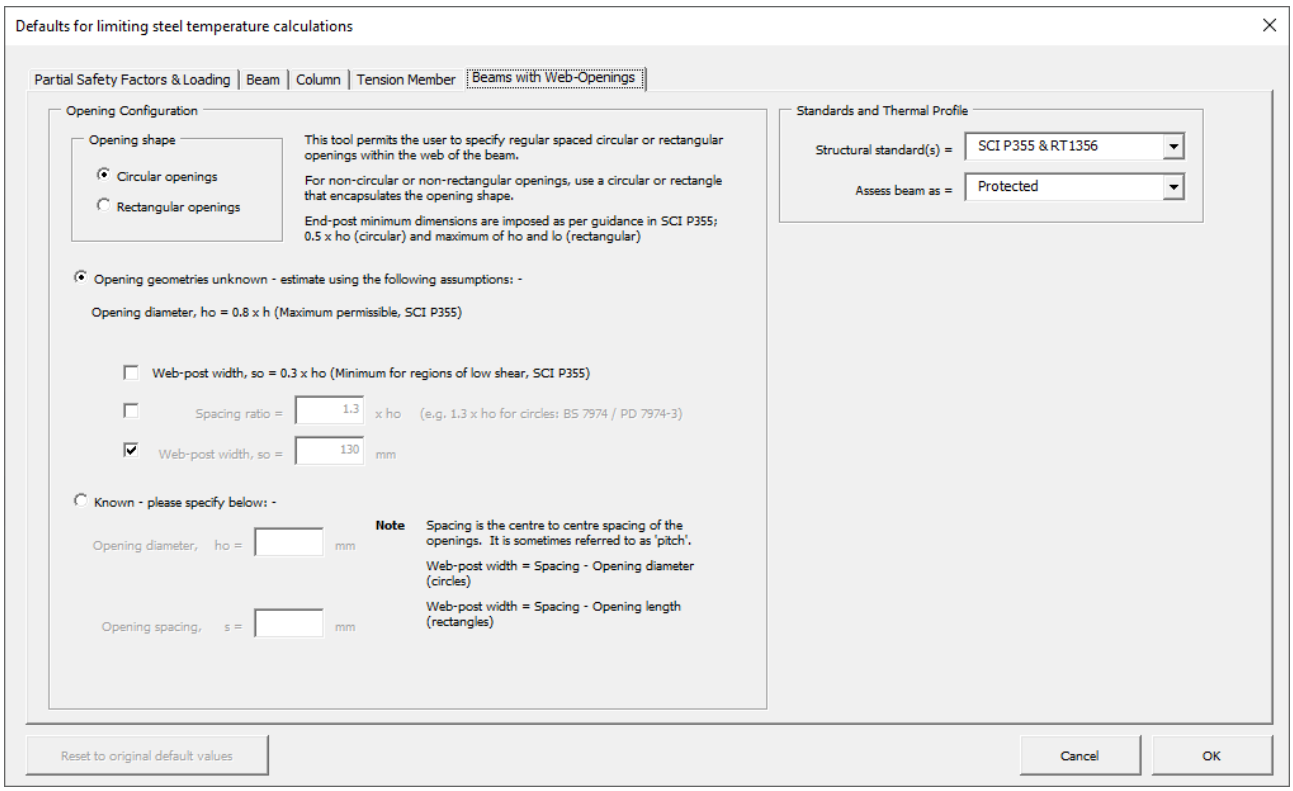



*Figure 110: Default inputs for beams with web-openings for advanced $T_{crit}$ calculations*

# 18 REPORTING

## 18.1 Create a report

After saving the Project, the user is able to produce a report by clicking on 'Create report' in the main Quantifire menu. This brings up the options menu shown in Figure 111. This section covers the customising options available to the user when producing a report.

The user can overwrite the most recently created revision of a report within the current working session. This feature is provided to permit modification to settings chosen when creating a report without the need to create a new revision. Note that once Quantifire is closed, or a different project is loaded, the most recent revision will be locked and cannot be overwritten.

The user can recreate a previous report at any time by loading the job it was created under and selecting the appropriate option after clicking to Create a Report. A list of which reports were created under which jobs can be viewed after selecting a project and package in the project selector window (accessible on the Get Started page).

## 18.2 Report types

*Bill of Quantity (BOQ) report*

This is the default report produced by Quantifire. It displays all the sections loaded by the user to the MTO builder and the estimated DFT and vol of PFP product required for each section with a number of other details as defined by the user.

An example BOQ report and Technical basis schedule can be found in Section 18.5.

*Technical basis schedule*

The secondary style of report available to the user. This is to be used in addition to the BOQ report in the case that the user is required to give more detail on the assumptions, details or parameters, that form the basis of the calculations on the main report.

*Cell beam schedule*

This is only available when the MTO includes cellular beams and is intended to be read in addition to the BOQ report. Users are recommended to create this report if they are required to give detail on the geometry of the cellular beams (noting the information is too extensive to fit comfortably on the standard BOQ report).

*Tekla input file*

A simplified report intended to be read by Tekla, giving the basic information for each section (as identified by the GUID number).

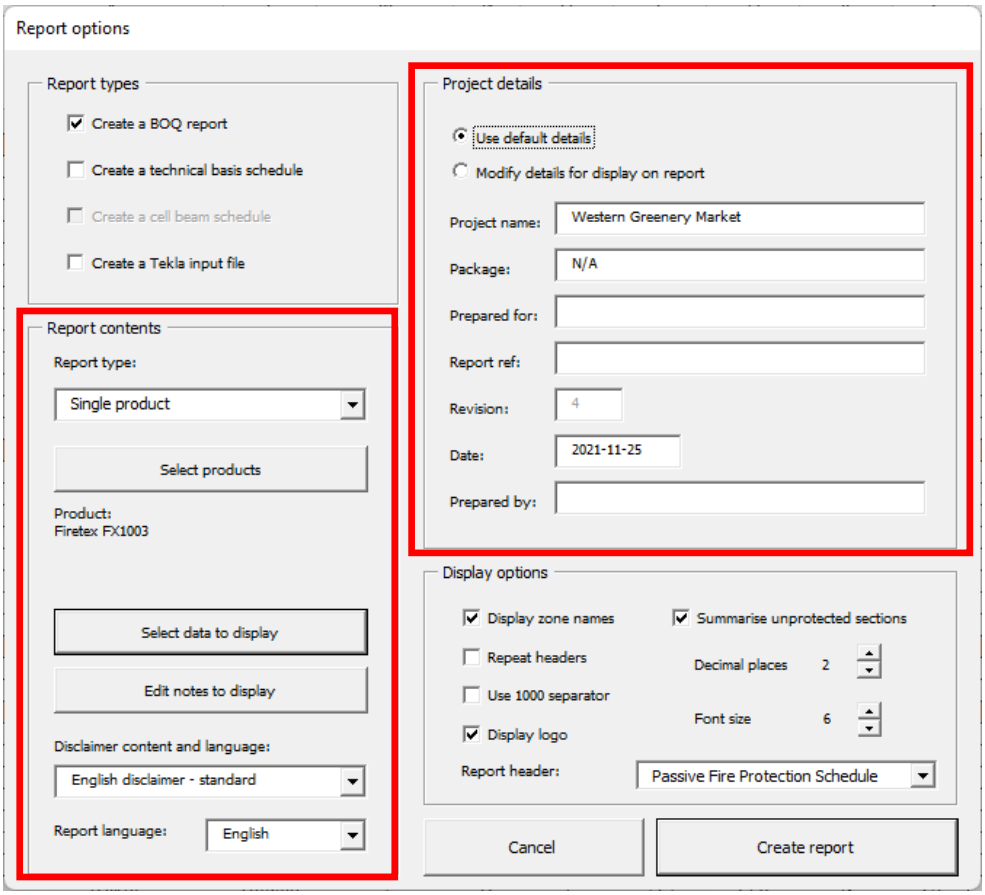



*Figure 111: Report options*

## 18.3 Project details

These details are displayed at the top of the report. The user can select to use the default information, as displayed in the greyed-out fields or to enter new details. Note that the revision cannot be modified. This is created by the database to ensure each report is uniquely identifiable from the project name, package name, and revision number.

## 18.4 Report contents

### *18.4.1 Report type*

If the estimation includes more than one product, the user can use the 'Report type' dropdown within the 'Report contents' frame to select how the report should display the estimations, see Figure 112. Each of the options, when selected, affects the way that the 'Select products' button immediately below it functions. These options are the same as those offered when setting the combined product summary column and explained in Table 2.

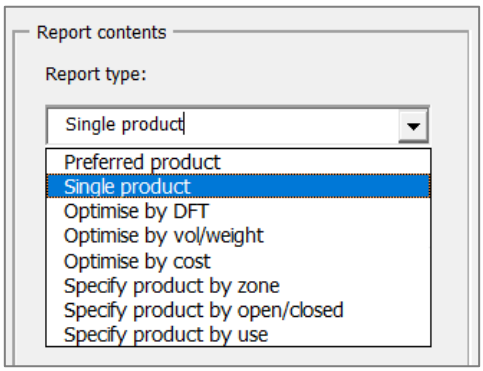



*Figure 112: Report type options*

### *18.4.2 Select columns to display*

It is possible for the report to display all or a selection of the columns displayed in the schedule on-screen. The user can use this 'Select columns to display' button to select which columns to display on the report.

The left box shows all columns available; the right box shows those to be included in the report. The user can move columns from one side to another by selecting the name and using the central arrow buttons. Note: the user can modify the columns visible in the BOQ or Technical schedule separately by selecting the appropriate tab at the top of the window. It is advisable to use the technical schedule report to display any more than a few additional columns, rather than overloading the BOQ report.

The report will automatically resize the columns to fit the number selected. The widths of the columns relative to each other are pre-set based on the typical length of contents.

### *18.4.3 Edit notes to display*

Notes are pre-set by Quantifire to capture assumptions made by the program or important settings. Notes are automatically selected based on the report contents, however, the user can choose to overwrite the default by checking the box to the left of a note. Notes checked in Figure 113 are included as default.

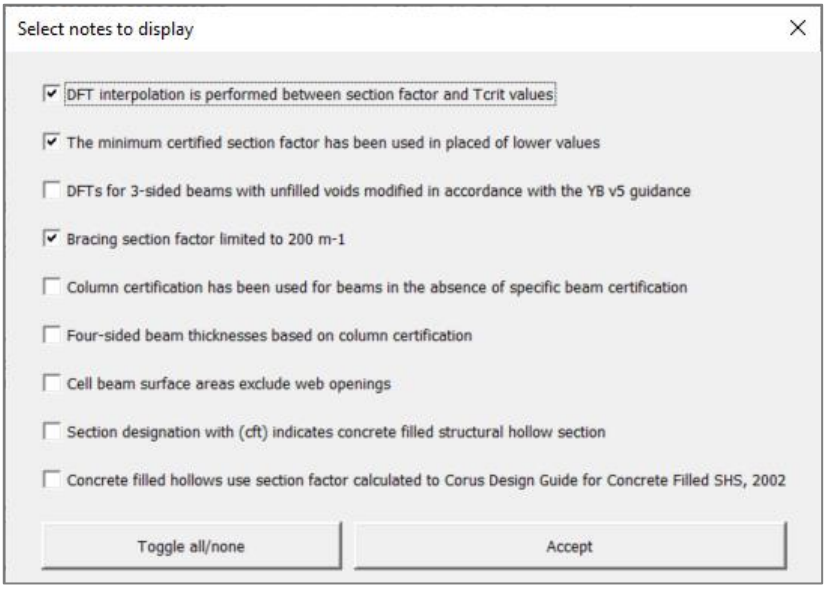



*Figure 113: Notes to display*

### *18.4.4 Disclaimers*

Disclaimers are provided by clients and are stored in their private database. There is no limit to the number of disclaimers a client can have. Users should select the appropriate disclaimer.

