STATIKO

Statiko user guide

Structural beam analysis and design to the Eurocodes

APP VERSION

0.9.5

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Struktura Software

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PART I

Getting started

CHAPTER 1

Installing and signing in

This chapter covers installing Statiko on Windows and getting past the sign-in screen to your projects. Statiko works offline with local project files: your projects and calculations never depend on an online service. In this version, development builds open with **Skip sign-in**, which needs no account and no internet connection.

Installing on Windows

Statiko for Windows comes as an MSI installer. Installers are published as releases of the public `statiko-releases` repository, and the download page on the website links there. Each release includes a `SHA256SUMS.txt` file, so you can check that the download is complete and unchanged.

1. Download the installer from the Statiko website.
2. Run it. The installer lets you choose the installation folder. Statiko is installed for every user of the computer.
3. When setup finishes, start Statiko from the **Statiko** group in the Start menu or from the desktop shortcut.

The installer also registers project files. Files ending in `.statiko` appear in Explorer as **Statiko project** with their own icon, and double-clicking one starts Statiko and opens that project.

Builds outside Production show their environment in the window title, for example **Statiko (Staging)**. A Production build shows just **Statiko**.

Source: spec/beam/workspace-shell.md rules 29 and 40.

Starting Statiko

On Windows, a small dark window with the Statiko mark, its name and version shows the moment you start it and closes when the first Statiko window opens. Then Statiko shows **Opening workspace…** while it prepares its workspace folder on your computer. If the folder cannot be created or read, Statiko shows **Statiko could not start** with one of these reasons:

- **The Statiko workspace folder could not be created or read.**
- **Statiko is not allowed to use its workspace folder.**

Fix the folder permissions, then choose **Try again**.

Next, Statiko decides where to go. If a saved session can be restored, it opens your projects straight away. If it cannot restore one, it shows the sign-in screen. Without a saved session, it opens your projects when this build already lets you create them, and shows the sign-in screen otherwise.

Only one Statiko runs per environment. If you open a project file while Statiko is already running, the file is handed to the running window, which comes to the front and opens it. A project file opened before you have signed in waits and opens once you reach your projects.

Source: spec/beam/workspace-shell.md rules 41 and 42.

The sign-in screen

In a wide window, the sign-in screen has a brand panel on the left with what Statiko does: analysis and Eurocode design of beams and columns, steel, timber and concrete members, Eurocode checks with National Annex values, and offline work with local project files. The sign-in form is on the right. Narrower windows show the form alone. The form scrolls, and it moves up when the on-screen keyboard opens.

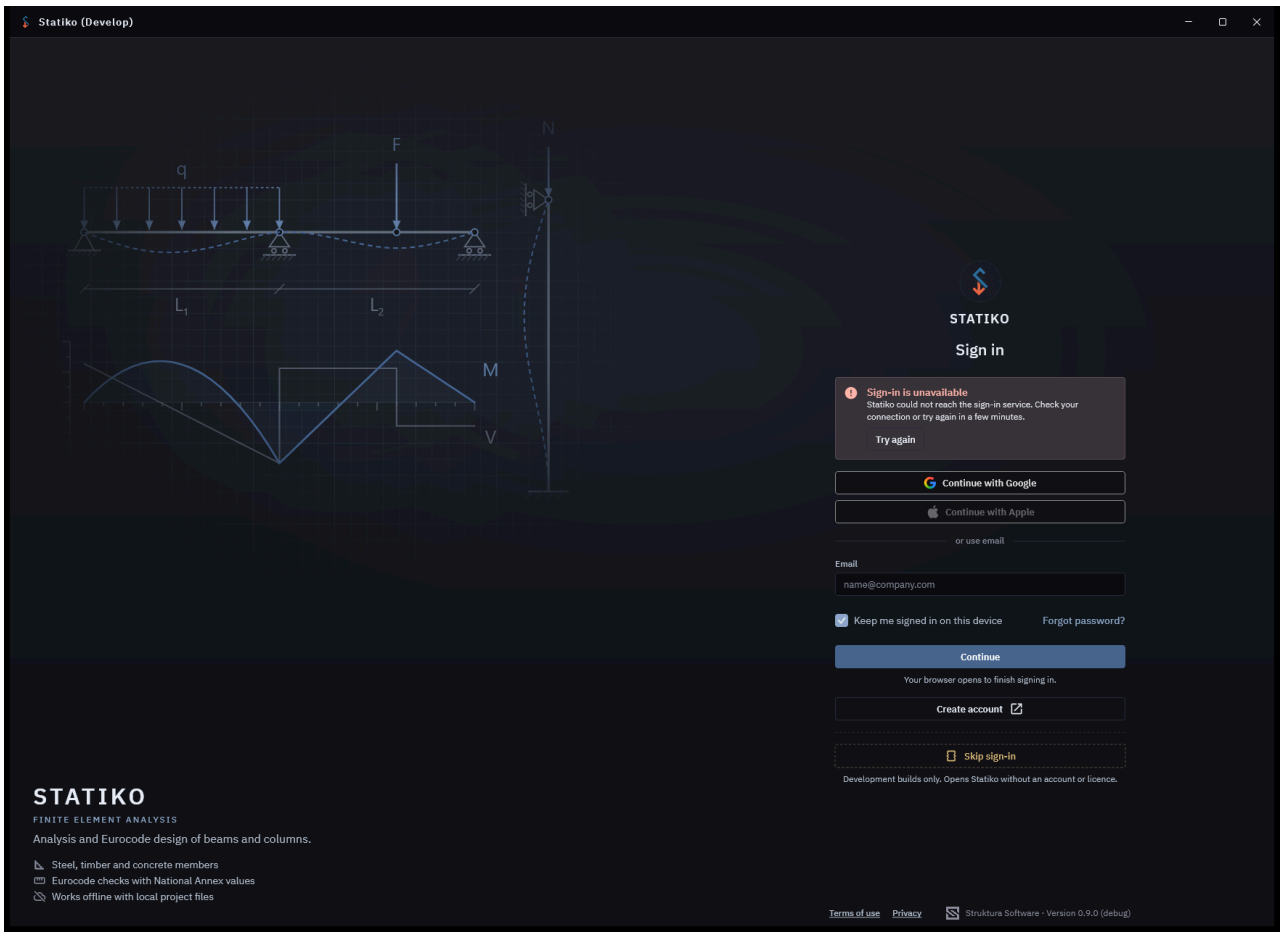


Figure 1.1 · The sign-in screen of a development build, showing the Sign-in is unavailable notice, the account options and Skip sign-in

From top to bottom, the form holds:

- the title **Sign in**, and below it a notice when there is something to tell you;
- **Continue with Google** and **Continue with Apple**;
- under **or use email**, the **Email** field (placeholder **name@company.com**);
- the **Keep me signed in on this device** checkbox, ticked by default, and the **Forgot password?** link;
- the **Continue** button with the note **Your browser opens to finish signing in.**;
- **Create account**, which opens the website;
- in development builds, **Skip sign-in** below a dashed line, with the note **Development builds only. Opens Statiko without an account or licence.** Other builds show the link **Open existing projects** in its place.

The footer has the **Terms of use** and **Privacy** links, the company name and the version, for example **Struktura Software · Version 0.9.5 (debug)**. Debug builds add **(debug)** to the version.

Continue with Apple is not available in this version. The button is always disabled and says **Coming soon**.

Skip sign-in: working offline

Skip sign-in is how you open Statiko in this version. It takes you straight to your projects in development access, with no account and no internet connection.

1. On the sign-in screen, choose **Skip sign-in**.
2. The hub opens on **Projects**. The navigation shows **Development access** where your account would be.

Development access grants no account and no paid licence. In the hub it reads **Not signed in. Development access grants no account or paid licence.**, and nothing is saved to an account. Your project files are ordinary files on your computer, so they are not affected.

Skip sign-in stays available when you are offline.

> To get back to the sign-in screen from the hub, open **Profile** and choose **Sign in**. This leaves development access. See Chapter 2.

Signing in with an account

Sign-in always finishes in your web browser, never inside Statiko. Type your email, or leave it empty, and choose **Continue** or **Continue with Google**. Pressing `Enter` in the email field does the same as **Continue**. Statiko opens your browser and shows **Continue in your browser** with a **Cancel** button, and the rest of the form is disabled until you finish or cancel. When the browser hands back, the button reads **Signing in…** until you are in.

These notices can appear above the form:

Notice	What it means	What you can do
Sign-in was cancelled	You chose Cancel or closed the browser page before finishing.	Try again when you are ready.
Verify your email	Your account email is not verified yet.	Open the link in the email, or choose **Resend email**.
You are offline	Signing in needs an internet connection. Google, Continue and Create account are disabled; **Forgot password?** does nothing while you are offline.	Connect and try again, or use Skip sign-in.
Sign-in is unavailable	Statiko could not reach the sign-in service, or this build has none.	Choose **Try again**.
Legal documentation is not available yet.	The Terms of use or Privacy page has no address in this build.	None.

Create account and **Forgot password?** open the matching pages in your browser. **Terms of use** and **Privacy** open the licence and privacy pages on the website.

Account sign-in is built, but the sign-in service is not offered to the public in this version, so you will usually see **Sign-in is unavailable**. Use **Skip sign-in**.

Licences in this version

Statiko never needs a service to open, calculate or save local projects. Builds without the development entry offer **Open existing projects**. It opens the hub for reading, where a notice explains: **A verified licence is required to create or edit projects. Existing files remain available for reading and recovery.**

The beta licence by invitation, the free trial, activated devices with their limits, offline licence periods and **Check licence again** are not available in this version.

CHAPTER 2

The hub

The hub is the first place you reach after signing in or choosing **Skip sign-in**. From here you start and open projects, set the language, theme and engineering units, read the legal documents and the About box, and check your account. It has four sections: **Projects**, **Settings & Units**, **Documentation & Legal** and **Profile**.

Moving around the hub

The navigation adapts to the size of the window. A wide window has a sidebar on the left. A medium-width window, or a window that is not very tall, has a narrow rail. A phone-width window has a bottom bar with short labels: **Projects**, **Settings** and **Legal**.

The navigation also shows who you are. In development access it reads **Development access** with **Not signed in** below it.

Projects

The **Projects** page is where your work starts. The **Open project…** button at the top right opens a `.statiko` file from your computer.

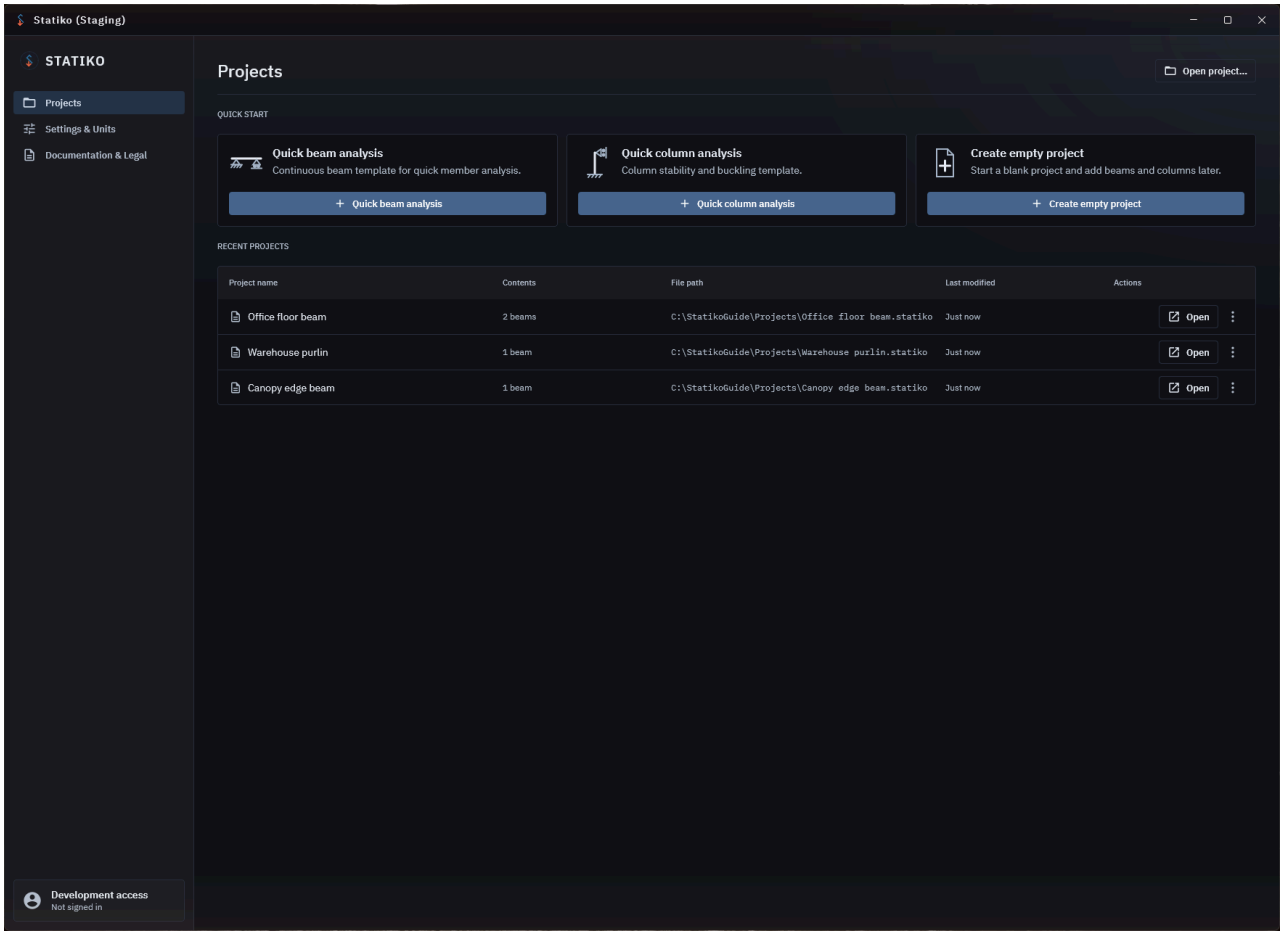


Figure 2.1 · The Projects page: the sidebar with its account block at the bottom, the three Quick start cards and the Recent projects table

Quick start

Three cards start a new project:

Card	What it does
Quick beam analysis	Continuous beam template for quick member analysis.
Quick column analysis	Column stability and buckling template.
Create empty project	"Start a blank project and add beams and columns later." You add them from the workspace (Chapter 3).

The cards are enabled only when this build lets you create projects. When it does not, a notice above them gives the reason, for example **No verified licence is available.**, followed by **A verified licence is required to create or edit projects. Existing files remain available for reading and recovery.** If column editing is not part of this build, choosing the column card shows **Column editing belongs to the next workspace milestone.**

Recent projects

Under **Recent projects** you find the last ten projects you saved or opened. A wide window shows them as a table with the columns **Project name**, **Contents** (for example "2 beams, 1 column"), **File path**, **Last modified** (for example "Just now", "3 hours ago" or "Yesterday") and **Actions**.

- **Open** opens the project.
- **Remove** takes it off the list. The file itself stays on your computer.
- When the file has moved, its path reads **File not found**. Choose **Locate…** to find it.

With no recent projects, the card reads **No recent projects**, **Projects you save or open appear here.** with an **Open project…** button. If the history itself cannot be read or saved, a notice says so, and your project files are not affected.

If a project cannot be opened, the page tells you why:

- **File not found. Locate it using Open project.**
- **The project file is inaccessible. Check file permissions.**
- **The project file is malformed. Its contents have been preserved.**
- **This project format or analysis is not supported by this workspace.**
- **The file operation failed. Existing project files are unchanged.**

Settings & Units

Settings take effect as soon as you change them. There is no Save button. After each change a short confirmation appears, such as "Theme changed." or "Metric (SI) preset applied." If a change cannot be stored on this device, the field shows **This change could not be stored on this device. Your previous settings are preserved. Reset to defaults** at the top restores the system theme, English and the recommended metric units.

General

- **Interface language**: **English** (the default), **Danish** or **Serbian**.
- **Theme**: **System** (the default), **Light** or **Dark**.

- On Windows, **AI agents (MCP)** lets AI assistants work with your Statiko projects. See Chapter 23.
- **Introductory guide**: **Show the tour at start** (ticked until you turn it off) and **Start the tour now**. See The introductory tour.

Units

The **Engineering units and precision** card sets, for each quantity, the **Input unit** you type in, the **Screen display** unit and the **PDF report** unit, with **Decimals** from 0 to 8 for display and report. It covers 17 quantities, from **Length** and **Force** to **Warping constant** and **Bending stiffness**. **Unit preset** applies **Metric (SI)** or **Imperial (US)** in one step.

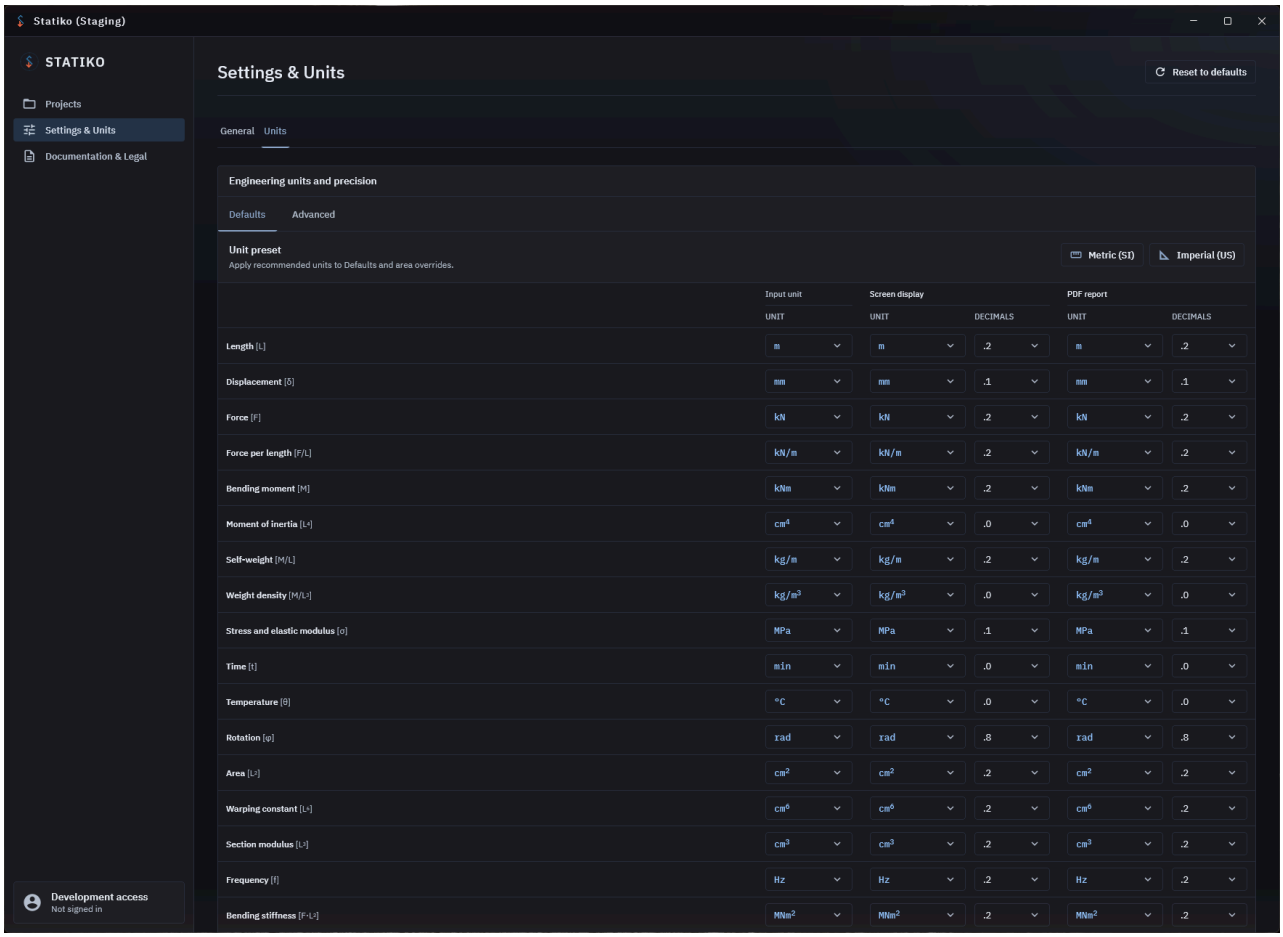


Figure 2.2 · Settings & Units, Units tab: the Metric (SI) and Imperial (US) presets above the table of input, screen and report units

The **Defaults** tab applies everywhere. The **Advanced** tab overrides units for one app area: **Cross-section / detailing**, **Supports**, **Loads** or **Results**. A field without an override shows **Global (…)**, and **Use global** clears the overrides of an area.

> Units change only how values are typed and shown, never a calculated value. The beam workspace uses your input and display units, but the PDF report still uses fixed SI units.

The introductory tour

At the first start the hub shows **Welcome to Statiko** over the **Projects** page. Choose a tour, **Steel**, **Timber**, **Glulam** or **Concrete**, and select **Take the tour**. **Not now** closes the dialog, and it does not show by itself again.

Each tour opens its sample beam as a new, unsaved project called **Statiko tour** · followed by the material. Your own files are not touched; if a project is open, the hub asks you to close it first, as **Open project…** does. The tour then walks through eight steps: design code, member, supports, loads, structural system, result graphs, checks and report. Each step lights up its part of the window, explains it in a sentence or two and links to the chapter of this guide that covers it. The results shown are Statiko's own calculation of the sample beam. While the tour runs, the beam cannot be edited.

Skip tour, the close button, `Esc`, Android Back and **Finish** on the last step end the tour and turn off **Show the tour at start**. The sample beam stays open for you to try; closing it after a change asks whether to save it, as with any new project. On a phone the tour's card is a sheet at the bottom of the screen, and the tour switches to the tab that holds each step.

To take the tour again, choose **Help** › **Introductory tour…** in a project (on a tablet it is in the ☰ menu's Help section), or **Start the tour now** in **Settings & Units** › **General**, which is the way on a phone.

While **Show the tour at start** is ticked, two hints appear once in a beam project: **Add your loads here** beside the Loads card while the beam has no load, and **Your PDF report** beside Report once a report can be made. **Got it** hides a hint for good; ticking the box again brings back any hint you have not dismissed. Hints do not show during the tour.

Documentation & Legal

This page opens with a reminder headed **Engineering responsibility**: results, diagrams and reports are engineering aids, and a qualified engineer must review and approve every design before construction or fabrication.

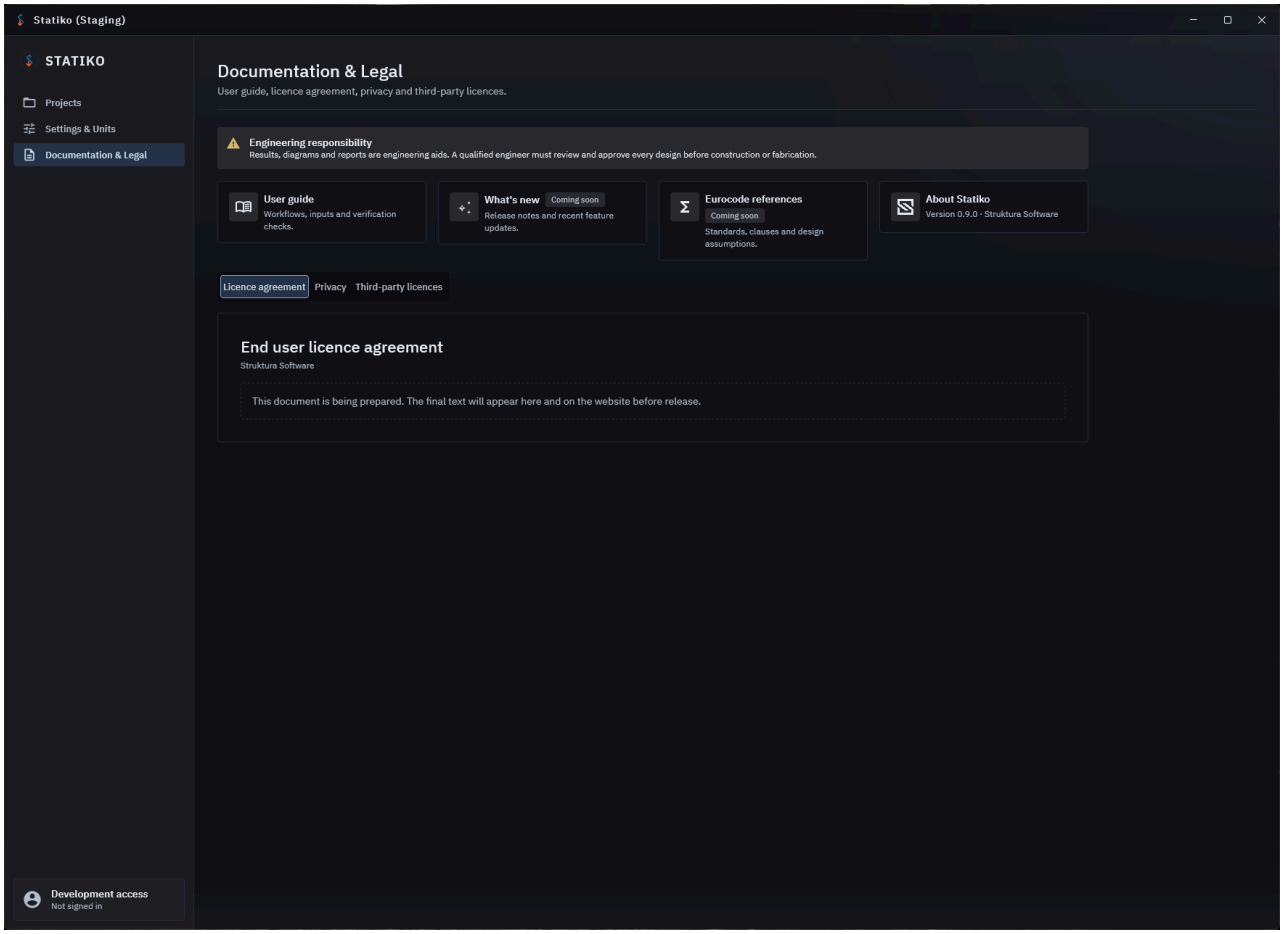


Figure 2.3 · Documentation & Legal: the engineering responsibility notice, the four tiles and the document tabs

Below it are four tiles. **About Statiko** shows the version and the company. **User guide** opens this guide. **What's new** and **Eurocode references** are tagged **Coming soon** and are not available in this version.

The tabs **Licence agreement**, **Privacy** and **Third-party licences** show the documents. The licence agreement and the privacy policy are still being prepared, and the page says that their final text will appear before release. **Third-party licences** lists the software bundled with Statiko; choose **View full third-party notices** to read all of it. When a document is also on the website, **Open on website** opens it in your browser.

About Statiko

The About box shows the version, the company (Struktura Software, strukturasoftware.com) and the licence (Proprietary, all rights reserved). Development builds also show the environment. On Windows, About and the third-party notices open in their own windows, which you can move. `Esc` or **Close** closes them. On phones and tablets they open as dialogs.

Profile

Profile shows your account, licence and activated devices. In development access it shows **Development access**, with the explanation that you are not signed in, that licensing is not checked in development builds and that nothing is saved to an account. **Sign in** returns you to the sign-in screen and ends development access.

When you are neither signed in nor in development access, the page shows **Not signed in** with **Sign in** and **Open projects**, and an **Account** card whose email, sign-in method, licence and offline-use rows are empty or **Unverified**.

Signed-in account management (managing your account, checking the licence again, activated devices and signing out) belongs to the beta licence, which is not available in this version.

CHAPTER 3

The beam workspace

The beam workspace is the window where you build and check a project. Its frame (title bar, menus, ribbon, analysis tabs and status bar) holds every command around the beam model. The regions inside it hold the inputs, the drawing, the result graphs and the checks, which later chapters describe. Statiko calculates by itself after every valid change, so there is no Calculate button: you edit, and the status bar tells you where the result stands.

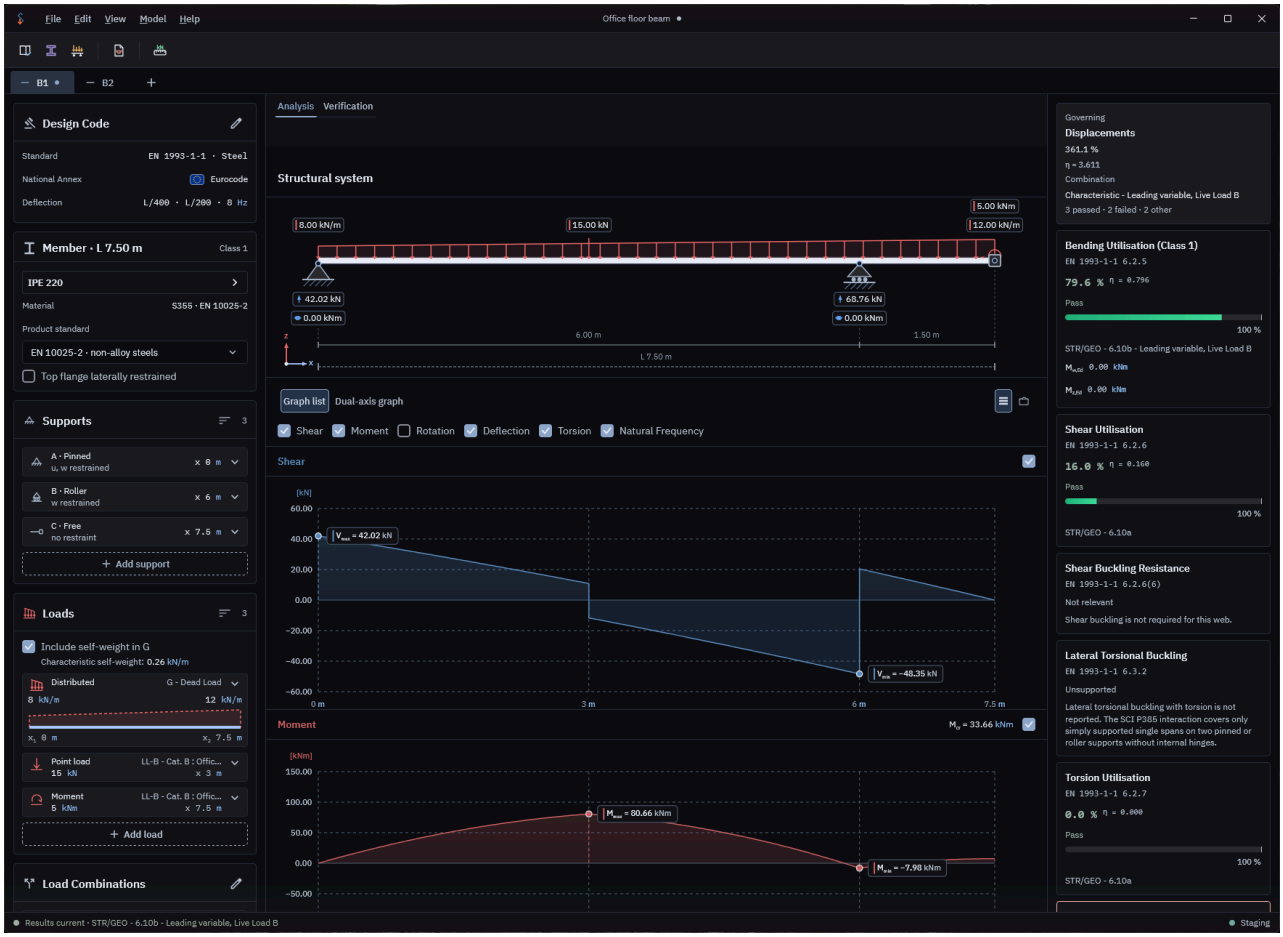


Figure 3.1 · The beam workspace: menus, ribbon, analysis tabs, inspector, canvas with the structural system and graphs, checks column and status bar

Title bar and analysis tabs

The title bar runs across the top of the window. On the left are the logo and the menus. In the centre is the project title, with a marker when there are unsaved changes. On the right are the Windows window controls. Drag the title to move the window, and double-click it to maximise or restore. The title is plain text; to rename the project, use **Project properties...** (see Project properties).

Below the ribbon is the strip of analysis tabs. Each tab shows a beam or column icon, the analysis name (new beams are named "Beam B1", "Beam B2" and so on) and the unsaved marker. Click a tab to switch analysis; switching alone does not make the project unsaved. With many tabs, scroll the strip sideways with the mouse wheel, and the selected tab moves to the centre. Tabs have no close button, and every analysis always keeps its tab.

The **+** at the end of the strip adds an analysis. **Beam analysis…** opens the dialog for a new beam, where **Create** opens the new beam and **Cancel** takes you back. **Column analysis…** belongs to columns, which this guide does not cover yet.

Source: spec/beam/workspace-shell.md rules 1 to 4, 35 and 45.

Menus and shortcuts

The menu bar holds **File**, **Edit**, **View**, **Model** and **Help**. Each menu shows its shortcuts at the right.

Menu	Command	Shortcut
File	**New project…**	`Ctrl` + `N`
	New analysis…	`Ctrl` + `Shift` + `N`
	Open project…	`Ctrl` + `O`
	Recover previous version	
	Save project	`Ctrl` + `S`
	Save as…	`Ctrl` + `Shift` + `S`
	Project properties…	
	Export PDF report…	`Ctrl` + `P`
	Close to launcher	`Ctrl` + `W`
Edit	**Undo**	`Ctrl` + `Z`
	Redo	`Ctrl` + `Y` or `Ctrl` + `Shift` + `Z`
	Settings & Units…	`Ctrl` + `,`
Model	**Section catalogue…**	
	Design code…	
	Load combinations…	
Help	**User guide…**	
	About Statiko	

New analysis… opens the same choice as the **+** on the tab strip. **Undo** and **Redo** are disabled when there is nothing to undo or redo. The **View** menu holds the graph choices **Graph list** or **Dual-axis graph**, and **Stacked** or **Tabs**. When a choice cannot be used, its tooltip says why. Chapter 11 describes the result graphs. In the **Help** menu, **User guide…** opens this guide; **Calculation methods…** is not available in this version.

A disabled command tells you why in a tooltip when you point at it or move to it with the keyboard. A command that is not built yet says **Not available yet**.

Using the menus from the keyboard

- `Alt` or `F10` moves to the menu bar. `Alt`+`F`, `E`, `V`, `M` or `H` opens that menu directly. The access letters are always underlined.
- `Left` and `Right` move between menus. `Up` and `Down` move between commands, and `Home` and `End` jump to the first and last.
- `Esc` closes the menu and returns to its title. `Tab` or a click outside also closes it.

Source: spec/beam/workspace-shell.md rules 5 to 13.

The ribbon

The ribbon under the title bar holds five icon buttons for the commands you use most:

Command	Opens
Design code	The design code window (Chapter 5).
Cross-section	The profile catalogue, the same as **Model** › **Section catalogue…** (Chapter 6).
Load combinations	The load combinations window (Chapter 15).
Report	The PDF report export (Chapter 14).
Units	The settings window on its **Units** tab.

Report, **File** › **Export PDF report…** and `Ctrl`+`P` follow one rule. They work when there is a current result, an outdated result, or a previous result while a new calculation runs. Otherwise they are disabled with **No current result is available for a report. Calculate first.**

The carbon chip

After the ribbon buttons a chip shows the selected beam's product stage carbon (A1-A3) in kg CO_2e, the same total the report prints. Click it to open the split per material: one row per material with its quantity, factor, kg CO_2e and share, then each factor's source. A material without a saved factor uses the generic conservative value of Boverkets klimatdatabas 02.07.000, named with its resource id. Timber and glulam add the line **Biogenic carbon stored (not included)**, which the total leaves out. While a material has no named factor the chip reads **No total** and the row **No factor**; while the result calculates it reads **Calculating**, and without a mass, a length or a concrete section with detailing it reads **Unavailable**. With no single beam selected there is no chip. You replace a factor in the cross-section window's Carbon tab (Chapter 6, Chapter 7).

Source: spec/beam/carbon.md rules 1 to 8.

Settings over the project

Units opens the settings window on **Units**, and **Edit** › **Settings & Units…** opens it on **General**. It holds the same settings as the hub (Settings & Units): interface language, theme, AI agents on Windows, and the engineering units with their **Defaults** and **Advanced** tabs. On Windows it is a separate window you can move. `Esc` or **Close** returns you to the project.

Source: spec/beam/workspace-shell.md rules 16 to 19.

The status bar

The status bar along the bottom always tells you the state of the result and, when results are current, which combination is shown. Read it after every change.

Status	Meaning	Report
Empty project	The project has no analysis yet.	Disabled
Not calculated	Nothing to calculate yet, for example a beam with no loads and self-weight off.	Disabled
Calculating…	A calculation is running (with a turning indicator).	Enabled only if a previous result exists
Results current · combination	Results match your inputs. Without a combination selected it reads **Results current**.	Enabled
Results outdated	The results shown no longer match the inputs.	Enabled
Invalid input	An input is not valid, so nothing can be calculated.	Disabled
The beam is not stable with these supports and cannot be calculated.	The supports leave the beam free to move.	Disabled
Calculation failed, **Calculation unsupported**, **Calculation unavailable**	No result could be produced.	Disabled

For the last two rows the drawing area also shows an error notice with the reason. The notices have no button: your next change starts a new calculation. The status bar grows to show the full sentence and never cuts it off. Builds outside Production end the status bar with the environment name, for example Staging.