### *18.4.5 Report language*

All text on the BOQ and Technical Schedule reports can be translated into alternative languages. A translation file is available on request for clients to complete if they wish the language to be made available.

### *18.4.6 Display options*

*Display logo*

Untick to remove the company logo from the top left of the report.

*Use 1000 separator*

If ticked, the native system thousand separator (e.g. ',' for the U.K., '.' for Germany) will be displayed.

*Repeat headers*

If ticked, the column headers will be repeated at the top of each page.

*Display zone names*

Select whether to break the BOQ reports into zones and display the zone headers

*Decimal places*

Set the number of decimal places to be used on the report. Note this does not affect integer values such as the quantity.

*Include unprotected sections in summary quantities*

By default, from v1.2.1.0 onwards, the Quantifire reports will exclude the steel dimensions (length, area, weight, quantity of items) from the summary totals if the items cannot be protected. Tick this option to include them.

## 18.5 Report layout

Summaries are always given on a new page. A total summary will always be present, in addition to a summary by zone if the 'display zones' option is checked, and a summary by product if multiple products are used in the report.

# 19 ADVANCED SETTINGS

Access to the advanced settings dialog box (see Figure 114) is by clicking the main Quantifire logo in the MTO Builder page.

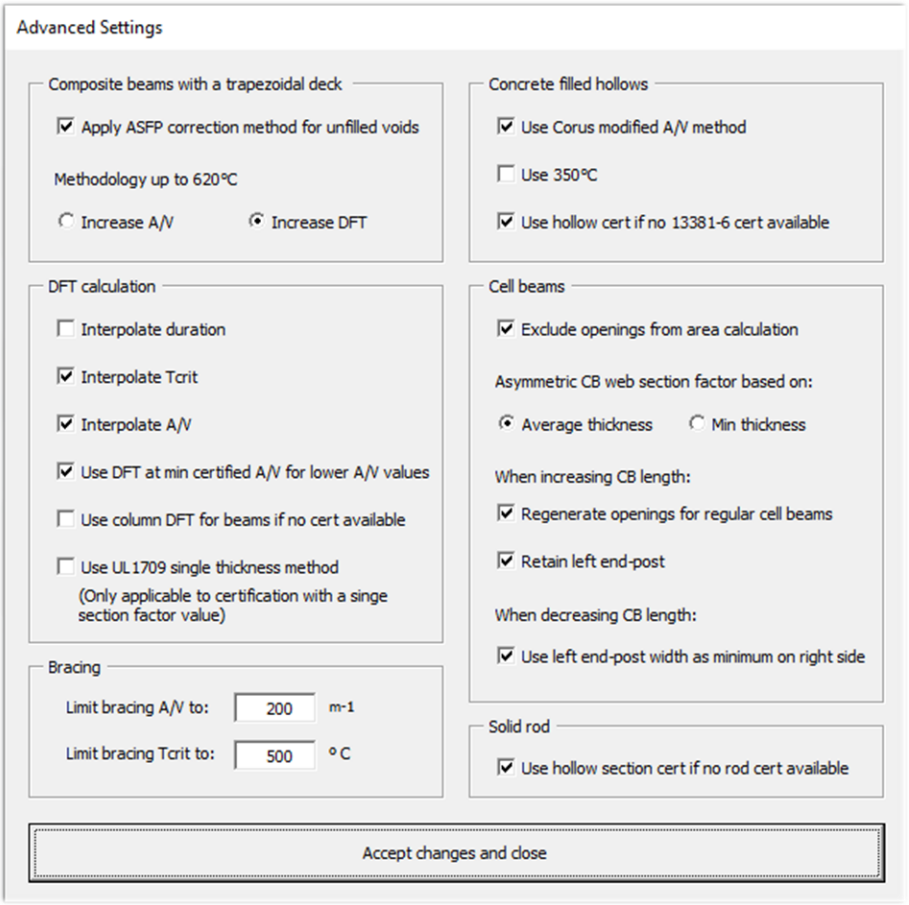



*Figure 114: Advanced settings*

- *Composite beams with a trapezoidal deck*

  The Association for Specialist Fire Protection (ASFP) in the UK gives guidance on how to handle voids left unfilled. Select whether the methodology they described is applied, and how. See Section 16.5.3.

- *DFT calculation*

  Select whether Quantifire interpolates between duration (by default: No), between $T_{crit}$ (by default: Yes), and section factor (by default: Yes).

Select whether sections below the minimum section factor shown on the certificate adopt the DFT at minimum shown section factor. If unchecked the notification message <*SFmin* will be given in these situations.

Selecting to use column DFT for beams will only provide a DFT if there is no beam certificate available. This option is intended for hydrocarbon scenarios, such as when UL1709 certification is widely used for 4-sided beams situations. Note that for 4 sided-beam situations some certification may have 4 sided beam applicability up to a DFT limit even without this setting enabled.

The UL1709 single thickness method is included for back-wards compatibility with older certificates that would test only a single section size (typically a W10x49). See section 24.4 for more information. **Users are encouraged to verify the acceptance of this approach on the project.**

- *Cell beams*

  By default, the surface area calculation for cell beams consider a solid web beam and excludes the influence of the openings. Uncheck to subtract the openings from the area. See Section 15.2.4.

  Table 21 discusses the section factor of a cellular beam and treatment of openings and end-posts when the beam's length is modified.

*Table 21: Cellular beam settings*

| Setting | Comments |
|---|---|
| Asymmetric CB web section factor based on: | The web section factor can be based on an average web thickness or a minimum web thickness (a more conservative approach). By default, Quantifire adopts the average web thickness. |
| When increasing CB length:<br><br>Regenerate openings for regular cell beams | If enabled, on changing the length of regular cell beams Quantifire will regenerate openings of the same shape, size and spacing to fill the beam. If not enabled, the extra length will be added to the right hand end-post. |

| | |
|---|---|
| When increasing CB length:<br><br>Retain left end post | If enabled, on changing the length of regular cell beams Quantifire will retain the left hand end-post as the minimum on both sides when regenerating openings. If not enabled Quantifire will create as many openings as possible that comply with geometric constraints. |
| When decreasing CB length:<br><br>Use left end-post width as minimum on right side | If enabled, the left hand end post will be retained as the minimum right hand end post width when deleting openings. If not enabled then the right hand end post can be less, with openings retained that would fall into this area. |

- *Concrete filled hollows*

  Quantifire provides several options for handling concrete filled hollows. See section 16.5.2.

- *Solid rods*

  Quantifire provides the option for users to use product-specific hollow section thicknesses in the absence of a specific rod thickness certificate, see section 16.5.4. This option will use SHS column data for square rods and CHS column data for round rods. This option is set to off or on automatically depending on whether a product with EN 13381-10 certificate is loaded or not (respectively).

## 20 PRODUCT AND SYSTEM DETAILS

The 'Product and System Details' window, shown in Figure 115, is accessed via the Quantifire logo. All products in the Quantifire database have information associated with volume solids, density, application method, loss factor, kit size, and maximum WFT. Within the dialogue box, these values can be overwritten as appropriate.

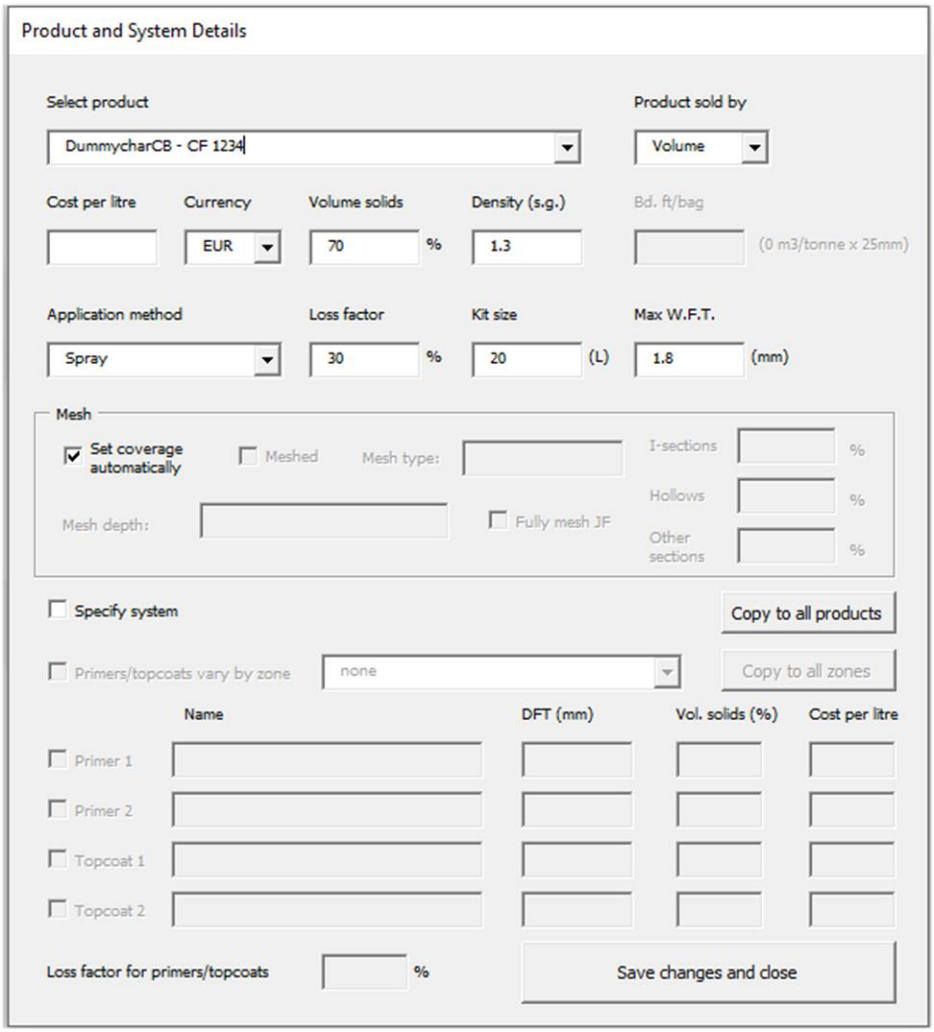



*Figure 115: Product and system details*

Quantifire records whether the product is sold by volume or by weight. With version 1.4.0.0 the user can modify this property, allowing products to be sold in different units to be compared more effectively.

With the introduction of SFRMs in v1.4.0.0 the measure of bd-ft / bag was introduced. This is a common measure of the theoretical coverage of SFRM products (and is not used for intumescent products in Quantifire). 1 bd-ft is equivalent to the volume of one square foot by one inch. The theoretical coverage of SFRMs will vary depending on the water mix ratio, therefore Quantifire uses the bd-ft/bag value stated on the product datasheet (the highest value given if there is a range). The

density of the products is also entered, however this is not used for the purposes of quantity calculations.

To add pricing to the reports (and to use the optimise by cost option) enter a price for each product.

To specify primers and topcoats first tick the box 'Specify system' and then select whether the primers and topcoats vary by zone. Note that it is not possible to assign primers and topcoats to individual sections. If the primer and topcoat offer is known to vary then divide the MTO into zones accordingly.

To specify mesh, tick the 'Meshed' box. The mesh type and depth are free text fields. Enter the average mesh % coverage to enable calculation of mesh quantities.

All system information is stored when the project is saved.

## 21 PROJECT STATISTICS

Users can view a statistical breakdown of the project by clicking 'View project statistics', found in the main menu. This feature can use either a single product or the same setting used for the *combined product summary column*.

In future version this feature will be further expanded and be a starting point for project optimisation tools.


*Figure 116 - Project statistics*

# 22 OPTIMISATION MODULE

The optimisation module within Quantifire is designed to assist users to implement a cost-benefit analysis to find the most economical solution by considering the combined price of steel, PFP material and application. It can also be useful to propose alternate section sizes when the parent section cannot be protected, e.g., in the case a high section factor and/or a low critical temperature.

## 22.1 Overview

Steel structures are typically designed for normal conditions with relatively little consideration given to their performance in fire, let alone their relationship with applied fire protection. A more comprehensive assessment would consider the costs of steel, PFP material and the application combined. This is illustrated in Figure 117. This process allows for consideration of alternate structural sections that may either permit sections to be protected or to rationalise the associated thickness and resultant application costs. From an ambient perspective, the cheapest solution may be the lightest steel section, however when fire protection is considered, a slight increase in steel weight may bring significant economic savings.

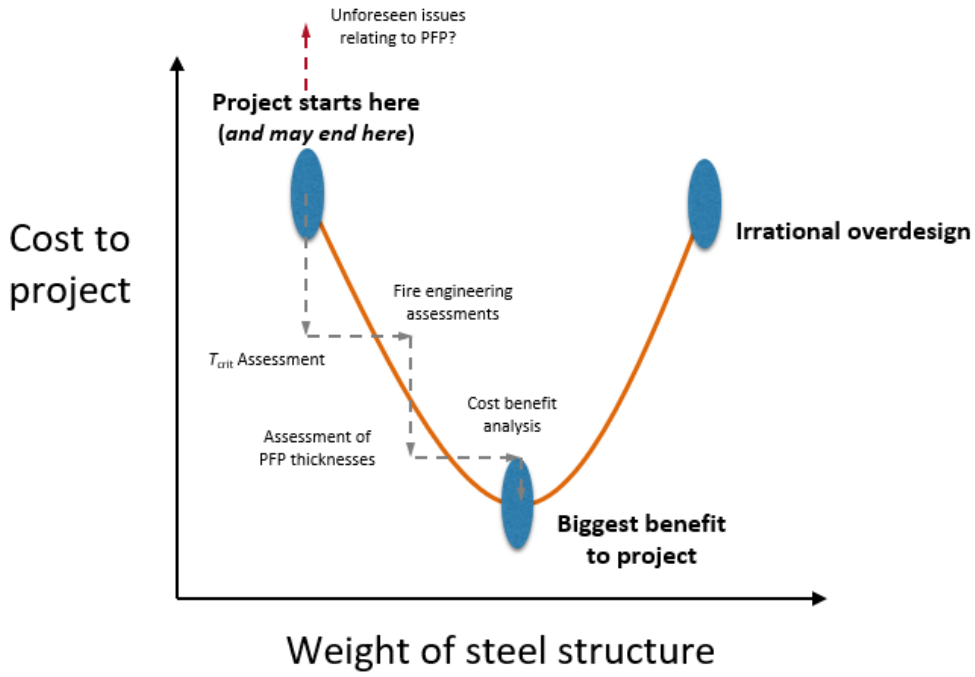



*Figure 117: Concept of a cost-benefit assessment to find the optimum section size when accounting for PFP*

The optimisation module within Quantifire allows fire protection estimators to have an informed discussion with designers. It can also be used directly by designers. This quick guide introduces the key features with an example.

## 22.2 Accessing the optimiser

The Optimiser can be accessed via the 'Optimise section' button in the Quantifire main menu, see Figure 118. Alternatively, it can be accessed via the 'Project statistics' display, see Figure 119.

Access to the optimiser is a permission set on an individual-user basis with access disabled by default. Contact your primary internal administrator to request access.

The optimiser allows users to consider a single section at a time. Therefore at least one section should be in the take-off on the MTO Builder screen to start. Note that at the time of writing, solid rods and "Custom" sections (defined by section factor or weight or heated perimeter alone) cannot be optimised.

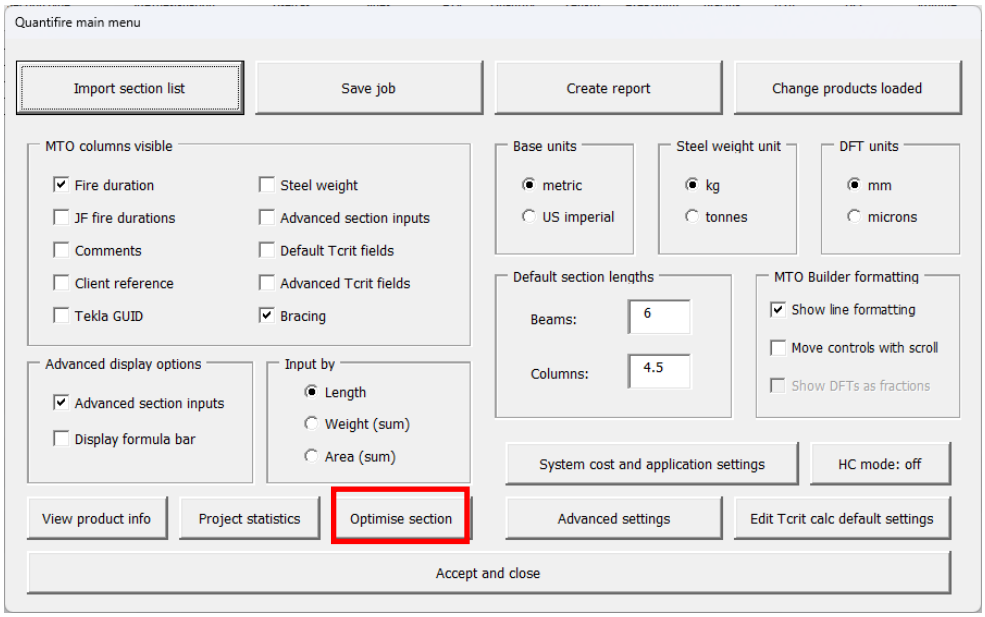



*Figure 118: Accessing the Optimiser via the main menu*

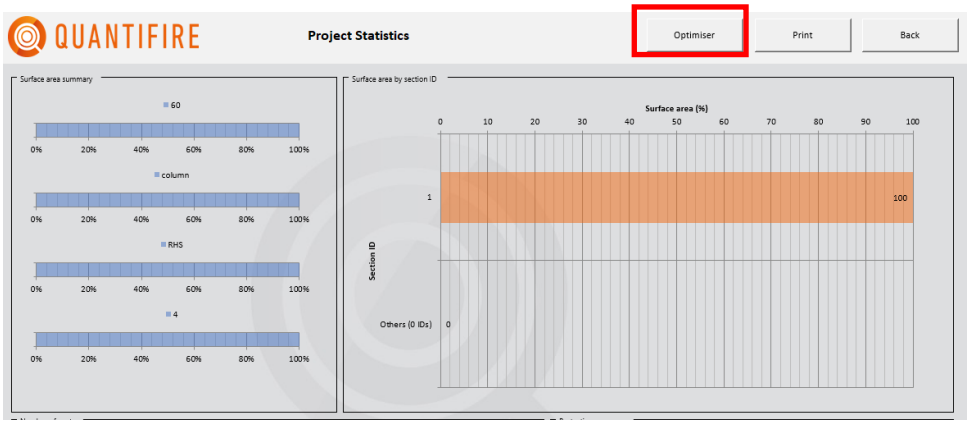



*Figure 119: Accessing the Optimiser via the Project Statistics display*

## 22.3 Entering cost information

On first use, unless they have been previously set, the Optimiser will prompt the user that the cost settings are incomplete, see Figure 120. To undertake the cost-benefit analysis, costs associated with steel, PFP product and application are required.

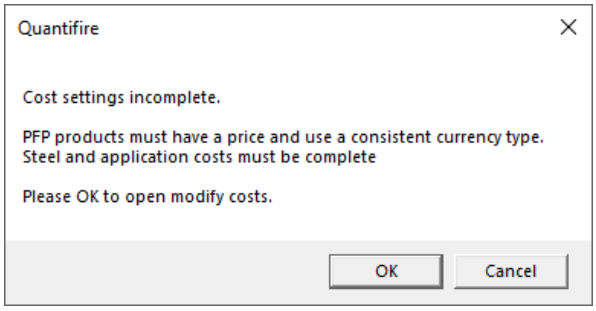



*Figure 120: User prompt to remind that cost settings need to be entered*

The steel and application cost settings window is shown in Figure 121. Example cost values are set in the textbox placeholders, but these should be modified to suit the project needs accordingly. The PFP material cost is entered by clicking the 'Edit material costs' button. This opens the 'Product and system details' window as shown in Figure 122. From this dialogue box, the cost per unit can be entered, together with the associated currency. Each loaded product must have a unit cost set, and the currency across all products must be consistent.

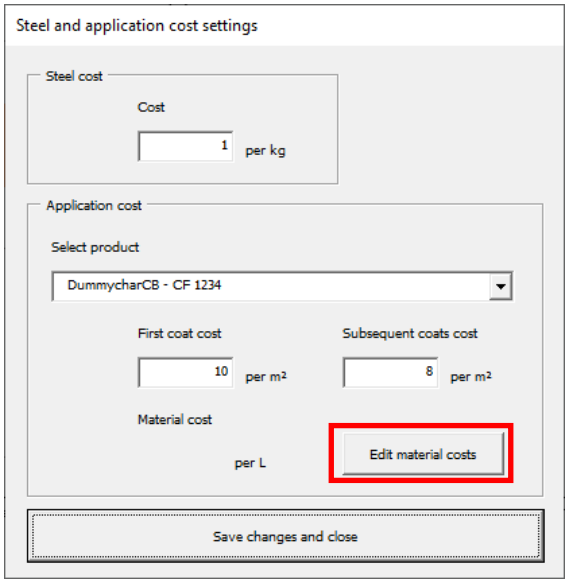



*Figure 121: Steel and application cost settings – values shown are illustrative examples only. PFP material costs are set via the 'Edit material costs' button as highlighted*