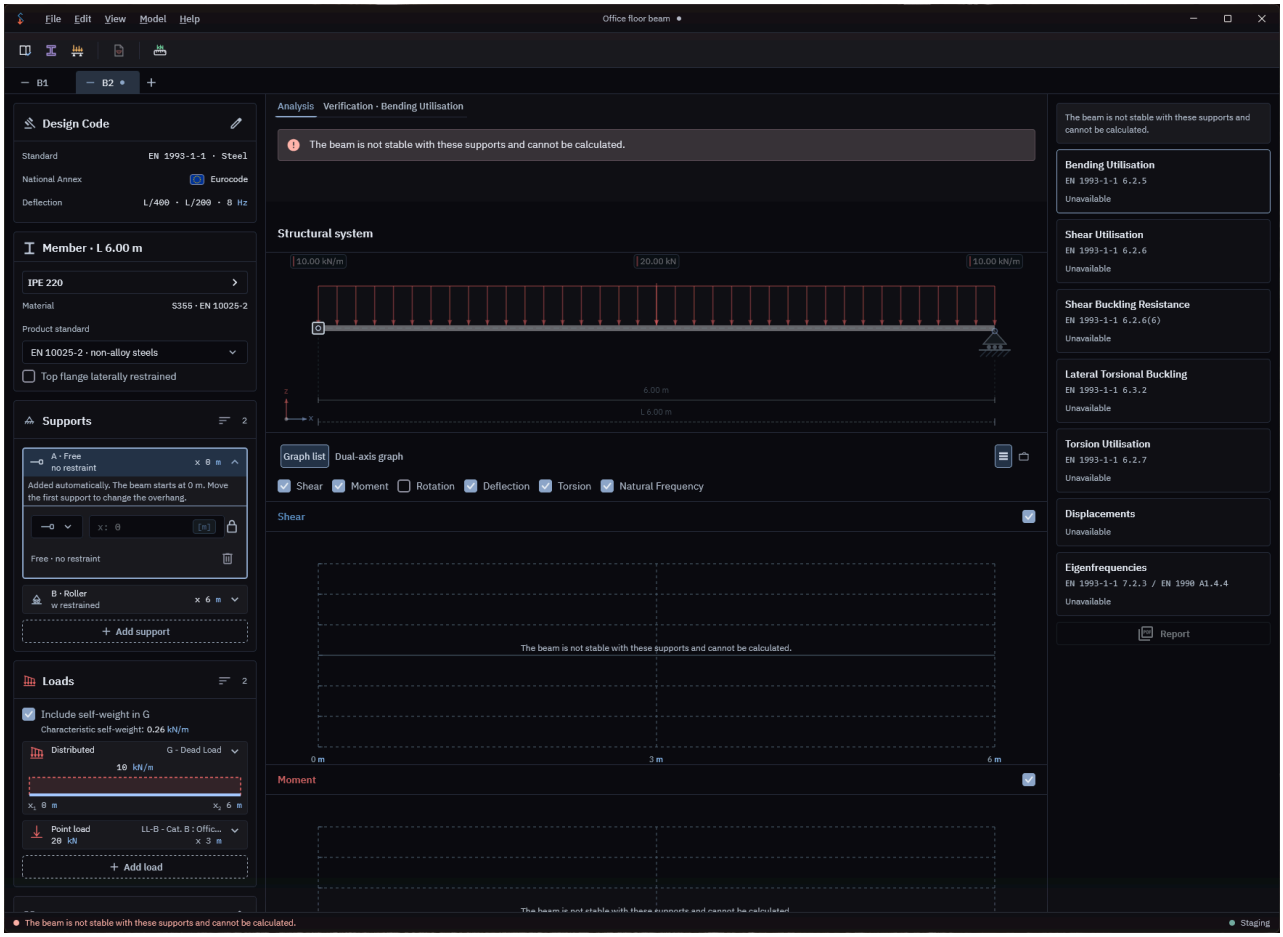


Figure 3.2 · A beam that is not stable with its supports: the notice on the canvas and in the status bar, every check Unavailable and Report disabled

Source: spec/beam/workspace-shell.md rules 20 to 25 and 36.

Project properties

File › **Project properties…** is where you rename the project and its analyses and delete analyses.

1. Open **Project properties…**. The **Project name** field is selected, ready for typing.
2. Edit the project name and the analysis names (**Analysis 1**, **Analysis 2** and so on).
3. To delete an analysis, choose its red bin button, **Delete analysis**. The row disappears at once, with no confirmation.
4. Choose **OK** to apply everything, or **Cancel** or `Esc` to leave without changes.

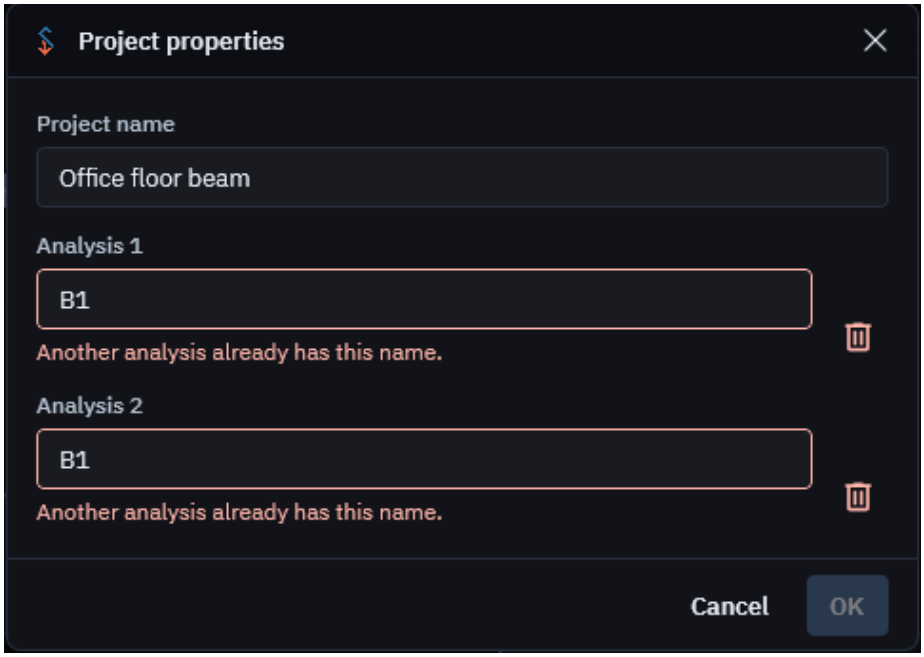


Figure 3.3 · Project properties with two analyses of the same name: the error under each field and OK disabled

OK applies all renames and deletions together as one undo step, so `Ctrl` + `Z` brings a deleted analysis back. Leading and trailing spaces are removed. **OK** stays disabled while a field shows **Enter a project name.**, **Enter an analysis name.** or **Another analysis already has this name.**

Source: spec/beam/workspace-shell.md rules 14 and 15.

Saving, opening and closing

The project file dialog shows only **Project file (*.statiko)**. When you save, Statiko adds `.statiko` if the name lacks it. The first save of a new project suggests the project name as the file name, and **Save as…** proposes the current file. A project that is still named **Untitled**, or has no name, takes the name of the file you save it to, so the title bar, the recent list and the report show the same name; a project you have named keeps its name whatever the file is called. Both dialogs start in the folder of the last project you opened, which Statiko remembers between sessions.

A project remembers the analysis that was selected when you saved it and opens on that analysis. If the file has no valid saved analysis, it opens with nothing selected, and the workspace offers to open or create one.

If you close to the launcher, close the window, or start or open another project while there are unsaved changes, **Unsaved changes** asks what to do: **Save**, **Discard and close** or **Cancel**.

If saving fails, the notice **Save failed** / **The file could not be saved.** offers **Try again** and **Save as**. Your work and its results stay as they were, and the unsaved markers remain until a save succeeds.

> Double-clicking a `.statiko` file in Explorer opens it in the running Statiko. If the current project has unsaved changes, you are asked about them first.

Source: spec/beam/workspace-shell.md rules 31, 32, 37 to 44.

Window sizes

From 840 to 1199 dp wide, the inputs panel (the inspector) sits on the left beside one scrolling column with the drawing, graphs and checks. From 1200 dp, the checks get their own column on the right. The smallest desktop window is 840 × 600 dp. `Tab` moves through the title bar, the ribbon, the inspector, the drawing, the checks and the status bar, in that order. Smaller windows, phones and tablets are covered in Chapter 4.

Source: spec/beam/workspace-shell.md rules 26 to 28.

CHAPTER 4

Phones and tablets

On Android phones, tablets and foldables, Statiko gives you the same beam workspace as on the desktop, arranged for small screens and touch. The features, inputs and numbers are the same: every result comes from the same calculation as on the desktop. This chapter shows where things move on a phone, how a touch tablet differs from the desktop, and how Back, the keyboard and rotation behave.

Which layout you get

Statiko picks the layout from the size of the window, not from the kind of device:

Window	Layout
Narrower than 600 dp (phones)	The phone layout: one column with **Model**, **Results** and **Checks** tabs.
600 to 839 dp (small tablets, open foldables)	The same phone layout, with a wider drawing.
Less than 480 dp tall	The phone layout at any width. Panes scroll, and sheets take at most 85 % of the height.
Touch tablets 840 dp and wider	The desktop regions of Chapter 3 with a touch menu.

On a foldable in book or tabletop posture, the whole workspace sits on one side of the fold, sized to that side. The other side shows **Not available yet**.

Source: spec/beam/phone-and-tablet.md rules 1 to 4.

The phone workspace

At the top of the phone workspace is the app bar. It holds:

- a back arrow to the launcher;
- the analysis title, which you tap to switch analysis;
- the Settings cog, which opens the settings as a full-screen sheet;
- **More actions**, with **Save project**, **Project properties**, which opens the project properties as a full-screen sheet, and **Close to launcher**.

Below the title, a subtitle shows the calculation state, such as **Calculating…** or **Results outdated**, in full. Under the app bar are three tabs:

- **Model**: the structural system drawing, then the inputs. When no result can be produced, for example for an unstable beam, the notice with the reason heads this tab.
- **Results**: the graph toolbar and the result graphs.
- **Checks**: the summary, the check cards and **Report**.

While a calculation runs, the **Results** and **Checks** tabs show a small turning indicator, so you can see when they are being refreshed.

Switching analysis

Tap the analysis title to open the analysis switcher, a sheet that slides up from the bottom and lists the analyses in the project. Pick one, or close the sheet with **Done**.

Source: spec/beam/phone-and-tablet.md rules 6 to 10.

Editing on a phone

When you tap an input on the **Model** tab, its editor opens as a sheet from the bottom, with a handle, a dimmed background and **Done**. **Done** stays above the on-screen keyboard, so you can always close the editor.

Unfinished entries such as `-` or `1,` stay as you typed them and are not treated as a value until they are valid, so you can finish typing. With a hardware keyboard, `Tab` follows the order on screen, including the unit buttons.

The structural system keeps its full symbol sizes on the phone, in a drawing 247 dp tall. On the **Results** tab, each graph is 280 dp high. **Graph list** with tabs is the default, and the toolbar above the graphs keeps the viewing and layout choices, including the dual-axis graph (Chapter 11).

On the **Checks** tab you see either the list of checks or one opened check, never both. Tap a check card to open it, and use Back to return to the list (Chapter 12).

Source: spec/beam/phone-and-tablet.md rules 11 to 15.

Touch tablets

A touch tablet 840 dp or wider shows the same regions as the desktop: the inspector, the drawing and graphs and, from 1200 dp, the checks column. There are no window controls. The desktop menu bar is replaced by a ☰ button, **Main menu**, which holds the same five sections: **File**, **Edit**, **View**, **Model** and **Help**. At the right are the Settings cog, **Undo** and **Redo**.

Every touch target is at least 48 dp. On a tablet, editors open inline under their card instead of as sheets.

Source: spec/beam/phone-and-tablet.md rules 16 and 17.

Android Back, rotation and text size

Back closes the innermost thing first. Each press closes, in this order:

1. the settings;
2. the report's Custom page;
3. the report export view, like **Cancel**, keeping what you chose;
4. an opened check;
5. an open editor sheet;
6. the analysis switcher;
7. the workspace itself, back to the launcher. If the project has unsaved changes, **Unsaved changes** asks first whether to save.

Phones stay in portrait. Tablets and foldables rotate, and when you rotate or fold the device, Statiko keeps the project, the analysis, the selected tab, an open editor with what you are typing, and the selected combination.

With large text (up to 200 %), input values move under their labels, a region may switch to the next smaller layout, and titles wrap rather than being cut off. Units and the status text are never truncated.

Source: spec/beam/phone-and-tablet.md rules 5, 18 and 19.

Reports on phones and tablets

Report on the phone **Checks** tab, and **Export PDF report…** in the tablet menu, open the report export view. Below 840 dp it fills the screen, with a **Back** button, the detail choice, the form sections and the footer. At 840 dp and wider it opens as a centred dialog. As on the desktop, both are disabled with **No current result is available for a report. Calculate first.** when there is no result to report. Back and **Cancel** return to the beam and keep your choices.

Below 600 dp, **Custom** opens as its own page with **Back to export options**. From 600 to 839 dp it opens in place. On a foldable the export view stays on one side of the fold.

> On Android, **Preview**, **Export PDF** and **Add logo** work as on the desktop and make the same PDF (Chapter 14). **Preview** fills the screen, **Export PDF** saves through the Android save page, **Print** opens the Android print dialog on A4, **Share** hands the saved file to another app, and **Add logo** opens the photo picker.

Source: spec/beam/phone-and-tablet.md rules 20 to 22.

PART II

Modelling a beam

CHAPTER 5

Design code, member and load combinations

The three cards at the top of the beam inspector tell you what Statiko calculates with: the standard and National Annex of the project, the member you are checking, and the load combination that the drawing, the graphs and the checks currently show. The cards show values and compute nothing. This chapter explains each card, the Design code dialog behind it, and how the deflection limits work.

The inspector sections

The inspector lists its sections in a fixed order: **Design Code**, **Member**, **Supports**, **Loads** and **Load Combinations**. Each section has an icon, a title and a divider. Design code, Member and Load combinations use the same icons as their ribbon commands.

Design code, Member and Load combinations are read cards. You change their contents through an **Edit** or **Change section** action, which opens the owning dialog, window or catalogue. The only inputs you edit directly on the Member card are the width and height of a rectangular section, the **Product standard** select of a steel beam and the **Top flange laterally restrained** checkbox.

Source: spec/beam/design-code-member-combinations.md rules 1–3.

The Design Code card

The card has three rows:

- **Standard** shows the standard and the material, for example **EN 1993-1-1 · Steel**, **EN 1995-1-1 · Timber** or **EN 1992-1-1 · Concrete**.
- **National Annex** shows the country flag and its name, or **Eurocode** for the recommended values.
- **Deflection** shows the limits as **L/400 · L/200 · 8 Hz** by default: the span limit, the cantilever limit and the natural-frequency limit. The row is read only.

The card has no γ_M row and no consequence-class row; you find those values in the dialog. The pencil button (**Edit**) on the card header opens the Design code dialog on its first tab.

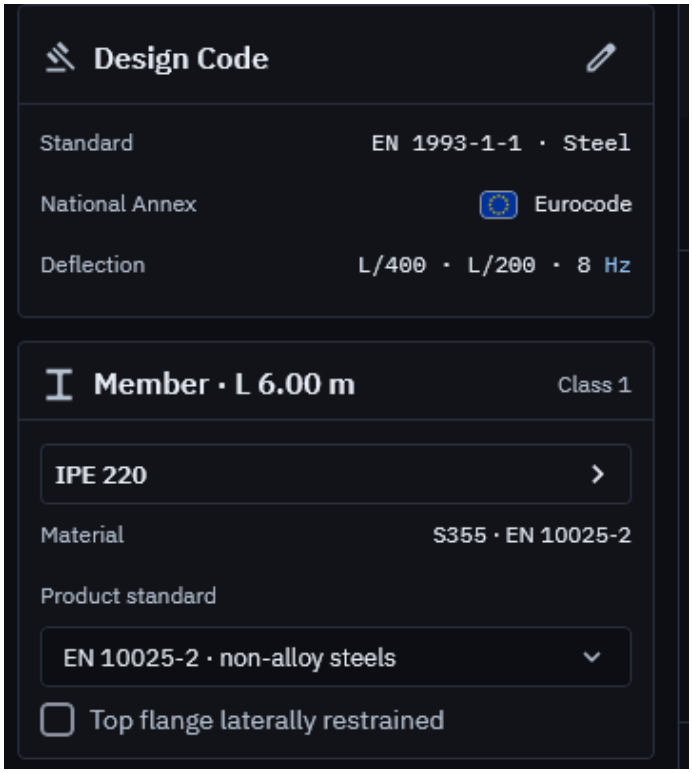


Figure 5.1 · The Design Code card and the Member card of an IPE 220 S355 beam

Source: spec/beam/design-code-member-combinations.md rules 4–6.

The Design code dialog

Open the dialog with the pencil button on the card, the ribbon command **Design code** or **Model › Design code…**. On desktop it opens as its own window with a title bar: you can drag it, the workspace stays drawn behind it, and a click outside does not close it. **Cancel**, the close control and `Esc` close it without changes; **Apply** writes your choices to the project.

Country and code

The select **Design standard and National Annex** offers five choices: **Eurocode recommended values**, **Denmark (DS EN)**, **Sweden (SS EN)**, **Serbia (SRPS EN)** and **Custom values**. Below it you set:

- **Consequence Class** with **CC1**, **CC2** and **CC3**. For Sweden the field reads **Safety class** with **SK1**, **SK2** and **SK3**.
- **Altitude (above sea level)** and **Characteristic snow load**, only for a country that uses these bands.
- **Service Class** with **Service Class 1**, **2** and **3**.
- **System Factor** with **1.0 - no system action**, **1.1 - normal system action** and **1.2 - full system action**.

The left column holds **Country & Code** and the material factor groups: **Steel material factors** γ_{M0}, γ_{M1}, γ_{M2} with the **Robustness** multiplier; **Timber material factors** (service class, $\gamma_{M,Solid}$, $\gamma_{M,Glulam}$, γ_3, k_{sys}); **Concrete** γ_C, γ_S, α_{cc}, α_{ct}.

Tabs

Tab	What it shows
Psi factors and actions	The consequence factor K_{FI} with its source; **Action partial factors** $\gamma_{Q,1}$, $\gamma_{Q,i}$, $\gamma_{G,inf}$, $\gamma_{G,sup}$; Ψ_0, Ψ_1 and Ψ_2 per action, grouped under imposed loads, snow loads and wind actions; under the table, the **Custom Load** with its own γ_Q, ψ_0, ψ_1 and ψ_2.
Load duration	One choice per action: **Permanent**, **Long-term**, **Medium-term**, **Short-term** or **Instantaneous**.
Deflection limits	The **Preset** select and the five limit fields described below.
Custom Combinations	The table of the project's custom combinations, described below.

For a concrete beam the steel and timber factor groups are hidden. For the other materials, the concrete group shows γ_C, γ_S, α_{cc} and α_{ct}; $\gamma_{C,fi}$ and $\gamma_{S,fi}$ stay hidden.

Custom values

The **Custom Load** block is editable under every country. Its **Values** select offers **Own values** and the live load categories A to H. A category fills the four fields with that category's ψ factors and the $\gamma_{Q,1}$ of the selected country, and follows the country when you change it. Typing in a field turns the select to **Own values** and keeps the other three values. γ_Q must be a number above zero; each ψ must be from 0 to 1, otherwise the field shows **Enter a number from 0 to 1.** A new project starts at $\gamma_Q = 1.5$ and $\psi_0 = \psi_1 = \psi_2 = 1.0$. The factors are stored with the project and apply to every Custom load in it (Chapter 15).

With **Custom values** the factor rows become number fields. A field that is not a finite number above zero shows **Enter a finite number greater than zero.** Custom adds one timber field, k_{cr}, after γ_3. It starts empty. Enter a value above 0 and up to 1, or leave it empty; anything else shows **Enter a number greater than zero and at most 1, or leave it empty. Apply** stays disabled while a custom factor or limit is invalid. If Apply fails, the dialog shows **The selection could not be applied. Try again.**

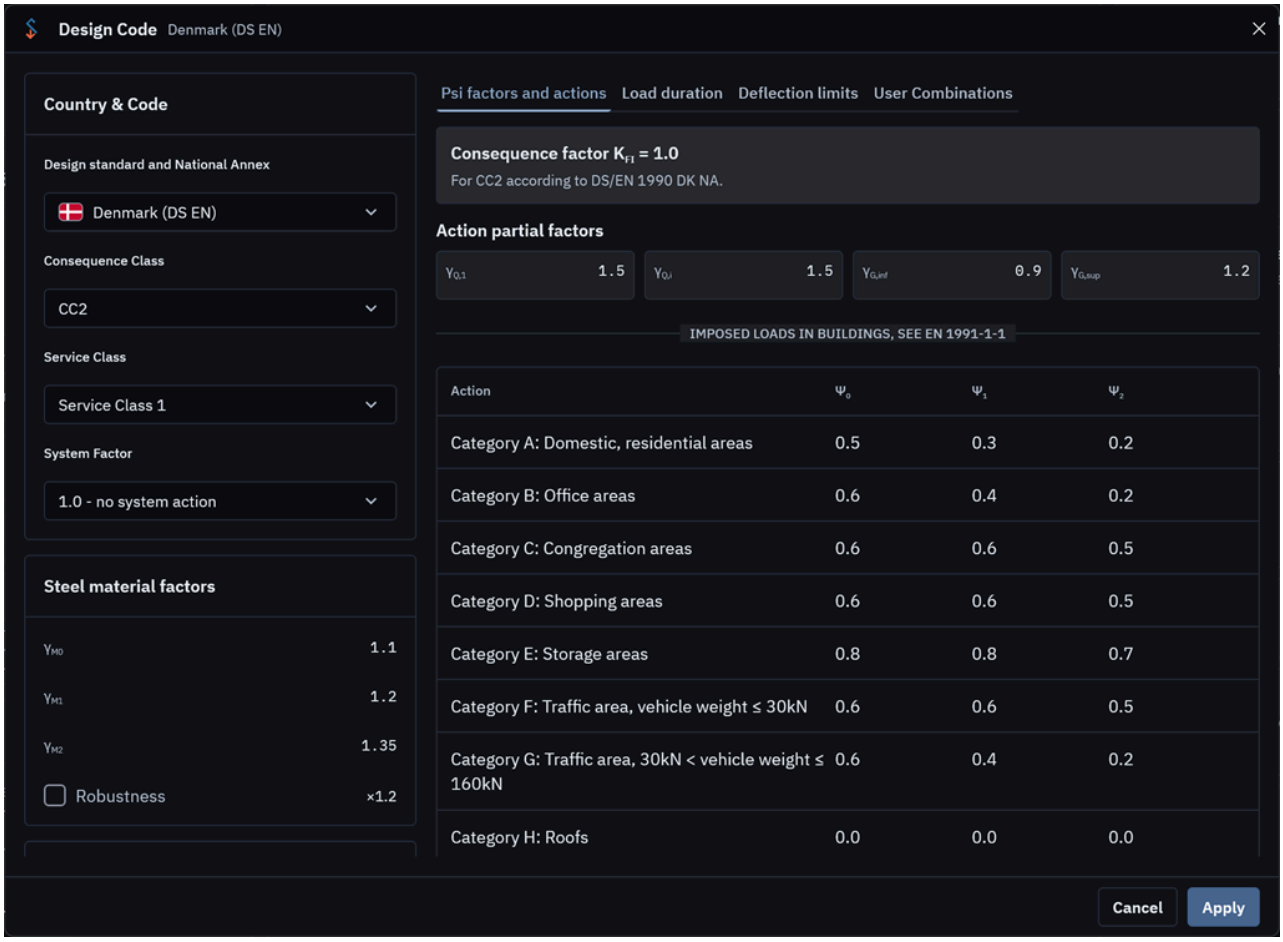


Figure 5.2 · The Design Code dialog for Denmark (DS EN): Country & Code and the material factors on the left, the Psi factors and actions tab open on the right, beside the Load duration, Deflection limits and Custom Combinations tabs

Custom combinations

The **Custom Combinations** tab holds the combinations you define yourself, next to the ones Statiko generates. The Load combinations window has the same tab (below); both edit the one list of the project. The table has one row per combination and one column per load case of the project: the permanent load, every load case a load of any beam or column has, and every load case a combination already holds a factor for, in the order dead, live A to H, snow, wind and Custom load. A row holds the **Name**, the **Limit state** (**ULS**, **SLS · Characteristic**, **SLS · Frequent**, **SLS · Quasi-permanent** or **Fire**), one factor field per load case and a delete button. A factor is the whole coefficient of its load case; an empty field leaves the load case out of the combination. **Add combination** under the table adds an empty row with **ULS**.

Apply stays disabled while a row is incomplete, and one line under the table names what to correct: **Enter a name for every combination.**, **Give every combination its own name.**, **Enter a factor of 0 or more.** or **Enter a factor above 0 for at least one load case of every combination.** The combinations are saved with the other values of the dialog, as one undo step. When you delete a combination that a beam or column has selected, or remove the last of its load cases that the member has, the member's selection moves to the first combination it can show. How a user-defined combination is used in the checks is described in Chapter 15.

Source: spec/beam/design-code-member-combinations.md rules 6, 18, 22, 36–41; spec/beam/concrete-workspace.md rule 3.

Deflection and frequency limits

On the **Deflection limits** tab the **Preset** select offers **Statiko default (L/400 · L/200 · 8 Hz)** and **Custom**. The five fields are **Span, instantaneous**, **Cantilever, instantaneous**, **Span, final** and **Cantilever, final**, each written as L/ followed by the number you enter, and **Frequency limit** in Hz. A field you change is labelled with **· Custom** after its name. A source line names where the values come from: **Statiko default**, or a project criterion under EN 1990 A1.4 with EN 1993-1-1 7.2.1 for steel or EN 1995-1-1 7.2 for timber. The fields are disabled when no beam is selected.

A limit L/400 means the deflection may be at most the span length divided by 400; L/200 applies the same rule to a cantilever. How Statiko checks deflection and natural frequency against these limits is described in Chapter 21.

A concrete beam has one limit instead: a **Deflection Limit** picker with **L/250**, **L/500** and **Custom** (a denominator above zero). The default is L/250. The same value shows in the card's Deflection row.

> The Deflection row on the card has no edit icon. To change the limits, use **Edit** on the Design code card.

Source: spec/beam/design-code-member-combinations.md rules 5, 17; spec/beam/concrete-workspace.md rule 4.

One design code per project

A project has one National Annex for all its analyses. A beam stores only its own deflection and frequency limits. Every factor (γ, ψ, load durations, γ_M, K_{FI}, service class, γ_3, k_{sys}) comes from the project's design code. When you change the design code, the change reaches every beam in every analysis: its checks, section properties, card and report. A file saved by an older version with a copy of the whole settings on a beam opens with that copy's limits as the beam's limits; its factors are dropped.

The country also decides how a steel beam's yield strength is found (Chapter 6). Concrete beams calculate with **Eurocode recommended values**, **Custom values**, **Denmark (DS EN)** and **Serbia (SRPS EN)**; **Sweden (SS EN)** gives **Concrete does not calculate under Sweden (SS EN): the Swedish National Annex to EN 1992-1-1 is not in Statiko yet.**

> In the Custom design code, an empty k_{cr} means there is no crack factor, so timber shear reads Unavailable with **The National Annex gives no crack factor for timber shear.** A value applies $b_{ef} = k_{cr} \cdot b$ (EN 1995-1-1 6.1.7(2)). Serbia never uses k_{cr}.

Source: spec/beam/design-code-member-combinations.md rules 21, 22.

The Member card

The header reads **Member · L 12.00 m**, with the member length in your Length unit and display precision. You never type the length: Statiko computes it from the supports (Chapter 8). With a current result, the section class shows at the right, for example **Class 1**.

- The section button, for example **IPE 220 ›**, runs the full width and shows the current section. It opens the cross-section window for the member's material (Chapter 6, Chapter 7).
- **Material** shows the grade with its standard, read only, for example **S355 · EN 10025-2**. You choose the grade in the cross-section window.

- **Product standard** appears for a steel beam with a catalogue grade, in every design country. For an open section you choose **EN 10025-2 · non-alloy steels**, **EN 10025-3 · normalised fine-grain steels** or **EN 10025-4 · thermomechanical fine-grain steels**. A standard that does not cover the grade stays in the list, unavailable, with **Not available for S235** (for example). A hollow section shows its standard locked, **EN 10210-1 · hot-finished hollow** or **EN 10219-1 · cold-formed hollow**, with **Set by the section. Change the section to change it.**
- Width and height fields appear only for a rectangular section sized in the member.
- **Top flange laterally restrained** is described in Chapter 8.

Choosing a product standard is a project edit like any other: Undo and Redo cover it, and the beam recalculates. A new open section takes EN 10025-2 for S235, S275, S355 and S450, and EN 10025-3 for S420 and S460.

Source: spec/beam/design-code-member-combinations.md rules 7–9, 12; spec/beam/steel-yield-strength.md rules 4–10.

The Load combinations card

The card holds one select. It lists **None** first, then this beam's combinations: ULS, then SLS, then Fire. Each option and the closed value carry a coloured **ULS**, **SLS** or **Fire** label before the name, for example **STR/GEO - 6.10a**, **Characteristic**, **Quasi-permanent** or **Fire - 6.11a/b**. The full name shows in the tooltip. The list widens to its longest item and closes when you click outside, press `Esc`, scroll outside it or resize the window.

The selected combination is shared: the drawing's reactions, the graphs and the checks all read it, and the status bar names it. Changing it is an edit, so the results become outdated and the calculation runs again for the new combination. No limit rows sit under the select; limits live in the design code.

Edit opens the Load combinations window, which opens as its own window like the Design code dialog. A beam without combinations shows only **None**, and Edit stays enabled. How the combinations are generated is described in Chapter 15.

After the Fire tab, the window has a **Custom Combinations** tab with the same table and rules as the Design code dialog (above). Its **Apply** saves the rows as one undo step and keeps the window open; it is unavailable while nothing changed or a row is incomplete. **Close** discards what you did not apply.

Every ULS, SLS and Fire row of the window has a **Show in report** box, ticked by default. Untick it to leave that combination out of the report's combination tables and per-combination diagrams for every beam of the project; a combination that governs a check is printed all the same (Chapter 14). The box is saved with the project and is one undo step. It never changes the calculation, which checks every automatic and user-defined combination. Deleting a user-defined combination drops its box in the same undo step.

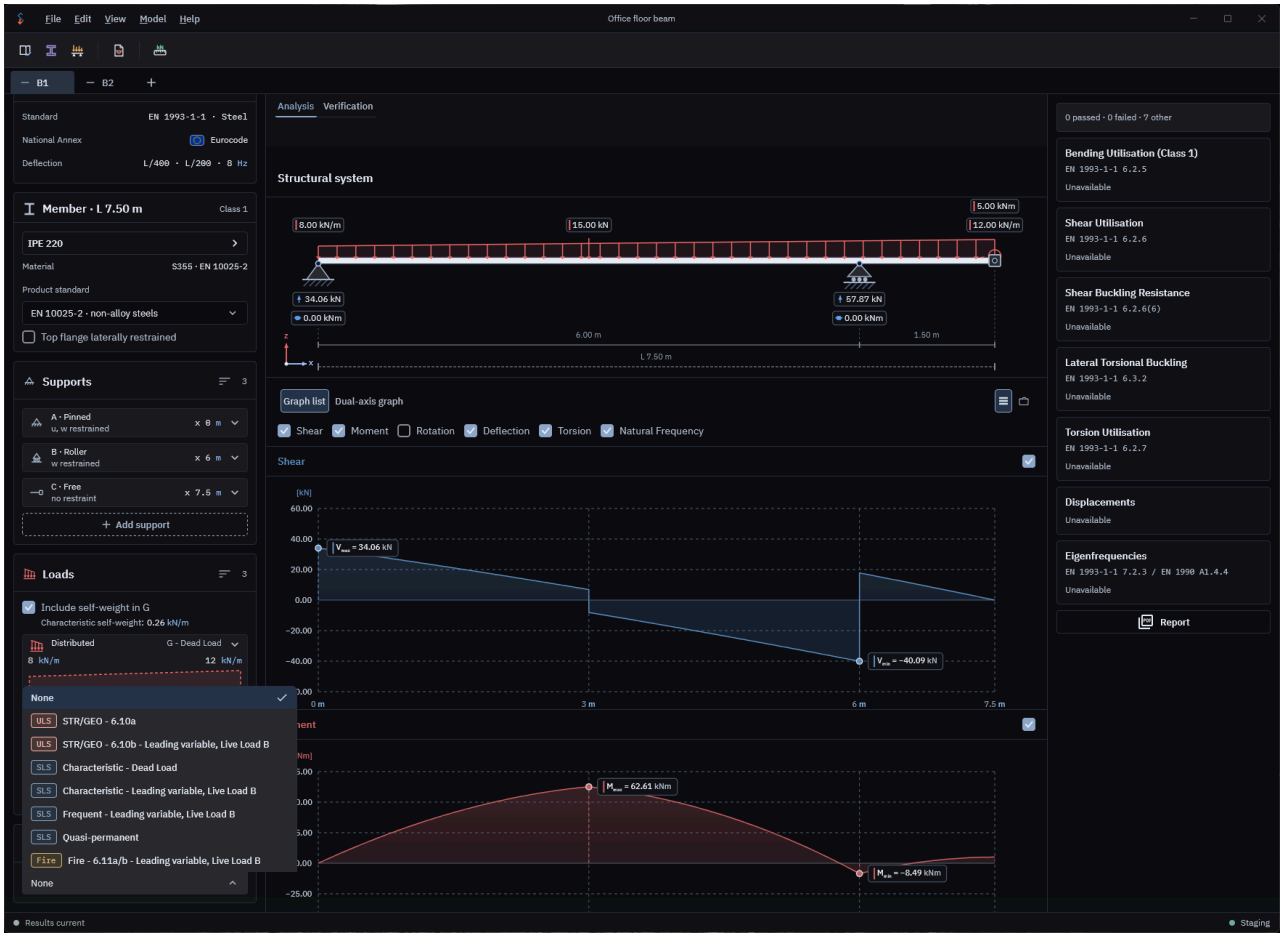


Figure 5.3 · The Load combinations select open: None, the ULS, SLS and Fire combinations with their coloured labels

Source: spec/beam/design-code-member-combinations.md rules 14–20, 43–45.

CHAPTER 6

Steel and timber cross-sections

The cross-section window is where a steel, timber or glulam beam gets its profile and grade. You pick a catalogue size or build a custom profile, and Statiko calculates the section properties and the steel cross-section class as you type. Nothing in the analysis changes until you press **Apply**. This chapter also explains how Statiko finds a steel beam's yield strength in each design country.

Opening the window

Open the window with **Change section** on the Member card, the ribbon command **Cross-section** or **Model › Section catalogue…**. It opens for the selected beam, on its section and grade. On desktop it is its own resizable window (at least 1240 × 800); while it is open you cannot edit the workspace behind it, and closing it is the same as **Cancel**. On a tablet or phone it is a full-screen page.

The title names the material and profile, for example **Steel cross-section — IPE 220**, **Timber cross-section — …** or **Glulam cross-section — …**. The subtitle says where the profile came from: **Catalogue profile IPE 220 · Grade S235**, **Custom profile · started from IPE 220 · Grade S235** or **Custom profile · not taken from the catalogue · Grade S235**.

The tabs **Steel**, **Timber** and **Concrete** sit at the top of the window's left column on desktop, and under the title in a narrow window or on a phone; glulam is under Timber. A tab of another material switches the beam's material when you apply. The new material starts empty: Steel and Timber open the catalogue and show **Choose a profile from the catalogue.**, and **Apply** stays disabled until you load a profile, which takes the default grade S235 or C24. The Concrete tab is described in Chapter 7.

Source: spec/beam/cross-section.md rules 1–4, 37.

Choosing from the catalogue

On desktop, and in any window at least 840 dp wide, the catalogue is always open in the left column under the tabs, as one expanding tree. On Steel it goes shape, family, size, for example **I and H sections** › **IPE** › **IPE 220**; on Timber it goes family, size. Each root row shows the shape glyph, the name and its number of sizes; family and size rows sit indented under their parent, and a size row shows only its designation. A root name too long for the column ends in an ellipsis and shows whole in a tooltip.

1. The tree opens down to the profile in the window. Click a branch to open or close it.
2. Or type in **Search designations**: every branch that holds a match opens. Clearing the search returns to the branches you had open.
3. Click a size. It loads into the window, the **Dimensions** card shows its values, and the tree stays as it is.
4. Check the properties and class, then press **Apply**.