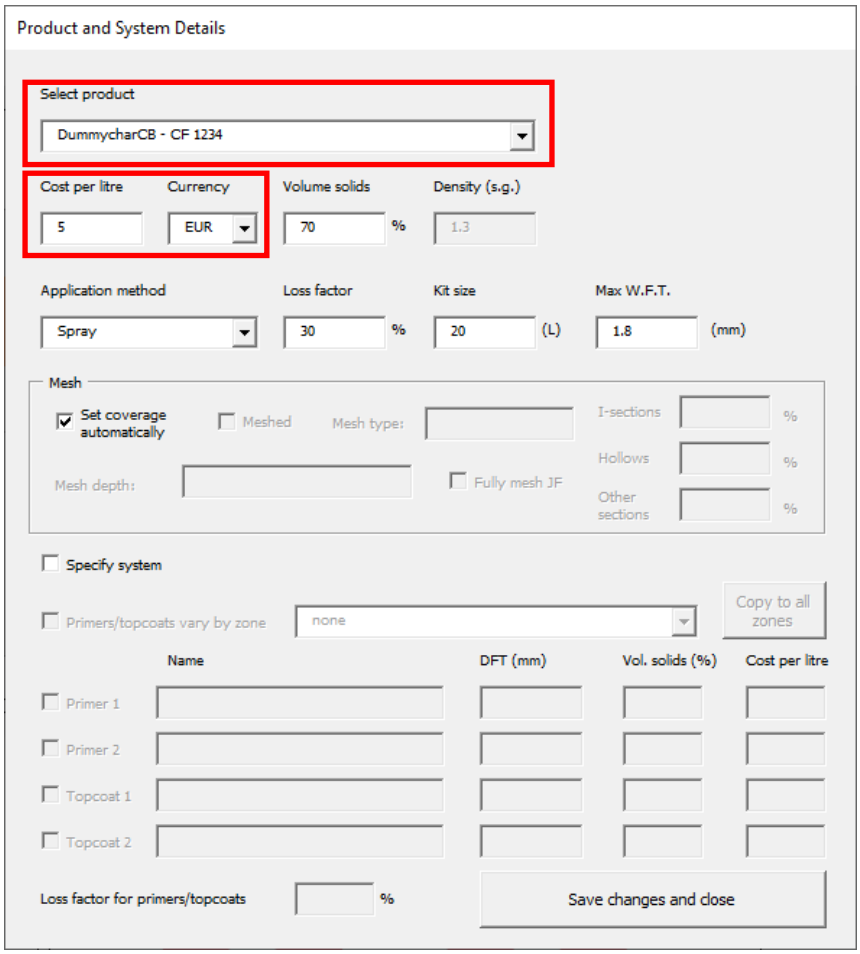



*Figure 122: Product-specific cost inputs on the Product and System Details dialogue box*

## 22.4 Optimising a section

When all costs inputs have been entered, the software prompts the user to identify which section ID from the MTO Builder screen is to be used as the parent section, see Figure 123

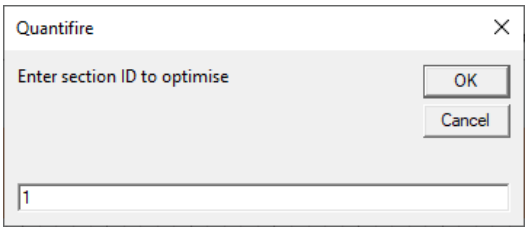



*Figure 123: Enter the section ID to optimise*

The Optimiser screen then opens, and the parent section and its associated properties are shown, as depicted in Figure 124. In the example in the figure, the parent section is an SHS 100x100x3.6.

Note that the critical temperature ($T_{crit}$) is shown as 223°C following an advanced calculation assessment and as a result, no thickness can be evaluated as this value is too low for the certified limits of the product (<Tcrit).

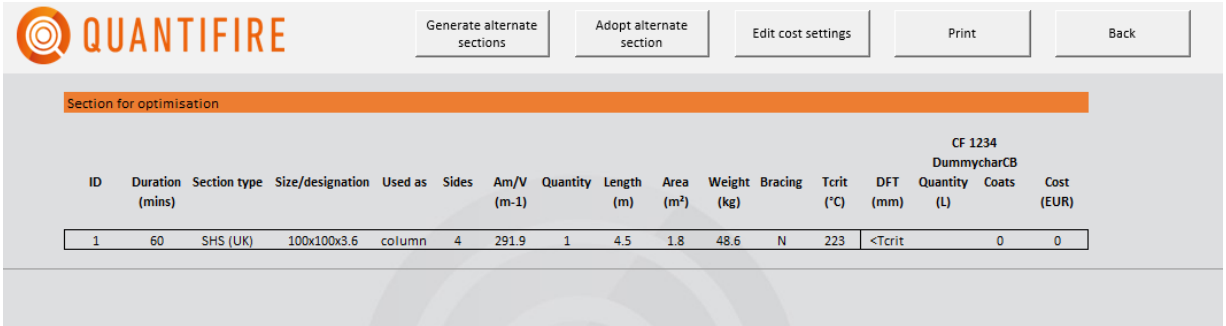



*Figure 124: Optimiser display screen and associated control buttons*

## 22.5 Defining alternate sections for consideration

Alternate sections can now be generated using the 'Generate alternate sections' button. The user is prompted as to whether this should be done automatically or manually, as shown in Figure 125.

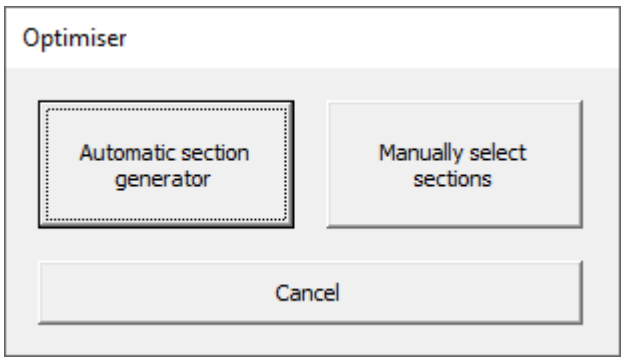



*Figure 125: Choose whether to let Quantifire determine the alternate sections or whether to select them manually*

## 22.6 Manually selecting alternative sections

This method allows the user to directly pick appropriate sections for consideration. In the example in Figure 126, the user has selected the range of serial sizes associated with an SHS 100x100, i.e., the range of wall thicknesses associated with that size. The '>>' button copies the relevant sections into the selected section list. The user can the choose to analyse all listed sections or highlight a select few and analyse those only.

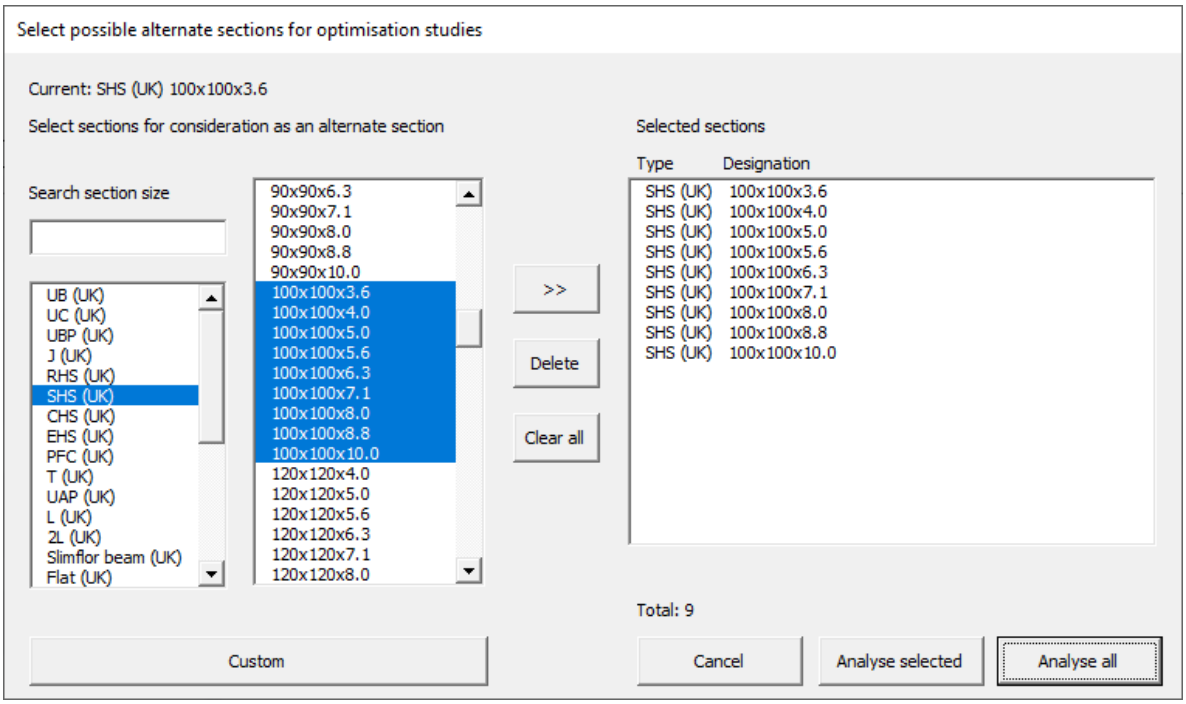



*Figure 126: Manual selection of alternate sections for consideration*

## 22.7 Automatically selecting alternative sections

Quantifire has built-in algorithms to determine potentially appropriate sections for consideration. These are compatible with I-sections, RHS, SHS, CHS and cellular beams only.

The user has significant control over the basis by which sections are generated, as depicted in Figure 127. In the example in the figure, the following settings have been applied (set by default based on the parent section): -

1. Serial sections only
2. RHS/SHS shapes
3. Overall depth and overall width dimensions fixed

Clicking on ‘Generate sections’ produces the list of proposed alternate sections for consideration. Only sections with an overall surface area equal to or greater than the parent section are generated.

Where the overall dimensions are permitted to change, the user can specify the deviation as a percentage from the parent section and the number of intervals to consider.

Where fabricated sections are to be generated, the user has control over permitted dimension deviations for flange thicknesses, web thicknesses and wall thicknesses.

For cellular beams, the user has control over whether the section is fabricated from two serial sections and/or from plate sections. They can also control the opening shapes and their positioning/spacing.

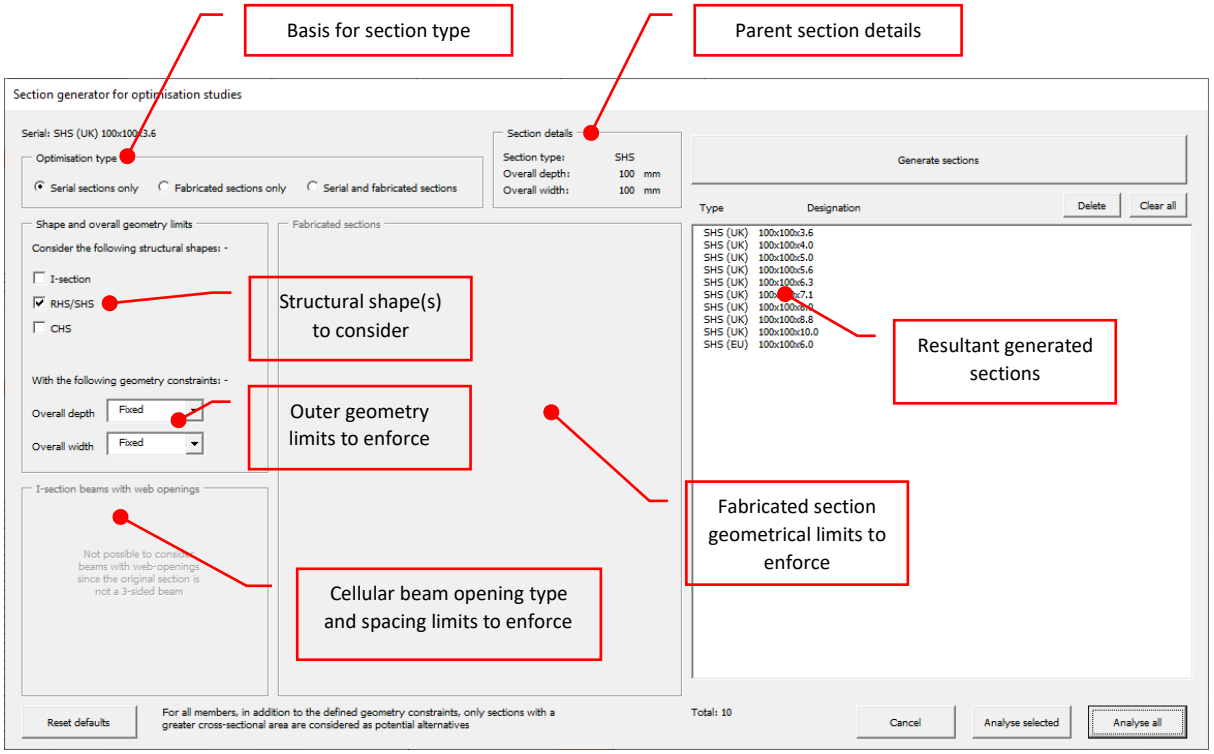



*Figure 127: Automatic selection of alternate sections for consideration*

## 22.8 Assessing the Proposed Alternate Sections

Once the sections for consideration have been defined, the user must select the assessment type, as shown in Figure 128. The assessment types are:

- **Retain temperature**: available in all assessments, unless the section is a cellular beam and has been assessed using an advanced method which maps product specific temperatures onto the member.
- **Advanced calculation**: available only when the parent section is based on an advanced calculation assessment from within Quantifire ($T_{crit}$ assessment)

The advanced calculation method takes the load used for the parent section and applies it to all other sections for consideration. This can be advantageous since benefit is not only gained from different section factors, but also from additional capacity of the sections which can result in higher critical temperatures.

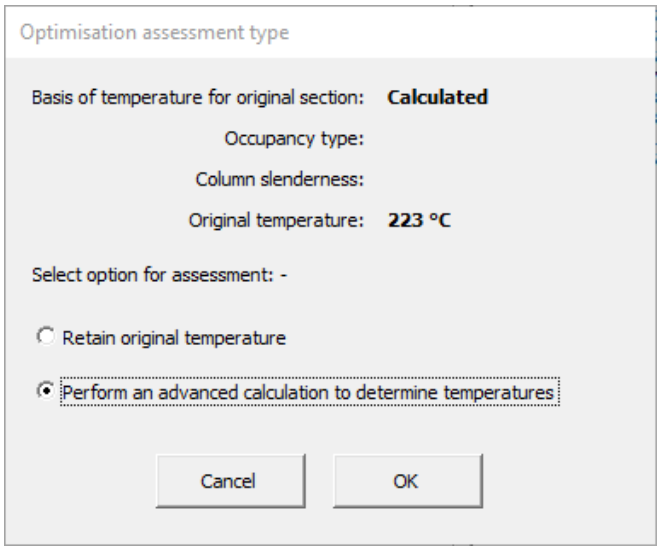



*Figure 128: Optimisation assessment type, i.e., to retain the original section ID's critical temperature to calculate it directly for each alternative section*

## 22.9 Optimiser Output

Figure 129 shows an example output following an optimisation assessment which uses an advanced calculation approach. A series of plots are presented with respect to weight (mass) of the respective sections. The red markers on the plots indicate the parent section.

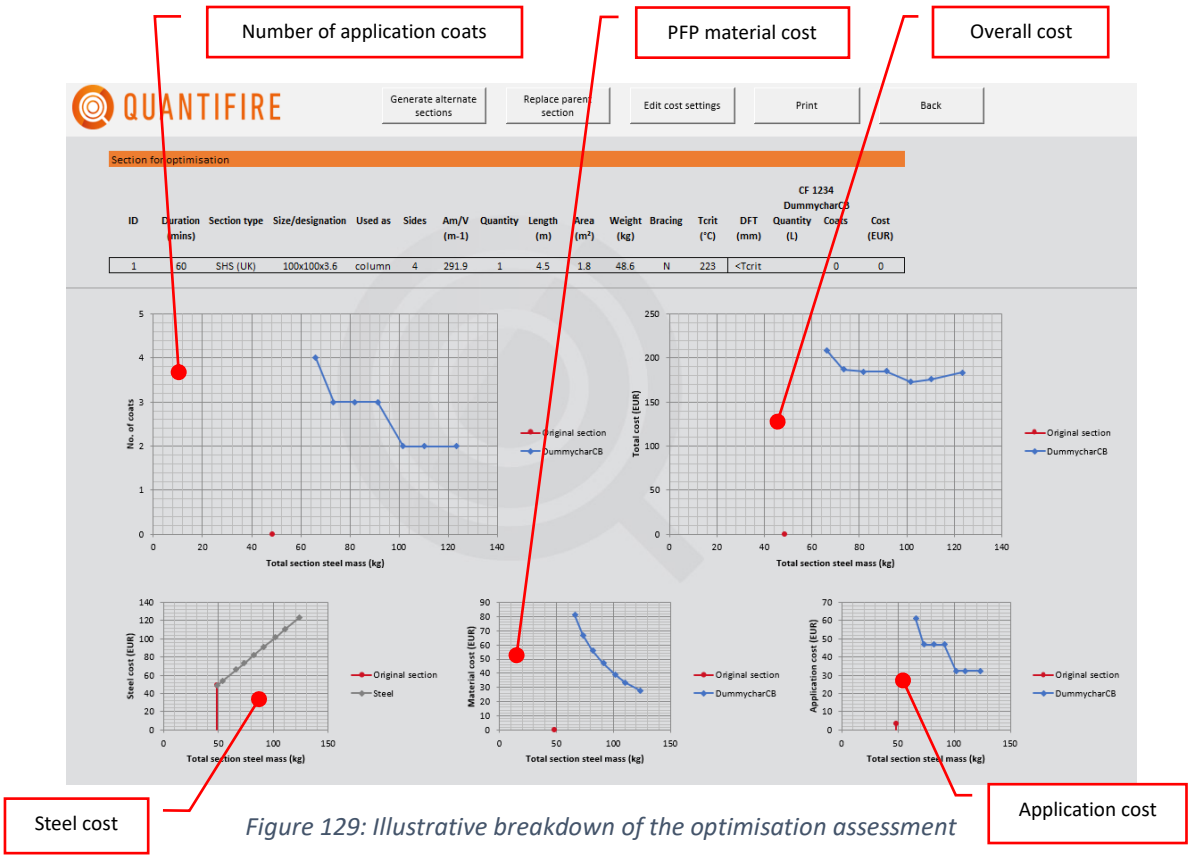
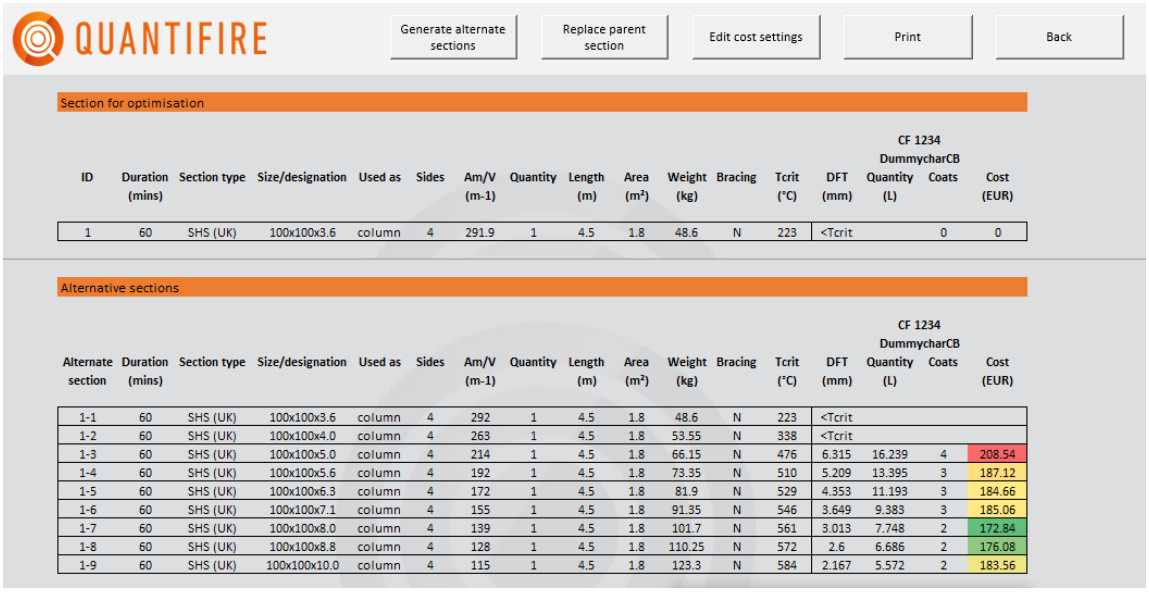



*Figure 129: Illustrative breakdown of the optimisation assessment*

Underneath the plots is detail relating to each potential alternate section. This is shown as an example in Figure 130. It is evident from the plots and the detailed output that, alternate section number 7, i.e., an SHS 100x100x8.0 can be protected and has the lowest overall cost of all sections considered.




Section for optimisation

| ID | Duration (mins) | Section type | Size/designation | Used as | Sides | Am/V (m-1) | Quantity | Length (m) | Area (m²) | Weight (kg) | Bracing | Tcrit (°C) | DFT (mm) | CF 1234 DummycharCB Quantity (L) | Coats | Cost (EUR) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 60 | SHS (UK) | 100x100x3.6 | column | 4 | 291.9 | 1 | 4.5 | 1.8 | 48.6 | N | 223 | <Tcrit | | 0 | 0 |

Alternative sections

| Alternate section | Duration (mins) | Section type | Size/designation | Used as | Sides | Am/V (m-1) | Quantity | Length (m) | Area (m²) | Weight (kg) | Bracing | Tcrit (°C) | DFT (mm) | CF 1234 DummycharCB Quantity (L) | Coats | Cost (EUR) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-1 | 60 | SHS (UK) | 100x100x3.6 | column | 4 | 292 | 1 | 4.5 | 1.8 | 48.6 | N | 223 | <Tcrit | | | |
| 1-2 | 60 | SHS (UK) | 100x100x4.0 | column | 4 | 263 | 1 | 4.5 | 1.8 | 53.55 | N | 338 | <Tcrit | | | |
| 1-3 | 60 | SHS (UK) | 100x100x5.0 | column | 4 | 214 | 1 | 4.5 | 1.8 | 66.15 | N | 476 | 6.315 | 16.239 | 4 | 208.54 |
| 1-4 | 60 | SHS (UK) | 100x100x5.6 | column | 4 | 192 | 1 | 4.5 | 1.8 | 73.35 | N | 510 | 5.209 | 13.395 | 3 | 187.12 |
| 1-5 | 60 | SHS (UK) | 100x100x6.3 | column | 4 | 172 | 1 | 4.5 | 1.8 | 81.9 | N | 529 | 4.353 | 11.193 | 3 | 184.66 |
| 1-6 | 60 | SHS (UK) | 100x100x7.1 | column | 4 | 155 | 1 | 4.5 | 1.8 | 91.35 | N | 546 | 3.649 | 9.383 | 3 | 185.06 |
| 1-7 | 60 | SHS (UK) | 100x100x8.0 | column | 4 | 139 | 1 | 4.5 | 1.8 | 101.7 | N | 561 | 3.013 | 7.748 | 2 | 172.84 |
| 1-8 | 60 | SHS (UK) | 100x100x8.8 | column | 4 | 128 | 1 | 4.5 | 1.8 | 110.25 | N | 572 | 2.6 | 6.686 | 2 | 176.08 |
| 1-9 | 60 | SHS (UK) | 100x100x10.0 | column | 4 | 115 | 1 | 4.5 | 1.8 | 123.3 | N | 584 | 2.167 | 5.572 | 2 | 183.56 |