The size in the window is highlighted, and every branch above it has a softer highlight, also while it is closed, so you can see where the size sits after you close the branches. The header **Catalogue** has two buttons: **Show selected** opens the branches down to the size in the window and scrolls it into view, and **Collapse all** closes every branch. Show selected is disabled while the window holds no catalogue size or saved profile, for example on a Timber tab that waits for its first profile. **Create custom profile** is pinned at the foot of the column.

In a window narrower than 840 dp, such as a phone, a narrow rail labelled **Catalogue** runs down the left edge on the Steel and Timber tabs. Click it to open the catalogue as a full-screen page. It opens on the sizes of the current family; the back arrow goes up to the families and shapes, and each size row shows the designation and its dimensions, each with its symbol, value and unit. A click on a size loads it and closes the page; Back closes the page without loading anything.

The **Custom** root comes first. It lists this project's saved custom profiles of the tab's material. Deleting one there removes it at once, without asking; beams that use it keep their own copy. If the catalogue cannot load, it shows **Unable to load the profile catalogue.**

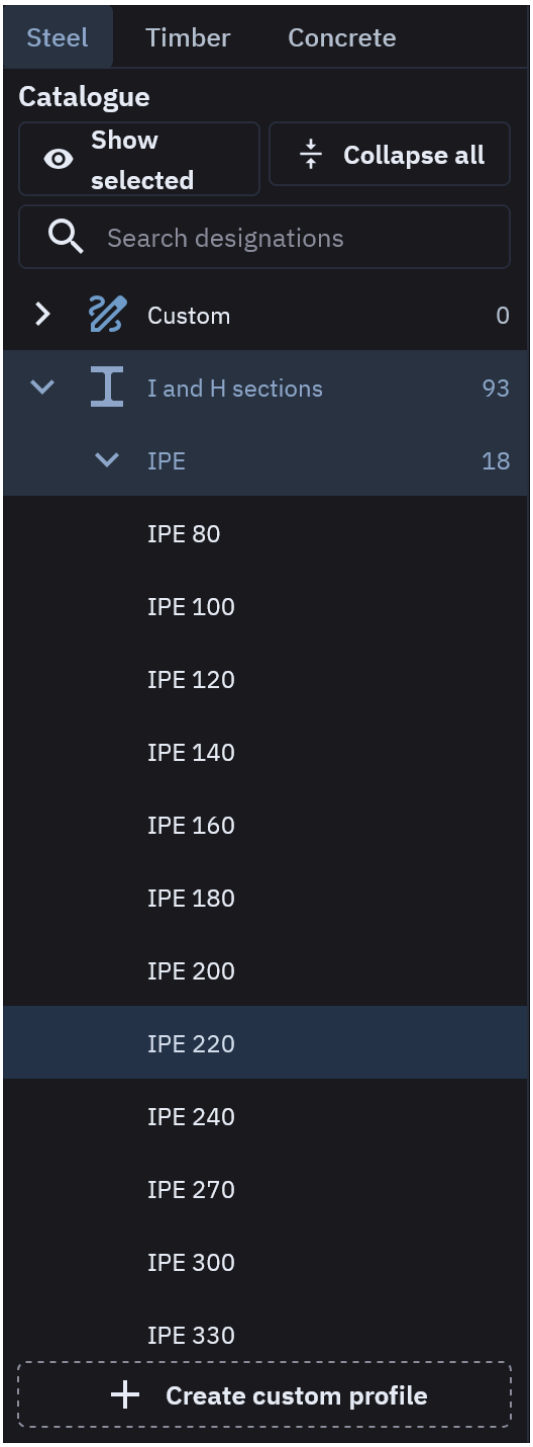


Figure 6.1 · The catalogue tree with IPE 220 in the window: the header with Show selected and Collapse all, Search designations, the Custom root first, I and H sections › IPE open with the soft highlight and IPE 220 selected

Source: spec/beam/cross-section.md rules 3, 13–15, 32, 38–42.

The Profile view

On desktop the window has three columns over a footer with the status, **Cancel** and **Apply**. The left column holds the tabs and the catalogue. The centre column shows the drawing large, then for steel the class tiles, then the section properties. The input panel on the right has its own tabs: **Section**, **Carbon** and **Fire** for steel, timber and glulam. Section holds the Profile, Dimensions and grade cards; a catalogue profile shows its dimensions read-only. The panel opens on Section and keeps its tab while the window is open. Each column scrolls on its own. In a window narrower than 840 dp everything is one column.

- The **Profile** card shows the shape glyph and designation. For steel it adds a **Rolled** or **Welded** tag and the family, for example **IPE · I and H sections**. In a narrow window **Create custom profile** sits underneath; on desktop it is at the foot of the catalogue.
- The drawing shows the section to scale, with **Centroid (C)**, **Shear centre (SC)** and the **Fillet Radius r**. Timber shows two dashed diagonals; glulam shows its lamellae with a callout such as **18 × 33.33 mm lamellae**.
- The **Dimensions** card lists each dimension with its symbol, name, value and unit, in your Cross-section unit (**Cross-section / detailing** in Settings › Units › Advanced).
- For steel, the **Steel Grade** card offers S235, S275, S355, S420, S450, S460 and **Custom steel grade**, with **Yield Strength** f_y and **Modulus of Elasticity** E under it. E is 210 000 MPa. For timber, the **Wood Grade** card offers the strength classes of the type: C14, C18, C24 and C30 for timber, GL24c, GL24h, GL28c, GL28h, GL30c and GL30h for glulam, with the class's material values.
- Section properties come in groups: **Classification** (steel only), **Geometric Properties**, **Section Moduli**, **Shear Properties**, **Moment of Inertia**, **Torsion & Warping** and Other. Each header counts its rows. On desktop, hover the info icon for the full name. Principal-axis rows appear only where the principal axes differ from y-y and z-z.
- For steel, the **Classification** group shows the class for N, M_y and M_z as chips: Class 1 and 2 in the success colour, Class 3 in the warning colour, Class 4 in the error colour. Class 4 adds A_{eff}, $W_{eff,y}$ and $W_{eff,z}$, which read Unavailable.
- The footer names the governing class, for example **Class 1 · S235** or **Class 4 for compression · S460**, or **Cross-section class unavailable · S235**. For timber it reads **Wood grade C24** (for example).

Every profile also has the card **Product stage carbon (A1-A3)**, on desktop in the Carbon tab, with **Steel factor** (timber and glulam: **Timber factor**) in kg CO_2e/kg and **Factor source**. A beam without a saved factor starts from Boverkets klimatdatabas 02.07.000: structural steel 3.15 (6000000150), sawn timber 0.08 (6000000007) and glulam 0.133 (6000000168). A line under the fields gives the member's mass (the section's mass per metre × length) and footprint, and the total. With a typed factor that is not usable it ends with **Enter a named EN 15804+A2 GWP-total factor.** and shows no total. Apply saves a typed factor with the profile in one Undo step; the report prints the same mass, factor, source, footprint and total at the end of 2.1 Materials.

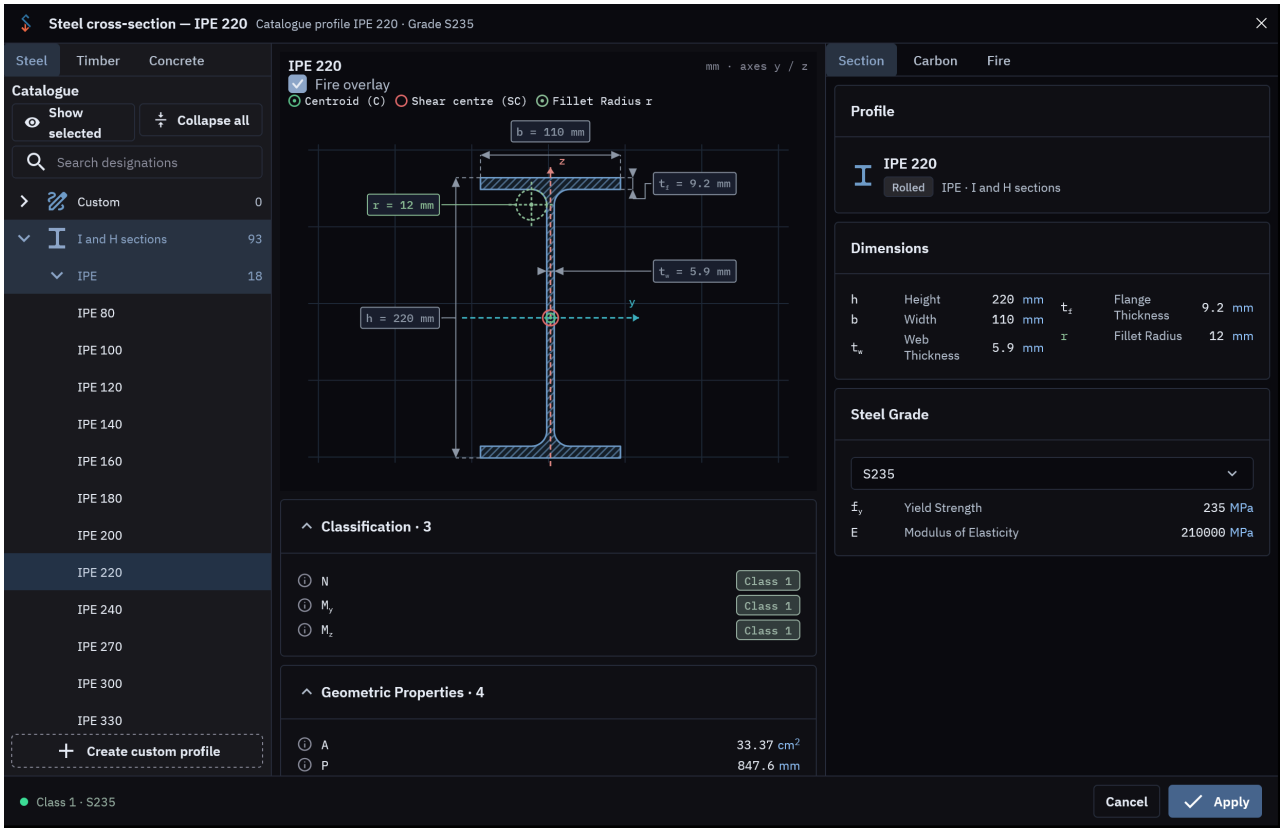


Figure 6.2 · The cross-section window for IPE 220 on desktop: the tabs and the catalogue tree on the left, the dimensioned drawing with the class tiles and the property groups in the centre, the Section tab with the Profile, Dimensions and Steel Grade cards on the right, and the footer Class 1 · S235

Source: spec/beam/cross-section.md rules 5–11, 33–35, 43, 44.

Custom profiles

1. Load the profile you want to start from, or any profile.
2. Press **Create custom profile**. The profile is copied into the editor with the name field **Custom profile name** and the line **Started from IPE 220.** (for example).
3. Choose a shape in the shape list if you want another one. It starts from that shape's empty values and the line changes to **Not taken from the catalogue.**
4. Enter the dimensions. The drawing and properties update as you type.
5. Press **Apply**. The beam takes the profile and the profile is saved in the project.

Steel offers twelve shapes: I and H, tee, rounded tee, zee, angle, parallel-flange channel, tapered-flange channel, box girder, rectangular hollow, circular hollow, rectangular bar and circular bar. Flanged, tee, rounded tee and both channel shapes have a **Rolled** | **Welded** choice, default Rolled. Welded sets the radius fields to zero and hides them; Rolled needs a root radius above zero. A box girder is always Welded and may have a zero fillet radius; hollow sections, angles, zee and bars are always Rolled. Timber has one shape, the rectangle, with a **Timber** | **Glulam** choice; height and width stay when you change the type.

New profiles are named **Custom profile**, **Custom profile 2** and so on. A name already used by a catalogue designation or another saved profile shows **The name is already used by another profile.** and disables Apply. With **Custom steel grade** you enter f_y and E yourself, each above zero; the custom grade belongs to this beam only.

Applying under an unchanged name replaces the saved entry; a new name adds one. Each beam keeps its own copy, so editing a saved profile later does not change beams that already use it. A custom-profile beam is calculated, checked and reported like a catalogue beam; the report says **Section properties calculated by Statiko from the custom profile geometry.**

Source: spec/beam/cross-section.md rules 16–20, 23, 24, 30.

Validation, Apply and leaving

Properties and classes recalculate after every edit. While they calculate, the rows say so. A value the engine did not return reads Unavailable, never a number. Number fields accept digits, the minus sign and both decimal separators; spaces are ignored.

If a dimension is invalid, one message shows under its field, for example **h must be greater than zero.** The drawing then shows the last valid geometry dimmed with **Section properties are unavailable**, properties read Unavailable, and Apply is disabled. A focused dimension field highlights its dimension line in the drawing.

Apply is one project edit, undone in one step. **Cancel**, the close control, `Esc` and Android Back leave the analysis unchanged. If you have edited a custom profile, Statiko asks **Discard changes?** (**The edited custom profile is discarded. The analysis stays as it was.**) before loading another profile, switching tab or closing; choose **Discard changes** or **Cancel**. A failed Apply shows **Unable to apply the selected profile.** and keeps your selection. If another document opens or the beam changes, the window closes without applying.

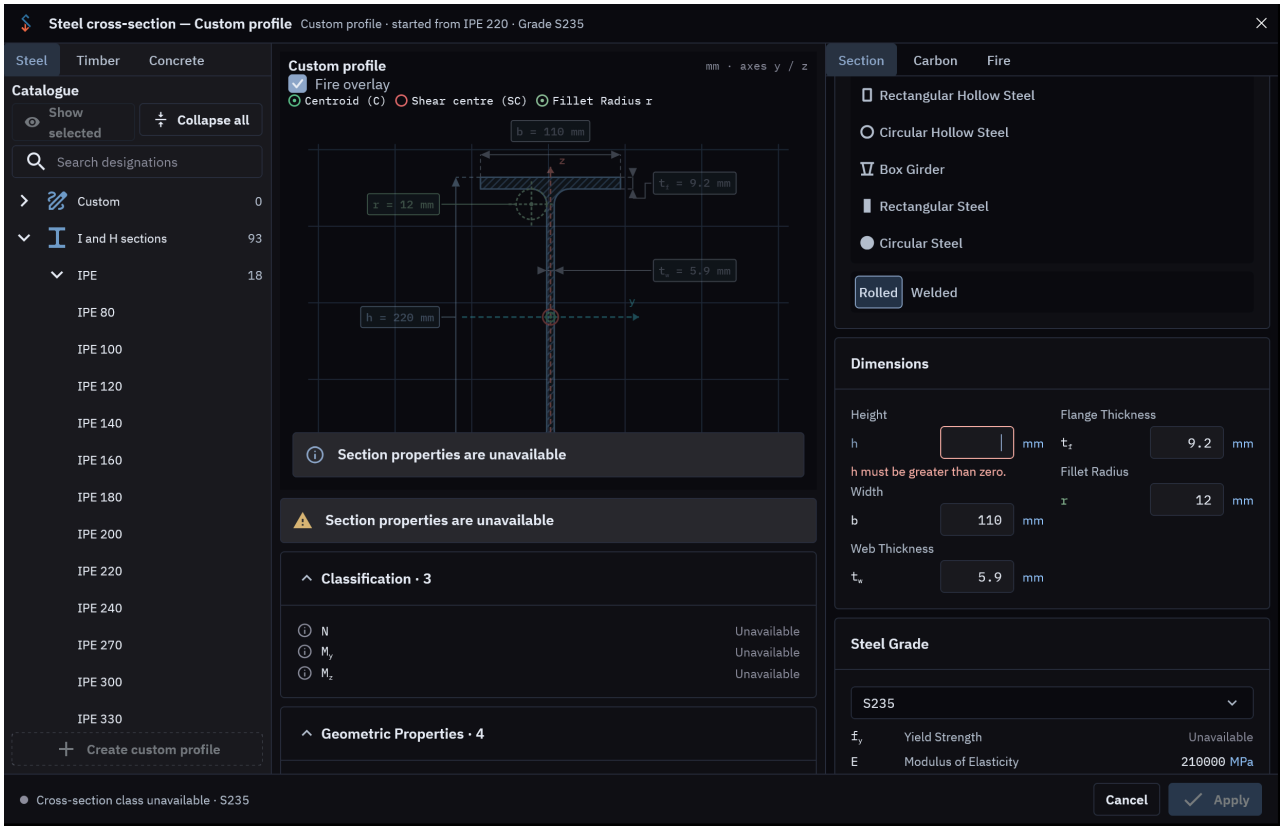


Figure 6.3 · A custom profile with h cleared: the message under the field in the Section tab, the dimmed drawing, Section properties are unavailable and Apply disabled

When you switch material, the beam keeps its fire inputs and its timber service class and load durations. It drops the carbon factor of the material it leaves, a custom steel grade and any concrete material and detailing.

Source: spec/beam/cross-section.md rules 12, 21, 22, 24–28, 37.

Yield strength per country

The f_y in the Steel Grade card is the design yield strength the classification and every steel check use for this profile and grade. It depends on the project's design country:

Country	f_y from
Denmark, Sweden	R_{eH} of the product standard, EN 1993-1-1 3.2.1(1) a)
Eurocode, Serbia	EN 1993-1-1 Table 3.1, 3.2.1(1) b)
Custom	Table 3.1 values; the steel report's material clause line notes “national choice not resolved”

In Denmark and Sweden f_y is R_{eH} of the thickness step that holds the governing thickness: EN 10025-2:2019 Table 6 for open sections, EN 10210-1 for hot-finished and EN 10219-1 for cold-formed hollow sections. A step includes its upper bound, so 16 mm counts as "≤ 16". The governing thickness is the thicker of web and flange for an open section, and the wall for a hollow section. For example, an S355 HE 300 B with a 19 mm flange has f_y = 345 MPa in Denmark and 355 MPa under Eurocode.

EN 10025-3, EN 10025-4, and EN 10025-2 for S450, are not registered in Statiko. In Denmark and Sweden they give Table 3.1 values, and the steel report's material clause line names the standard, for example “EN 10025-3 not registered”. A custom open section takes its standard as a catalogue open section. A custom hollow section offers EN 10210-1 and EN 10219-1 and starts at EN 10219-1 (cold-formed, buckling curve c, the lower resistance). A custom steel grade keeps f_y as entered in every country.

A lower f_y raises $\varepsilon = \sqrt{(235 / f_y)}$ and can move a section into a better class, so a check can pass under route a) and fail under Table 3.1. Compare results per country, not by f_y alone.

Above the last thickness step of the table in use, the class reads **Cross-section class unavailable · S355** (with the grade in use) and every steel check reads Unsupported with **The element thickness is outside the yield strength table for this steel grade.** The last steps are 400 mm (EN 10025-2), 120 mm or 65 mm (EN 10210-1), 40 mm (EN 10219-1) and 80 mm (Table 3.1). S450 on a hollow section is refused in every country: **S450 is not delivered as a hollow section: EN 10210-1 and EN 10219-1 have no S450.**

The class tiles show the class for pure compression and pure bending; combined compression and bending is not included. Effective Class 4 properties are not available in this version. The steel checks are described in Chapter 18.

Source: spec/beam/steel-yield-strength.md rules 1–3, 11–17; spec/beam/cross-section.md rules 9, 23, 31.

CHAPTER 7

Concrete beams

A concrete beam is modelled in two places. The concrete cross-section window holds the shape, the reinforcement, the stirrups, the materials, the cover and the serviceability inputs. The workspace inspector holds the shear angle, the T-flange shear inputs and the optional anchorage and lap details. This chapter walks through both, in the order you normally fill them in.

Creating a concrete beam

In the **Create Beam Analysis** dialog the **Material** field offers **Steel** (tagged EN 1993-1-1) and **Concrete** (tagged EN 1992-1-1); Steel is the default. Choose Concrete, set the **Beam Length** and create the beam.

A new concrete beam starts with a rectangular section h 600 × b 400 mm, concrete **C30**, reinforcement steel **Y-550** with ductility class B, cover 30 mm, stirrups Ø8 at 200 mm, 2 Ø16 at the top and 3 Ø16 at the bottom, and the default detailing settings. Self-weight is on: its line weight is the section area times the concrete density.

You can also turn an existing beam into a concrete beam: open the cross-section window and choose the **Concrete** tab (Chapter 6). There is no concrete catalogue; the tab opens the concrete editor on Rectangular with its defaults.

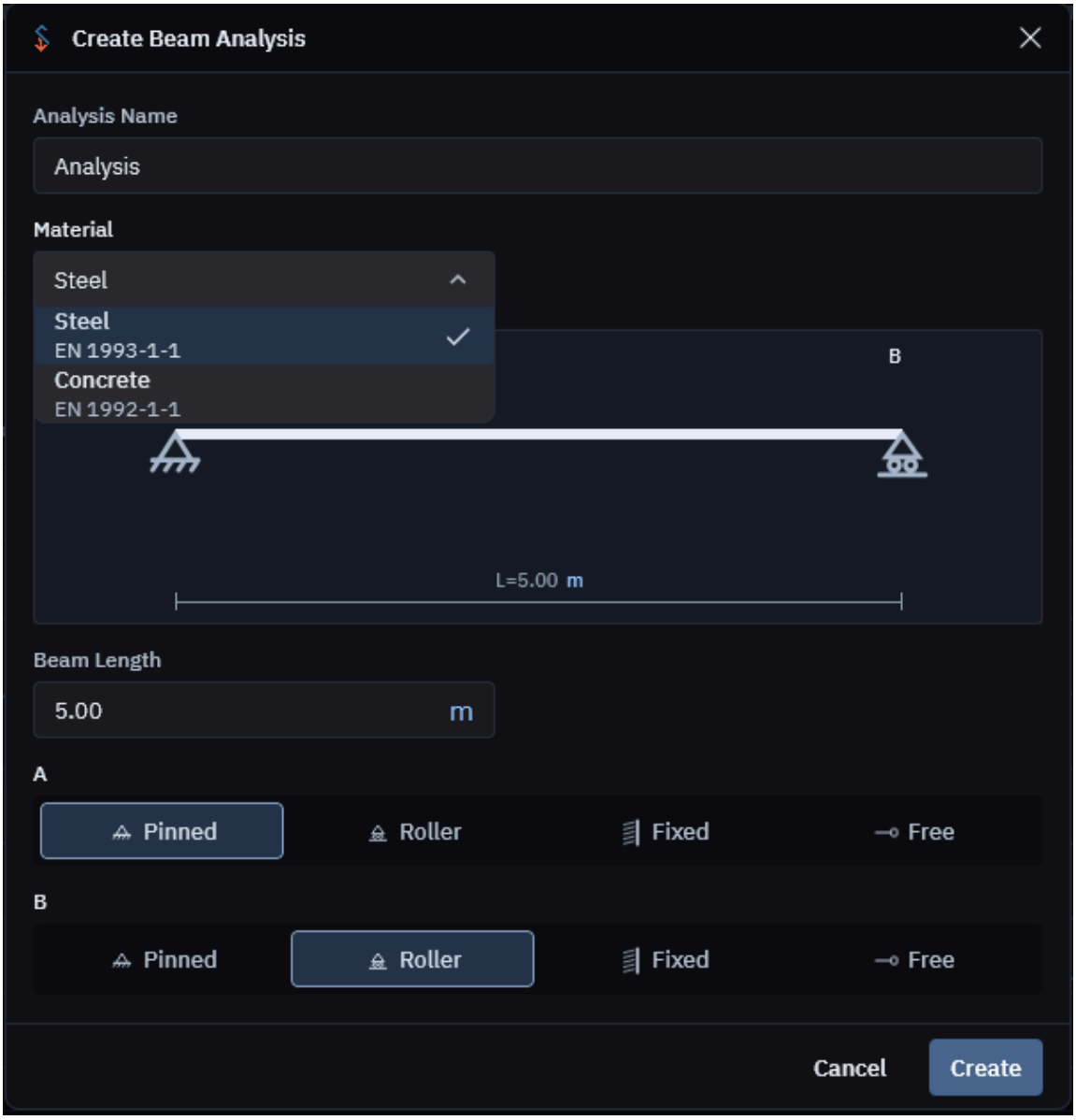


Figure 7.1 · The Create Beam Analysis dialog with the Material list open on Steel (EN 1993-1-1) and Concrete (EN 1992-1-1)

Source: spec/beam/concrete-workspace.md rules 1–2; spec/beam/concrete-section.md rules 1, 3, 6.

The concrete cross-section window

The title reads **Concrete cross-section — Rectangular** (or T, Circular) and the subtitle names the shape and concrete class, for example **Rectangular · C30**. The footer shows **C30 · Y-550**, or **Invalid input**, with **Cancel** and **Apply**. On desktop, and in any window at least 840 dp wide, the window has three columns. The left column holds the material tabs and the shape list, each shape with its glyph. The centre column shows the section drawing large, elevation A under it and the properties under that. The input panel on the right has the tabs **Section** (dimensions, longitudinal and shear reinforcement), **Materials**, **Carbon**, **Durability and service** and **Fire**. In a narrower window everything is one column.

Shape and dimensions

Choose **Rectangular**, **T** or **Circular** in the shape list, or in a narrow window in the choice above the dimensions. Changing the shape loads that shape's defaults and keeps your materials. All dimensions are in mm.

Shape	Dimensions and defaults	Reinforcement default
Rectangular	h 600, b 400, cover 30	Top 2 Ø16, bottom 3 Ø16, c 46; stirrups Ø8 at 200
T	h 600, **Flange width** b_f 800, **Flange thickness** h_f 150, **Web width** b_w 300, cover 30	Flange 2 Ø16, web 3 Ø16, c 46; stirrups Ø8 at 200
Circular	**Diameter** D 600, cover 30	8 Ø20 on a ring of radius 252 to the bar centres; ties Ø8 at 190

Longitudinal reinforcement

A rectangular section has **Top reinforcement** and **Bottom reinforcement**; a T section has **Flange reinforcement** and **Web reinforcement**. Each group is a list of rows with **Count** n, **Size** Ø and **Axis distance** c. A group with several rows adds the row count to its title.

- **Add new** copies the row with the largest c and places it at c + c / rows. A new row in an empty group is 2 Ø20 at c 48.
- Changing a bar size moves c by ΔØ/2, so the bar keeps its clearance.
- You can remove rows down to none.

A circular section has one ring with **Count** (a whole number, at least 3), **Size** and **Radius** r; a size change moves r by −ΔØ/2.

Shear reinforcement

Stirrup reinforcement is on by default, with **Stirrups size** and **Stirrups spacing**. Untick it and the size and spacing are disabled, no stirrup is stored and none is drawn. **Cot(Θ)** offers 1, 2, 2.5 and Custom (1 to 2.5); the default is 2.

Source: spec/beam/concrete-section.md rules 1–5; spec/beam/cross-section.md rule 5.

Materials

Concrete strength offers C12 to C90 and Custom; the default is C30 (C30/37). **Cylinder compressive strength** f_{ck}, **Cube compressive strength** $f_{ck,cube}$ and **Density** are editable only for Custom. A class weighs 25 kN/m³, reinforced concrete by EN 1991-1-1 Table A.1 note 1, so its density is 25 000 / 9.81 = 2548.4 kg/m³. The older classes C8, C28, C32 and C100 open and show in older projects but are not offered.

Reinforcement steel offers **Y-550**, **K-500** and Custom; the default is Y-550 with f_{yk} 550 MPa and E_s 200 000 MPa, editable only for Custom. **Ductility class** is A, B or C, default B.

The **Carbon** tab holds the card **Product stage carbon (A1-A3)** with **Concrete factor** in kg CO_2e/m³ and **Reinforcement factor** in kg CO_2e/kg, each with its **Factor source**. They start from the beam's saved factors, else from Boverkets klimatdatabas 02.07.000: the ready-mix row of the strength class (C12/15 and C16/20 have none and start empty), which follows the class while you have not typed a factor, and reinforcement 0.745 (6000000154). The lines under

them give the concrete volume (gross area × length) and the longitudinal bars' mass, each with its footprint, and the total. Apply saves typed factors with the section.

A strength class above C90/105 is outside EN 1992-1-1 Table 3.1: the beam shows **The concrete strength class lies above C90/105, outside EN 1992-1-1 Table 3.1.**

Source: spec/beam/concrete-section.md rule 6.

Cover, durability and serviceability

Cover and durability

This group holds **Concrete cover**, **Maximum aggregate size** (default 16 mm), **Exposure class** X0 to XA3 (default XC1, **Dry or permanently wet**), **Durability minimum cover** $c_{min,dur}$ and **Execution deviation** Δc_{dev}.

When you pick an exposure class, Statiko sets $c_{min,dur}$ and Δc_{dev} for the project's National Annex and sets the cover to $c_{nom} = c_{min,dur} + \Delta c_{dev}$. An XF or XA class leaves all three unchanged.

National Annex	$c_{min,dur}$ table	Δc_{dev}
Denmark	DS/EN 1992-1-1 DK NA Tabel 4.4N NA	5 mm
Eurocode, Sweden, Serbia, Custom	EN 1992-1-1 Table 4.4N, S4 (Eurocode recommended)	10 mm

$c_{min,dur}$ and Δc_{dev} are standard value pickers: they offer the standard's values and Custom last, which opens a number field. A derived value shows its source, for example **XC1 · Table 4.4N** (Denmark **XC1 · Table 4.4N NA**), and a note naming the annex, **Eurocode recommended** or **DS/EN 1992-1-1 DK NA**. A stored value that matches no choice shows as Custom. A new concrete member starts from the XC1 values of the project's annex.

Serviceability

The **Serviceability** group is collapsed by default. It holds **Cement class** (**Slow**, **Normal**, **Rapid**; default Normal), **Relative humidity** (Inside 50 %, Outside 80 %, Custom 0–100; the default 70 % shows as Custom), **Loading age** t_0 (default 28 d), **Design age** (50 years, 100 years, or Custom above t_0; default 50 years) and **Crack width limit** w_{max}. w_{max} follows the exposure class from Table 7.1N (Denmark Tabel 7.1 NA), 0.4 mm for XC1; an XF or XA class leaves it. The deflection limit is set in the design code (Chapter 5).

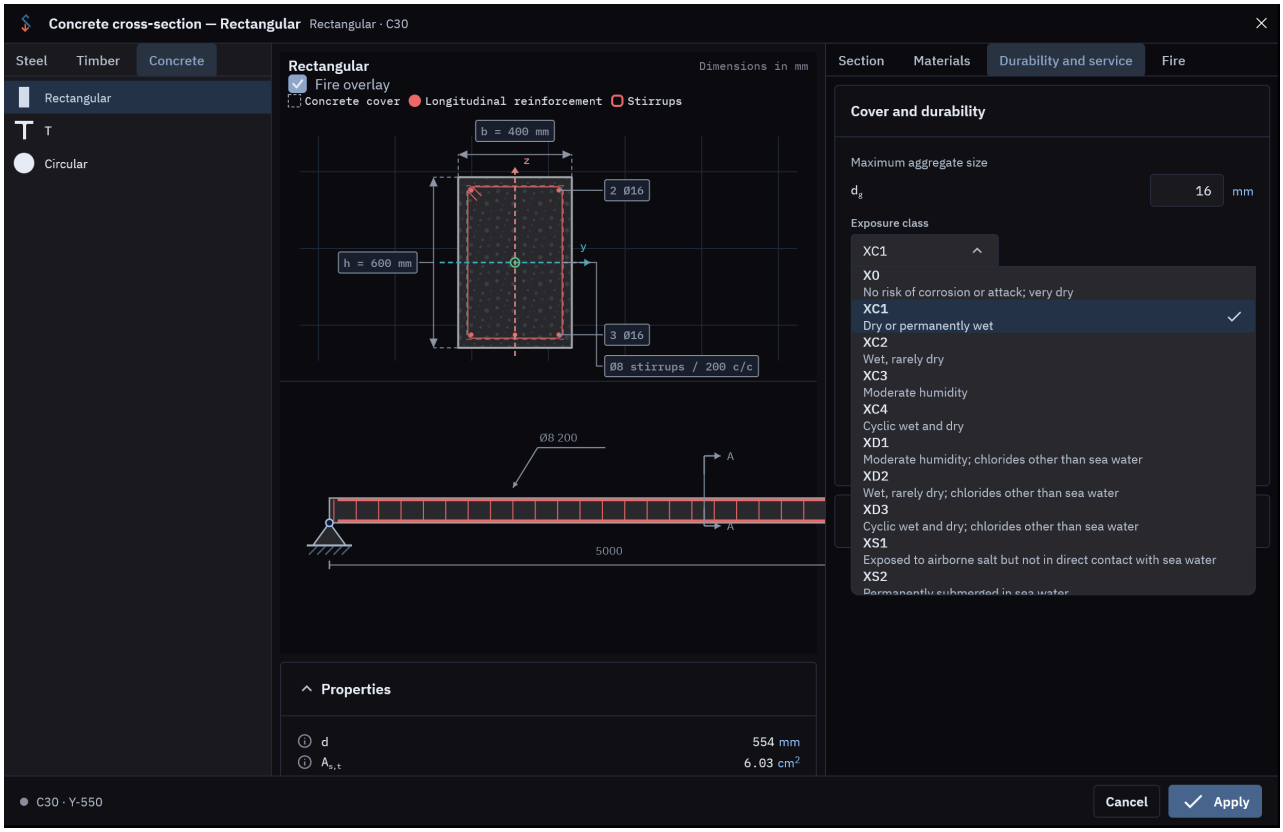


Figure 7.2 · The Exposure class list open in the Durability and service tab, each class from X0 with its description and XC1 Dry or permanently wet ticked

Source: spec/beam/concrete-section.md rules 7–9.

Properties, drawing and Apply

The properties are **Effective depth** d, **Tension reinforcement area** $A_{s,t}$, **Compression reinforcement area** $A_{s,c}$, **Area of cross section** A, and I_y and I_z. Statiko calculates them on every valid change; a value the engine does not give shows Unavailable, never 0.

The section drawing shows the outline to scale, the dashed cover line, the stirrup, the bars, the overall width and height, callouts such as **2 Ø16** and **Ø8 stirrups / 200 c/c**, a legend and **Dimensions in mm**. Elevation A below it shows the beam at its length with supports and point loads, the section cut, the stirrups and the bar lines with a dimension chain.

Each field is checked as you type. The messages are **Must be greater than zero.**, **Cover and stirrup must fit inside the section.**, for a T **Web width must not exceed flange width.**, **Flange thickness must be less than height.** and **Cover and stirrup must fit inside the web and flange.**, for a circle **Enter a whole count of at least 3.** and **Cover, stirrup, bar and radius must fit inside the section.**, for rows **Enter a non-negative whole count.**, and **Cot(Θ) must be between 1 and 2.5.** While a field is invalid the drawings stay at the last valid geometry, dimmed, with **Last valid geometry** and **Correct the marked field to update the drawing.**, and Apply is disabled.

Apply writes the section, the materials and the detailing settings in one project edit, undone in one step. Cancel, close, `Esc` and Back leave the analysis unchanged; an edited draft asks **Discard changes?** first. There is no create, rename or delete for concrete profiles: the section belongs to the member.

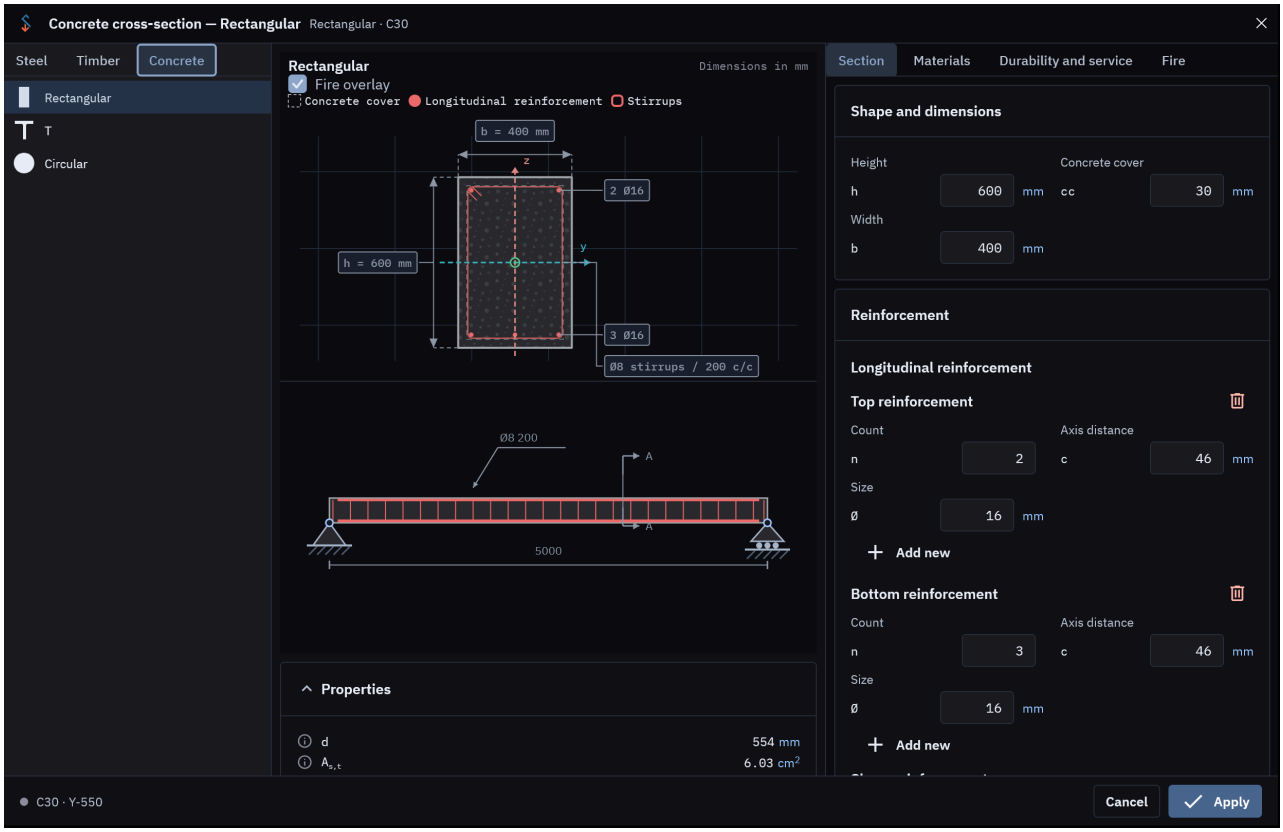


Figure 7.3 · The concrete cross-section window on desktop: the material tabs and the shape list on the left, the section drawing with its callouts, the elevation with cut A and the properties in the centre, the Section tab on the right

Source: spec/beam/concrete-section.md rules 10–16.