*Figure 130: Detail associated with breakdown of each alternate section considered*

## 22.10 Replacing a Parent Section in the Take-Off

To substitute a parent section, click on 'Replace parent section' at the top of the Optimiser screen. The user can then select which alternate section is to be brought back into the main take-off. When this is done, the original parent section is displayed in the comments for informative purposes, see Figure 131. This can be edited or deleted if required, using the edit function (pen icon) on the MTO Builder screen.

| Comment | ID | Duration | Section type | Size/designation | Used as | Sides | $A_m/V$ ($m^{-1}$) | Quantity | Length (m) | Area (sum) ($m^2$) | Bracing | Tcrit (°C) | CF 1234 DummycharCB DFT (mm) | CF 1234 DummycharCB Volume (L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Modified from SHS (UK) 100x100x3.6 | 1 | 60 | SHS (UK) | 100x100x8.0 | column | 4 | 139 | 1 | 4.5 | 1.8 | N | 561 | 3.013 | 7.75 |

*Figure 131: MTO Builder screen after adopting an alternate section – note the 'Comments' column now displays a message to indicate that it has been modified*

## 23 PRODUCT COMPARISON REPORT AND CERTIFICATION REPORT

Users can view a side-by-side comparison of the physical properties of the products loaded by clicking 'View product comparison report', found in the main menu, see Figure 132. Under each product a button allows the user to see a list of each individual assessment table held in the Quantifire database(s).

Different shapes (e.g., I-section, CHS) and use (e.g., beam, column) will be shown on separate lines. The duration, Tcrit and section factor scopes are given. If a product has meshing requirements or is a hydrocarbon product additional fields will be visible.

The certification report button allows users to view the scope of product DFT data for each product loaded, and to recreate full DFT tables.

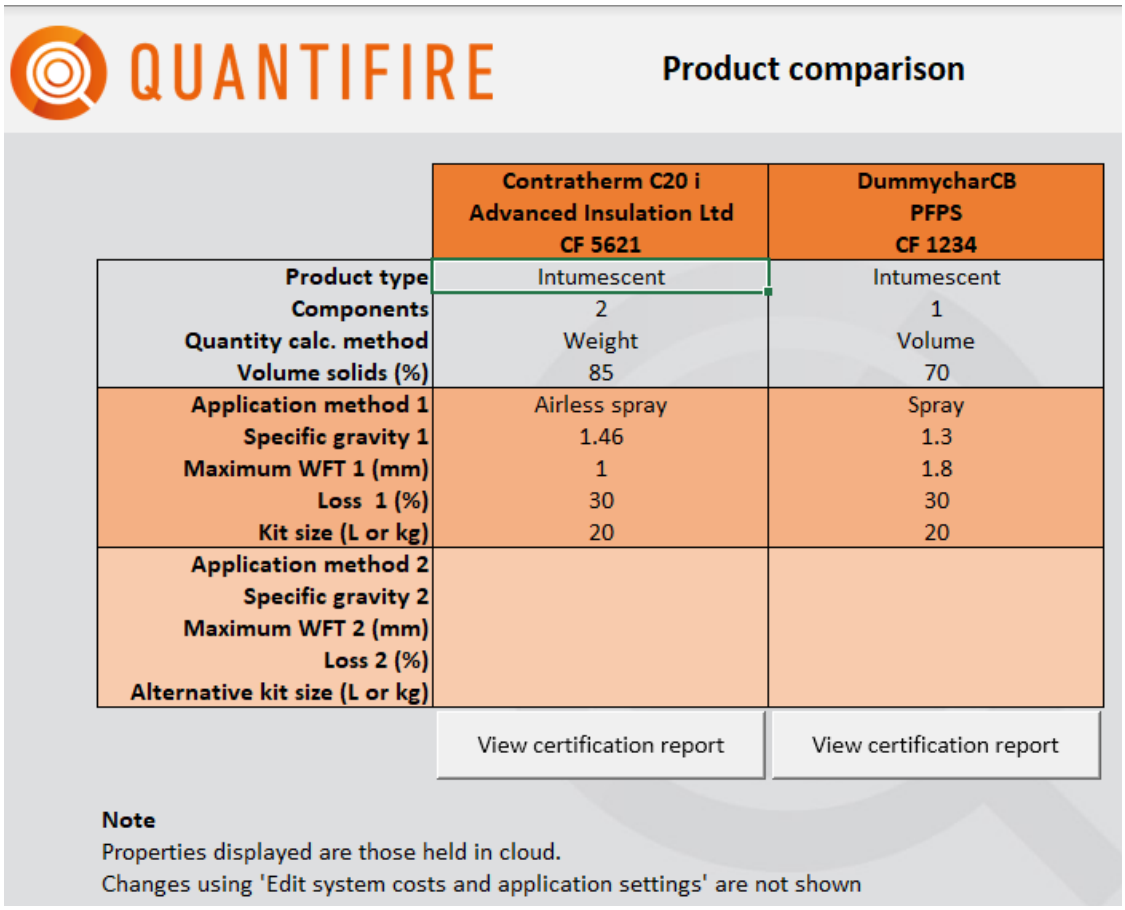



*Figure 132: Product comparison report and accessing the certification report*

# 24 HYDROCARBON SPECIFIC FEATURES

## 24.1 Hydrocarbon mode

Version 1.7.0.0 introduced a hydrocarbon mode. This grouped hydrocarbon-product options, introduced new methods of calculating the protected area and section factor of beams, and made the enabling (and disabling) of these options explicit through the mode setting on the main menu. Previous versions would automatically turn on the hydrocarbon-specific options when loading products with hydrocarbon certification, From v1.7.0.0 onwards the user is prompted to enabled HC mode when a product with hydrocarbon certification is loaded, or the user can turn the mode on manually via the *Hydrocarbon Mode Options* menu, accessed by a button on the main menu, see Figure 133.

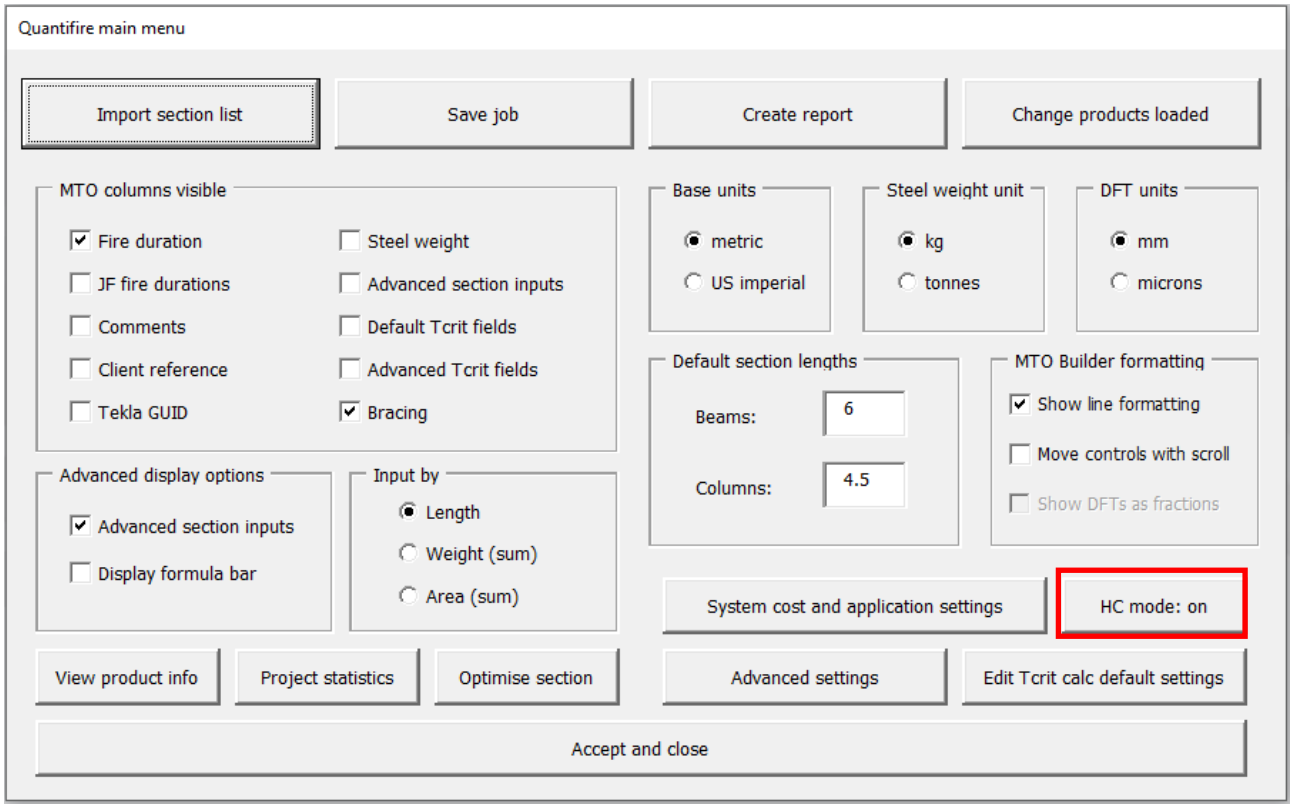



*Figure 133: HC mode button*

The *Hydrocarbon Mode Options* menu allows the mode to be turned on or off. Enabling the hydrocarbon mode has the following effects:

1. The MTO builder interface will display the jet fire duration entry boxes
2. Bracing, concrete-filled and composite options will automatically be turned off
3. Hydrocarbon DFT calculation options are enabled (jet fire erosion factor with minimum and maximum DFT limits applied)
4. UL single thickness mode becomes available.
5. Beam default sides and three-sided beam calculation options become available

6. Report display modifications become available

It should be noted that the options apply across the entire job. Therefore it is not possible to enter a mix of options (for example it is not possible for some sections to 3 sided composite beams with the ASFP void handling method and further sections as top flange-exposed).

Figure 134 shows the hydrocarbon options menu. Further information on the options shown is given below.

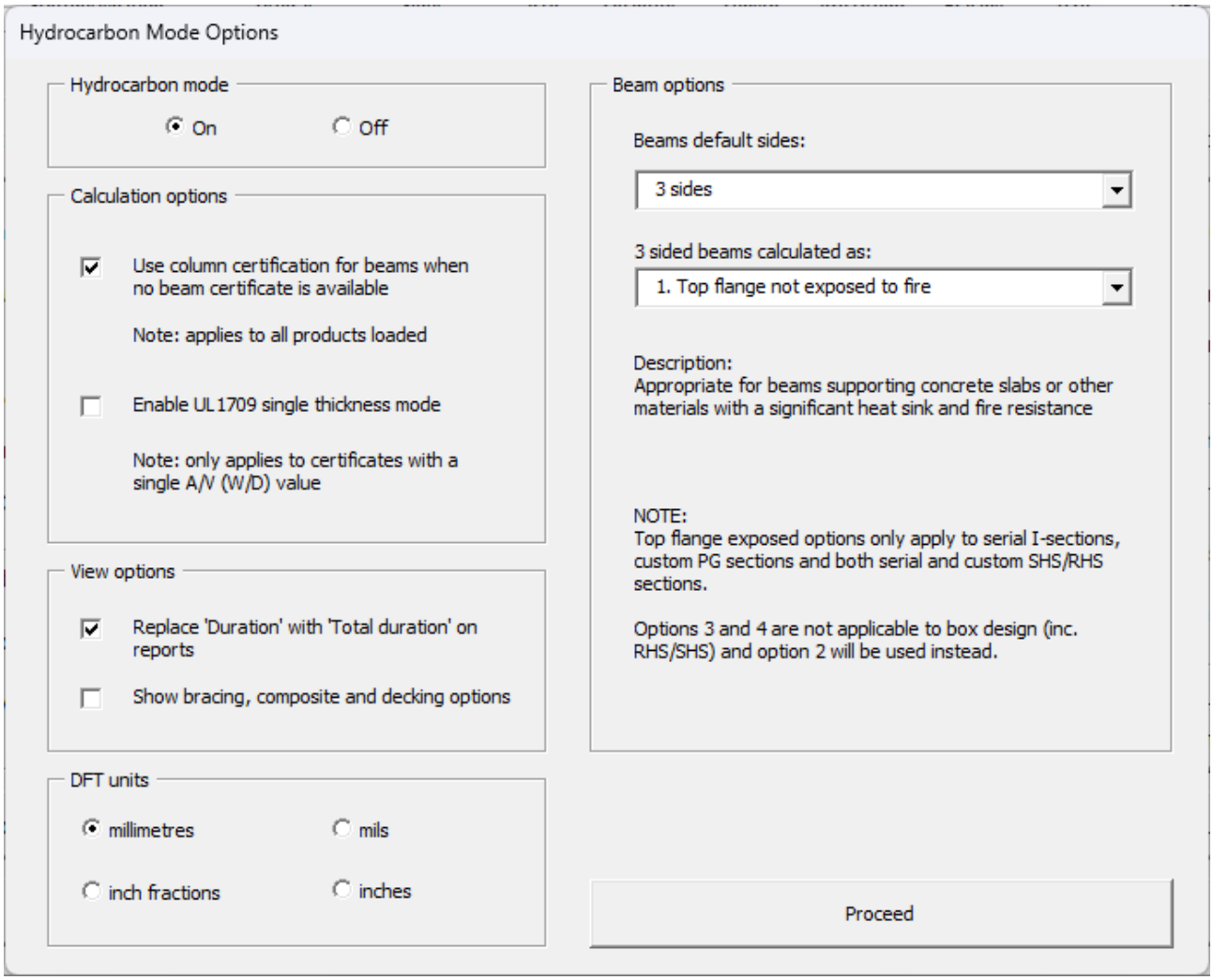



*Figure 134: Hydrocarbon mode options menu*

Calculation options

- Use column certification for beams
  This has the same function as the option available in the advanced settings, see section 19, and therefore applies regardless of whether the HC mode is on or off. It is provided here as the setting is commonly used with HC products

- Enable UL1709 single thickness mode
  See section 24.3 for explanation of this option

View options

- Replace Duration with Total duration on reports
  This option is provided for improved clarity when handling combination fire scenarios

- Show bracing, composite and decking options
  The check boxes for these options are hidden by default when the HC mode is selected as they are not applicable to four-sided beams or beams supporting deck plates that are common in HC design

DFT units

- A unit selection option is provided here for convenience. This has the same function as the units option on the main menu, see Figure 65.

Beam options

- Beam default sides
  Allows the user to override the automatic selection of 3 sides whenever a beam is selected in the list of serial section or when a beam is imported from the import canvas. Four sides can be selected as an alternative.

- 3 sided beams calculated as
  Allows the user to change the surface area and section factor calculation method for three sided beams. Note this method will only apply to I shape (or PG), RHS and SHS sections, and only applies when the HC mode is turned on and when the section is entered as a 3 sided beam. See section 24.5 for further detail.

## 24.2 Method of DFT calculation

When one or more products are loaded with hydrocarbon certification (e.g., UL 1709 or BS 476-20 Appendix D), then the jet fire (JF) and high heat flux (HHF) duration boxes will be shown on the MTO Builder page. When jet fire durations are greater than zero the DFT calculation routine will undertake the following steps:

1) Calculate the DFT from the hydrocarbon pool fire certificate
2) Calculate the JF erosion thickness from the jet fire certificate
3) Calculate the HHF erosion thickness from the HHF certificate
4) Sum the three above values to give a total thickness

5) Check the total thickness against the certified minimum and maximum thicknesses. Increase the DFT to the minimum if below or return an error message if the DFT is greater than the maximum certified.

The minimum and maximum DFT checks are not performed for non-hydrocarbon products as the certification inherently includes the limitations.

In version 1.3.2.0 a new type of jet fire certificate was introduced that provided an erosion thickness as a function of total hydrocarbon fire duration, in addition to being a function of Tcrit and jet fire duration. The user experience will not differ depending on the type of certificate.

## 24.3 Total fire duration calculation

It is important to note that if you are given a fire scenario split into parts (e.g., 15 minutes jet fire followed by 15 minutes pool fire) then the total duration (i.e., 30 minutes in this case) must be calculated and entered accordingly.

For divisions, the total fire duration is inherent in the H-rating selected. No adjustment of the H-rating should be made due to the presence of any jet fire.

## 24.4 UL 1709 single thickness approach

The historical approach to using UL 1709 certification was to test a W10x49 column and to apply the thickness derived for a given period of fire resistance to all sections, regardless of section factor. This approach is changing over time, due in part to evolution of the UL 1709 standard and in part to increasing understanding in industry of how the section factor concept reflects rate of heating, however it is still common in some areas.

To allow Quantifire users to meet the expectations of clients requesting a single-thickness approach, the advanced settings (accessed via the main menu by clicking on the Quantifire logo) have an option that can be clicked to give a thickness regardless of the section factor of the section entered, see Figure 135.

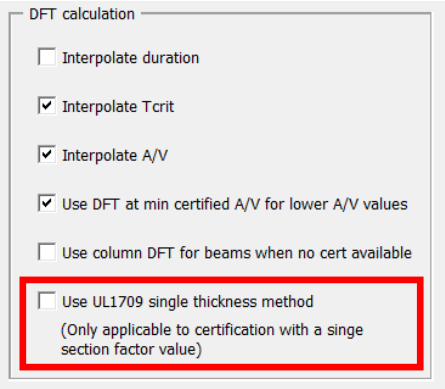



*Figure 135: Advanced settings showing UL1709 single thickness method option*

Please note this methodology is only applicable to certificates with a single thickness, products with multi-section factor values will be unaffected by this option. Note that the use of this approach is not endorsed in any way by PFP Specialists.

## 24.5 Three-sided beam calculation options for hydrocarbon

Four different options are available for the calculation of surface area and section factor of beams:

1. **Top flange not exposed to fire**
   This can be considered the 'standard' 3-sided approach for cellulosic fires, whereby the top flange is in contact with concrete or other material that is insulative and has fire resistance equivalent to, or better than, the protected section. This option would be suitable for a protected deck plate.
   *Protected area:* 3-sides
   *Section factor:* 3-sided exposure with a concrete slab on top
   *Applicable to:* all section types, box and profile design.

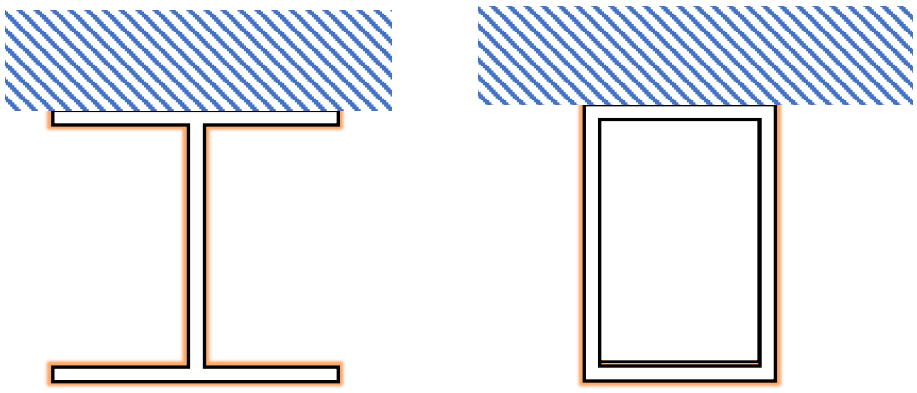


*Figure 136: Beam calculation method 1 - as per described in section 16.2*

2. **Top of top flange exposed but unprotected**
   This represents a typical hydrocarbon scenario where the top of the top flange is left unprotected, as discussed in API 2218 as an option.
   *Protected area:* as per 3-sided exposure
   *Section factor:* as per 4-sided exposure
   *Applicable to:* I-sections, RHS sections, SHS sections. These can be serial or custom, box and profile design.

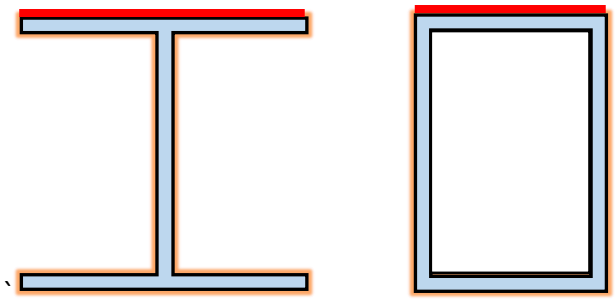


*Figure 137: Beam calculation method 2 – red line exposed to fire and excluded from protected surface area, section factor based on 4 sided exposure of shape shaded blue*

3. **Top and sides of top flange exposed but unprotected**
   As option two, but with the sides of the top flange unprotected, representing termination on the underside of the bottom flange as is common for intumescents.
   *Protected area:* as per 3-sided exposure less the sides of the top flange
   *Section factor:* as per 4-sided exposure
   Applicable to: I-sections with profile design only. These can be serial or custom.
   NOTE: RHS, SHS and I-section box designs will revert to option 2

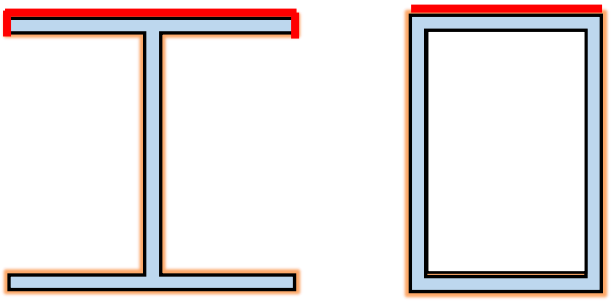


*Figure 138: Beam calculation method 3 – red line exposed to fire and excluded from protected surface area, section factor based on 4 sided exposure of shape shaded blue*

4. **Top flange exposed and entirely ignored**
   This option ignores the top flange for the purposes of both surface area and section factor calculation, thereby giving a more conservative DFT. The section is essentially treated as an inverted tee, ignoring any root radius at the web/top flange interface.
   *Protected area:* as per tee (web and bottom flange only)
   *Section factor:* as per the 4-sided section factor of the bottom tee
   *Applicable to:* I-sections with profile design only. These can be serial or custom.
   NOTE: RHS, SHS and I-section box designs will revert to option 2.