Detailing inputs in the inspector

The inspector of a concrete beam has a **Shear** group with **Cot(Θ)** (1, 2, 2.5 and Custom 1 to 2.5), the same value as in the window.

On a T section the group adds the checkbox **T-flange/web longitudinal shear**, off by default. Switch it on to show **T-flange · compression** (1.0, 2.0, Custom 1.0 to 2.0), **T-flange · tension** (1.0, 1.25, Custom 1.0 to 1.25), each noted **Eurocode recommended**, and A_{sf} / s_f in mm²/m. It starts at 2.0, 1.25 and 0.

Tick **Specify anchorage and lap details** to open the **Anchorage** and **Laps** groups, for rectangular and T sections. A circular section has no detailing inputs.

Anchorage

Add anchorage adds a card for the first free bar and end, titled for example **Bar 1 · Ø16 · Start**. Each card has **Force state** (**Tension**, **Compression**), **Bond condition** (**Good bond**, **Poor bond**), **End shape** (**Straight**, **Standard bend**, **Standard hook**, **Standard loop**), **Design stress** σ_{sd} in MPa, **Available length** in mm, **Mandrel diameter** in mm (not for Straight) and Delete. A new card is Tension, Good bond, Straight, 0 MPa, 0 mm.

Laps

Tick **Lap schedule is complete (including no laps)** when the list is complete. **Add lap** adds a lap on the first bar. Each lap has the bar, start and end position, force state, bond condition, design stress, **Bars lapped at section** (**< 25 %**, 33 %, 50 %, **> 50 %**, Custom 0 to 100), **Clear spacing between lapped bars** in mm, **Provided transverse reinforcement area** in mm^2, the checkboxes **Transverse reinforcement distributed in outer thirds**, **Required close-lap links provided** and, under Compression, **Compression-lap end bars provided**, and Delete.

Every detailing field is validated by the engine; an invalid field shows its message, keeps the last valid input, and the checks show Invalid input. Each edit is one Undo step and the calculation runs automatically.

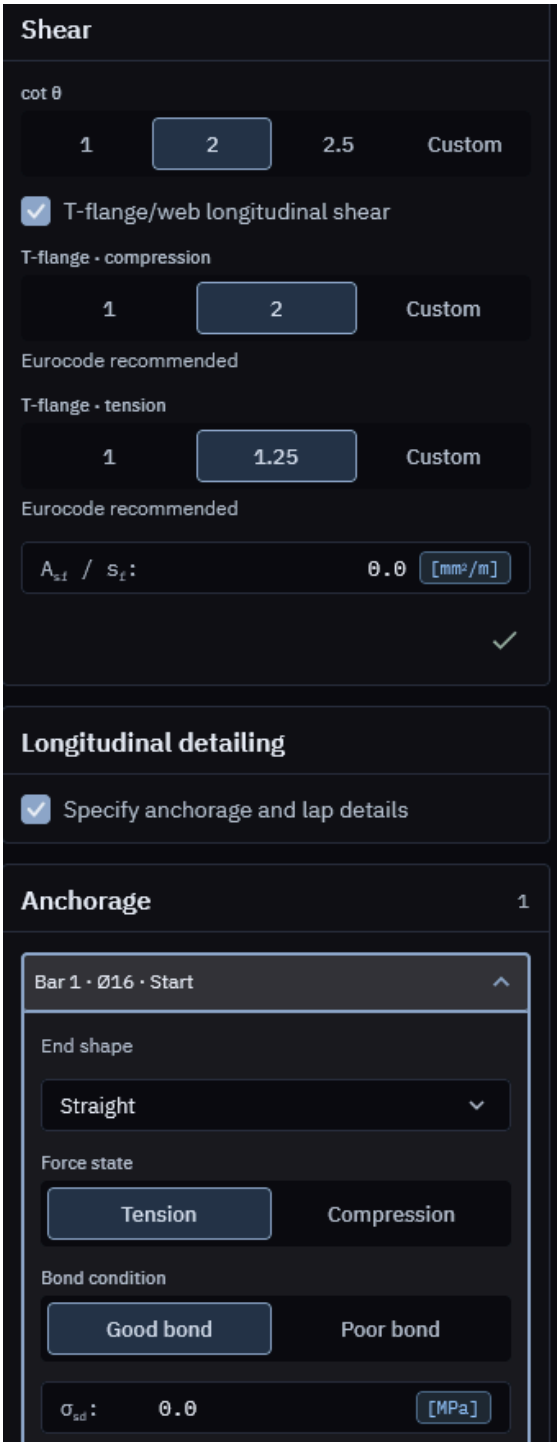


Figure 7.4 · A concrete T beam: the Shear group with cot θ, T-flange/web longitudinal shear ticked with its compression and tension choices, Specify anchorage and lap details ticked and the anchorage card **Bar 1 · Ø16 · Start**

Source: spec/beam/concrete-workspace.md rules 5–11.

Design code and checks

For a concrete beam the Design code card shows **EN 1992-1-1 · Concrete**, and the dialog shows γ_c, γ_s, α_{cc} and α_{ct} with Eurocode recommended values, editable under Custom values. The deflection limit is **L/250**, **L/500** or Custom, default L/250.

Concrete beams calculate with **Eurocode recommended values**, **Custom values**, **Denmark (DS EN)** and **Serbia (SRPS EN)**. **Sweden (SS EN)** gives **Concrete does not calculate under Sweden (SS EN): the Swedish National Annex to EN 1992-1-1 is not in Statiko yet.** Serbia uses the Eurocode recommended values (Chapter 20).

The checks column lists Bending +, Bending −, Shear, Stresses, Crack width, Deflection, Anchorage, Laps, T-flange longitudinal shear (T sections only) and Torsion, each with its clause. How they are calculated is described in Chapter 20; reading them is described in Chapter 12. Concrete fire design is in Chapter 13.

Source: spec/beam/concrete-workspace.md rules 3, 4, 12.

CHAPTER 8

Supports and lateral restraint

Supports decide where the beam is held and how, and they also decide its length: Statiko computes the member length from the first and last support or hinge, so you never type a span. This chapter covers the Supports section of the inspector, the timber bearing length, and the top flange restraint on the Member card, which changes how lateral-torsional buckling is treated.

Support cards

The **Supports** section sits after the Member card. Its header shows the sort button (**Sort by position**) and the number of supports. Each support is a card showing its glyph, a title, a restraint line, its position and a chevron.

- The title is a letter and the kind, for example **A · Fixed**. Letters A, B, C … always follow position from left to right, also for supports you have just added.
- The restraint line says what the support holds.
- The value is **x** and the position, without trailing zeros.

Kind	Restraint line
Fixed	w, φ restrained
Pinned	u, w restrained
Roller	w restrained
Hinge	moment release
Free	no restraint

Here u is the axial displacement, w the vertical displacement and φ the rotation. A hinge is an internal moment release in the beam. A support whose restraints match none of the five kinds, for example from an older file, is shown as Custom with its own glyph and its restrained symbols; you cannot pick Custom yourself.

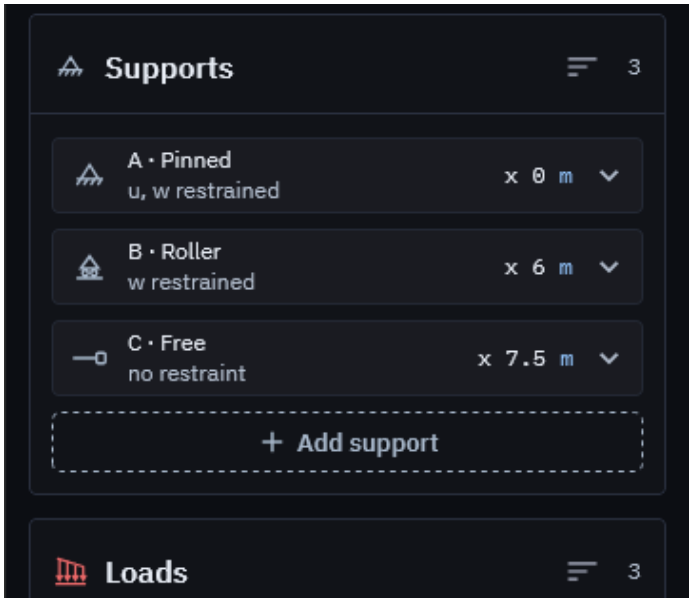


Figure 8.1 · The Supports section with three closed cards, A · Pinned, B · Roller and C · Free, and the dashed Add support row

Source: spec/beam/supports.md rules 1, 5–8, 16.

Adding and editing supports

Click a card to open it under its summary. Click the header again or press `Esc` to close it; there is no Done button. Only one card is open at a time across Supports and Loads, and opening a card selects that support in the drawing. Closing the card, or clicking the selected support again, returns the selection to the member.

An open card has two rows. The first holds the type picker and the **x** field. The second shows the kind and restraint line, with the bin button **Delete support**. Changing the kind keeps the position and recalculates.

1. Click **Add support** at the end of the section.
2. Choose **Fixed**, **Pinned**, **Roller**, **Hinge** or **Free** from the palette. With the keyboard, use `↑` and `↓` and press `Enter`.
3. Type the position in **x**. Until it is valid, the card is a draft: its summary shows **x —**, it sits last, the status is Invalid input, and the calculation uses the model without it.
4. Press `Tab` or `Enter`. The support takes its letter in position order.

Cards keep their order while you edit, so a card never jumps away from the cursor. Press **Sort by position** to reorder them by x. `Tab` moves through the open card, then into the next support card, and from the last support into the first load card; `Shift`+`Tab` goes back. On a phone a card opens without raising the keyboard.

Number fields accept digits, the minus sign and both decimal separators. Positions use the Supports unit from Settings › Units › Advanced when you have set one, otherwise your Length unit. Changing the unit changes only the display, not the stored value or the results. Undo and Redo cover every change to a support in the model. A draft is not in the model yet, so Undo and Redo leave it and its open card as they are.

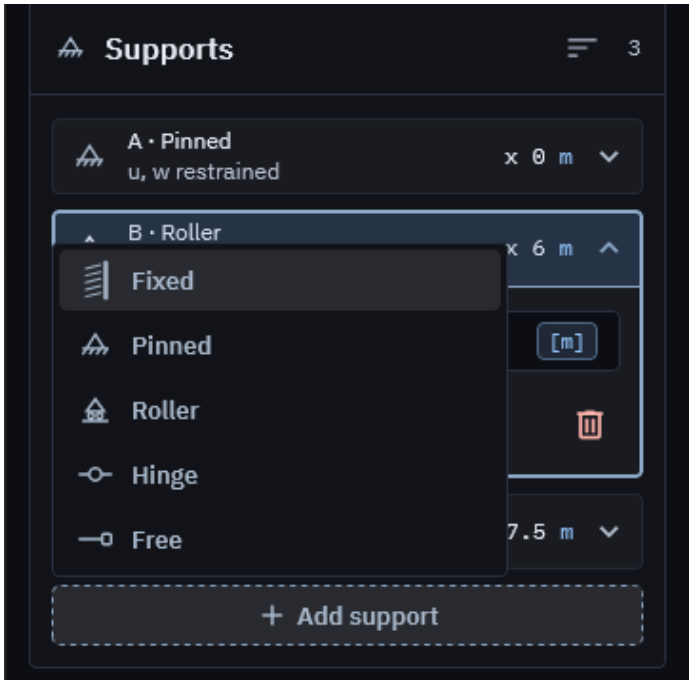


Figure 8.2 · Support B open with its type list: Fixed, Pinned, Roller, Hinge and Free

Source: spec/beam/supports.md rules 2, 3, 9–11, 13, 14, 17–19, 26, 27.

Length, origin and the minimum of two supports

The member length L is the position of the last support or hinge minus the position of the first, Free supports included. It shows in the Member card header and at the end of the dimension chain. Moving a support recomputes the length; it never moves another support.

x = 0 is always the left end. If your first support is at a positive x, Statiko adds a Free support at 0 for the left overhang. Its x is locked, and its card always says **Added automatically. The beam starts at 0 m. Move the first support to change the overhang.** The Free support at the right end stays editable.

A beam starts with two supports and always keeps at least two, the automatic Free support included. With two left, **Delete support** is disabled with the tooltip **At least two supports are needed for calculation.** If you delete the automatic left Free support, every support, hinge and load (both ends of a distributed load) shifts left so that the first support is at 0.

> Two supports are the minimum, not a guarantee of stability. Two supports that leave the beam unstable still show the unstable error.

Source: spec/beam/supports.md rules 22–24, 29.

Support errors

A position error marks the card in the danger colour and shows the sentence once: under x on the open card, or in the issue line on a closed card.

- **Negative support positions are not allowed (−1.00 m).**
- **Support position at 4.00 m is unavailable.** (another support is already there)

- **Hinge on fixed end at position 0.00 m is not allowed.**
- **Free end cannot be inside beam bounds at location 3.00 m.**
- **Hinge at position 9.00 m is outside of beam bounds.**

An error that involves two supports, such as **Hinge-Hinge element from 2.00 m to 4.00 m is not allowed.**, marks both cards. An unstable beam, **Hinge amount exceeds the allowed amount according to the Equilibrium equation.**, marks the offending hinge cards. Too few supports shows **At least two supports are needed for calculation.** under the section header.

While any support error remains, the previous result is shown as outdated; it never shows a pass.

Source: spec/beam/supports.md rules 20–22, 25.

Timber bearing length

On a timber or glulam beam, each **Fixed**, **Pinned** and **Roller** support card has a second field under x: the bearing length l_b (**Bearing length**), in the Supports unit, empty by default. Hinge and Free supports, and every support of a steel beam, have no such field.

> While a timber support has no bearing length, the bearing check is Not checked with **Support B has no bearing length.** (naming the support), and the timber summary is built from the other checks. Enter l_b on every bearing support to have the bearing verified. The check itself is described in Chapter 19.

Source: spec/beam/supports.md rule 30.

Top flange lateral restraint

The Member card has the checkbox **Top flange laterally restrained** under the Material and Product standard rows, for steel and timber beams. It is unticked for every new beam and for files saved before this option existed. Ticking it is a project edit: Undo and Redo cover it, and the beam recalculates. With the box ticked, the Member header meta reads **Class 1 · top flange restrained**, or **top flange restrained** without a current result.

Tick the box when a slab, deck or sheeting holds the top flange laterally along the whole length. Bottom-flange restraints, restraints at discrete points and restraint over part of the length are not available in this version.

> By ticking the box you declare that the restraint is sufficient. Statiko does not check its sufficiency (EN 1993-1-1 Annex BB.2).

Which combinations it covers

A ULS combination is covered when the box is ticked and no moment along the beam is negative, so the top flange is in compression everywhere. A combination with a hogging moment anywhere, over an internal or fixed support, on a cantilever or under uplift, is not covered, and lateral-torsional buckling is checked for it as usual. The LTB model treats every support that holds a translation as a fork support, holding lateral displacement and twist.

Material	Covered combination
Steel	LTB is Not evaluated (EN 1993-1-1 6.3.2.1(2)); no M_{cr}, χ_{LT} or $M_{b,Rd}$. The card is neutral and reads **Top flange laterally restrained: not susceptible to lateral-torsional buckling (EN 1993-1-1 6.3.2.1(2)).** Bending keeps its bending and warping interaction.
Timber	LTB stays evaluated with k_{crit} = 1.0 (EN 1995-1-1 6.3.3(5)). The card adds **Top flange laterally restrained: k_crit = 1.0 (EN 1995-1-1 6.3.3(5)).**

Not evaluated is its own state and is never counted as a pass. The LTB card shows the worst state first, then the checked combination with the highest utilisation; only when every ULS combination is covered does it show Not evaluated. If a combination is not covered, the card adds **The top flange restraint does not cover** followed by the combination and **the bottom flange is in compression.**

In the check details the **Restraint** line reads **Top flange laterally restrained** or **None**. The steel report states the declaration in its structural system section and lists it among the limitations in the appendix. How M_{cr} and the buckling checks are calculated is described in Chapter 17.



Figure 8.3 · A simply supported IPE 220 with Top flange laterally restrained ticked: the Member card reads Class 1 · top flange restrained, the Lateral Torsional Buckling card is neutral with the not-susceptible sentence, and the Moment header shows no M_{cr}

Source: spec/beam/lateral-restraint.md rules 1–16.

CHAPTER 9

Loads and self-weight

The Loads section lists every characteristic load on the beam: point loads, moments and distributed loads. Each load has a load action, which tells the EN 1990 combinations which partial and ψ factors apply. The section also holds the self-weight switch. This chapter shows how to add and edit loads, where a load acts over the section height, and what the load errors mean.

The Loads section and self-weight

The **Loads** section follows Supports in the inspector. Its header shows **Sort by position** and the number of loads.

Under the header, tick **Include self-weight in G** to add the beam's own weight to the permanent action G. A line then shows **Characteristic self-weight:** and the value from the current section, in your force-per-length unit. If the section cannot be resolved, a reason shows instead of the value. A new concrete beam starts with self-weight on; other new beams start with it off.

> A beam with no load and self-weight off cannot be calculated: **There is no load to calculate. Add a load or include the self-weight.**

Source: spec/beam/loads.md rule 1; spec/beam/concrete-workspace.md rule 2.

Reading a load card

Load cards look and behave like support cards: a neutral border, lighter when closed and stronger when open or selected. Only one card is open at a time across Supports and Loads; `Esc` closes it.

- A point load or moment shows two lines: the type and the load action, then the value and **x** with its position.
- A distributed load shows the type and action, then a small span diagram: the end values above, the load shape on the member line, and x_1 and x_2 below. The shape may be uniform, sloped or change sign.

Values have no plus sign; negative values use the true minus −. Trailing zeros are dropped. A new load shows — for each value until you enter it.

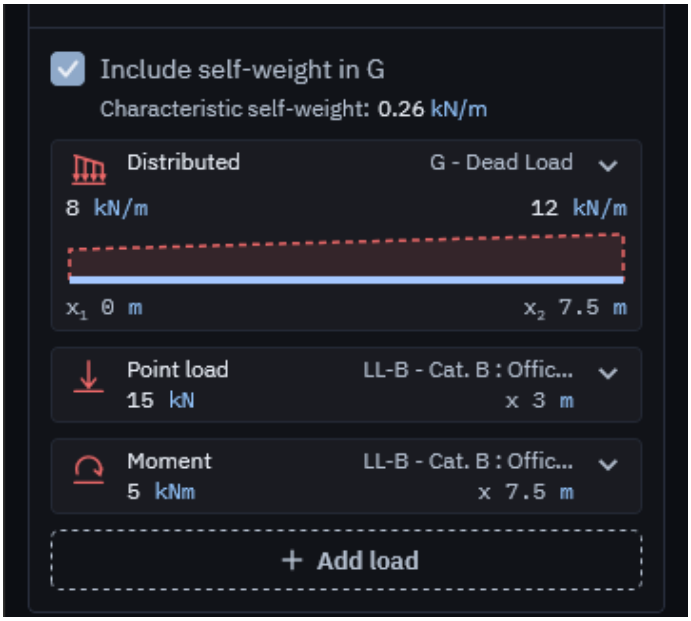


Figure 9.1 · The Loads section: Include self-weight in G with the characteristic self-weight, a sloped distributed load, a point load, a moment and the dashed Add load row

Source: spec/beam/loads.md rules 2–7.

Adding and editing loads

1. Click **Add load** at the end of the section.
2. Choose **Point**, **Moment** or **Distributed**. The new load takes the action **Dead Load** (G), its card opens and the first field has focus.
3. Choose the load action in the select next to the type picker.
4. Enter the values, each on its own row: for a point load x and F; for a moment x and M; for a distributed load x_1, x_2, q_1 and q_2.
5. Press `Tab` or `Enter`. The calculation runs automatically.

Until its fields are valid, a new load is a draft: it sits last, the status is Invalid input, and the calculation runs without it. Changing the type keeps the action and the start position and clears values the new type does not have. The bin button **Delete load** sits on the card's last row.

The load action select lists Dead Load, the imposed-load categories A to H (for example A **Domestic, residential areas**, B **Office areas**, H **Roofs**), Wind Load, Snow Load and Custom Load, each with its glyph. Long names end with an ellipsis; the full name is in the tooltip. How each action enters the combinations is described in Chapter 15.

Cards keep their order while you edit. **Sort by position** orders them by x, or x_1 for distributed loads, and is one Undo step. `Tab` moves through type, action, values, the application point buttons, e_z (only when unlocked), e_y and Delete, then into the next load card; after the last load it reaches **Add load**. On a phone a card opens without raising the keyboard.

Number fields accept digits, the minus sign and both decimal separators. An unfinished entry such as `-` or `1,` keeps its text, marks the card and shows **Enter valid numbers before calculating.** Positions, forces, line loads, moments and self-weight use the Loads unit from Settings › Units › Advanced when you have set one.

Source: spec/beam/loads.md rules 8–12, 19–22, 25, 27.

Application point and eccentricity

Point and distributed loads have an application point that says where over the section height the load acts. The card shows **Top**, **Middle**, **Bottom** and a lock on one row, then the vertical eccentricity e_z (e_{Pz} for a point load), then the lateral eccentricity e_y. Moments have no application point.

- **Top** is the top fibre above the centroid ($z_{max} - z_C$), **Middle** is 0 and **Bottom** is the bottom fibre ($z_{min} - z_C$), from the current section and not rounded. For an IPE 220 that is +0.11 m, 0 and −0.11 m.
- While the lock is closed, the pressed preset drives e_z and the field is disabled.
- Open the lock to type your own e_z; the presets are no longer marked.
- Closing the lock again picks the preset that matches e_z within 0.5 mm, or Top if none matches.
- e_y is 0 by default.

The tooltips read **Attack Point Top**, **Attack Point Middle**, **Attack Point Bottom**, **Enable custom load attack point for LTB** and **Disable custom load attack point for LTB**: the application point matters for lateral-torsional buckling (Chapter 17).

A new point or distributed load starts locked at Top. When you change the section, every locked load keeps its preset and takes the new height; your own values stay. If the section fibre heights cannot be found, the presets and lock are disabled with a reason on the card, such as **Application point presets require a valid section.**, and e_z keeps its value. An older distributed load with different start and end eccentricities shows **Start and end eccentricities differ. The start values are shown; editing an eccentricity applies it to both ends.**

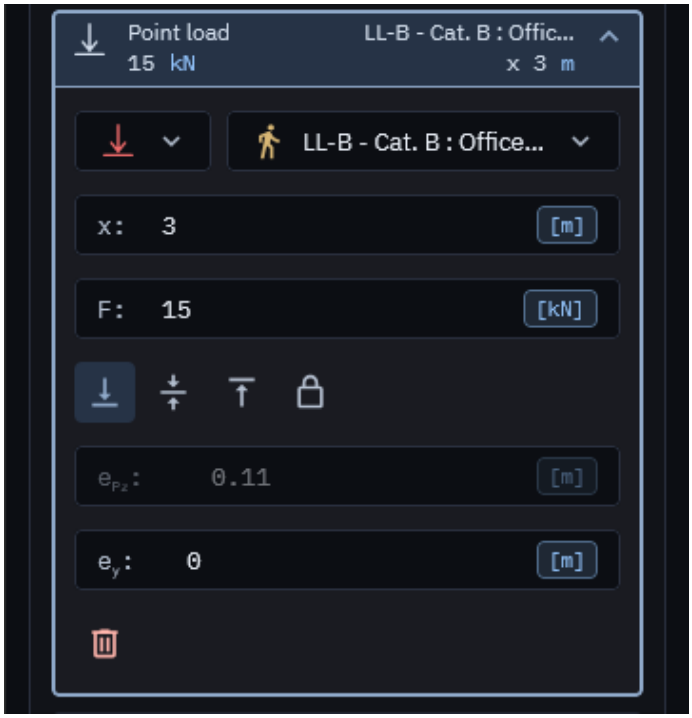


Figure 9.2 · An open point load: x and F, the three application point buttons with the lock, e_{Pz} disabled, e_y and the delete button

Source: spec/beam/loads.md rules 13–17.

A moment on a hinge

When a moment sits on a hinge (within 1 mm of its position), the card shows **Acts on** with **Left of the hinge** and **Right of the hinge**, default Right, and the hint **The results differ by side.** Choose the side the moment is applied to: each side belongs to a different part of the member. Moving the moment off the hinge hides the choice and keeps your side.

Source: spec/beam/loads.md rule 18.

Load errors and axial loads

A load must lie between the first and the last support, hinges and Free supports included. Otherwise the card turns to the danger colour and shows **Load positions must be within the member bounds.** under the position. A distributed load whose end is not after its start shows **The end position must follow the start position.** The status is Invalid input and the drawing marks the load.

> Loads keep their positions when you move supports. If you shorten the beam, a load past the new end stays in error until you move it; the error clears as soon as it is inside again. Only deleting the automatic left Free support shifts loads (Chapter 8).

An axial load from an existing file shows as a read-only card with its action, position and force and **Axial loads are not editable yet.** You cannot add axial loads in this version.

Source: spec/beam/loads.md rules 23, 24, 26.

CHAPTER 10

The structural system drawing

The Structural system drawing shows the beam as you have modelled it: the member, its supports, the characteristic loads, the support reactions of the selected load combination, and the dimension chain with the computed length. Use it to check your input at a glance and to read the reactions. The drawing never changes the model; you edit supports and loads in the inspector.

The panel

The panel sits at the top of the workspace, under the header **Structural system**, with the result graphs below it. It has a fixed height and a plain dark canvas without a grid. The X and Z axes sit at the bottom left.

The drawing and every result graph share one horizontal scale with the same margins, so a support, a load position and a graph station at the same x line up at every window width. Dashed vertical guides run down from each support and hinge to the dimension line.

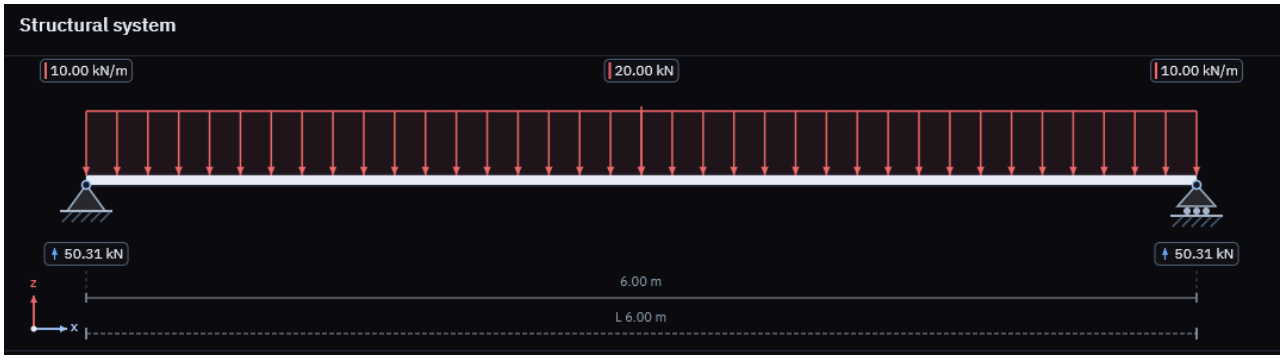


Figure 10.1 · A steel beam pinned at 0 and on a roller at 6 m with a distributed and a point load and a current result: load badges, reaction badges on the guides, the dimension chain ending L 6.00 m and the axes

Source: spec/beam/structural-system-drawing.md rules 1–6.

Member, supports and loads

The member is drawn with a dashed reference axis and split into parts at internal hinges. When the Member card is selected, all parts glow light blue.

Support	Glyph
Fixed at an end	One bold line through the beam end with five thin hatches on the outer side
Fixed inside the span	Two bold lines across the beam with five hatches between them
Pinned, Roller	Triangles on hatched ground
Hinge	A ring
Free end	A square

Loads sit above the member in the load colour: point loads as arrows, moments as arcs, distributed loads as a filled area with arrows. A distributed load that changes sign is drawn as one straight line across the member with a fill triangle on each side of the zero.

The drawing always shows the characteristic loads you entered. It never multiplies a load by a partial factor; the factored design loads appear only in the PDF report's figure (Chapter 14).

Source: spec/beam/structural-system-drawing.md rules 7–10, 26.

Values and reactions

Each force value sits in a small badge with a thin grey outline. A load badge has a short red bar before its value; a reaction badge has its light-blue glyph there instead. Load and reaction values show two decimals.

- Load values keep their sign with the true minus −, for example **24.50 kN/m** or **−16.20 kN/m**.
- Reaction values are magnitudes: the arrow or the turning direction of the arc shows the direction. A downward reaction reads **1.34 kN** under a down arrow.

Each support shows one badge per non-zero reaction component of the selected combination: vertical force, moment and torque. Zero components are not drawn. The badges sit below the member, centred on the support's guide, stacked force, moment, torque. A badge that would overlap a neighbour drops one row. In the sign convention, a positive force points up and a positive moment turns anticlockwise. Tables and the report keep the signed components with their axis system named.

The reactions belong to the combination selected on the Load combinations card (Chapter 5); change the combination and the reactions change with it.

> Every non-zero support moment is drawn, whatever the support kind. A moment at a pinned or roller support points to an engine fault; it stays visible so that you notice it.

Source: spec/beam/structural-system-drawing.md rules 11–14, 18.

Dimensions and crowded labels

Positions live on the dimension chain under the beam: the segment lengths between supports and hinges, then **L** and the member length. No node names or positions are written on the member. Each dimension label is centred on its segment; if it overlaps its neighbour it moves to the other side of the line, and if neither side has room it moves past the end of the chain with a dotted leader. Where the drawing ends first, as on a phone with large text, the label moves in from the right edge to the first free row above, so it is always shown whole.

When load badges still overlap after placement, they fold into one cluster badge that reads the front value, a bar and the number of hidden labels, for example **5.00 kN | +4**. The front shows a point force first, then a distributed load, then a moment, and the largest value within that type.

1. Hover the cluster on desktop, or tap it on a touch screen. A list opens with each clustered load's type, value and x, sorted by x.
2. Hover a row to highlight that load in the drawing.
3. Click a row to select that load; its card is selected with it.

Zooming in or widening the window splits clusters again when the badges fit. Because the panel height is fixed, labels get their space first and the beam fits in the rest, mainly by shorter load arrows; the graphs below never move.

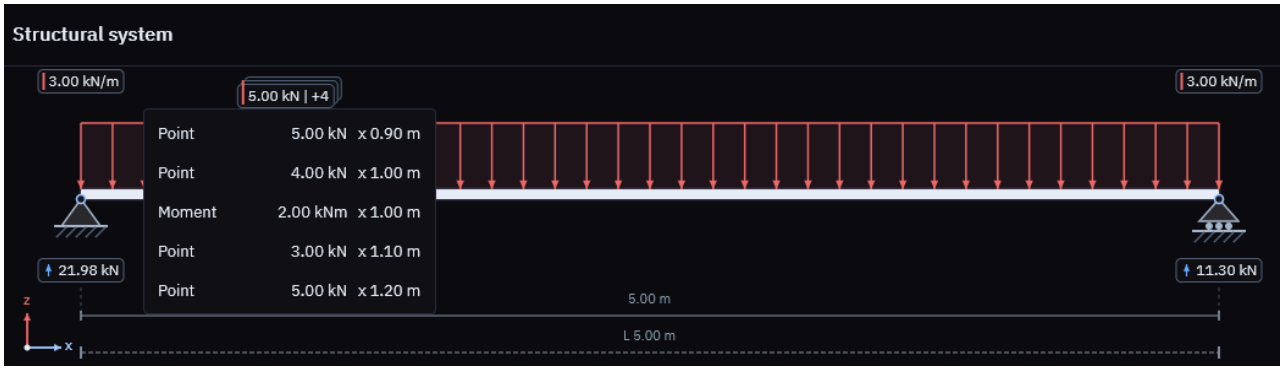


Figure 10.2 · The cluster badge 5.00 kN | +4 with its list of the loads it holds, sorted by x

Source: spec/beam/structural-system-drawing.md rules 16–18a.

Selection and errors

Select a support or load on its card or in the drawing. The selected element takes a stronger shade of its own colour, and every other element fades to about 40 %. The card and the drawing always agree. Hovering an element, its card or a cluster row strengthens only that element, without fading the rest.

A support or load with an input error is drawn in the danger colour, and its card carries the danger mark. A support in error has a red outline. An invalid load is drawn in danger red with a dashed outline and a small warning icon at its anchor. The unstable hinge of an unstable beam is drawn in the danger colour. An error that belongs to the whole section, such as too few supports, marks no element.

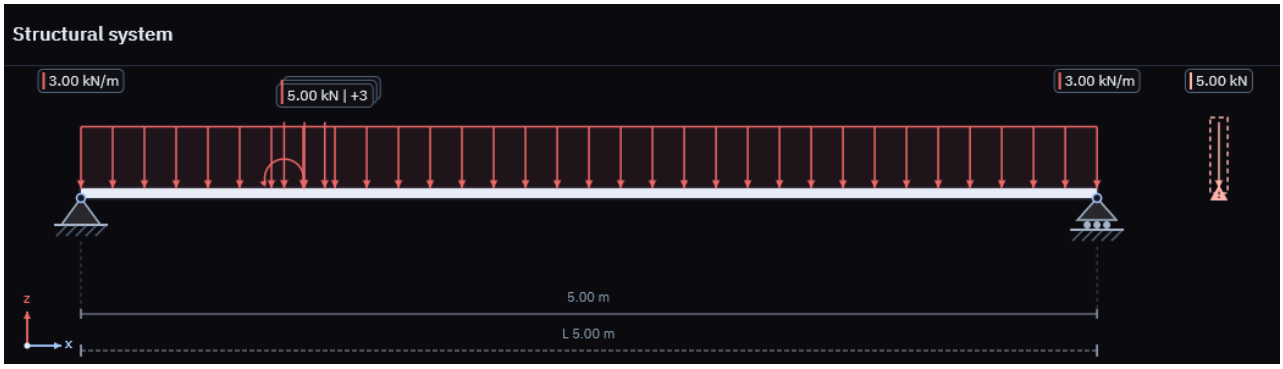


Figure 10.3 · A point load past the last support: drawn in red with a dashed outline and a warning icon, and no reactions

Source: spec/beam/structural-system-drawing.md rules 19–21a.

Calculation states

State	What you see
Current result	Member, supports, loads, reactions and dimension chain

State	What you see
First calculation running	No reactions; a progress line runs on the panel edge
Recalculating after a change	The previous reactions, dimmed, and the progress line
Not calculated (no loads)	The system without loads or reactions
Invalid input	No reactions; the invalid element in the danger colour

Reactions appear only for a current result, or for a previous result shown as outdated. The drawing has no Design loads view in this version.

Source: spec/beam/structural-system-drawing.md rules 15, 25, 29, 30.

PART III

Reading the results

CHAPTER 11

Result graphs

The result graphs show how the beam carries its loads: shear, moment, rotation, deflection, torsion and the natural vibration mode, plotted along the member for the load combination you have selected. Every curve is read from the same calculation result that the checks and the PDF report use, so what you see on the graph is exactly what the checks verify. This chapter explains the two graph views, what each part of a graph means, how the cursor readout works and what the graphs show while a calculation is running or cannot run.

Graph list and Dual-axis graph

The graphs fill the canvas of the beam workspace, under the **Analysis** tab. The canvas toolbar switches between two views:

- **Graph list** shows each quantity on its own plot, one below the other or one at a time.
- **Dual-axis graph** puts two quantities on one plot, with a ruler on each side, so you can compare them at the same position.

The same choice is in the **View** menu: **View › Graph list** and **View › Dual-axis graph** follow the toolbar and the toolbar follows the menu. On a phone both views are in the Results tab, which keeps the canvas toolbar with Dual-axis and shows the Graph list in Tabs by default (Chapter 4).

Source: spec/beam/graph-list.md rules 15–18; spec/beam/dual-axis-graph.md rule 14.