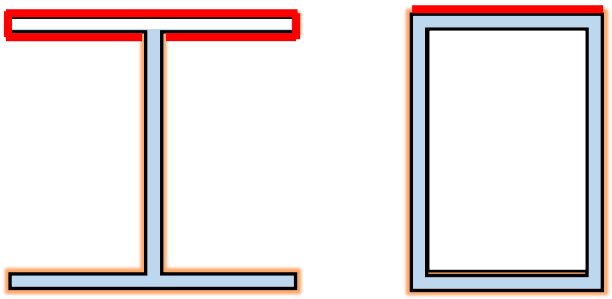


*Figure 139: Beam calculation method 4 – red line exposed to fire and excluded from protected surface area, section factor based on 4 sided exposure of shape shaded blue*

Further notes on three-sided beam calculation methods

- When any method other than *1. Top flange not exposed to fire* will not permit beams to be entered as composite. Changing the 3-sided beam method from method 1 to any other method will change any composite beams to be non-composite. This change cannot be undone.
- When any method other than *1. Top flange not exposed to fire* is used, the advanced $T_{crit}$ calculation will be disabled. Changing the 3-sided beam method from method 1 to any other method will change the temperature calculation setting of any sections entered as advanced $T_{crit}$ to be User-set. The given temperature will not change.
- Hydrocarbon product certification should not be used for cellular beams as the RT 1356 structural model and the web-post factors are, by definition, for cellulosic fire exposures. Users should be aware, however, that 3-sided beam modifications will not apply to cell beams.

## 24.6 Importing hydrocarbon sections from the canvas

The default number of sides for beams will be applied to beam sections when the HC mode is set to on and there is no specific number of sides given (i.e., when no sides column is set or when this column is set but no recognisable value is given).

The beam calculation methods 3 and 4 give a different protected area per linear metre of steel to the ‘standard’ 3-sided beam area calculations. These inputs therefore overrule given areas, even

when the option to “use canvas areas” is checked. Use of these beam calculation methods will result in calculation of a new, reduced, area after calculation of the total length of steel during import.

## 24.7 Divisions

Divisions must be added as custom sections. It is necessary to complete all fields before clicking ‘Quick insert’ or ‘OK’, see Figure 140.

The total area to be protected should be entered here. If a division is corrugated or includes stiffeners to be coated at the same thickness as the plate, these factors should be considered in the total area calculation.

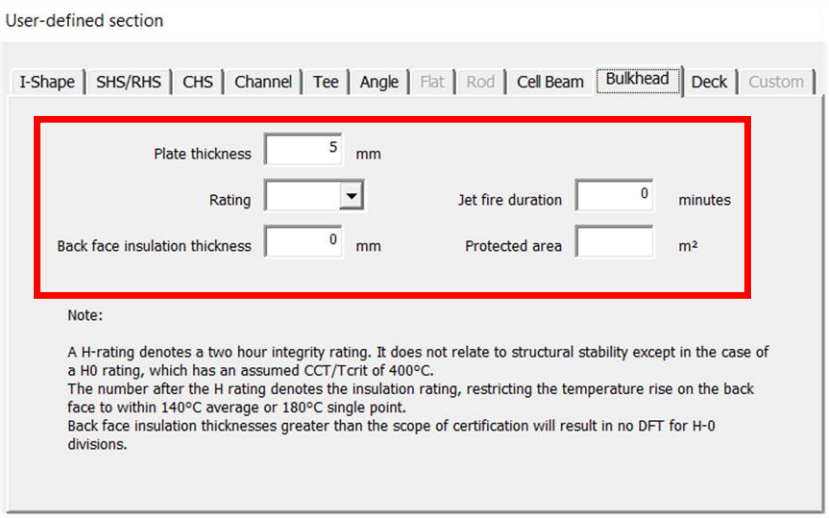



*Figure 140: Entering divisions as custom sections*

The logic behind calculating a DFT is shown in the flow chart in Figure *141*. Note that after calculating a DFT the jet fire thickness is calculated and the maximum/minimum DFT checks are performed as described in Section 24.1.

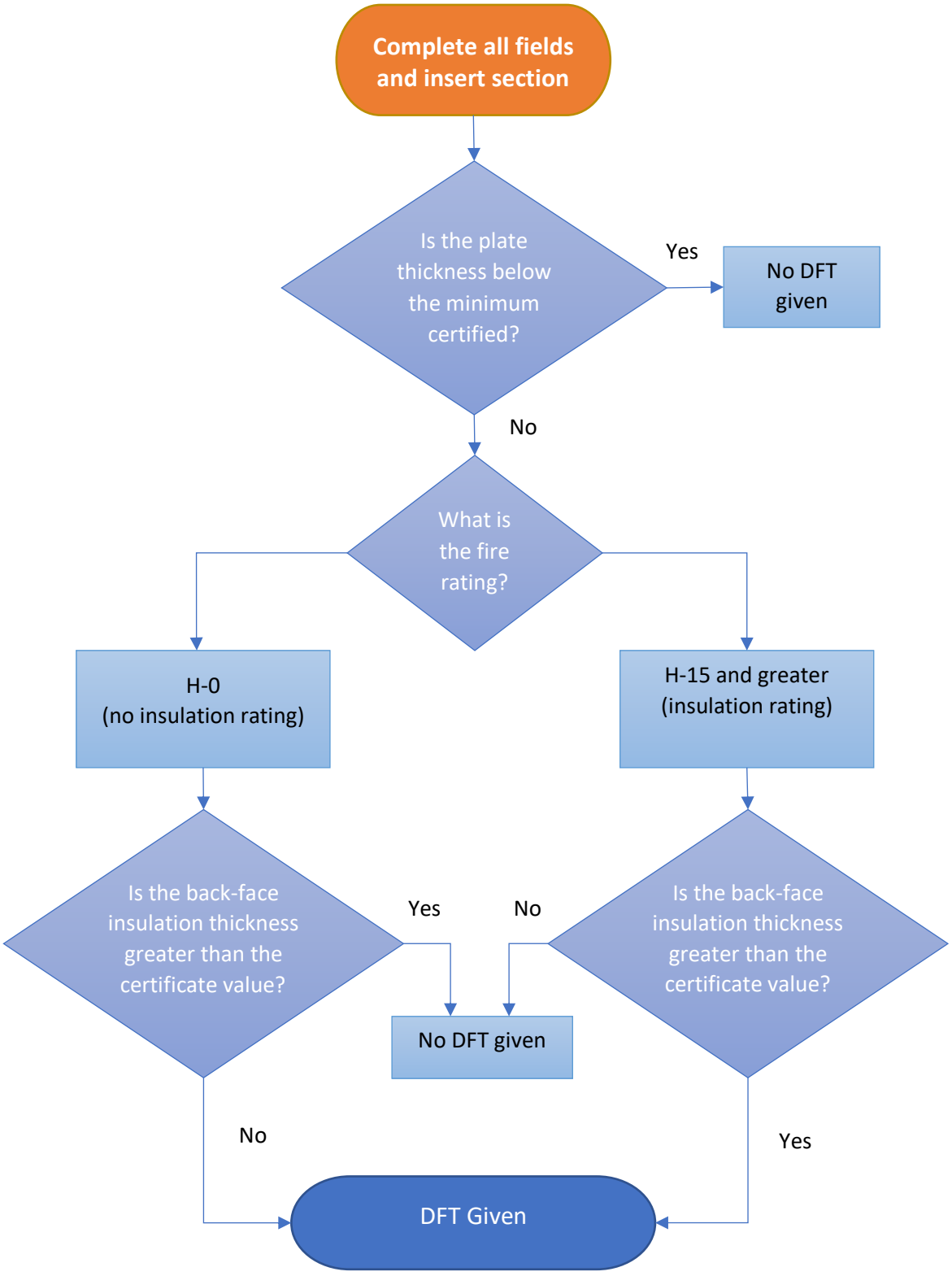



*Figure 141: Flowchart to arrive at a DFT for a division*

# 25 REFERENCES

[1] BS 476-20:1987 Fire tests on building materials and structures. Method for determination of the fire resistance of elements of construction (general principles).

[2] BS 476-21:1987 Fire tests on building materials and structures. Method for determination of the fire resistance of load-bearing elements of construction.

[3] EN 1363-1:2012 Fire resistance tests. General requirements.

[4] EN 13381-8:2013 Test method for determining the contribution to the fire resistance of structural members. Applied reactive protection to steel members.

[5] EN 13381-6:2012 Test method for determining the contribution to the fire resistance of structural members. Applied protection to concrete filled hollow steel columns.

[6] EN 13381-9:2015 Test methods for determining the contribution to the fire resistance of structural members. Applied fire protection systems to steel beams with web openings.

[7] prEN 13381-10 Test methods for determining the contribution to the fire resistance of structural members. Applied fire protection to solid steel bar in tension.

[8] DIN 4102-2:1977 Fire behaviour of building materials and building components. Building components. Definitions. Requirements and tests.

[9] ASTM E119-19 Standard test methods for fire tests of building construction and materials. ASTM International, West Conshohocken, PA, 2019.

[10] UL 263 Edition 14, Standard for fire tests of building construction and materials, 2011.

[11] IS 834-10:2014 Fire resistance tests – Elements of building construction – Part 10: Specific requirements to determine the contribution of applied fire protection materials to structural steel elements.

[12] ISO 834-11:2014 Fire resistance tests – Elements of building construction – Part 11: Specific requirements for the assessment of fire protection to structural steel elements.

[13] Design Guide for SHS concrete filled columns, Corus Tubes, The Steel Construction Institute, 2002.

[14] BS 449-2:1969 Specification for the use of structural steel in building. Metric units. Withdrawn.

[15] BS 5950-8:2003 Structural use of steelwork in building. Code of practice for fire resistant design. Withdrawn.

[16] EN 1990:2002 Basis of structural design

[17] EN 1991-1-2:2002 Eurocode 1. Actions on structures. General actions. Actions on structures exposed to fire.

[18] EN 1993-1-2:2005 Eurocode 3. Design of steel structures. General rules. Structural fire design.

[19] EN 1994-1-2:2005+A1:2004 Eurocode 4. Design of composite steel and concrete structures. General rules. Structural fire design.

[20] NA to BS EN 1993-1-2:2005 UK National Annex to Eurocode 3. Design of steel structures. General rules. Structural fire design.

[21] NA to BS EN 1994-1-2:2005 UK National Annex to Eurocode 4. Design of composite steel and concrete structures. General rules. Structural fire design.

[22] BS 7974:2019 Application of fire safety engineering principles to the design of buildings. Code of practice.

[23] PD 7974-3:2019 Application to fire safety engineering principles to the design of buildings. Structural response to fire and fire spread beyond the enclosure of origin (Sub-system 3).

[24] SCI P355 Design of composite beams with large web openings. The Steel Construction Institute. 2011.

[25] RT 1356 Fire design of composite beams with rectangular and circular web openings. The Steel Construction Institute. 2012.

[26] Fire protection for structural steel in buildings. 5th edition. Volume 1 of 2. (Yellow Book). The Association for Specialist Fire Protection. 2018.

[27] UL 1709, 5th Edition, February 24, 2017 - UL Standard for Safety Rapid Rise Fire Tests of Protection Materials for Structural Steel