The six graphs

Graph list shows six graphs, always in this order:

Graph	Symbol	Default unit and decimals	Shown by default
Shear	V	kN, 2 decimals	Yes
Moment	M	kNm, 2 decimals	Yes
Rotation	θ	mrad, 2 decimals (rad or ° also available)	No
Deflection	δ	mm, 1 decimal	Yes
Torsion	T	moment unit (torque) or rotation unit (twist)	When the beam carries torsion
Natural Frequency	f_1	Hz, 2 decimals	For an SLS combination

Units follow **Settings › Units** (see Chapter 24). Rotation is off at first; tick it to see it.

The selected load combination drives every curve, deflection included. With **None** selected the graphs show the characteristic actions with unit factors. Changing the combination counts as an edit: the curves go outdated for a moment and then show the new combination.

Some graphs only make sense in some cases, so the app never draws an empty or meaningless plot. Instead the graph's checkbox or tab stays visible, greyed out, with its reason:

- Torsion: “No torsion: all loads act in the plane of the beam through the shear centre.”
- Natural Frequency with a ULS, fire or None combination: “Natural Frequency is shown for SLS combinations.”
- Any graph without a result: “No current result is available.”

Source: spec/beam/graph-list.md rules 1–7, 12, 13, 24.

Stacked and Tabs

In Graph list the two icons at the right end of the toolbar choose the layout:

- **Stacked** shows the graphs one below the other. A row of six checkboxes above them lets you hide a graph and bring it back; each visible graph also has its own checkbox. Stacked is the default from 840 dp window width.
- **Tabs** shows one graph at a time with all six tabs present. It is the default in narrower windows. A disabled tab keeps its reason.

View › Stacked / Tabs shares this choice. In the Dual-axis graph the layout icons are hidden and the menu item is disabled with “Choose Graph list to change its layout.”

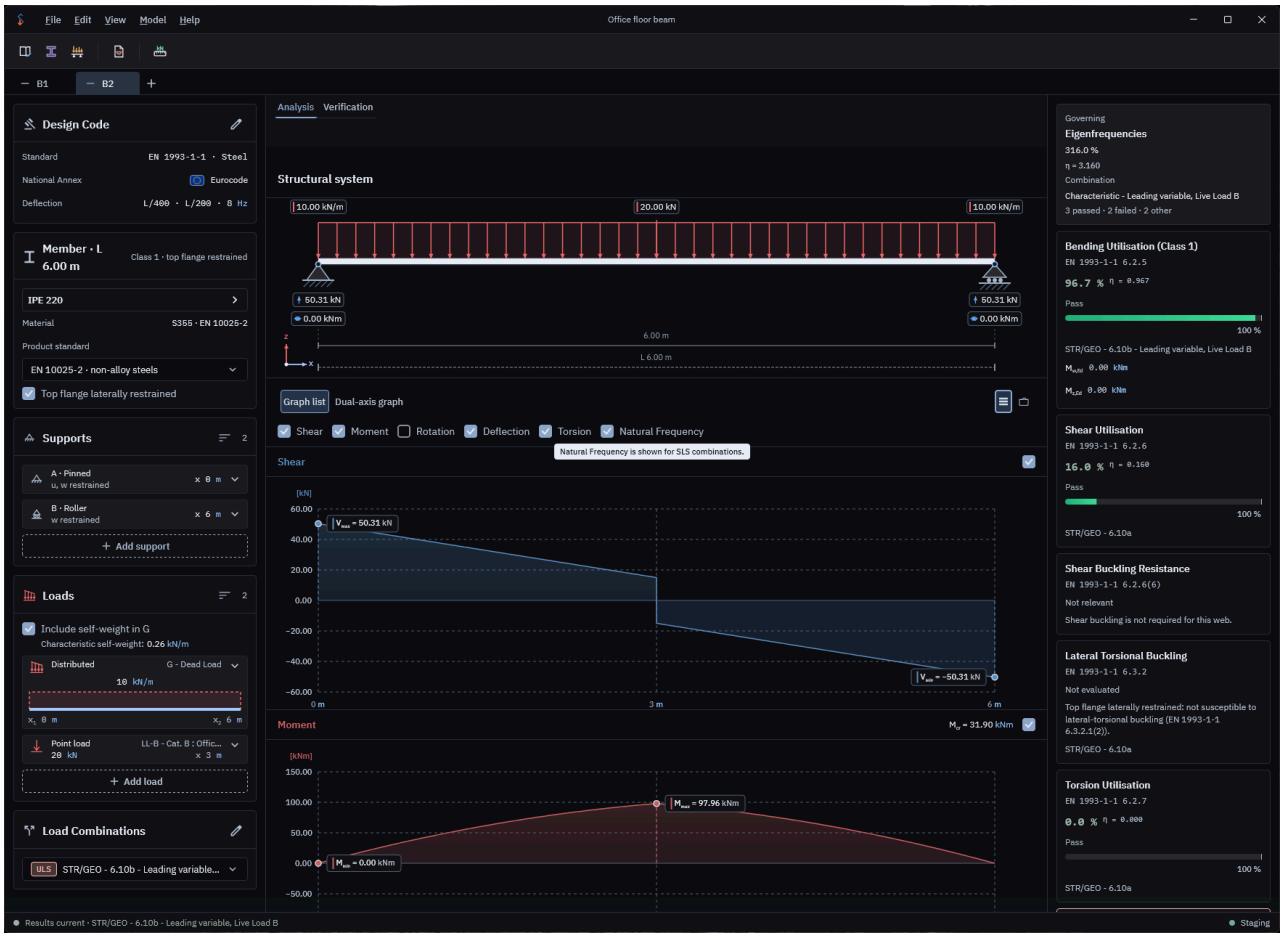


Figure 11.1 · The Graph list, Stacked, for a ULS combination: the checkbox row with Rotation unticked, the Natural Frequency reason, and the Shear and Moment plots with their badges and M_{cr}

Source: spec/beam/graph-list.md rules 15–18.

Reading a graph

Each graph is a flat panel on the workspace background with a thin line above it. Inside it you see:

- the curve in the quantity's colour, with a soft gradient fill down to the zero line;
- dashed vertical guides at the supports and other structural nodes, placed exactly where the structural system drawing above puts them, so positions line up;
- a ruler with plain values and, once above it, the unit in brackets in the curve's colour, for example **[kNm]**;
- the largest and smallest values marked with a filled dot, a dashed drop line and a small boxed badge such as **M_{max} = 29.70 kNm** or **δ_{max} = 12.4 mm**. Badges move to a free side so they never cover each other or the curve's edge.

Values have no plus sign; negative values use the true minus "−".

Two graphs add a reference:

- **Deflection** draws the span limit line **L/<limit>** from the design code, but only for an SLS combination; other combinations have no limit line.
- **Natural Frequency** draws the normalised mode shape for an SLS combination and shows the frequency in Hz in its badge. The shape's height is not a physical amplitude.

The Rotation graph includes both sides of a hinge.

The cursor readout

Move the pointer over a plot. A hollow ring appears on the curve at that position with a value badge beside it, and a small badge on the x axis reads **x = <position>**. The status bar never shows cursor values; it always shows the calculation state.

Source: spec/beam/graph-list.md rules 3–5, 8–12.

Controls in the graph headers

Four graphs carry extra information or controls in their header.

Torsion: Torque or Twist

A **Torque** / **Twist** switch chooses what the Torsion graph shows. Torque is the default. Twist plots the angle of twist ϕ along the beam in the rotation unit, with ϕ_{max} and ϕ_{min} badges. The choice lasts for the session and is not saved in the project file. The Dual-axis graph uses the same choice.

Natural Frequency: Mode and Animate

The **Mode** picker offers **Mode 1** up to the number of computed modes, at most five. The badge shows that mode's frequency f_n. Each new result returns to Mode 1. Tick **Animate** to see the shape swing: it repeats every two seconds whatever the frequency, while the axis stays fixed. Animate is off at first and lasts for the session.

Moment: M_{cr}

The Moment header shows **M_{cr} = <value>**, the elastic critical moment the lateral-torsional buckling check computed for the moment distribution of the selected combination (see Chapter 17). It is shown only when the check computed

it; while calculating, or when it is not available, the header has no M_{cr}.

Deflection of timber and glulam: u_{inst} and u_{fin}

For a timber or glulam beam with a characteristic SLS combination selected, the Deflection graph adds a dashed curve u_{fin}, the final deflection the final deflection check verifies, beside the instantaneous u_{inst}. The header reads **u_{inst} = … / u_{fin} = …** and the cursor badge shows both. Other combinations and materials show u_{inst} only.

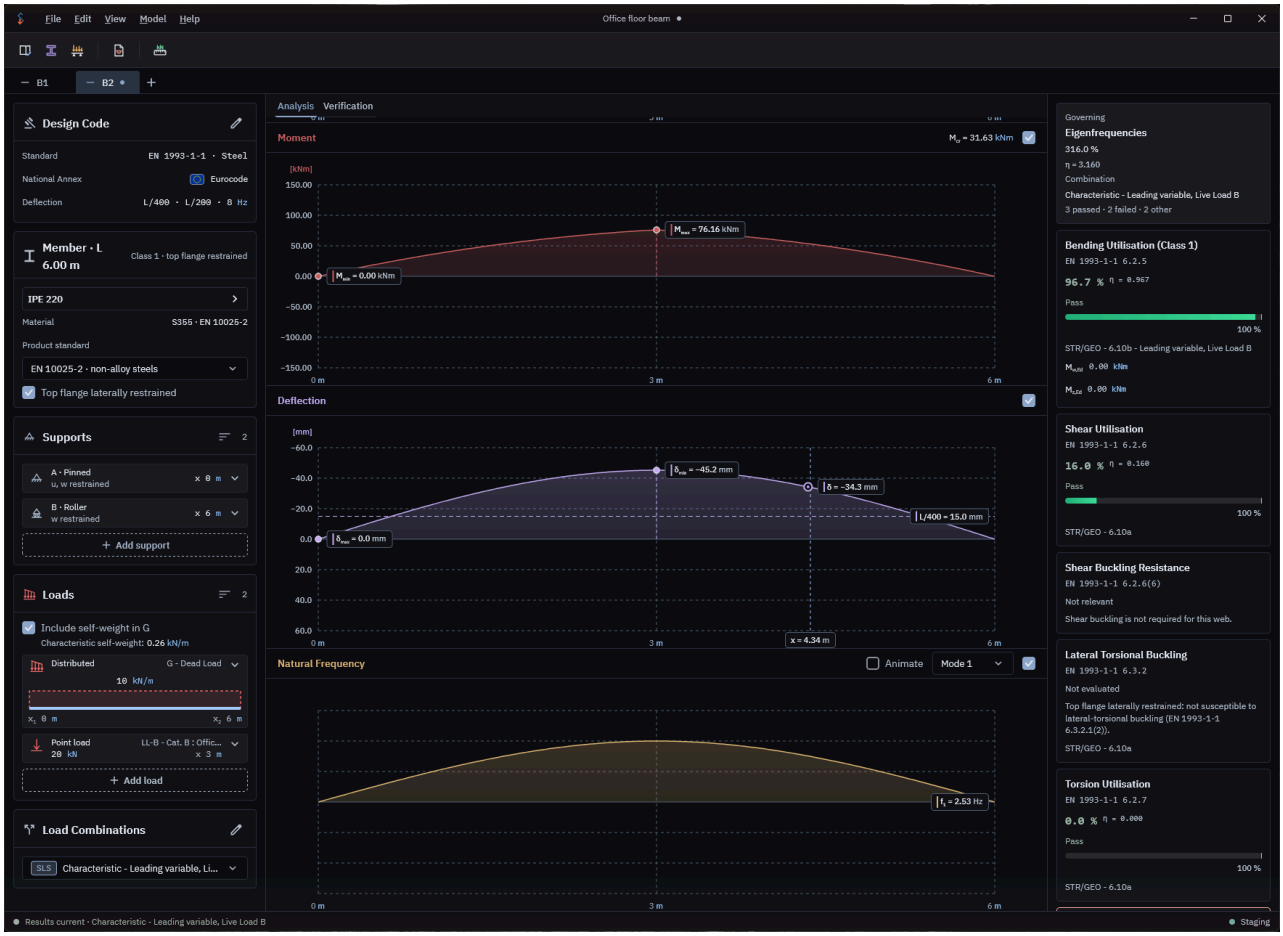


Figure 11.2 · An SLS combination with the pointer over Deflection: the hover ring and badges, the L/400 limit line, and Natural Frequency with the Mode picker and f_1

Source: spec/beam/graph-list.md rules 25–32.

The Dual-axis graph

The Dual-axis graph draws two quantities on one plot with one shared zero line, a left ruler for the left curve and a right ruler for the right curve, each with its unit above it in the curve's colour. Use it to see, for example, where the shear crosses zero under a moment peak.

A row below the toolbar holds up to three selects; a preset shows only Compare:

- **Compare** offers the presets **Moment + Shear** (default), **Deflection + Rotation**, **Shear + Torsion** and **Moment + Deflection**, then **Custom**.
- **Left** and **Right**, shown for Custom, list all six quantities. The right select disables the quantity chosen on the left with “Already selected on the left.”

A preset or quantity without data stays in the list, disabled with the same reason as in Graph list, for example Shear + Torsion on a beam without torsion. The deflection ruler names the selected combination and shows the limit line only for an SLS combination. Your choice is kept for each analysis while the project is open; it is not saved in the project file.

Both curves get extreme badges and, under the pointer, a ring and a value badge each, sharing one x badge.

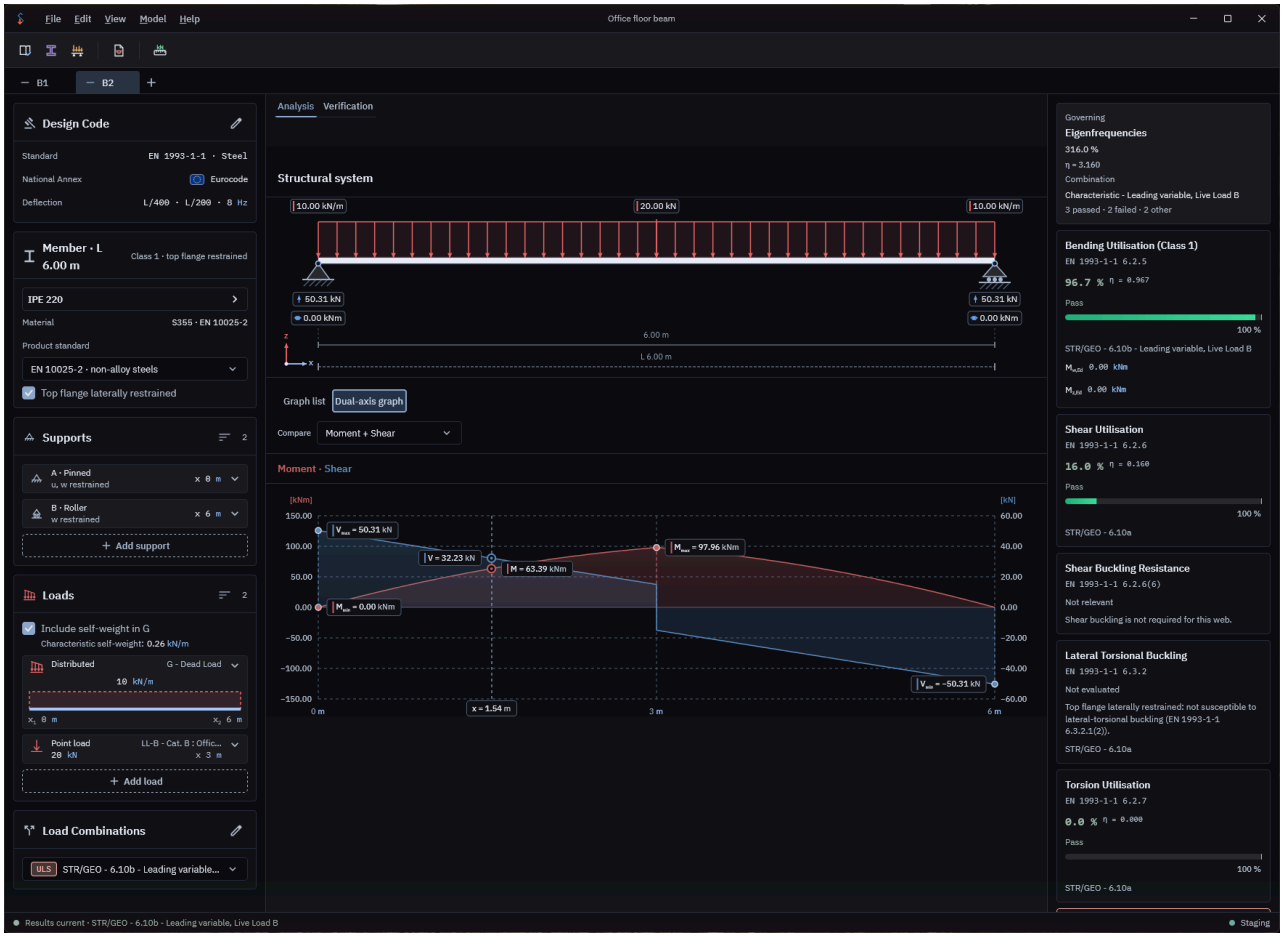


Figure 11.3 · The Dual-axis graph, Compare = Moment + Shear: the kNm ruler on the left, the kN ruler on the right and the two-value cursor readout

Source: spec/beam/dual-axis-graph.md rules 1–11, 15.

While calculating and when there is no result

Statiko calculates automatically after every valid edit; there is no Calculate button. The graphs tell you which state the result is in, with the same words as the status bar:

State	Graph list	Dual-axis graph
First calculation	The empty frame (zero line, x axis, guides), a circular indicator and “Calculating…”	“Calculating…”, no curves
Calculating with a previous result	The previous curves dimmed, a progress line on the panel edge	“Calculating…”, no curves

State	Graph list	Dual-axis graph
Outdated	Curves dimmed, “Results outdated”	“Results outdated”, no curves
Invalid input	Curves dimmed, “Results outdated”, and “Enter valid numbers before calculating.” when a field holds an unreadable number, otherwise “Invalid input. Review the beam geometry and load.”	The same sentence, no curves
Not calculated, Unstable, Failed, Unsupported, Unavailable	The state's sentence, for example “The beam is not stable with these supports and cannot be calculated.”, and no curve	The same sentence, no curves

A dimmed curve is a previous result, not the current one. Read values only when the status bar says **Results current**.

If Natural Frequency or the limit line is missing, check the selected combination first: both appear only for SLS combinations, and u_{fin} only for characteristic ones.

Source: spec/beam/graph-list.md rules 19–23; spec/beam/dual-axis-graph.md rules 12–13; spec/beam/workspace-shell.md rules 20–25.

CHAPTER 12

The checks column and check details

The checks column tells you whether the beam passes its Eurocode verifications. Each check is a card with the engine's utilisation and verdict, and a summary above the cards names the governing check. Open a card and you see how the result was reached: the governing combination, the equations with your numbers and every value used. The derivation on screen is the same one the PDF report prints. Statiko shows the engine's numbers and verdicts; the column itself decides nothing.

Where the checks are

In a large desktop window the checks sit in a 320 dp column on the right of the workspace. In an expanded window they follow the graphs in the scrolling centre column as a grid of cards, at least 220 dp wide each. In compact and medium windows the list shows alone, and a card opens its check full width with the Checks back button. On a phone they are in the Checks tab (see Chapter 4).

At the end of the column the **Report** button opens the PDF export (see Chapter 14). It is enabled for current and outdated results; otherwise it is disabled with “No current result is available for a report. Calculate first.”

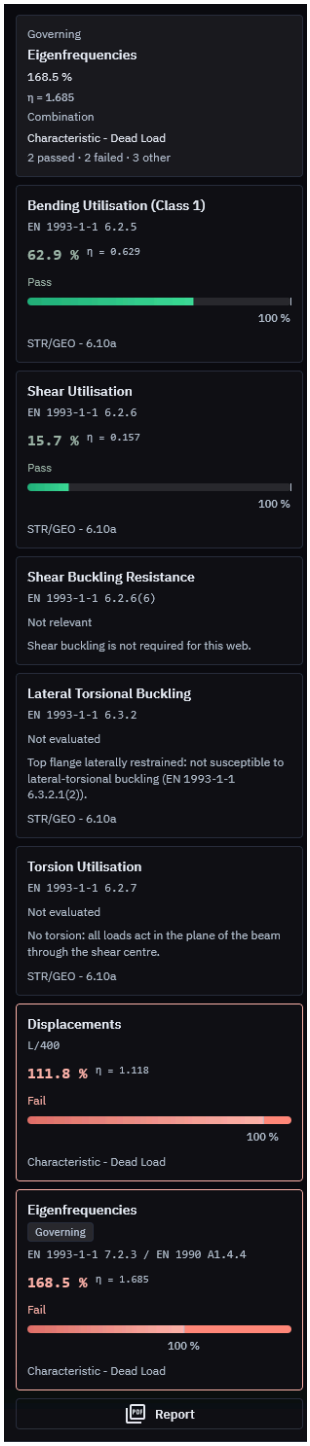


Figure 12.1 · The checks column of a steel beam: the governing summary, seven cards with Torsion Not evaluated and a failing Displacements card, Eigenfrequencies marked Governing, and the Report button

Source: spec/beam/checks-column.md rules 21, 22.

Which checks are listed

The list depends on the material and never changes length: the same cards appear while calculating, when current, outdated or failed, so nothing jumps around as you edit.

Steel	Timber and glulam
Bending Utilisation (Class n) · EN 1993-1-1 6.2.5	**Bending** · EN 1995-1-1 6.1.6
Shear Utilisation · EN 1993-1-1 6.2.6	**Shear** · EN 1995-1-1 6.1.7
Shear Buckling Resistance · EN 1993-1-1 6.2.6(6)	**Bearing** · EN 1995-1-1 6.1.5
Lateral Torsional Buckling · EN 1993-1-1 6.3.2	**Torsion** · EN 1995-1-1 6.1.8
Torsion Utilisation · EN 1993-1-1 6.2.7	**Lateral Torsional Buckling** · EN 1995-1-1 6.3.3
Displacements	**Displacements** (u_{inst} and u_{fin} in one card)
Eigenfrequencies · EN 1993-1-1 7.2.3 / EN 1990 A1.4.4	**Eigenfrequencies** · EN 1995-1-1 7.3.3 / EN 1990 A1.4.4

There is no separate bending-and-shear card for steel: the high-shear interaction is the last row of the opened Bending check. A timber or glulam beam with fire input adds **Fire verification** at the end (see Chapter 13). Concrete beams have their own list, described in Chapter 7 and Chapter 20.

Torsion is always listed. Without torsion it reads **Not evaluated** with "No torsion: all loads act in the plane of the beam through the shear centre." Shear Buckling Resistance reads **Not relevant** when the web does not need it. Lateral Torsional Buckling reads Not evaluated only when the engine gives a reason, such as a declared top flange restraint (see Chapter 8).

Source: spec/beam/checks-column.md rules 1–6; clauses from resources notation BeamCheckNotation.kt.

Reading a check card

Each card shows the check's title and clause, the utilisation as a percentage with one decimal and the ratio η beside it, for example **86.2 %** and **η = 0.862**, and the verdict word **Pass** or **Fail**.

The bar under the numbers has a marker at 100 %. A passing fill runs green up to the value; a failing fill is red and grows stronger past the marker. Above 100 % the scale stretches so the marker stays inside the card. Green and red appear only with a real Pass or Fail, and always with the word.

The steel and timber Lateral Torsional Buckling cards also show M_{cr} for the check's governing combination; Bending and LTB cards show the warping moment $M_{w,Ed}$ and the minor-axis moment $M_{z,Ed}$ when the engine reports them.

The governing summary

Above the cards a line counts the results, "<n> passed · <n> failed · <n> other", and names the governing check with its combination. The governing check is the evaluated check with the greatest utilisation, and its card carries the **Governing** mark. It can be an SLS check such as Eigenfrequencies. While calculating, the summary shows "Calculating…" and no verdict.

Every check is verified over all of this beam's combinations, whichever combination the **Load combinations** card shows. With **None** selected the cards show the same governing results as with any combination selected; only the graphs change, and the Moment graph then shows no M_{cr}.

Source: spec/beam/checks-column.md rules 7–13, 19.

When a check has no ratio

Statiko keeps every kind of "no result" distinct, so a missing check is never mistaken for a pass.

Status	What the card shows
Unsupported	Neutral, no ratio or bar, the reason, e.g. "The web slenderness requires a shear buckling check (EN 1993-1-5 section 5), which is outside the supported scope."
Unavailable	Neutral with its reason, e.g. "Mode 1 natural frequency is not available."
Invalid input	Warning colour, no ratio
Failed calculation	Error colour, no ratio
Not evaluated / Not relevant	Neutral with a one-sentence reason; counted under "other", never as a pass
Outdated	"Outdated", the previous ratio dimmed, no green
Calculating, first run	The real cards with placeholder values and an empty bar

Other reasons you may meet include "Support B has no bearing length." (naming the support), "The beam carries an axial force; the beam checks cover beams without axial force.", "Statiko does not cover the Swedish National Annex crack factor for timber shear." and "No load combination applies to this check." When the whole analysis has failed or is unsupported, every card shows that sentence instead of a ratio.

> A list of passes does not prove that every required member check was made. Read the neutral cards: each one names a check Statiko did not verify for this beam.

Source: spec/beam/checks-column.md rules 14–18 and Strings.

Opening a check

Click a card to open its derivation. On desktop and tablets two tabs sit over the centre, **Analysis** and **Verification**. The card opens under Verification, named **Verification · <check>**; the drawing and graphs wait under Analysis. The Verification view lists every check of the beam in the list's order, each as its compact card followed by its derivation, and scrolls to the one you clicked. The checks column stays in place with the opened card outlined. With nothing opened, Verification reads "Choose a check to see its derivation." Click the Analysis tab to go back.

On a phone the card opens full width with a **Checks** back button above the title; Android Back closes the check before leaving the workspace.

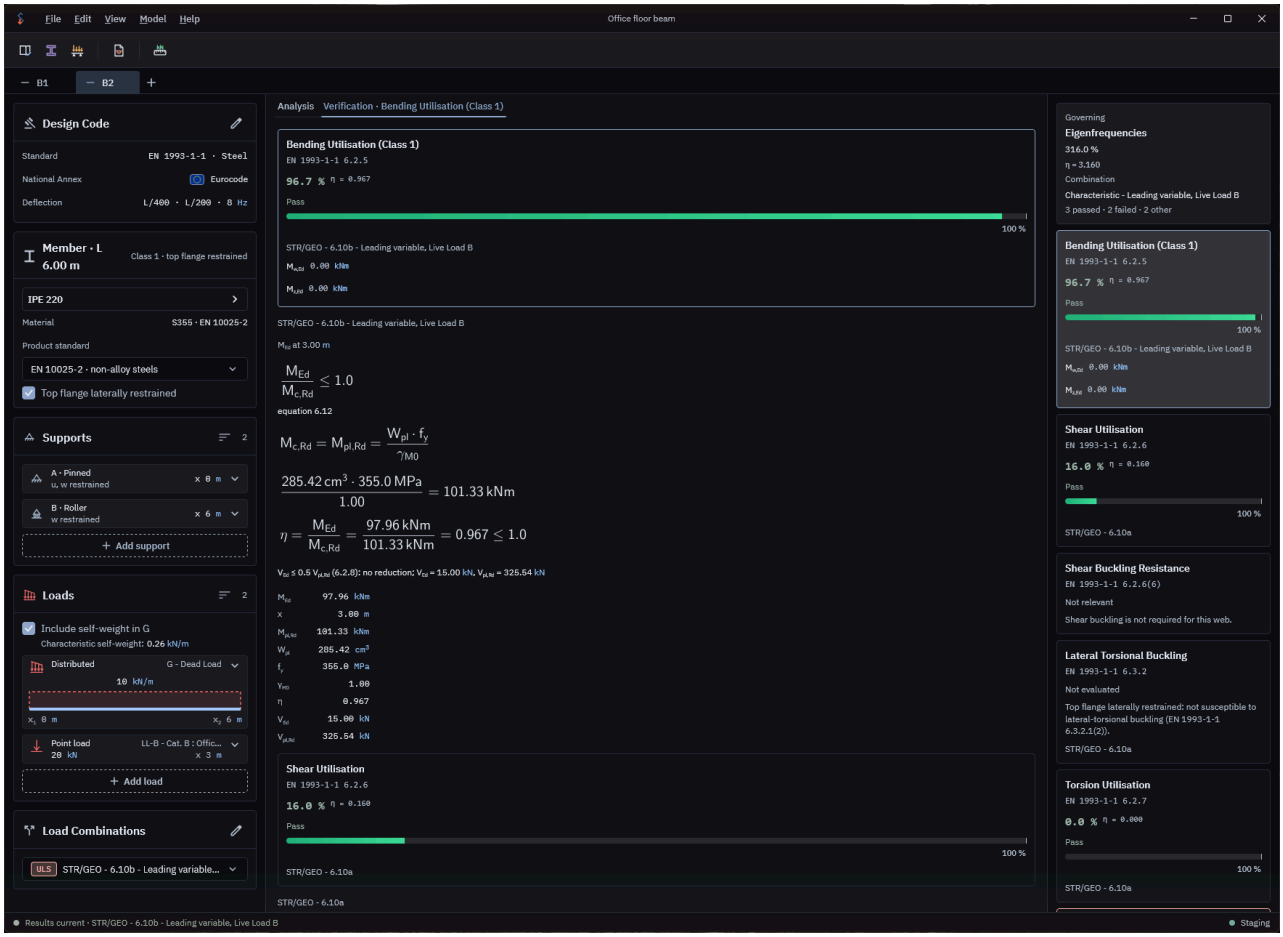


Figure 12.2 · Bending Utilisation opened in the Verification tab: utilisation and Pass, M_{Ed} at its position, the steps, the high-shear row and the value table

Source: spec/beam/check-details.md rules 1–4, 25.

What the derivation shows

From top to bottom an opened check shows:

1. the title, clause, utilisation, verdict word and bar, exactly as on the card;
2. the governing combination, with the governing position where the engine gives one, for example "M_{Ed} at 2.40 m"; a section check without a combination says so, for example "Section check for IPE 220. No load combination.";
3. for a concrete Bending + or Bending − check, the flexure figure of the report: the section, the strain and stress diagrams and the detail of the compression zone, with x, the stress block and the forces C_c, C_s and T_s; in a narrow view it scrolls sideways;
4. the derivation steps: the governing inequality with its equation number, the resistance formula, the formula with your values substituted, and the utilisation line;
5. the value rows, a tight table of symbol and value with unit.

The equations are those of the method the engine used. Steel Bending uses W_{pl}, $W_{el,min}$ or W_{eff} according to the section class, and ends with the high-shear row: V_{Ed}, $V_{pl,Rd}$, ρ and $M_{y,V,Rd}$ when the reduction applies, or "$V_{Ed} \le 0.5\ V_{pl,Rd}$ (6.2.8): no reduction". Lateral Torsional Buckling shows M_{cr}, α_{LT}, $\bar{\lambda}_{LT}$, Φ_{LT}, χ_{LT} and $M_{b,Rd}$ with γ_{M1}.

Eigenfrequencies shows f_1, f_{lim} (“limit from project settings”), the mass basis and $\eta = f_{lim} / f_1$. Timber Bending begins with **Service Class** and **Shortest load duration**, the two inputs that set k_{mod}, then $\sigma_{m,y,d}$ and $f_{m,d}$. The methods themselves are explained in Chapter 18 and Chapter 19.

Every number comes from the engine result or your inputs; the screen only formats it. A value the engine does not give reads **Unavailable**. Unsupported, invalid and failed checks show only the verdict word and the reason, with no equations. While the first calculation runs, the view reads “Equation values are not available until a calculation finishes.”; when outdated, the previous derivation stays with the Outdated word.

> The screen uses your display units; the PDF uses the report's print precision, so the last digit can differ between the two.

Source: spec/beam/check-details.md rules 5–11, 14–21, 23, 24.

CHAPTER 13

Fire design: inputs and checks

Fire design verifies that a steel, timber, glulam or concrete beam keeps enough resistance for the required fire period. You choose the required resistance and how the beam is exposed; Statiko takes the design effects from the fire combinations it already generates (EN 1990 6.11b) and runs the simple Eurocode method for the material. This chapter shows where the fire inputs are, what each one does and how to read the result. How the methods calculate is explained in Chapter 22.

Where the fire inputs are

The fire inputs live in the cross-section window, in the same draft as the profile. On desktop they are in the input panel's **Fire** tab, with the fire results under them; in a narrow window they sit under the profile. The region is titled **Steel fire design (EN 1993-1-2)**, **Timber fire design (EN 1995-1-2)** or **Concrete fire design (EN 1992-1-2)**.

- **Apply** saves the profile and the fire inputs together. Cancel, close, Back and `Esc` ask once if you changed either: "The edited profile and fire inputs are discarded. The analysis stays as it was."
- The **Fire overlay** switch in the drawing header, on by default, draws the exposed faces, protection or charred layer on the section. Turning it off hides only the drawing and its legend.
- The window's footer adds an available fire verdict to the profile status, for example "Class 1 · S235 · Resistance satisfied".

Fire inputs belong to the beam, not the profile: choosing another profile keeps them. Inputs for another material stay dormant and come back if you switch back. A fire edit is a normal project edit with Undo and Redo, it is saved in the project file, and the beam recalculates automatically.

Source: spec/beam/fire.md rules 4–11.

Required fire resistance and exposure

Required fire resistance offers **None**, R30, R60, R90, R120 and **Custom (minutes)**, which shows **Custom fire resistance (min)**. None is the default for new beams and for older files: the beam then has no fire result, no fire card and no fire verdict. An empty or zero custom time gives "Enter the required fire resistance time (minutes)."

For steel and timber, **Fire exposure** offers **Four sides (all around)**, **Three sides + slab on top** (steel: "… slab on top flange") and **Custom faces**, which shows **Left**, **Top**, **Right** and **Bottom** under **Custom exposed faces**. Picking a preset ticks its faces; changing a face switches to Custom. Steel starts on four sides, timber on three.

Each fire combination is verified with its own design effects and the result names the governing one. You never type a fire moment or a reduction factor.

> Fire is the accidental design situation. Its verdict never changes the governing check, the checks summary or the report's governing check.

Source: spec/beam/fire.md rules 2, 12–16, 19.

Steel

The region opens with "μ0 = E_fi,d / R_fi,d,0 (EN 1993-1-2). The η_fi = 0.65 shortcut is not used." and a notice on how far the section is supported: I and H sections have the full path, hollow sections are supported for heating, other open sections are partial, and circular hollow, round bar, angle and zee sections read Unavailable with the inputs disabled but kept.

- **At continuous support (κ2)** applies the continuity factor at intermediate supports and fixed ends of a statically indeterminate beam. Under Custom faces, **Slab on top flange (κ1)** also appears and removes Top.
- **Protection type**: **Unprotected**, **Contour protected** or **Box protected**. Protected shows the protection thickness d_p, conductivity λ_p, specific heat c_p and density ρ_p, all typed by you; there is no product list. For intumescent coatings the app shows **Intumescent coatings are outside EN 1993-1-2 Eq. (4.27) simple heating — Unavailable.**
- **Steel thermal properties**: $c_a(\theta)$ from EN 1993-1-2 3.4.1.2 with ρ_a = 7850 kg/m³ by default, or **Custom ca and ρa**. **Initial steel temperature θ_a,0** is 20 °C by default.

Under **Fire verification** two methods sit side by side. The **Critical temperature method** shows μ_0, κ_1, κ_2, $\gamma_{M,fi}$ with its source, $\theta_{a,cr}$, A_m/V, the steel temperature at the required time, the margin $\theta_{a,cr} - \theta_a$ and the verdict. The **Resistance method** shows $M_{fi,t,Rd}$, $V_{fi,t,Rd}$ and $M_{b,fi,t,Rd}$ with $\chi_{LT,fi}$, each with its utilisation. The **Steel fire verdict** is the worse of the two, so neither can hide a failure.

> The critical temperature method can rule out lateral-torsional buckling only where the top flange restraint holds the compressed flange. Otherwise it reads "Lateral-torsional buckling in fire is not verified" and the resistance method gives the verdict. A Class 4 section uses 350 °C and the resistance method is not available for it.

> With torsion in the fire combination, for example from an eccentric load, the critical temperature method reads "The critical temperature method does not cover torsion; the resistance method gives the verdict." The resistance method then adds $T_{fi,Ed}$ against $T_{fi,t,Rd}$ and shows the moments $M_{z,fi,Ed}$ and $M_{w,fi,Ed}$ of the torsion interaction (Chapter 22).

Steel results appear in the cross-section window and in the report, and with fire input the steel checks list ends with a **Fire verification** card (EN 1993-1-2 4.2.3, 4.2.4) with the same note as the timber card; opening it shows the fire derivation and verdict in the check details. A Custom design country reads "Custom National Annex steel fire factors are not verified in Statiko."

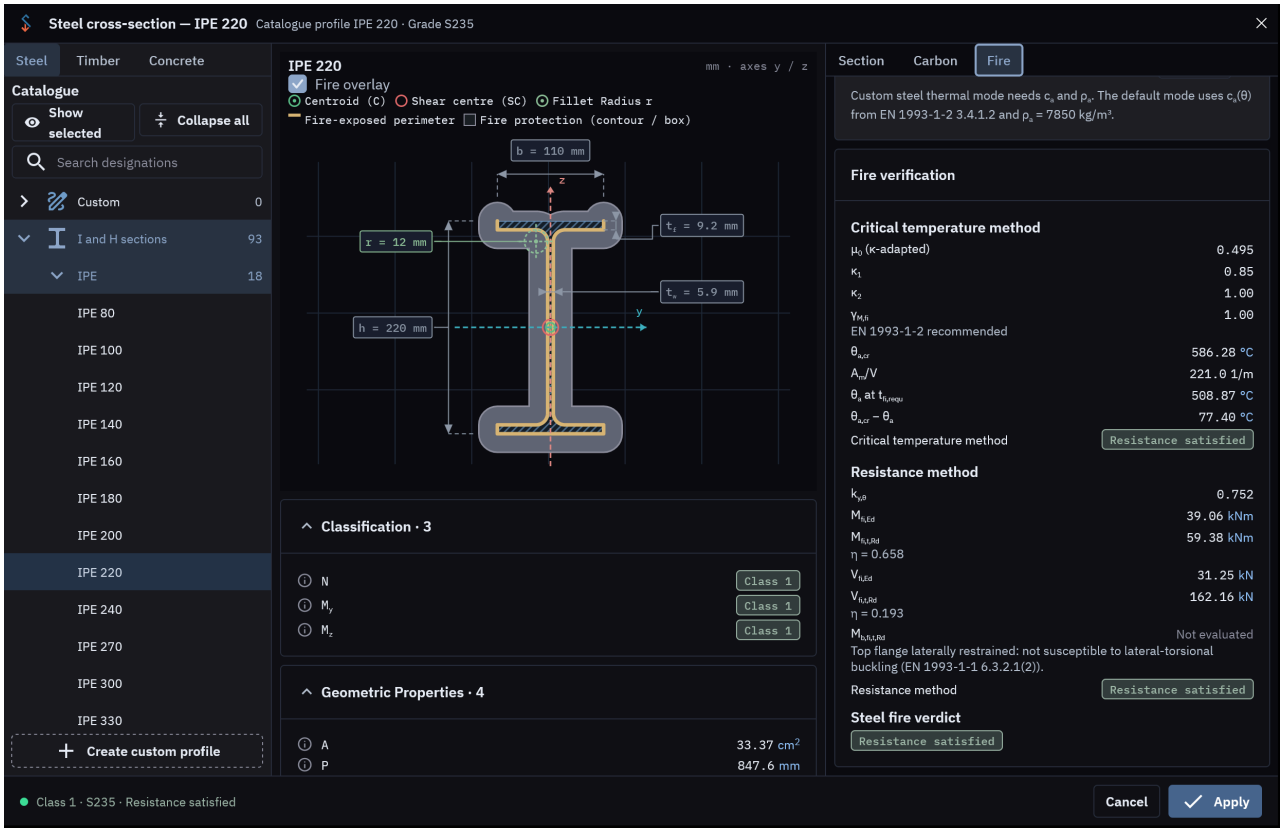


Figure 13.1 · An IPE 220 at R60 with contour protection: the fire-exposed perimeter and the contour on the drawing, and the Fire tab scrolled below the protection values to Fire verification with the critical temperature method, the resistance method and the Steel fire verdict

Source: spec/beam/fire.md rules 20–35.

Timber and glulam

Timber and glulam use the reduced cross-section method, for rectangular sections and Eurocode recommended values only. **Fire cladding** is **Unprotected** or **Gypsum plasterboard type A**, which needs **Cladding h_p**.

The result shows four groups: **Parameters** ($k_{mod,fi}$, $d_{char,n}$, d_{ef}, b_{fi}, h_{fi} and the **Charring phase**), **Design capacities** ($f_{m,d,fi}$, $f_{v,d,fi}$), **Cross-section checks** (bending and shear ratios) and **Stability checks** ($\sigma_{m,crit}$, $\lambda_{rel,m}$, k_{crit} and the buckling ratio). The overlay draws the charred layer and residual section, and the cladding solid while effective and dashed after its fall-off time.

With fire input, the timber checks list ends with a **Fire verification** card (EN 1995-1-2 4.2.2) noting “Fire verification is the fire design situation; it is not part of the governing check.”

Glulam has no lateral-torsional buckling check in fire, so a glulam result is always a **Partial result**, never a Pass. Another section shape reads “Only rectangular solid timber / glulam sections are supported for fire.”, and a country other than the Eurocode recommended values reads “Timber fire National Annex values are not verified for this country — verification stays unavailable.”

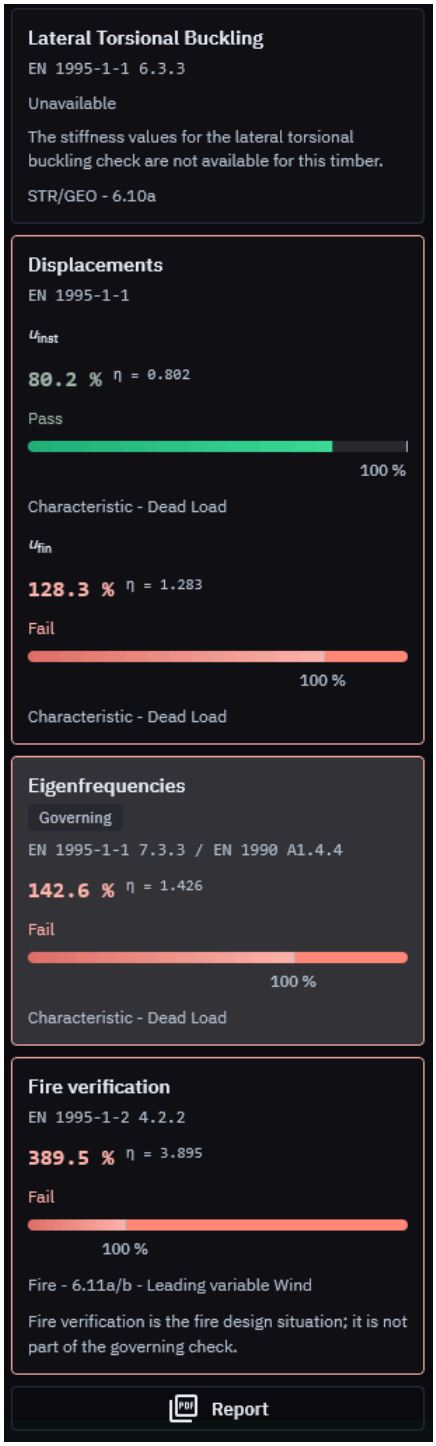


Figure 13.2 · A C24 45×220 beam at R30 behind gypsum plasterboard type A: the timber checks column ends with the Fire verification card (EN 1995-1-2 4.2.2) and its note

Source: spec/beam/fire.md rules 36–43.

Concrete

Concrete uses the tabulated data of EN 1992-1-2 5.6 from the beam's own section, bars and supports. The region holds **Fire exposure**, **Three sides + slab on top** (default) or **Four sides (all around)**, and the required fire resistance. There are no other fire fields.

The result compares the width b with b_{min} and the axis distance a with a_{min}, and names the table (**Table 5.5 · simply supported** or **Table 5.6 · continuous beam**), the column and the **Table row**; a custom time uses the next row up. Each requirement reads OK or Fail.

The tables do not cover every case, and Statiko says so rather than guessing. These read Unavailable with their reason: a cantilever or a single span with a fixed end, four-sided exposure, a circular section, more than R240, concrete above C50/60, concrete above 2600 kg/m³, and the National Annexes of Denmark, Serbia, Sweden or a Custom country. A continuous beam at R90 or more that meets the width b and axis distance a reads Unavailable, because the top reinforcement rule over the supports is not verified; one that fails b or a reads Fail. Table 5.7 (R120 and above) is not verified either.

Concrete results appear in the cross-section window and the report, and with fire input the concrete checks list ends with a **Fire verification** card (EN 1992-1-2 5.6) with the same note as the timber card; opening it shows the tabulated derivation and verdict in the check details.

Source: spec/beam/fire.md rules 44–50.

Fire in the report

With fire input, the report's fire chapter (5.6 for steel, timber and glulam, 5.2 for concrete) prints at every detail level: the method, the section figure with its fire overlay, the inputs, the results and the verdict; steel prints both methods and the governing verdict. Without fire input the chapter keeps its one sentence, such as “Fire design according to EN 1993-1-2.” The Summary has one fire row, outside the governing check, and Basis of design prints the fire protection requirements you typed in the export form. A fire result that is Unavailable, Invalid or partial cannot be deselected in Custom. See Chapter 14.

Source: spec/beam/fire.md rules 51–55.

CHAPTER 14

The report and the PDF

The report turns your calculated beam into an A4 PDF that a checker can read: the basis of design, the beam and its loads, the internal forces, every check with its clause and derivation, and the verdict. You fill in the project details once, choose how much detail to print, preview the pages exactly as they print, and save or print them. The report prints the engine's values, clauses and verdicts from the same result the screens show; it computes nothing of its own.

Opening the report

Open the export view in any of these ways: **Report** in the ribbon, **File › Export PDF report...**, `Ctrl`+`P`, or the **Report** button at the end of the checks column.

Preview and **Export PDF** work only for a complete result of the current input. While results are missing, outdated, calculating or invalid, both are disabled and the view shows “No current result is available for a report. Calculate first.” You can still fill in the form. As soon as the automatic calculation finishes, both buttons enable without reopening the view.

> On Android, **Preview**, **Export PDF** and **Add logo** work as on the desktop. **Add logo** opens the photo picker.

Source: spec/beam/report.md rules 1, 2; spec/beam/workspace-shell.md rule 18; spec/beam/phone-and-tablet.md rule 22.

The export form

The export view opens as its own window with one form column. Its footer holds **Export PDF**, **Preview** and **Cancel**; Cancel and Close return to the beam and keep what you typed.

Group	Fields
Project Info	Name, Number, Title, Address, Initials, Date, Project Description, Prepared by, Checked by, Revision
Project Requirements	Building construction class, Fire protection requirements
Company Info	Name, Company Details, the logo with **Add logo** and **Remove**
Title Page	The checkbox **Print a title page** and **Location drawing** with **Add drawing**, **Replace drawing** and **Remove**

Every field, the logo and the title page are saved in the project file, so you fill them in once per project. Empty fields print nothing; the grey hints are never printed.

Title page

Tick **Print a title page** to start the PDF with a cover. It is page 1, before the contents, and counts in “Page x of y”; unticked, the report has no such page. The cover has no page header and keeps the footer. From the top it prints your logo, company name and company details, then the report title, “<number>-<name>” and the name of the

analysis, then the location drawing, and at the bottom the filled-in project facts: Address, Date, Prepared by, Initials, Checked by and Revision. If the title is empty, the project name is printed in its place.

The location drawing shows where the beam sits in the building. **Add drawing** imports a PNG, JPG or PDF, for example a plan or a section. Of a PDF, the first page is placed like an image. A PDF that cannot be read shows "The PDF drawing could not be read. It may be encrypted, empty or damaged." The logo stays PNG or JPG. Click the drawing to place the marker of the open beam, and click again to move it; each analysis has its own marker on the one drawing. The PDF prints the drawing whole inside a thin frame with the marker as a red ring and the analysis name beside it, and the caption "Location of <analysis name>" below. A drawing without a marker for the analysis prints without marker and caption, and without a drawing the cover prints the text only.

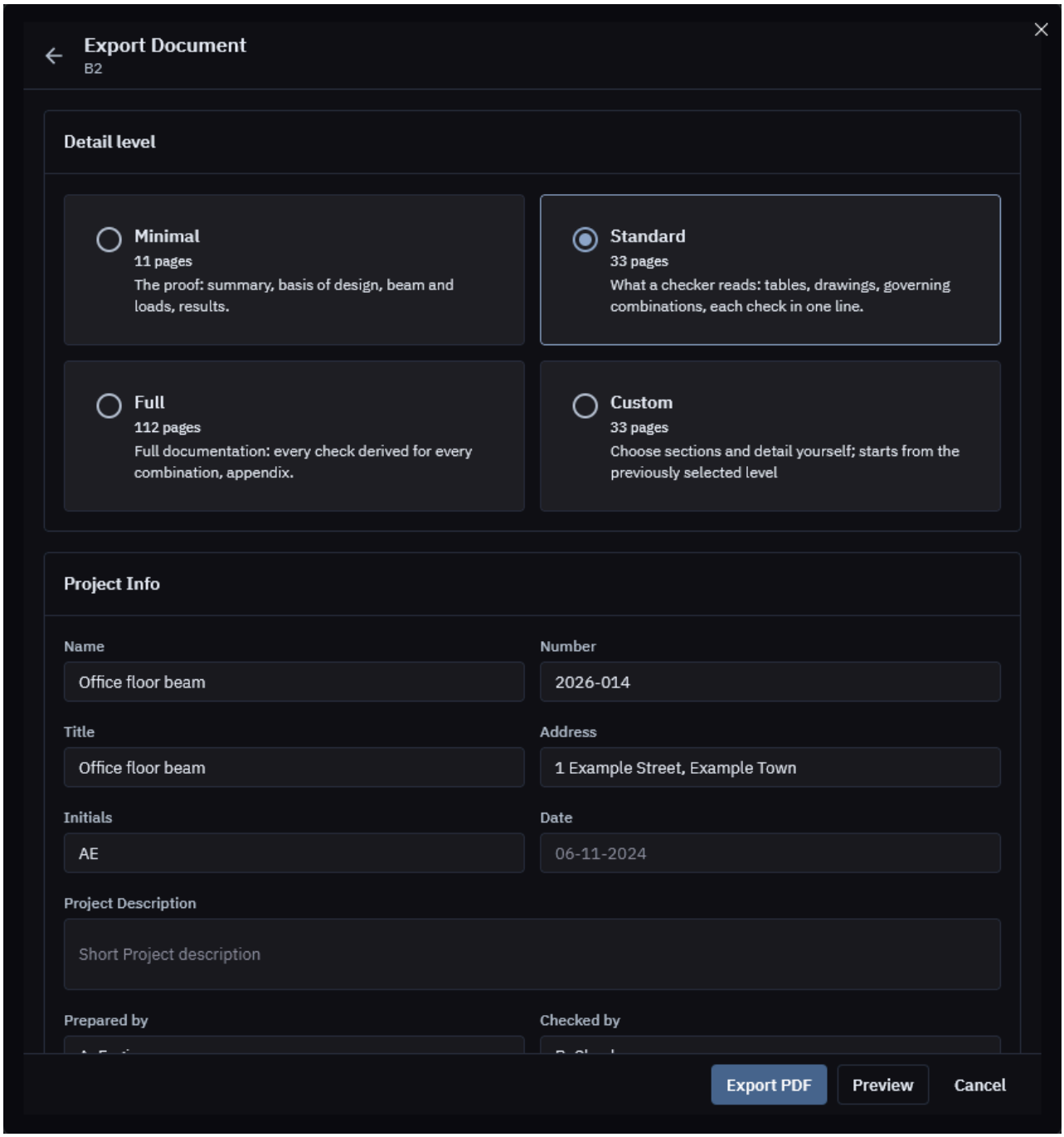


Figure 14.1 · The export view with Standard selected among the four detail levels, the Project Info fields and the footer buttons

Source: spec/beam/report.md rules 4–7 and 62–66; rule 5 for the failure and permission messages.

Detail levels

Choose how much the report prints with the **Detail level** cards:

- **Minimal**: “The proof: summary, basis of design, beam and loads, results.” No equations.
- **Standard** (default): “What a checker reads: tables, drawings, governing combinations, each check in one line.” No appendix.
- **Full**: “Full documentation: every check derived at its governing combination, the others tabulated, appendix.”
- **Custom**: “Choose sections and detail yourself; starts from the previously selected level”.

Each card shows the real page count for your current result, worked out in the background (“Counting pages…” the first time).

Some content is always printed whatever you choose: the header, the Basis of design and the Summary, and every check whose verdict is not OK, not checked or unsupported. A check that did not pass is printed in its compact form even if you deselect it. The contents and page numbers follow the pages actually printed.

Custom

Custom opens a section tree below the cards. Ticking a parent ticks its children. Locked rows explain themselves: the header, Basis of design and Summary read “Always in the report.”, a check that did not pass reads “Always printed: this check did not pass.” Below the tree you choose:

- **Checks**: Full derivation, Compact or Summary row only;
- **Combinations**: All relevant or Governing only; with Full derivation, All relevant derives every check in full for every relevant combination;
- **Diagrams**: Per combination, Governing only or None;
- **Appendix** on or off;
- **Language**: English, Dansk or Српски;
- **Units and decimals**: “Follows Settings › Units.”

Save as preset… stores the tree and options under a name in your app settings, so the preset is available in every project. **Reset to Standard** closes Custom.

> The report language follows the app's interface language unless you change it under Custom. Units and decimals always follow **Settings › Units** (see Chapter 24).

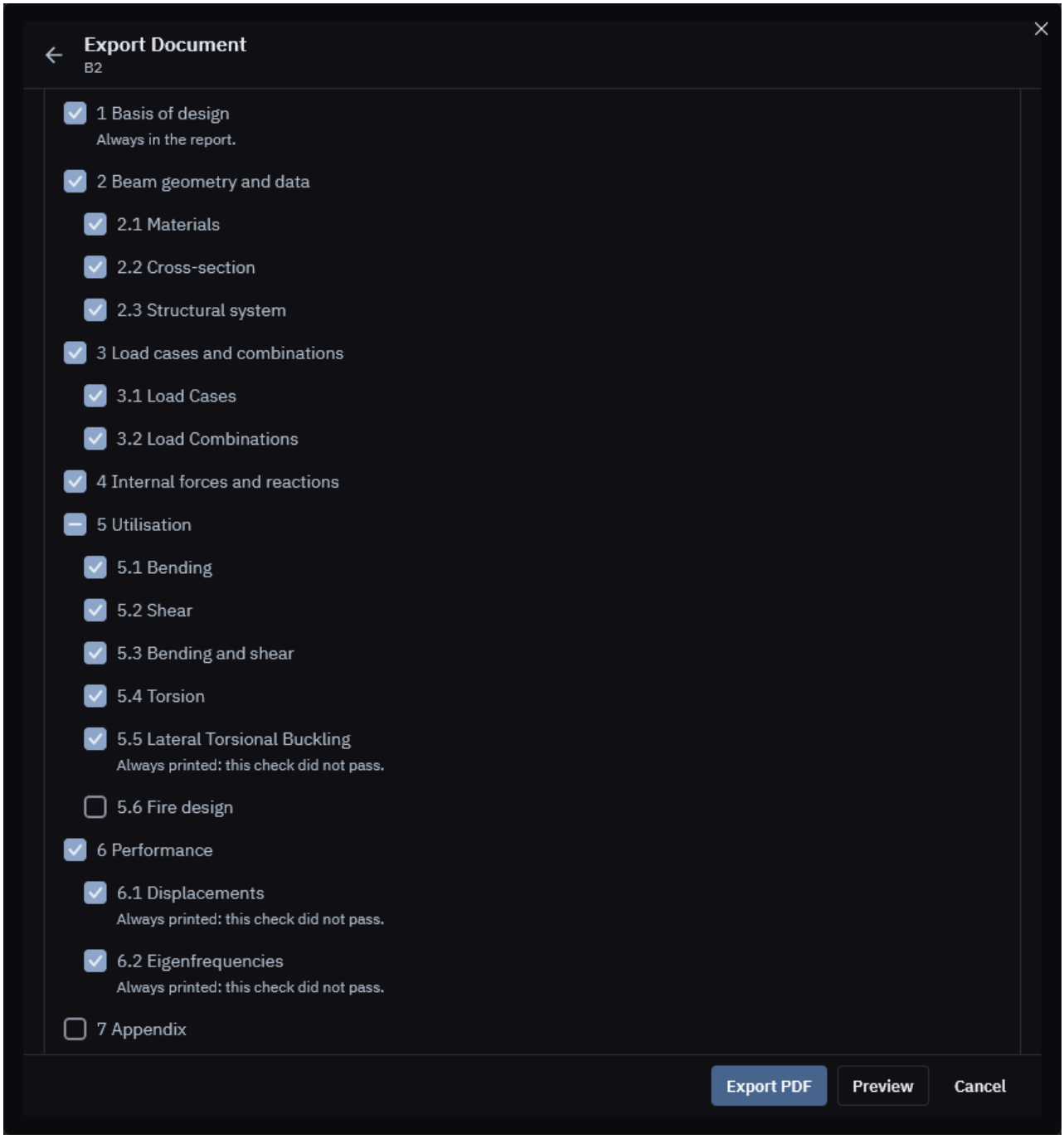


Figure 14.2 · Custom: the section tree, with checks that did not pass locked as Always printed

Source: spec/beam/report.md rules 8–17.

Preview, print and save

Preview opens the PDF view in its own window. Its toolbar has **Back to export options**, the file name, **Page x of y** with a page field and arrows, **Fit width**, **Fit page**, 100 % with zoom out and zoom in, **Print** and **Export PDF**.

1. While the report is written you see “Generating…”, a progress bar and the section in progress, for example “Section: 5 Utilisation”. The project cannot be edited during this time, so the result cannot change under the report. **Cancel** stops and writes no file.
2. When ready, page 1 appears exactly as it prints.

3. **Export PDF** opens the system save dialog with “<project name>.pdf” proposed. After saving the view shows “Report exported”, the file name and **Open folder**; on Android **Share** takes its place and sends the saved file to the share sheet.
4. **Print** sends the same pages to the system print dialog on A4.

If writing fails you see “Export failed” with the reason, for example “The report file could not be written.”, and **Retry**.

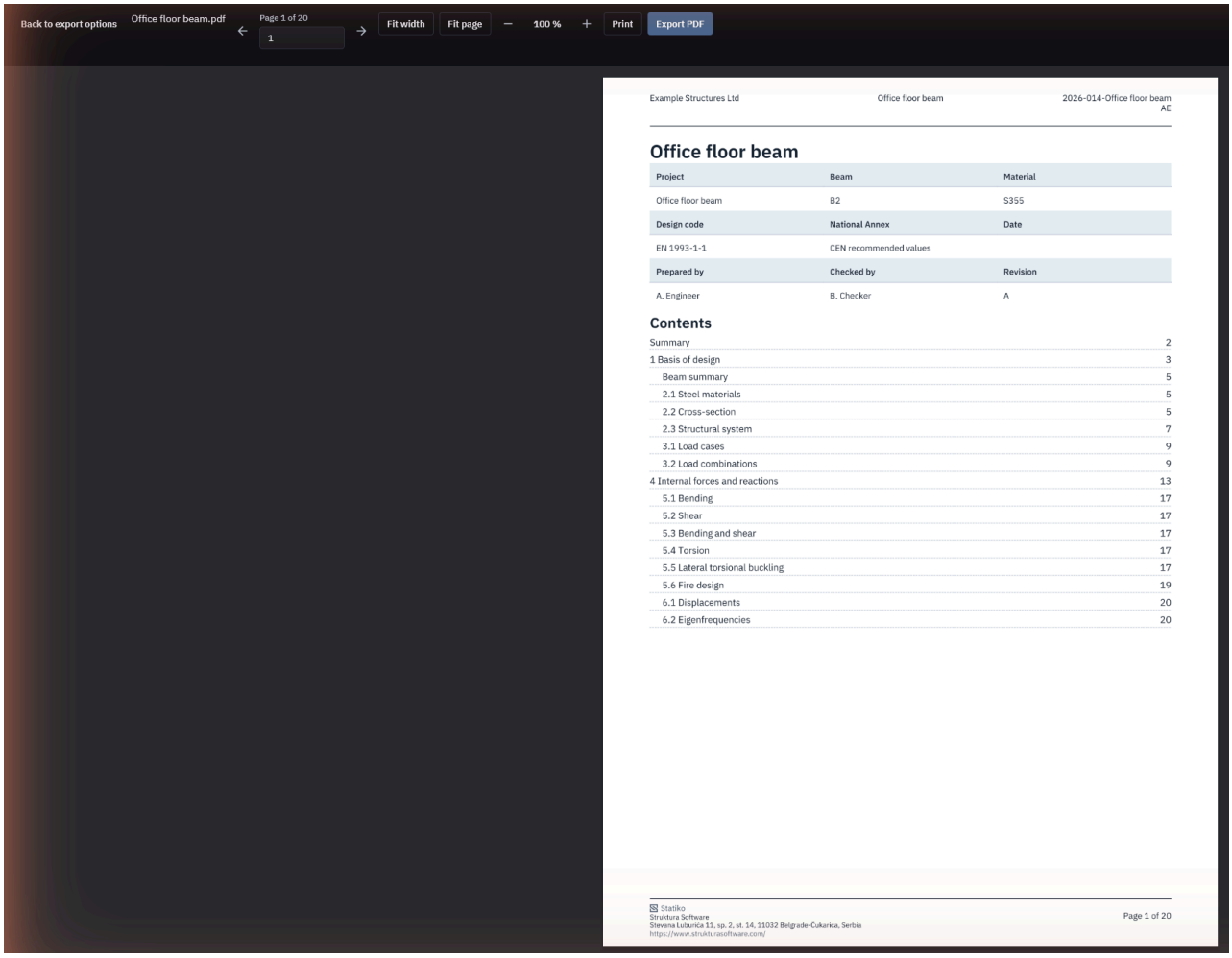


Figure 14.3 · The PDF view on page 1: Back to export options, page, zoom, Fit width, Fit page, Print and Export PDF

On Android the PDF view fills the screen at every width, on a foldable the side of the workspace, and Back returns to the export options. **Print** opens the Android print dialog.

Source: spec/beam/report.md rules 3, 18–21; spec/beam/phone-and-tablet.md rule 22.

What the pages contain

Pages are A4 and always light. Every page has a header with your logo, company details, “<number>-<name>”, “<date> / <initials>” and the project title, and a footer with the app name and “Page x of y”. Numbered chapters start on a new page, tables and equations are never split, and a continued section repeats its heading with “(continued)”.

Chapter	Steel	Timber and glulam
Summary	The overall verdict and one row per check: clause, governing combination, position, utilisation, verdict and reason. One fire row sits outside the governing check.	
1 Basis of design	Design code and edition, CEN recommended values or the National Annex, consequence class and K_{FI}, your project requirements, the units, and the axes and sign convention figure	
2 Beam geometry and data	Beam summary; 2.1 Materials (f_y, f_u, γ_{M0}, γ_{M1}, γ_{M2}, and the product stage carbon (A1-A3) table with its total); 2.2 Cross-section with the section figure, properties and plate classification; 2.3 Structural system	Beam summary; 2.1 Materials (strength class, strengths, stiffness, density, design factors with k_{mod} per combination and k_{def}, and the product stage carbon (A1-A3) table with its total); 2.2 Cross-section; 2.3 Structural system
3 Load cases and combinations	3.1 Load cases with the loads figure; 3.2 every relevant combination with its EN 1990 equation and the action factor table	
4 Internal forces and reactions	Per relevant combination: a reaction figure that draws the combination's design loads over the characteristic loads as faint dashed outlines, with the legend *Design loads · formula* at the top left; extremes and support reactions; the M, V and T diagrams for the governing combinations (every combination with Custom › Diagrams: Per combination)	
5 Utilisation	5.1 Bending, 5.2 Shear, 5.3 Bending and shear, 5.4 Torsion, 5.5 Lateral torsional buckling, 5.6 Fire design	5.1 Bending, 5.2 Shear, 5.3 Torsion, 5.4 Lateral torsional buckling, 5.5 Bearing at supports, 5.6 Fire design
6 Performance	6.1 Displacements with the project limit and its source; 6.2 Eigenfrequencies with “This criterion is not a full floor vibration check.”	
7 Appendix	Program and calculation module versions, calculation date, the input listing and the limitations the engine reports for this beam	

The structural system drawing prints every load value next to its arrow. Where loads are too crowded, a position gets a letter badge (A, B, …) and a load table under the drawing lists them. The diagrams and section figures are drawn by the same builders as the app's graphs and cross-section window.

Each check prints its derivation from the same model as the opened check in the app (see Chapter 12): in Full once at its governing combination, followed by a table of the other relevant combinations (combination, position, design value, resistance, utilisation and verdict), in Standard as one compact line with the governing value, resistance, utilisation, clause and verdict.

A combination whose **Show in report** box is unticked in the Load combinations window (Chapter 5) leaves the combination tables and the per-combination diagrams, unless it governs a check. The calculation still checks it.

Source: spec/beam/report.md rules 7, 22–32, 36–48, 49–53, 56–59; spec/beam/design-code-member-combinations.md rule 44.

Concrete beam reports

A concrete beam prints its own chapter list: Summary; 1 Basis of design (with the National Annex status, γ_C, γ_S, α_{cc}, α_{ct} and cot θ); 2 Beam geometry and data with 2.1 Materials and cross-section (materials, the section figure and elevation, the bar and stirrup table, durability rows, section properties and the product stage carbon (A1-A3) table with a Concrete and a Reinforcement row) and 2.3 Structural system; 3 Load cases and combinations; 4 Internal forces and reactions; 5 Concrete verification with one block per check, 5.1 Assumptions, warnings and scope and 5.2 Fire design. There is no Performance or Appendix chapter: deflection is one of the check blocks. Each bending block prints a flexure figure with the compression zone, strains and forces.

Source: spec/beam/concrete-report.md rules 1–13.

How values are printed

Symbols are typeset with real subscripts. Section properties print with four significant figures, forces and moments with two decimals, utilisations with three. Every minus is the true minus “−”.

> The report never fills a gap. A value the engine does not give prints “Unavailable”; a check the engine does not run prints its verdict, Not checked, Unsupported or Unavailable, with the reason. Read these rows before you sign the report: they name what Statiko did not verify for this beam.

Source: spec/beam/report.md rules 33, 34; spec/beam/concrete-report.md rule 10.

PART IV

How Statiko calculates

CHAPTER 15

Load combinations

This chapter explains how Statiko builds the load combinations that every analysis and check uses. You never type a combination factor: the app generates all combinations from the project's design code, following EN 1990 and the National Annex you chose. Reading this chapter tells you which combinations exist, which partial and combination factors each one applies, and why a combination appears or does not appear in the list.

Kernel paths in this chapter are under `engineering/src/commonMain/kotlin/statiko/engineering/`.

How Statiko generates combinations

One project has one National Annex for all its beams. When you choose the country in the **Design code** dialog, Statiko resolves the partial factors γ_G and γ_Q, the reduction applied in expression 6.10b, the consequence factor K_{FI} and the table of combination factors ψ_0, ψ_1 and ψ_2. It then walks a fixed, ordered list of combination definitions and, for each one, computes a single coefficient per action type. Before the static analysis runs, every load of that action type is multiplied by the coefficient.

The countries available are Eurocode (the recommended CEN values), Denmark, Sweden, Serbia and Custom. Eurocode, Serbia and Custom follow the CEN combination policy; Denmark and Sweden each have their own policy. A completed set of coefficients is arithmetic on the factors of the chosen code; it is not a statement that a National Annex has approved the result.

Source: `combinations/generateCombinations.kt:10-82`; `design/DesignCodePresets.kt:22-69`; ai/architecture/engineering-rules.md, Combination generation and load application.

What you enter

- **Design code.** The country, the consequence class CC1, CC2 or CC3, the altitude band (used for the CEN snow factors) and the snow load band (used for the Swedish snow factors). Open it with **Edit** on the **Design code** card.
- **The action of each load.** Dead load; Live load categories A to H; Wind; Snow; Custom load. Every variable action can lead a combination: wind, snow, live loads A to H and the Custom load.
- **The selected combination.** The **Load combinations** card lists None, then this beam's ULS, SLS and Fire combinations. The selection drives the reactions, the graphs and the status bar; the drawing keeps the characteristic loads, and the PDF report draws each combination's design loads (Chapter 14). The checks always show the governing result over all combinations, with None selected too (Chapter 12). Changing it recalculates the beam.

The deflection and frequency limits stored with each beam are not combination factors; Chapter 21 covers them.

The combination list

Statiko generates the combinations in this order. "Leaders" are wind, snow, live load categories A to H and the Custom load, in that order. A beam with dead load and Custom load alone so gets a 6.10b combination that holds the Custom load, under every country. Under the Serbian annex items 1 to 3 are replaced by **STR/GEO - 6.10** once for each leader, then 6.10 with favourable permanent load and wind leading.

1. **STR/GEO - 6.10a**, without a leading action.
2. **STR/GEO - 6.10b**, once for each leader.
3. 6.10b with favourable permanent load (G,inf) and wind leading, shown as **Leading variable Wind + G.inf**.
4. **Characteristic** without a leader (permanent load only), then once for each leader, then the G,inf variant with wind leading.
5. **Frequent** once for each leader, then the G,inf variant with wind leading.
6. **Quasi-permanent**.
7. **Fire - 6.11a/b** once for each leader, then the G,inf variant with wind leading.

A combination is offered for your beam only when it is relevant: its leading action is present on the beam, or, for a combination without a leader, a present action has a coefficient other than zero. The quasi-permanent combination is always offered.

Source: `combinations/combinationDefinitions.kt:6-20` ; `combinations/combinationRelevance.kt:6-9` .

Ultimate limit state: 6.10a, 6.10b and 6.10

EN 1990 6.4.3.2 gives the fundamental combination as the less favourable of two expressions. Statiko computes one coefficient c per action from these rules:

> $$c_G = \gamma_G \cdot K_{FI}$$
>
> EN 1990 6.4.3.2 (6.10a), (6.10b) · kernel `combinations/calculateCombination.kt:96-118`

> $$c_{Q,1} = \gamma_{Q,1} \cdot K_{FI} \text{ (leading action)}$$
>
> EN 1990 6.4.3.2 (6.10b) · kernel `combinations/calculateCombination.kt:104-120`

> $$c_{Q,i} = \gamma_{Q,i} \cdot \psi_{0,i} \cdot K_{FI} \text{ (accompanying actions)}$$
>
> EN 1990 6.4.3.2 (6.10a), (6.10b) · kernel `combinations/calculateCombination.kt:106-120`

In these rules γ_G is $\gamma_{G,sup}$ for 6.10a, the reduced $\gamma_{G,sup}$ for 6.10b, and $\gamma_{G,inf}$ for the G,inf variant, where the permanent load is not multiplied by K_{FI}. Expression 6.10a has no leading action, so every variable action takes ψ_0.

Which actions take part depends on the policy. Under the CEN policy 6.10a contains all actions. Under the Danish and Swedish policies 6.10a contains the permanent load only, the option EN 1990 6.4.3.2(3) Note 3 allows. The G,inf variants contain only the permanent load and wind.

Under the Serbian annex Statiko uses EN 1990 Eq. 6.10 alone, as Serbian design practice to SRPS EN 1990/NA:2012 does: each leader gets one 6.10 combination with $\gamma_G = \gamma_{G,sup} = 1.35$ on the permanent load, $\gamma_{Q,1}$ on the leading action and $\gamma_{Q,i} \cdot \psi_{0,i}$ on the others, all times K_{FI}. There is no 6.10a combination and no reduction factor ξ. The G,inf variant with wind leading stays. The ψ factors, $\gamma_{G,inf}$, K_{FI} and the SLS and fire combinations are the same as under the Eurocode recommendation. A beam whose selected 6.10a or 6.10b combination the Serbian annex no longer generates moves to the first combination it can show when you apply the design code.

Country	$\gamma_{Q,1} = \gamma_{Q,i}$	$\gamma_{G,sup}$ in 6.10a	$\gamma_{G,sup}$ in 6.10b	$\gamma_{G,inf}$
Eurocode, Custom	1.5	1.35	1.35 × 0.85	1.0

Country	$\gamma_{Q,1} = \gamma_{Q,i}$	$\gamma_{G,sup}$ in 6.10a	$\gamma_{G,sup}$ in 6.10b	$\gamma_{G,inf}$
Denmark	1.5	1.2	1.0	0.9
Sweden	1.5	1.35	1.35 × 0.89	1.0
Serbia	1.5	1.35 in 6.10 (no 6.10a or 6.10b)		1.0

Consequence class	Eurocode, Custom (K_{FI})	Denmark (K_{FI})	Sweden (γ_d)
CC1	0.9	0.9	0.83
CC2	1.0	1.0	0.91
CC3	1.1	1.1	1.0

The CEN values are those of EN 1990 Table A1.2(B). The Danish values follow DS/EN 1990 DK NA Tabel A1.2(B+C), combinations 1 and 2; the Swedish reduction 0.89 and the safety-class factor γ_d follow EKS 12 Table B-3 and the safety classes SK1 to SK3.

Source: `design/actionFactorPresets.kt:9-68`; `combinations/generateCombinations.kt:104-127`; ai/eurocode/en1990_basis_of_design/10_ndp_national_annex_divergence_matrix.md.

Serviceability and fire combinations

The SLS combinations follow EN 1990 6.5.3. No partial factor and no K_{FI} enter them, and the permanent load always takes 1.0.

> Characteristic: $c_{Q,1} = 1.0, c_{Q,i} = \psi_{0,i}$
>
> EN 1990 6.5.3 (6.14b) · kernel `combinations/calculateCombination.kt:39-43`

> Frequent: $c_{Q,1} = \psi_{1,1}, c_{Q,i} = \psi_{2,i}$
>
> EN 1990 6.5.3 (6.15b) · kernel `combinations/calculateCombination.kt:49-53`

> Quasi-permanent: $c_{Q,i} = \psi_{2,i}$
>
> EN 1990 6.5.3 (6.16b) · kernel `combinations/calculateCombination.kt:62`

The characteristic combination without a leader contains the permanent load alone. The characteristic G,inf variant takes wind at 1.0 and no other variable action; the frequent G,inf variant takes wind at ψ_1 and no live, snow or custom load.

The fire combination follows EN 1990 6.4.3.3:

> $c_{Q,1} = \psi_{1,1}, c_{Q,i} = \psi_{2,i}, c_G = 1.0$
>
> EN 1990 6.4.3.3 (6.11b) · kernel `combinations/calculateCombination.kt:67-87`

The fire G,inf variant contains only the permanent load and wind (`combinations/generateCombinations.kt:120-124`). In a Swedish fire combination led by live load category C, ψ_1 of that action is 0.5, after EKS 12 C chapter 1.1.2 article 12.

Source: `combinations/generateCombinations.kt:45-58`.

Combination factors ψ

Action	Eurocode, Custom $\psi_0/\psi_1/\psi_2$	Denmark	Sweden
Live A	0.7 / 0.5 / 0.3	0.5 / 0.3 / 0.2	0.7 / 0.5 / 0.3
Live B	0.7 / 0.5 / 0.3	0.6 / 0.4 / 0.2	0.7 / 0.5 / 0.3
Live C	0.7 / 0.7 / 0.6	0.6 / 0.6 / 0.5	0.7 / 0.7 / 0.6
Live D	0.7 / 0.7 / 0.6	0.6 / 0.6 / 0.5	0.7 / 0.7 / 0.6
Live E	1.0 / 0.9 / 0.8	0.8 / 0.8 / 0.7	1.0 / 0.9 / 0.8
Live F	0.7 / 0.7 / 0.6	0.6 / 0.6 / 0.5	0.7 / 0.7 / 0.6
Live G	0.7 / 0.5 / 0.3	0.6 / 0.4 / 0.2	0.7 / 0.5 / 0.3
Live H	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Wind	0.6 / 0.2 / 0	0.3 / 0.2 / 0; 0.6 / 0.2 / 0 with category E leading	0.3 / 0.2 / 0

Snow depends on the context. Eurocode and Custom: altitude above 1000 m 0.7 / 0.5 / 0.2, below 1000 m 0.5 / 0.2 / 0. Denmark: 0.3 / 0.2 / 0; 0.6 / 0.2 / 0 with category E leading; 0 / 0 / 0 with wind leading. Sweden by characteristic snow load s_k: above 3 kN/m² 0.8 / 0.6 / 0.2; 2 to 3 kN/m² 0.7 / 0.4 / 0.2; 1 to 2 kN/m² 0.6 / 0.3 / 0.1. Dead load takes $\psi = 1.0$. The CEN values are those of EN 1990 Table A1.1.

The Custom load is not a row of this table. It has its own γ_Q, ψ_0, ψ_1 and ψ_2, one set per project, which you enter or take from a live load category in the **Design code** dialog (Chapter 5). They start at $\gamma_Q = 1.5$ and $\psi = 1.0$. The combinations treat it as any variable action with these factors: $\gamma_Q \cdot K_{FI}$ leading and $\gamma_Q \cdot \psi_0 \cdot K_{FI}$ accompanying at ULS, 1.0 and ψ_0 in the characteristic, ψ_1 and ψ_2 in the frequent and fire combinations, and ψ_2 in the quasi-permanent combination. Its ψ values are the same whichever action leads, in Denmark too.

Source: `design/psiFactorPresets.kt:34-92`; `design/customLoadFactorPresets.kt`; spec/beam/design-code-member-combinations.md rules 23–27.

Custom combinations

A combination you enter on the **Custom Combinations** tab of the **Design code** dialog (Chapter 5) is not generated from EN 1990. Each factor you enter is the whole coefficient of its load case: Statiko applies no γ, ψ or K_{FI} on top of it, and the self-weight takes the factor of the permanent load, as in every combination. A load case with no factor, or with the factor 0, is left out.

A user-defined combination is checked together with the generated combinations of its limit state and can govern: ULS in the material checks, SLS characteristic in the instantaneous deflection and, for timber, the final deflection, and

Fire in the fire checks. For the timber final deflection Statiko adds the creep of the quasi-permanent loads to your factors: k_{def} on the permanent load and $\psi_2 \cdot k_{def}$ on every variable load case of the combination, with the ψ_2 of the project's design code (EN 1995-1-1 2.2.3(5)). A limit state that has no check for the beam's material gives none.

A beam lists a user-defined combination when the combination holds a factor above 0 for a load case the beam has. It stands after the generated combinations of its limit state in the **Load combinations** card, the window and the report, under its own name. The report prints its equation as the sum of factor times load case symbol, and its EN 1990 equation cell reads **Not relevant**.

Source: spec/beam/design-code-member-combinations.md rules 30–34; kernel `combinations/applyCombination.kt`; `verification/TimberFinalCombination.kt`.

Applying a combination to the loads

> $$F_d = c_{action} \cdot F_k$$
>
> kernel `combinations/applyCombination.kt:6-26`

Every point force, axial force, moment and distributed load (both start and end intensity) of an action is multiplied by that action's coefficient; positions, offsets and directions stay as you entered them. The **Load combinations** window shows each combination's formula row with γ, ψ, K_{FI} and the final coefficient per action.

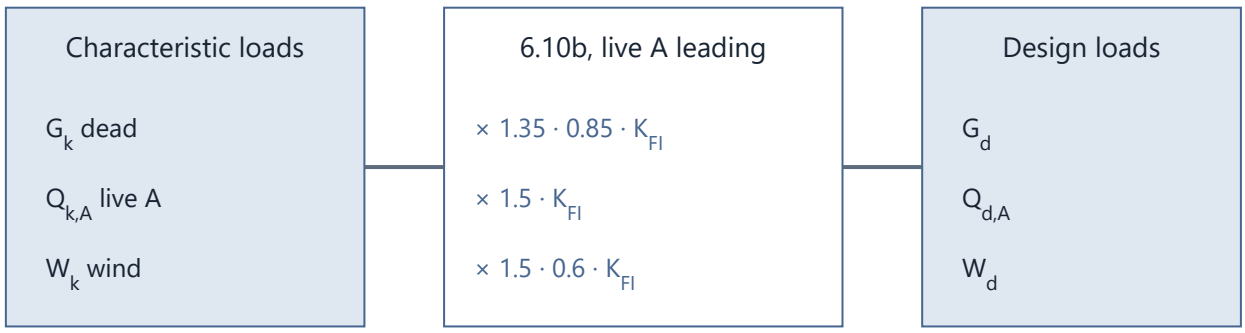


Figure 15.1 · One CEN combination: each action's characteristic loads are scaled by one coefficient.

Limits

Each action type is factored as a whole. Statiko does not split loads of one action into favourable and unfavourable parts and does not generate pattern loading over spans: every load acts over the extent you entered. Place loads yourself where a pattern governs. On a continuous beam the live load then acts on every span in every combination, so a span moment or deflection that governs with only some spans loaded (EN 1991-1-1 6.2.1(1)) needs its own beam: model the pattern as a separate beam with the live load on the spans you choose.

- Geotechnical combinations, EQU and UPL (Set A) and Set C are not available in this version.
- Missing or duplicate factors, invalid values and numerical overflow stop the generation; the app never shows a partial set of combinations.

CHAPTER 16

Static analysis

This chapter describes how Statiko finds the internal forces, reactions and deflections of your beam. For each load combination the app solves the factored beam with its own finite-element model, then reads every check from that one result. Knowing how the model is built helps you place supports and loads so the result is what you intend, and tells you why a beam is refused as a mechanism.

Kernel paths in this chapter are under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/`.

The beam model

Eurocode does not prescribe a beam analysis formulation; EN 1990 and EN 1993-1-1 leave the structural analysis method to the designer. Statiko uses its own finite-element method: one-dimensional Euler–Bernoulli beam elements with cubic Hermite shape functions and no shear deformation. Each node has two degrees of freedom, the vertical displacement v and the rotation θ. An internal hinge gives its node a second, independent rotation, so the left and right sides can turn separately.

Within each element, the linearly varying distributed load is added back through the exact particular solution of EI·w'''' = q. The moments, shears and deflections are therefore exact at every point for the load types a beam carries, not only at the nodes. The analysis is linear elastic and first order, and bending is about the strong axis.

Source: `fem/dof/BeamBendingDofs.kt:3-9`; `fem/statics/ExactBeamModel.kt:115-123`; `fem/statics/ExactBeamElement.kt`; ai/architecture/engineering-rules.md, Eurocode first, FEM beyond, practice always.

What feeds the model

- **Supports.** Their positions and the directions they restrain, and internal hinges. The member runs from the first support to the last.
- **Loads.** Point forces, moments (with a hinge side when placed on a hinge) and distributed loads with a start and end intensity, each with its Y and Z offset.
- **Section and material.** The bending stiffness EI uses the strong-axis second moment of area of the section and the elastic modulus E, 210 GPa for steel. Timber keeps its mean stiffness in the static analysis.
- **Self-weight.** When **Include self-weight** is on, added as a uniform load over the whole member, w = 9.81 × mass per metre, multiplied by the dead-load coefficient of the combination (`calculation/StaticBeamCalculationService.kt:343-357`).
- **The combination.** Every load is first scaled by its combination coefficient (Chapter 15).

Source: `calculation/BeamKernelModel.kt:12-53`; `fem/statics/StaticBeamAnalysisCalculator.kt:29`; `verification/BeamSectionAnalysisProperties.kt:46-51`.

Mesh and stations

Analysis nodes sit at every support, point load, moment load and distributed-load end. Result stations add 250 equal divisions of the member and a neighbour 1 mm either side of every support and load, so peaks and jumps are caught. Positions closer than about 1 mm are merged into one node.

Two placement rules keep loads from vanishing into a free degree of freedom: a point load on a hinge is moved 1 mm to the right, and a moment on a hinge is moved 1 mm to the side you chose. At a node the app reports both the

left and the right value, so a jump in the shear force shows in the graph.

> Because positions closer than about 1 mm merge, two supports or two loads that you mean to keep apart must be at least 1 mm from each other; closer than that, Statiko treats them as one point. A point load you place exactly on a hinge acts 1 mm to its right, so it is carried by the span on the right of the hinge, never lost in the hinge's free rotation.

Source: `fem/element/UnequalElementStrategy.kt:65-96` ; `fem/element/MinimumNodeSpacing.kt:21-34` ; `project/src/commonMain/kotlin/statiko/project/domain/support/BeamNodeSpacing.kt:7-11` ; ai/architecture/engineering-rules.md, mesh rules 1 and 2.

Element stiffness and loads

The element stiffness matrix for the degrees of freedom (v_1, θ_1, v_2, θ_2) of an element of length L is:

$$k = EI \cdot [\ 12/L^3,\ 6/L^2,\ -12/L^3,\ 6/L^2\ ;\ 6/L^2,\ 4/L,\ -6/L^2,\ 2/L\ ;\ -12/L^3,\ -6/L^2,\ 12/L^3,\ -6/L^2\ ;\ 6/L^2,\ 2/L,\ -6/L^2,\ 4/L\ ]$$

Statiko finite-element method · kernel `fem/matrix/BeamBendingMatrices.kt:86-96`

A distributed load varying from w_1 to w_2 over the element gives the equivalent nodal loads:

$$f = [\ L(7w_1 + 3w_2)/20,\ L^2(3w_1 + 2w_2)/60,\ L(3w_1 + 7w_2)/20,\ -L^2(2w_1 + 3w_2)/60\ ]$$

Statiko finite-element method · kernel `fem/statics/ExactBeamElement.kt:11-16`

Point forces act on the vertical degree of freedom of their node; a moment acts on the rotation of its side.

Supports, solution and mechanisms

A support that restrains vertical translation fixes v; one that restrains rotation fixes θ. Before solving, Statiko checks the reduced stiffness matrix by Gaussian elimination with scaled partial pivoting and treats it as singular when a pivot is at most 10^{-10} times its row scale. A singular beam is refused with the message "The beam is a mechanism: its supports and hinges allow free movement"; it is never solved.

The remaining system $K_{ff} \cdot u_f = F_f$ is solved with the LAPACK routine `dgesv` (LU factorisation with partial pivoting).

Source: `fem/statics/ExactBeamModel.kt:57-68, 142-148` ; `fem/statics/StiffnessStability.kt:4-26` ; `fem/statics/UnstableBeamException.kt:3-4` ; `linalg/LinAlgImpl.kt:133-171` .

> If your beam is refused as a mechanism, its supports and hinges together allow free movement. Add a restraint or remove a hinge; the app shows no results for a mechanism.

Reactions, moments, shears and deflections

> $$R = -(K_{row} \cdot u - F)$$
>
> Statiko finite-element method · kernel `fem/statics/ExactBeamModel.kt:150-166`

Within an element the displacement is the Hermite interpolation of the nodal values plus the particular solution $v_p(s) = (w_1 s^4/24 + (w_2 - w_1)/L \cdot s^5/120) / EI$, corrected so the nodal values are kept. From it:

> $$\text{deflection} = -v,\ \text{rotation} = v',\ M = -EI \cdot v'',\ V = -EI \cdot v'''$$
>
> Statiko finite-element method · kernel `fem/statics/ExactBeamElement.kt:18-48`

Sagging moments are positive. Values smaller than 10^{-9} are shown as zero. The reactions, the result graphs and every check of the selected combination read this one result (Chapter 11).

Torsion

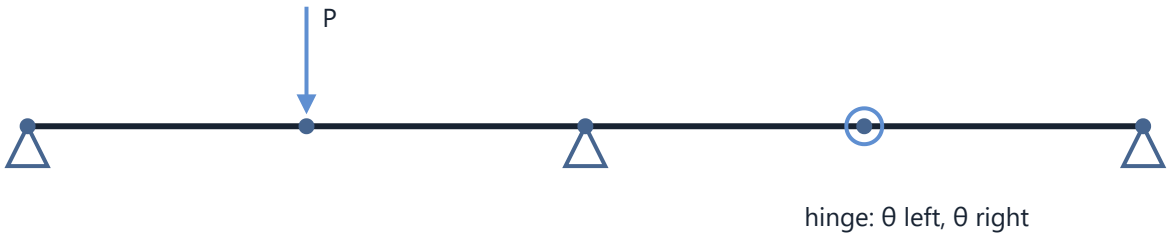
When the shear centre is offset from the centroid by more than 10^{-6} m, or a load has an offset, Statiko runs a second finite-element model for torsion. Each node has the twist θ and its gradient θ′ (warping). The element stiffness combines warping and St Venant torsion:

> $$k_T = EI_w \cdot k_{Hermite} + GI_t/(30L) \cdot [\ 36,\ 3L,\ -36,\ 3L\ ;\ 3L,\ 4L^2,\ -3L,\ -L^2\ ;\ -36,\ -3L,\ 36,\ -3L\ ;\ 3L,\ -L^2,\ -3L,\ 4L^2\ ]$$
>
> Statiko finite-element method · kernel `fem/matrix/TorsionMatrices.kt:13-35`; `fem/torsion/TorsionMatrixAssembly.kt:59-71`

> $$m_T = P \cdot (e_y - y_{sc}) \text{ and } m_T = w \cdot (e_y - y_{sc})$$
>
> Statiko finite-element method · kernel `fem/torsion/TorsionMatrixAssembly.kt:73-107`

A support that holds a translation fixes the twist; one that holds a rotation also fixes warping. The torsion constant I_t, the warping constant I_w and the shear centre come from the finite-element section analysis. The torque, twist and twist gradient at each station feed the steel shear, torsion and warping checks (Chapter 18).

Source: `verification/BeamTorsionAnalysis.kt:7-15, 104`; `fem/data/SupportRestraints.kt:50-55`; `fem/torsion/TorsionPostProcessor.kt:15-46`.



nodes at supports, loads, hinge; 250 stations and ±1 mm neighbours between

Figure 16.1 · The beam as Statiko models it: nodes at supports and loads, a hinge with two independent rotations.

Limits

- Linear elastic, first-order analysis with Euler–Bernoulli elements; shear deformation is not included.
- Vertical loads and strong-axis bending only. A non-zero axial load makes the beam checks Unsupported: axial force is not available in this version of the beam.
- Torsion is not analysed when the section is symmetric about the load line and every load is central.

CHAPTER 17

Lateral-torsional buckling

This chapter explains how Statiko checks lateral-torsional buckling, the sideways buckling and twisting of a beam whose compression flange is not held. It describes how the app finds the elastic critical moment M_{cr} over the whole member, and how M_{cr} then gives the steel reduction factor χ_{LT} and the timber factor k_{crit}. Use it to understand the values in the LTB check details and what the **Top flange laterally restrained** box changes.

Kernel paths in this chapter are under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/` unless they begin with `steel/`, `timber/` or `verification/CriticalMomentResult.kt`, which are under `engineering/src/commonMain/kotlin/statiko/engineering/`.

Critical moment as an eigenvalue

EN 1993-1-1 6.3.2.2(2) requires M_{cr} to be based on gross section properties and to take into account the loading conditions, the real moment distribution and the lateral restraints. The standard gives no formula for it. Statiko therefore computes M_{cr} with its own finite-element linear buckling analysis over the whole member. From the static moments, shears and loads of the combination it builds a stiffness matrix K and a geometric stiffness matrix K_G, and solves the generalised eigenvalue problem:

> $$K \cdot \varphi = \lambda \cdot K_G \cdot \varphi$$
>
> Statiko finite-element method · kernel `fem/ltb/CriticalBucklingCalculator.kt:39`

The smallest positive eigenvalue λ_{cr} is the factor by which the combination's loads must grow before the beam buckles. The critical moment is that factor times the largest moment of the static solution:

> $$M_{cr} = \lambda_{cr} \cdot |M_{max}|$$
>
> Statiko finite-element method · kernel `verification/BeamCriticalMoment.kt:71`

Because the whole member, its real moment diagram, its supports and the height of each load enter the model, no equivalent uniform moment factor or effective length is needed.

What feeds the analysis

- The supports, hinges and loads of the beam and the selected combination (Chapter 15, Chapter 16).
- The Z offset of each point and distributed load: its height relative to the shear centre. A load above the shear centre lowers M_{cr}. Self-weight acts with zero offset.
- The section: I_y, I_z, the product of inertia, I_t, I_w, the shear centre and the monosymmetry constants, all from the section analysis.
- E and G of the material. For timber the eigenproblem uses the characteristic $E_{0,05}$ and G_{05}; for rectangular softwood $G_{05} = E_{0,05}/16$ (Swedish Wood, Design of timber structures 1, 2016, p86; Centrum Hout, Houteigenschappen, 2014/3, p2).
- The **Top flange laterally restrained** box on the **Member** card (Chapter 8).

Source: `calculation/BeamKernelModel.kt:15-41`; `verification/BeamCriticalMoment.kt:16-32`; `timber/TimberStabilityStiffnessResolver.kt:12-57`.

The buckling model

Each node has four degrees of freedom: lateral displacement u, lateral slope u′, twist φ and warping φ′. The member is meshed with 50 equal divisions plus nodes at the supports and loads. At an internal hinge the right side gets its own lateral slope and warping; a hinged model that can move sideways as a mechanism is refused.

The elastic stiffness combines lateral bending, g · EI_z times the Hermite beam matrix, with warping and St Venant torsion, for example:

> $k_{33} = 12EI_w/L^3 + 6GJ/(5L), k_{34} = 6EI_w/L^2 + GJ/10, k_{44} = 4EI_w/L + 2GJL/15, k_{48} = 2EI_w/L - GJL/30$
>
> Statiko finite-element method · kernel `fem/matrix/LateralTorsionalBucklingMatrices.kt:6-40`

> $g = 1 - (EI_{yz})^2 / (EI_y \cdot EI_z)$
>
> Statiko finite-element method · kernel `fem/ltb/CriticalBucklingMatrixAssembly.kt:37`

The geometric stiffness of each element adds the moment M_1 and shear V_1 at the element start (giving the linear change of moment along it), every point load P with its height term ($e_z - y_0$), every applied moment, and every distributed load q with its height ($a_y - y_0$). The monosymmetry term is:

> $a_x = [I_y(I_x\beta_x - I_{xy}\beta_y) - 2I_{xy}(I_y x_0 - I_{xy} y_0)] / (I_x I_y - I_{xy}^2)$
>
> Statiko finite-element method · kernel `fem/ltb/CriticalBucklingMatrixAssembly.kt:40`

Here x_0, y_0 are the shear centre coordinates and β_x, β_y the section's monosymmetry constants, in the kernel's section axes.

Source: `fem/dof/BeamLtbDofs.kt:3-10`; `fem/ltb/BeamLtbDofMap.kt:14-21`; `fem/ltb/LtbHingeStability.kt:9-30`; `fem/ltb/CriticalBucklingMatrixAssembly.kt:72-123`.

Restraints and the eigenvalue solution

Every support that holds a vertical translation is a fork support: it fixes the lateral displacement u and the twist φ. A support that holds a rotation also fixes u′ and φ′. Restrained degrees of freedom are removed from K and K_G. Discrete lateral restraints between supports and restraint over part of the length are not available in this version.

1. K and K_G are scaled by $s_i = 1/\sqrt{K_{ii}}$.
2. LAPACK `dsygvd` solves $K_G \cdot x = \mu \cdot K \cdot x$ with K as the positive definite matrix; $\lambda = 1/\mu$.
3. Modes with $|\mu| \le n \cdot \mathrm{ulp}(1) \cdot \max|\mu|$ are dropped.
4. Each λ is refined by the Rayleigh quotient $\lambda = (\varphi^T K \varphi) / (\varphi^T K_G \varphi)$ with compensated summation, and the list is sorted.

5 λ_{cr} is the first positive eigenvalue.

Source: `fem/data/SupportRestraints.kt:57-68` ; `linalg/LinAlgImpl.kt:8-71` (`computeSymmetricDefiniteEigenvalues`); `fem/data/LTBData.kt:8`. The non-symmetric path keeps only real, finite eigenvalues (`linalg/realGeneralizedEigenvalue.kt:5-8`).

The result is one of four kinds: computed, not computed (no moment, no positive eigenvalue or an unsupported section), unavailable (the native solver is missing) or failed calculation. Only a computed M_{cr} can give a result (`verification/CriticalMomentResult.kt:3-11`).

Steel: χ_{LT} and $M_{b,Rd}$

Statiko follows the general case of EN 1993-1-1 6.3.2.2.

> $$\bar{\lambda}_{LT} = \sqrt{(W_y \cdot f_y / M_{cr})}$$
>
> EN 1993-1-1 6.3.2.2 · kernel `steel/SteelMemberVerifier.kt:427`

> $$\Phi_{LT} = 0.5 \cdot [1 + \alpha_{LT} \cdot (\bar{\lambda}_{LT} - 0.2) + \bar{\lambda}_{LT}^2]$$
>
> EN 1993-1-1 6.3.2.2 (6.56) · kernel `steel/SteelMemberVerifier.kt:428`

> $$\chi_{LT} = 1 / (\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \bar{\lambda}_{LT}^2)}) \leq 1.0$$
>
> EN 1993-1-1 6.3.2.2 (6.56) · kernel `steel/SteelMemberVerifier.kt:429-436`

> $$M_{b,Rd} = \chi_{LT} \cdot W_y \cdot f_y / \gamma_{M1}, \text{utilisation} = M_{Ed} / M_{b,Rd}$$
>
> EN 1993-1-1 6.3.2.1 (6.54), (6.55) · kernel `steel/SteelMemberVerifier.kt:273-275`

W_y is the plastic modulus for Class 1 and 2 and the elastic modulus for Class 3. The buckling curve follows Table 6.4, general case:

Section	h/b ≤ 2	h/b > 2
Rolled I	a (α_{LT} = 0.21)	b (α_{LT} = 0.34)
Welded I	c (α_{LT} = 0.49)	d (α_{LT} = 0.76)
Other sections	d (α_{LT} = 0.76)	

Source: `steel/SteelLateralTorsionalCurve.kt:9-20` ; `steel/SteelBucklingCurve.kt:3-9` ; EN 1993-1-1 Tables 6.3 and 6.4.

For beams Statiko does not use the optional exemption of 6.3.2.2(4) ($\bar{\lambda}_{LT} \leq 0.2$ or $M_{Ed}/M_{cr} \leq 0.04$), and it does not use the rolled-section method of 6.3.2.3. χ_{LT} is always computed by (6.56).

When you tick **Top flange laterally restrained** and no station moment of a combination is negative, that combination is covered: steel LTB is Not evaluated for it, by EN 1993-1-1 6.3.2.1(2), and no M_{cr} is computed. A combination with hogging anywhere is checked as normal.

When torsion produces a warping demand, Statiko checks LTB only on a simply supported single span, with the member interaction of SCI P385 3.2; on other beams the LTB check is Unsupported. The interaction, with $k_w = 0.7 - 0.2 \cdot M_{w,Ed}/M_{w,Rd}$, is:

> $$M_{y,Ed}/M_{b,Rd} + 1.0 \cdot M_{z,Ed}/M_{z,Rd} + k_w \cdot (1 - M_{z,Ed}/M_{z,Rd}) \cdot 1/(1 - M_{y,Ed}/M_{cr}) \cdot M_{w,Ed}/M_{w,Rd}$$
>
> SCI P385 3.2 · kernel `steel/SteelMemberVerifier.kt:109-133`

Source: spec/beam/lateral-restraint.md rules 6 to 8; `verification/SteelBeamChecks.kt:285-308, 567-568, 683-689`.

Timber: k_{crit}

> $$\sigma_{m,crit} = M_{cr} / W_y$$
>
> EN 1995-1-1 6.3.3 · kernel `timber/TimberBeamUtilizationCalculator.kt:164`

> $$\lambda_{rel,m} = \sqrt{(f_{m,k} / \sigma_{m,crit})}$$
>
> EN 1995-1-1 6.3.3 (6.30) · kernel `timber/TimberBeamUtilizationCalculator.kt:174`

> $$k_{crit} = 1 \text{ for } \lambda_{rel,m} \le 0.75;\ 1.56 - 0.75 \cdot \lambda_{rel,m} \text{ for } 0.75 < \lambda_{rel,m} \le 1.4;\ 1/\lambda_{rel,m}^{\,2} \text{ for } \lambda_{rel,m} > 1.4$$
>
> EN 1995-1-1 6.3.3 (6.34) · kernel `timber/TimberBeamUtilizationCalculator.kt:175-179`

> $$\sigma_{m,d} / (k_{crit} \cdot f_{m,d}) \le 1,\ f_{m,d} = f_{m,k} \cdot k_{mod} \cdot k_h \cdot k_{sys} / \gamma_M$$
>
> EN 1995-1-1 6.3.3 (6.33) · kernel `timber/TimberBeamUtilizationCalculator.kt:43-44, 181`

k_{sys} enters $f_{m,d}$ only, not the slenderness. For a covered combination $k_{crit} = 1.0$ by EN 1995-1-1 6.3.3(5); the fork supports provide the torsional restraint that clause also requires. Statiko does not use the effective lengths of Table 6.1: M_{cr} comes from the eigenvalue problem. Without a computed M_{cr} the timber LTB check is Unavailable.

What you see

The **Lateral torsional buckling** check card and its details show M_{cr}, α_{LT}, $\bar{\lambda}_{LT}$, Φ_{LT}, χ_{LT}, γ_{M1} and $M_{b,Rd}$ for steel, or $\sigma_{m,crit}$, $\lambda_{rel,m}$, k_{crit} and $f_{m,d}$ for timber (Chapter 12). The report prints the same derivation in its LTB section (Chapter 14).

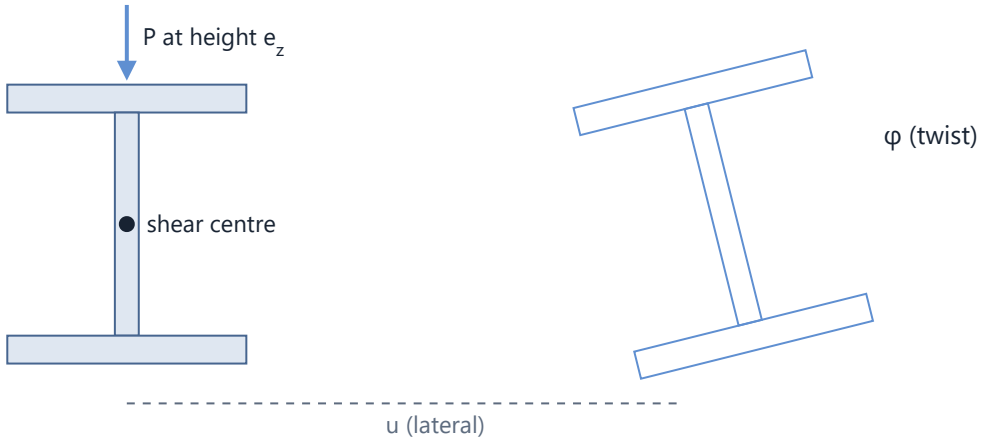


Figure 17.1 · Lateral-torsional buckling: the section moves sideways by u and twists by φ; a load above the shear centre makes it worse.

CHAPTER 18

Steel checks

This chapter explains how Statiko verifies a steel beam against EN 1993-1-1 for every ultimate limit state combination. It covers the partial factors of each National Annex, the cross-section classification, the resistances in bending, shear and torsion and how they interact, and where the stability check of Chapter 17 fits in. Use it to read the four steel check cards and their details, and to understand why a section is refused rather than passed.

Kernel paths in this chapter are under `engineering/src/commonMain/kotlin/statiko/engineering/`, except `verification/SteelBeamChecks.kt` and `verification/limitedToBeamAxialScope.kt`, which are under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/`.

How the steel checks run

For every ULS combination Statiko takes the station results of the static analysis (Chapter 16) and checks each station. It first resolves the design yield strength and the partial factors, classifies the section for strong-axis bending, refuses a Class 4 section, and picks the plastic or elastic modulus by class. It then produces four checks: **Bending**, **Shear**, **Torsion** and **Lateral torsional buckling**. Each check names its governing combination and position.

What feeds the checks: the profile and its manufacturing (rolled or welded), the steel grade and product standard, which give f_y by thickness (Chapter 6), the design code with its country and steel robustness setting, the top flange restraint, and the loads with their offsets.

Source: `verification/SteelBeamChecks.kt:160-517`; ai/architecture/engineering-rules.md, Steel classification and effective-section boundary, Profile feasibility boundary.

Partial factors

National Annex	γ_{M0}	γ_{M1}	γ_{M2}
Eurocode	1.0	1.0	1.25
Denmark	1.1	1.2	1.35
Sweden	1.0	1.0	1.1
Serbia	1.0	1.0	1.25
Custom	the values you enter in the **Design code** dialog		

The Eurocode values are the recommended values of EN 1993-1-1 6.1. When you switch on steel robustness, every γ_M is multiplied by 1.2:

> $\gamma_{M,used} = 1.2 \cdot \gamma_M$ (robustness on)
>
> kernel `steel/SteelDesignFactorResolver.kt:6-13`

Source: `design/materialFactorPresets.kt:18-58`.

Cross-section classification

> $$\varepsilon = \sqrt{(235\ \text{MPa} / f_y)}$$
>
> EN 1993-1-1 Table 5.2 · kernel `steel/classification/steelBeamClassificationEpsilon.kt:6-12`

f_y is the design yield strength for the governing thickness. Each plate of the section is compared with the Table 5.2 limits on c/t:

Part	Class 1	Class 2	Class 3
Internal part, compression	33ε	38ε	42ε
Internal part, bending	72ε	83ε	124ε
Outstand, compression	9ε	10ε	14ε
Tube, d/t	$50\varepsilon^2$	$70\varepsilon^2$	$90\varepsilon^2$
Angle, h/t and (b + h)/2t	–	–	15ε and 11.5ε

A ratio above the Class 3 limit is Class 4, and the section takes the class of its least favourable plate. Beam checks classify for strong-axis bending. The class shows in the **Member** card header.

Source: `steel/classification/BucklingElement.kt:12-117`; `steel/classification/BucklingElementRow.kt:18-24`; `verification/SteelBeamChecks.kt:181-186, 889`.

> A Class 4 beam is refused: every steel check reads Unsupported with the reason Class 4 section. Effective-section resistance for Class 4 beams is not available in this version. Choose a stockier section.

Bending

> $$M_{c,Rd} = W \cdot f_y / \gamma_{M0},\ W = W_{pl} \text{ for Class 1 and 2},\ W = W_{el,min} \text{ for Class 3}$$
>
> EN 1993-1-1 6.2.5 (6.13), (6.14) · kernel `steel/SteelMemberVerifier.kt:405-417`; `steel/SteelResistanceSectionResolver.kt:63-72`

The utilisation is $|M_{Ed}| / M_{c,Rd}$ at every station; the highest governs.

When the coexistent shear at a station exceeds half the shear resistance, the moment resistance is reduced by EN 1993-1-1 6.2.8:

> $$\rho = (2 \cdot V_{Ed}/V_{Rd} - 1)^2$$
>
> EN 1993-1-1 6.2.8 · kernel `steel/SteelShearBendingReduction.kt:37-38`

> $$M_{y,V,Rd} = (W_{pl,y} - \rho \cdot {A_w}^2 / (4\, t_w)) \cdot f_y / \gamma_{M0} \le M_{c,Rd},\ A_w = h_w \cdot t_w$$
>
> EN 1993-1-1 6.2.8 (6.30) · kernel `steel/SteelShearBendingReduction.kt:39-47`

V_{Rd} is the shear resistance already reduced for torsion. The reduction is applied for equal-flange I and H sections in Class 1 or 2 without warping demand; for other shapes, Class 3, or a shear ratio above 1, Bending reads Unsupported with the reason shear-bending interaction required.

When torsion creates a warping bimoment, Bending uses the cross-section interactions of SCI P385 3.1:

> $\text{plastic: } (M_{y,Ed}/M_{y,Rd})^2 + M_{z,Ed}/M_{z,Rd} + M_{w,Ed}/M_{w,Rd} \le 1\text{; elastic: } M_{y,Ed}/M_{y,Rd} + M_{z,Ed}/M_{z,Rd} + M_{w,Ed}/M_{w,Rd} \le 1$
>
> SCI P385 3.1.2 and 3.1.1 · kernel `steel/SteelMemberVerifier.kt:97-107`

Source: `verification/SteelBeamChecks.kt:352-479`.

Shear and shear with torsion

> $V_{pl,Rd} = A_v \cdot (f_y / \sqrt{3}) / \gamma_{M0}$
>
> EN 1993-1-1 6.2.6 (6.18) · kernel `steel/SteelShearTorsionResistance.kt:5-8`

The shear area A_v follows EN 1993-1-1 6.2.6(3):

Section	A_v
Rolled I or H	$A - 2bt_f + (t_w + 2r)t_f$, not less than $\eta \cdot h_w \cdot t_w$
Welded I or H	$\eta \cdot h_w \cdot t_w$
Rolled channel	$A - 2bt_f + (t_w + r)t_f$
Rolled T	$A - bt_f + (t_w + 2r)t_f/2$
Welded T	$t_w \cdot (h - t_f/2)$
Box with equal flanges	$\eta \cdot 2 \cdot h_w \cdot t_w$
Rectangular hollow	$A \cdot h / (b + h)$
Circular hollow	$2A / \pi$

For zee and solid sections, welded channels and boxes with inclined webs, Statiko uses the shear area from its finite-element section analysis; the check details name this basis. Angles use the elastic shear resistance $V_{Rd} = (f_y/\sqrt{3})/\gamma_{M0} \cdot I \cdot t / S$ (EN 1993-1-1 6.2.6(4), (6.19) and (6.20); `steel/SteelShearTorsionResistance.kt:40-51`), and with torsion $V_{Rd,T} = (1 - \tau_t / ((f_y/\sqrt{3})/\gamma_{M0})) \cdot V_{Rd}$ (6.2.7(5) with 6.2.1(5); `steel/SteelShearTorsionResistance.kt:53-62`). $\eta = 1.2$ for $f_y \le 460$ MPa and 1.0 above (EN 1993-1-5 5.1(2) Note 2).

Source: `steel/SteelShearArea.kt:12-151` ; `design/SteelShearEtaResolver.kt:20-35`.

With torsion, the shear stress $\tau_{t,Ed}$ reduces the shear resistance by EN 1993-1-1 6.2.7(9). For I and H sections and channels it is the St Venant stress $\tau_{t,Ed} = T_t \cdot t / I_t$, with $T_t = G \cdot I_t \cdot \theta'$ when a twist gradient exists and the total torque otherwise (`steel/SteelShearTorsionCalculator.kt:93-106` , `:150-158`). For hollow sections it is the Bredt stress

$\tau_{t,Ed} = |T| / (2 \cdot A_m \cdot t)$, with A_m the area enclosed by the wall midline and t the wall thickness (`steel/SteelShearTorsionResistance.kt:16-19`):

> I or H: $V_{pl,T,Rd} = \sqrt{(1 - \tau_{t,Ed} / (1.25 \cdot (f_y/\sqrt{3})/\gamma_{M0}))} \cdot V_{pl,Rd}$
>
> EN 1993-1-1 6.2.7(9) (6.26) · kernel `steel/SteelShearTorsionResistance.kt:20-24`

> Channel: $V_{pl,T,Rd} = [\sqrt{(1 - \tau_{t,Ed} / (1.25 \cdot (f_y/\sqrt{3})/\gamma_{M0})) - \tau_{w,Ed} / ((f_y/\sqrt{3})/\gamma_{M0})}] \cdot V_{pl,Rd}$
>
> EN 1993-1-1 6.2.7(9) (6.27) · kernel `steel/SteelShearTorsionResistance.kt:26-37`

> Hollow: $V_{pl,T,Rd} = [1 - \tau_{t,Ed} / ((f_y/\sqrt{3})/\gamma_{M0})] \cdot V_{pl,Rd}$
>
> EN 1993-1-1 6.2.7(9) (6.28) · kernel `steel/SteelShearTorsionResistance.kt:63-66`

Before the shear check, Statiko tests whether the web is slender enough for shear buckling:

> $h_w / t_w > 72 \cdot \varepsilon / \eta \Rightarrow$ shear buckling check required
>
> EN 1993-1-1 6.2.6(6) (6.22) · kernel `steel/SteelShearBucklingRelevance.kt:14-41`

If it is, Shear reads Unsupported with the reason shear buckling required: the EN 1993-1-5 shear buckling resistance is not available in this version.

Torsion

The torsion check compares the largest torque with a resistance from the section's torsion modulus W_t, which Statiko's finite-element section analysis provides. This resistance form is Statiko's own method; the utilisation follows $T_{Ed}/T_{Rd} \le 1$ of EN 1993-1-1 6.2.7.

> $T_{Rd} = W_t \cdot (f_y / \sqrt{3}) / \gamma_{M0}$, utilisation $= |T_{Ed}| / T_{Rd}$
>
> Statiko method · kernel `steel/SteelTorsionCalculator.kt:33-36`

Stability

Lateral-torsional buckling follows EN 1993-1-1 6.3.2 with M_{cr} from the eigenvalue analysis, χ_{LT} and $M_{b,Rd} = \chi_{LT} \cdot W_y \cdot f_y / \gamma_{M1}$; Chapter 17 gives every step. Flexural buckling under compression is not checked for beams, because the beam carries no axial force.

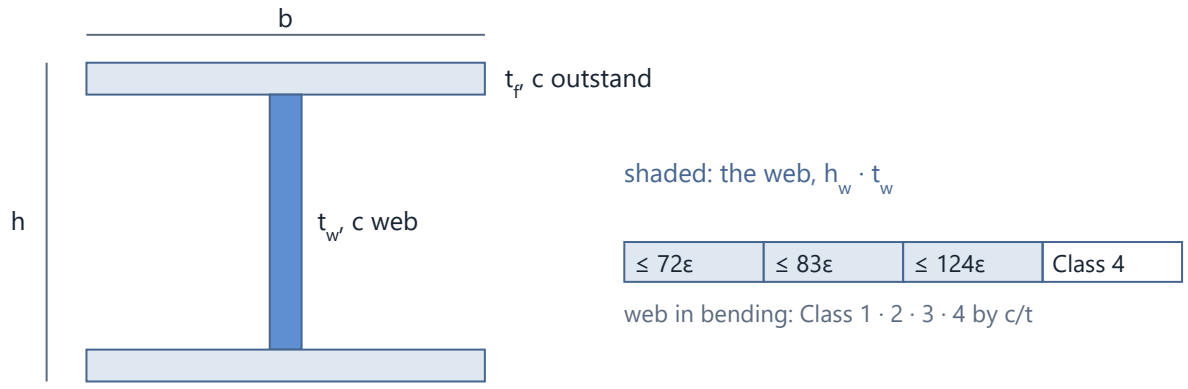


Figure 18.1 · The plate widths c and thicknesses used for classification, and the class bands for a web in bending.

Results and limits

Each card shows the utilisation, status and governing combination and position; the check details show the terms: W_y, class, f_y and γ_{M0} for Bending; A_v and its basis, $V_{pl,Rd}$, V_{Rd} and the buckling-relevance terms for Shear; W_t for Torsion (Chapter 12).

- Unsupported, Unavailable, Invalid input and Failed calculation are separate statuses and never count as a pass.
- Not available in this version: Class 4 beams, shear buckling resistance, the 6.2.8 reduction (6.29) for shapes other than equal-flange I and H, bending with axial force (6.2.9) and beam-column stability (6.3.3). A non-zero axial load makes every steel check Unsupported.
- Torsion with lateral-torsional buckling is checked only on a simply supported single span.

Source: `verification/SteelBeamChecks.kt:166-233, 501-516`; `verification/limitedToBeamAxialScope.kt:4-15`.

CHAPTER 19

Timber and glulam checks

This chapter explains how Statiko checks a solid timber or glulam beam at the ultimate limit state. You see where every factor in a timber check comes from (k_{mod}, k_h, k_{sys}, γ_M, k_{cr}, k_{crit} and $k_{c,90}$), which inputs drive them, and what each check card means. The basis is EN 1995-1-1:2004 + A1:2008. Serviceability, with the final deflection and k_{def}, is in Chapter 21, and fire is in Chapter 22.

Kernel paths in this chapter are under `engineering/src/commonMain/kotlin/statiko/engineering/` unless they start with `verification/`, which is under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/`.

How the checks run

For every ultimate limit state combination (EN 1990 6.10a, 6.10b, 6.10b with G_{inf}, 6.10 and 6.10 with G_{inf} under the Serbian annex, and Custom), Statiko takes the bending moment, shear force and torque at every station of the finite-element result (Chapter 16) and the support reactions. It then checks a rectangular section by elementary stresses against design strengths. Five checks run: bending, shear, torsion, lateral-torsional buckling and bearing. Each check keeps its worst station. Across combinations, the governing combination is the one with the largest utilisation.

Only ultimate limit state combinations govern these checks. Serviceability and fire combinations never do. The Unit expression is used only when the beam has no ultimate limit state combination.

Source: ai/architecture/engineering-rules.md, Timber member factor boundary; kernel `timber/TimberUlsCombination.kt:5-16`, `timber/TimberGoverningCombinationSelector.kt:6-25`.

What you enter

- **Material grade.** C14, C18, C24 or C30 from EN 338:2016, or GL24c, GL24h, GL28c, GL28h, GL30c or GL30h from EN 14080:2013. Each grade carries its characteristic strengths, stiffnesses and densities. For example, C24 has $f_{m,k}$ = 24 MPa, $f_{v,k}$ = 4.0 MPa, $f_{c,90,k}$ = 2.5 MPa and $E_{0,05}$ = 7 400 MPa.
- **Section.** A rectangle b × h.
- **Design code.** The design country sets γ_M: 1.30 for solid timber and 1.25 for glulam (Eurocode, Sweden, Serbia), or 1.35 and 1.30 (Denmark). A Custom design country takes your own values.
- **Service class** 1, 2 or 3, and the **system factor** k_{sys}: 1.0, 1.1 or 1.2.
- **Load duration** for each action: Permanent, Long-term, Medium-term, Short-term or Instantaneous.
- **Stability stiffness** for lateral-torsional buckling (see below).
- **Lateral restraint** of the top flange, and the **bearing length** l_b on every Fixed, Pinned or Roller support (Chapter 8).

Source: kernel `project/src/commonMain/kotlin/statiko/project/domain/material/TimberGradeType.kt` (EN 338:2016, EN 14080:2013); `design/materialFactorPresets.kt:24-29`; EN 1995-1-1 2.4.1 Table 2.3; spec/beam/supports.md rule 30.

Design strength factors

Load duration and k_{mod}

An action takes part in a combination when its coefficient in that combination is not zero. Every participating action needs exactly one load duration; a missing or duplicated duration makes the timber checks Invalid input. The governing duration is the shortest duration among the participating actions, as EN 1995-1-1 3.1.3(2) requires. k_{mod} then comes from Table 3.1 for solid timber and glulam:

Service class	Permanent	Long-term	Medium-term	Short-term	Instantaneous
1 and 2	0.60	0.70	0.80	0.90	1.10
3	0.50	0.55	0.65	0.70	0.90

Source: EN 1995-1-1 3.1.3, Table 3.1; kernel `timber/TimberDesignFactorResolver.kt:54-72`, `:87-103`.

Size factor k_h

A shallow section gets a higher bending strength. With h the section depth:

> $$\text{solid timber: } k_h = \min[(150 / h)^{0.2} ; 1.3] \text{ for } h < 150 \text{ mm, otherwise } 1.0$$
>
> EN 1995-1-1 3.2(3) (3.1) · kernel `timber/TimberRectangularSection.kt:9-13`

> $$\text{glulam: } k_h = \min[(600 / h)^{0.1} ; 1.1] \text{ for } h < 600 \text{ mm, otherwise } 1.0$$
>
> EN 1995-1-1 3.3(3) (3.2) · kernel `timber/TimberRectangularSection.kt:14-17`

Design strengths

> $$f_{m,d} = f_{m,k} \cdot k_{mod} \cdot k_h \cdot k_{sys} / \gamma_M$$
>
> EN 1995-1-1 2.4.1 (2.14), 3.2, 6.6 · kernel `timber/TimberBeamUtilizationCalculator.kt:43-44`

> $$f_{v,d} = f_{v,k} \cdot k_{mod} \cdot k_{sys} / \gamma_M$$
>
> EN 1995-1-1 2.4.1 (2.14), 6.6 · kernel `timber/TimberBeamUtilizationCalculator.kt:45-46`

EN 1995-1-1 6.6 allows k_{sys} above 1.0 only when several equally spaced members are joined by a load-distributing system. Statiko applies the value you choose and does not check that condition. Keep 1.0 for an isolated beam.

Bending, shear and torsion

Bending

The beam bends about one axis, so the bending check is the uniaxial form of EN 1995-1-1 6.1.6:

> $\sigma_{m,d} = |M_{Ed}| / W_y \; ; \eta = \sigma_{m,d} / f_{m,d}$
>
> EN 1995-1-1 6.1.6 (6.11) · kernel `timber/TimberBeamUtilizationCalculator.kt:47`, `:54`

Shear and the crack factor k_{cr}

Shear uses the peak shear stress of a rectangle on the effective width $b_{ef} = k_{cr} \cdot b$, which allows for drying cracks:

> $\tau_d = 1.5 \cdot |V_{Ed}| / (A \cdot k_{cr}) \; ; \eta = \tau_d / f_{v,d}$
>
> EN 1995-1-1 6.1.7 (6.13), (6.13a) · kernel `timber/TimberRectangularSection.kt:20-22`, `timber/TimberBeamUtilizationCalculator.kt:55-75`

The design country sets k_{cr}:

Design country	k_{cr} in Statiko
Eurocode	0.67
Denmark	1.0 (DS/EN 1995-1-1 DK NA:2024 6.1.7(2))
Serbia	0.67, the same value as Eurocode
Sweden	Shear Unavailable: EKS 12 ties k_{cr} to rain and sun exposure, which the input does not hold
Custom	Your value, above 0 and at most 1.0; shear Unavailable until you enter it

Source: kernel `timber/TimberShearCrackFactorResolver.kt:6-19`, `timber/TimberShearCrackFactor.kt:8-14`.

Statiko includes every load near a support in the shear force. The reduction of EN 1995-1-1 6.1.7(3) is not available in this version.

Torsion

The torsional shear stress is $\tau_{tor,d} = |T| / W_{tor}$, with the torque T of the torsion analysis and $W_{tor} = h \cdot b^2 / (3 + 1.8 \cdot b/h)$. This torsion modulus is the kernel's own; EN 1995-1-1 gives none (`timber/TimberBeamUtilizationCalculator.kt:49-53`). With h the larger and b the smaller side, it is checked against the shear strength raised by the shape factor:

> $k_{shape} = \min(1 + 0.15 \cdot h / b \; ; 2.0) \; ; \eta = \tau_{tor,d} / (k_{shape} \cdot f_{v,d})$
>
> EN 1995-1-1 6.1.8 (6.14), (6.15) · kernel `timber/TimberBeamUtilizationCalculator.kt:52-53`, `:79`

Lateral-torsional buckling

When the top flange is laterally restrained, k_{crit} = 1.0 (EN 1995-1-1 6.3.3(5)) and the check is the bending check. Otherwise Statiko uses the critical moment M_{cr} of the member, the lowest eigenvalue of the buckling problem in Chapter 17, rather than the effective lengths of Table 6.1.

M_{cr} needs fifth-percentile stiffnesses. The material carries their basis:

- **Rectangular softwood**: $G_{0,05} = E_{0,05} / 16$, from Swedish Wood, *Design of timber structures 1* (2016) p. 86, and Centrum Hout, *Houteigenschappen* (2014/3) p. 2. This is an industry source, not a Eurocode value. The grades C14 to C30 use it.
- **Declared**: $G_{0,05}$ with its source. Glulam always needs a declared value; the grades GL24c to GL30h declare $G_{0,05}$ = 540 MPa from EN 14080:2013 Tables 4 and 5.
- No basis: lateral-torsional buckling is Unavailable, and the other checks still run. A project saved before this version keeps the basis it was saved with.

> $$\sigma_{m,crit} = M_{cr} / W_y \; ; \; \lambda_{rel,m} = \sqrt{(f_{m,k} / \sigma_{m,crit})}$$
>
> EN 1995-1-1 6.3.3 (6.30) · kernel `timber/TimberBeamUtilizationCalculator.kt:164-174`

> $$k_{crit} = 1.0 \text{ for } \lambda_{rel,m} \leq 0.75 \; ; \; 1.56 - 0.75 \cdot \lambda_{rel,m} \text{ for } 0.75 < \lambda_{rel,m} \leq 1.4 \; ; \; 1 / {\lambda_{rel,m}}^2 \text{ for } \lambda_{rel,m} > 1.4$$
>
> EN 1995-1-1 6.3.3 (6.34) · kernel `timber/TimberBeamUtilizationCalculator.kt:175-179`

> $$\eta = \sigma_{m,d} / (k_{crit} \cdot f_{m,d})$$
>
> EN 1995-1-1 6.3.3 (6.33) · kernel `timber/TimberBeamUtilizationCalculator.kt:180-181`

The slenderness uses the characteristic strength $f_{m,k}$ alone; k_{sys} enters only $f_{m,d}$.

k_{crit} assumes the straightness limits of EN 1995-1-1 section 10. A missing M_{cr} makes the check Unavailable, never a pass.

Source: kernel `timber/TimberStabilityStiffnessResolver.kt:11-57`, `verification/TimberBeamChecks.kt:241-291`.

Bearing at the supports

Bearing is compression perpendicular to the grain over each Fixed, Pinned or Roller support. Statiko centres the contact length l_b you enter on the support. At each side, the contact length is extended by the smallest of 30 mm, l_b, half the clear distance l_1 to the next contact, or the distance to the member end (Figure 6.2). The member starts and ends at its first and last support, so at an end support the outer extension is 0 and only the inner side is extended.

> $$l_{ef} = l_b + e_{left} + e_{right} \; ; \; A_{ef} = l_{ef} \cdot b$$
>
> EN 1995-1-1 6.1.5(1), Figure 6.2 · kernel `timber/TimberBearingCalculator.kt:57-89`

$$f_{c,90,d} = k_{mod} \cdot f_{c,90,k} / \gamma_M$$

EN 1995-1-1 2.4.1 (2.14) · kernel `timber/TimberBearingCalculator.kt:46-47`

$$\sigma_{c,90,d} = R / A_{ef} \; ; \; \eta = \sigma_{c,90,d} / (k_{c,90} \cdot f_{c,90,d})$$

EN 1995-1-1 6.1.5 (6.3), (6.4) · kernel `timber/TimberBearingCalculator.kt:91-95`

k_h and k_{sys} do not enter the bearing strength. $k_{c,90}$ is 1.0 unless every clear distance l_1 to an adjacent contact is at least 2h (one distance at an end support, two at an internal one) and the material qualifies; a single bearing with no neighbour keeps 1.0 (`timber/TimberBearingCalculator.kt:146-156`). Then $k_{c,90}$ is 1.5 for solid softwood, and 1.75 for glulam when $l_b \le 400$ mm (6.1.5(4), discrete supports). The governing support is the one with the largest utilisation.

A support without a bearing length makes the check Not checked with "Support B has no bearing length." A support that carries a moment (a fixed end) makes the check Unsupported.

Source: kernel `timber/TimberBearingCalculator.kt:141-156`, `verification/TimberBeamChecks.kt:169-239`; spec/beam/supports.md rule 30.

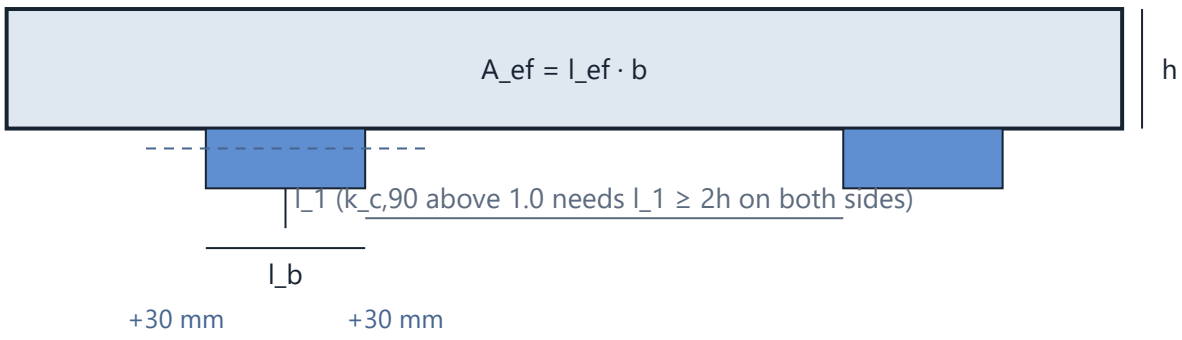


Figure 19.1 · The effective contact length l_{ef}: l_b centred on the support, extended up to 30 mm at each side; at an end support only the inner side is extended.

What you see

The timber checks column shows **Bending**, **Shear**, **Torsion**, **Lateral-torsional buckling** and **Bearing**, and a timber utilisation summary. Each check shows its utilisation, governing combination and position. Its detail lists the terms: k_{mod} with the service class and governing duration, k_h, k_{sys}, γ_M, the characteristic and design strengths and the stress. Shear adds k_{cr} and b_{ef}. Torsion adds k_{shape}. Lateral-torsional buckling adds $\sigma_{m,crit}$, $\lambda_{rel,m}$, k_{crit} and M_{cr}. Bearing adds l_{ef}, A_{ef}, $k_{c,90}$ and the reaction. The report prints the same result; it never recalculates.

A check that cannot run reads Unavailable with its reason, Not checked, Unsupported, Invalid input or Calculation failed. None of these counts as a pass. A utilisation above 1.0 is a failed check that is still printed in full.

Limits of this version

- Rectangular solid timber and glulam only, bending about one axis; axial force is outside the beam check.
- Hardwood (D) strength classes are not available in this version.
- No National Annex factor is inferred from a country name; Custom values are yours to source.
- The eligibility of k_{sys} is not checked.
- Bearing uses the discrete-support factors only; the continuous-support values of 6.1.5(3) are not used.

CHAPTER 20

Concrete checks

This chapter explains how Statiko verifies a reinforced concrete beam to EN 1992-1-1. It covers the material values, the bending resistance from strain-plane equilibrium, shear, torsion, the detailing rules, and the serviceability checks: stresses, crack width and deflection. Read it to understand what each concrete check card means and which of your inputs change it. Concrete in fire is in Chapter 22.

Kernel paths in this chapter are under `engineering/src/commonMain/kotlin/statiko/engineering/` unless they start with `verification/`, which is under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/`. The calculation follows EN 1992-1-1:2004 with its 2008 and 2010 corrigenda; the result names the intended edition EN 1992-1-1:2004+A1:2014 (spec/beam/concrete-calculation.md rule 14).

How the verification runs

Statiko runs one verification per beam, in a fixed order. It validates the input and derives the material values from f_{ck}. It resolves the National Annex parameters and takes the signed actions per station and combination from the finite-element result (Chapter 16). Then it calculates:

1. ULS bending resistance, positive and negative, by strain compatibility and force equilibrium;
2. ULS shear, without and with links;
3. torsion, where a non-zero torsional moment is proven;
4. detailing limits;
5. SLS stresses;
6. cracking, minimum steel and crack width;
7. short-term and creep-adjusted deflection.

Stresses and the short-term deflection use the characteristic combinations. The quasi-permanent concrete stress limit, crack width, minimum crack steel and creep-adjusted deflection use the quasi-permanent combinations. Internally every value is SI.

Source: spec/beam/concrete-calculation.md rules 17, 18 and 22.

Materials and partial factors

All strengths are derived once from f_{ck} (MPa), EN 1992-1-1 Table 3.1, for classes up to C90/105:

> $$f_{cm} = f_{ck} + 8 \; ; \; f_{ctm} = 0.30 \cdot f_{ck}^{2/3} \; (f_{ck} \le 50),\; 2.12 \cdot \ln(1 + f_{cm} / 10) \; (f_{ck} > 50)$$
>
> EN 1992-1-1 3.1.2, Table 3.1 · kernel `concrete/ConcreteStrengthProperties.kt:10-20`

> $$f_{ctk,0.05} = 0.7 \cdot f_{ctm} \; ; \; f_{ctk,0.95} = 1.3 \cdot f_{ctm} \; ; \; E_{cm} = 22\,000 \cdot ((f_{ck} + 8) / 10)^{0.3}$$
>
> EN 1992-1-1 Table 3.1 · kernel `concrete/ConcreteStrengthProperties.kt:22-25`

> $f_{cd} = \alpha_{cc} \cdot f_{ck} / \gamma_C$; $f_{ctd} = \alpha_{ct} \cdot f_{ctk,0.05} / \gamma_C$; $f_{yd} = f_{yk} / \gamma_S$
>
> EN 1992-1-1 3.1.6 (3.15), (3.16) · kernel `concrete/ConcreteAnnexFactors.kt:57-87`

The design country sets the factors:

Design country	γ_C	γ_S	α_{cc}, α_{ct}	Status
Eurocode	1.50	1.15	1.0	Eurocode recommended
Denmark	1.45	1.20	1.0	DS/EN 1992-1-1 DK NA:2024
Serbia	1.50	1.15	1.0	Eurocode recommended; the Serbian National Annex was not checked
Sweden	not calculated			Unsupported
Custom	your values			Custom

Serbia calculates with the Eurocode recommended values, and the report says that the Serbian National Annex was not checked. Sweden does not calculate for concrete until its National Annex to EN 1992-1-1 is in Statiko; the beam reads Unsupported with **Concrete does not calculate under Sweden (SS EN): the Swedish National Annex to EN 1992-1-1 is not in Statiko yet.**

Source: kernel `concrete/ConcreteAnnexFactors.kt:99-157`; spec/beam/concrete-calculation.md rules 13 and 15; spec/column/column-calculation.md rule 23.

Bending resistance

Stress-strain laws

Beam bending uses the rectangular stress block of 3.1.7(3), written as a strain law:

> $\varepsilon_{cu3} = 3.5$ ‰ $(f_{ck} \le 50)$, $(2.6 + 35 \cdot ((90 - f_{ck}) / 100)^4)$ ‰ $(f_{ck} > 50)$
>
> EN 1992-1-1 Table 3.1 · kernel `concrete/ConcreteUlsMaterialRules.kt:25-29`

> $\lambda = 0.8 - (f_{ck} - 50) / 400$; $\eta = 1.0 - (f_{ck} - 50) / 200$ ($\lambda = 0.8, \eta = 1.0$ for $f_{ck} \le 50$)
>
> EN 1992-1-1 3.1.7(3) (3.19)–(3.22) · kernel `concrete/ConcreteUlsMaterialRules.kt:31-41`

> $\sigma_c = \eta \cdot f_{cd}$ for $\varepsilon_c \ge (1 - \lambda) \cdot \varepsilon_{cu3}$, otherwise 0
>
> EN 1992-1-1 3.1.7(3) · kernel `concrete/Ec2RectangularStressBlockConcreteModel.kt:18-27`

When the compression zone narrows towards the extreme fibre, for example in a T beam bending the other way, η is multiplied by 0.9 and the section is solved again (3.1.7(3)). The reinforcement is elastic-perfectly plastic, $\sigma_s = E_s \cdot \varepsilon$

limited to $\pm f_{yd}$, with the design ultimate strain $\varepsilon_{ud} = 0.9 \cdot \varepsilon_{uk}$.

Source: kernel `concrete/ConcreteFlexureUlsCalculator.kt:13-26`, `concrete/ElasticPerfectlyPlasticReinforcementModel.kt:16-20`, `concrete/ConcreteUlsMaterialRules.kt:22-23`.

Strain-plane equilibrium

The extreme compression fibre is held at ε_{cu}, and the strain varies linearly with the distance d_c from the compression face:

$$\varepsilon(z) = \varepsilon_{cu} \cdot (1 - d_c(z) / x)$$

EN 1992-1-1 6.1(2) · kernel `concrete/ConcreteBendingSolver.kt:82-89`

$$N(x) = \int \sigma_c(\varepsilon(z)) \cdot b(z)\, dz + \Sigma\, \sigma_s(\varepsilon_i) \cdot A_{s,i} = 0$$

EN 1992-1-1 6.1 · kernel `concrete/ConcreteBendingSolver.kt:54-80`

The neutral-axis depth x is the root of N(x) = 0 between a small fraction of h and h, found by bisection (up to 256 iterations, stopping on a position or force tolerance). The concrete integral uses adaptive Simpson integration over the section's real outline. M_{Rd} is the first moment of the concrete and bar forces at that root, and the utilisation is $|M_{Ed}| / M_{Rd}$ for the governing positive or negative moment. If the root is not found, the check reads Calculation failed, never a pass.

Source: kernel `concrete/BoundedRootSolver.kt:6-45`, `concrete/AdaptiveSimpsonIntegrator.kt`, `concrete/ConcreteBendingSolver.kt:22-46`, `concrete/ConcreteFlexureUlsCalculator.kt:27-30`.

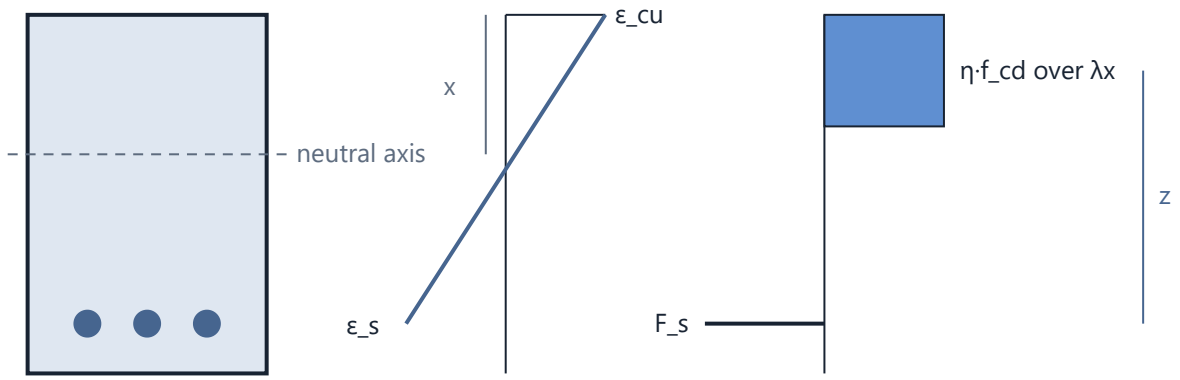


Figure 20.1 · Strain plane and stress block: x is found from force equilibrium, and M_{Rd} follows from the forces and the lever arm z.

Shear and torsion

Without links

$$k = \min(2.0 ; 1 + \sqrt{(200 / d)}) ; \rho_l = \min(0.02 ; A_{sl} / (b_w \cdot d))$$

EN 1992-1-1 6.2.2(1) · kernel `concrete/ConcreteShearUlsCalculator.kt:54-55`

$$V_{Rd,c} = \max[C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} ; v_{min}] \cdot b_w \cdot d ; v_{min} = c \cdot k^{1.5} \cdot f_{ck}^{0.5}$$

EN 1992-1-1 6.2.2 (6.2a), (6.2b) · kernel `concrete/ConcreteShearUlsCalculator.kt:56-61`

Statiko uses $C_{Rd,c} = 0.18 / \gamma_C$ and $c = 0.035$ for every design country except Denmark, which uses $c = 0.051 / \gamma_C$ (DS/EN 1992-1-1 DK NA:2024 6.2.2(1)). Units are MPa and mm. The beam has no axial force, so there is no $k_1 \cdot \sigma_{cp}$ term.

Source: kernel `concrete/ConcreteShearDesignParameters.kt:13-31`.

With vertical links

$$z = 0.9 \cdot d ; V_{Rd,s} = (A_{sw} / s) \cdot z \cdot f_{ywd} \cdot \cot \theta$$

EN 1992-1-1 6.2.3 (6.8) · kernel `concrete/ConcreteShearUlsCalculator.kt:68-71`

$$V_{Rd,max} = \alpha_{cw} \cdot b_w \cdot z \cdot \nu_1 \cdot f_{cd} / (\cot \theta + \tan \theta) ; \nu_1 = 0.6 \cdot (1 - f_{ck} / 250) ; \alpha_{cw} = 1.0$$

EN 1992-1-1 6.2.3 (6.9), 6.2.2(6) (6.6N) · kernel `concrete/ConcreteShearUlsCalculator.kt:73-77`

The shear resistance is $\min(V_{Rd,s} ; V_{Rd,max})$. You choose cot θ between 1.0 and 2.5. The beam shear check uses $\nu_1 = 0.6 \cdot (1 - f_{ck} / 250)$ for every design country, including Denmark. Only vertical links are supported.

Solid circular sections follow Orr et al. (2010), a published extension outside EN 1992-1-1. The lever arm z comes from the section's own bending solution, $z = M_{Rd} / F_{td}$.

Source: kernel `concrete/ConcreteShearUlsCalculator.kt:22-24`, `:142-349`; spec/beam/concrete-calculation.md rule 17.

Torsion

Torsion is checked only where the analysis proves a non-zero torsional moment. It uses a thin-walled closed cell (the closed web cell for a T beam) with $t_{ef} = \max(A / u ; 2 \cdot$ axis distance of the longitudinal bars$)$:

$$T_{Rd,links} = 2 \cdot A_k \cdot (A_{sw} / s) \cdot f_{yd} \cdot \cot \theta ; T_{Rd,long} = 2 \cdot A_k \cdot \Sigma A_{sl} \cdot f_{yd} / (u_k \cdot \cot \theta)$$

EN 1992-1-1 6.3.2(3) (6.28) · kernel `concrete/torsion/ConcreteTorsionCalculator.kt:141-143`

$$T_{Rd,max} = 2 \cdot A_k \cdot t_{ef} \cdot \nu \cdot f_{cd} / (\cot \theta + \tan \theta)$$

EN 1992-1-1 6.3.2(4) (6.30) · kernel `concrete/torsion/ConcreteTorsionCalculator.kt:144-145`

Here ν is 0.6 · (1 − f_{ck} / 250), or 0.7 · (0.7 − f_{ck} / 200) for Denmark. The interactions are T / $T_{Rd,max}$ + V / $V_{Rd,max}$ ≤ 1 (6.29). For the links, V / $V_{Rd,s}$ + T / $T_{Rd,links}$ ≤ 1 (6.3.2(2)). For the longitudinal bars, the bending utilisation plus T / $T_{Rd,long}$ must not exceed 1. Detailing follows 9.2.3: link spacing at most min(u / 8 ; least dimension), and longitudinal bar spacing at most 350 mm.

Source: kernel `concrete/torsion/ConcreteTorsionGeometryCalculator.kt:123-125`, `concrete/ConcreteStrutStrengthReduction.kt:3-24`, `concrete/torsion/ConcreteTorsionCalculator.kt:147-182`.

Detailing and cover

> $$A_{s,min} = \max(0.26 \cdot f_{ctm} / f_{yk} \cdot b_t \cdot d ; 0.0013 \cdot b_t \cdot d) ; A_{s,max} = 0.04 \cdot A_c$$
>
> EN 1992-1-1 9.2.1.1 (9.1N), 9.2.1.1(3) · kernel `concrete/ConcreteBeamDetailingRules.kt:21-35`

> $$\rho_{w,min} = 0.08 \cdot \sqrt{f_{ck}} / f_{yk} ; s_{l,max} = 0.75 \cdot d$$
>
> EN 1992-1-1 9.2.2 (9.5N), (9.6N) · kernel `concrete/ConcreteBeamDetailingRules.kt:37-45`

> $$\text{clear spacing} \geq \max(\varphi ; 20\ \text{mm} ; d_g + 5\ \text{mm})$$
>
> EN 1992-1-1 8.2(2) · kernel `concrete/ConcreteBeamDetailingRules.kt:47-58`

> $$c_{min} = \max(c_{min,b} ; c_{min,dur} ; 10\ \text{mm}) ; c_{min,b} = \varphi, \text{ or } \varphi + 5\ \text{mm when } d_g > 32\ \text{mm} ; c_{nom} = c_{min} + \Delta c_{dev}$$
>
> EN 1992-1-1 4.4.1.2 (4.2), Table 4.2 · kernel `concrete/ConcreteBeamDetailingRules.kt:60-72`

The cover you enter is the nominal cover c_{nom}, measured to the outermost bar, normally the link. $c_{min,dur}$ comes from Table 4.4N for structural class S4 and reinforcing steel; Denmark uses the DK NA values X0 10, XC1 10, XC2 to XC4 20, XD1 30, XD2 40, XD3 40, XS1 30, XS2 30 and XS3 40 mm (`concrete/ConcreteExposureDurabilityResolver.kt:37-50`). Δc_{dev} is 10 mm (Eurocode) or 5 mm (Denmark):

Exposure	X0	XC1	XC2, XC3	XC4	XD1, XS1	XD2, XS2	XD3, XS3
$c_{min,dur}$ (mm), Eurocode	10	15	25	30	35	40	45

Source: kernel `concrete/ConcreteExposureDurabilityResolver.kt:18-51`; spec/beam/concrete-calculation.md rule 20.

Stresses, cracks and deflection

Stress limits

$\sigma_c \leq 0.6 \cdot f_{ck}$ and $\sigma_s \leq 0.8 \cdot f_{yk}$ under characteristic combinations. Under quasi-permanent combinations, $\sigma_c \leq 0.45 \cdot f_{ck}$, the limit for linear creep (7.2(2), (3), (5)).

Source: kernel `concrete/ConcreteSlsDesignParameters.kt:17-24`, `concrete/ConcreteBeamSlsVerifier.kt:196-215`.

Creep and effective modulus

The creep coefficient $\varphi(t, t_0)$ follows EN 1992-1-1 Annex B. The inputs are the notional size $h_0 = 2A_c / u$, the relative humidity, the temperature-adjusted loading age (corrected for cement class and not less than 0.5 days), and the factors $\beta(f_{cm}) = 16.8 / \sqrt{f_{cm}}$, $\beta(t_0) = 1 / (0.1 + t_0^{0.2})$, φ_{RH}, β_H and β_c. The long-term modulus is:

> $$E_{c,eff} = E_{cm} / (1 + \varphi(t, t_0))$$
>
> EN 1992-1-1 7.4.3(5) (7.20), Annex B · kernel `concrete/ConcreteCreepCalculator.kt:11-51`, `concrete/ConcreteBeamSlsVerifier.kt:17-19`

Cracked stiffness and deflection

> $$\zeta = 1 - \beta \cdot (M_{cr} / M)^2 \text{ for } M > M_{cr}, \text{ otherwise } 0 \; ; \; I_{eff} = 1 / [\zeta / I_{II} + (1 - \zeta) / I_I]$$
>
> EN 1992-1-1 7.4.3 (7.18), (7.19) · kernel `concrete/ConcreteBeamSlsVerifier.kt:146-166`

$M_{cr} = f_{ctm} \cdot I_I$ / (distance from the centroid to the tension fibre). β is 1.0 for the short term (characteristic) and 0.5 for the long term (quasi-permanent). Statiko takes one ζ per combination and bending direction, from that combination's largest moment. It then rescales the linear-elastic deflection of the finite-element analysis:

> $$\delta = |\delta_{FEM}| \cdot (E \cdot I)_{ref} / (E_c \cdot I_{eff}) \; ; \; \text{limit} = \text{span} / \text{ratio}$$
>
> kernel `concrete/ConcreteBeamSlsVerifier.kt:377-402`, `verification/ConcreteBeamChecks.kt:113-127`

E_c is E_{cm} for the short-term deflection and $E_{c,eff}$ for the long-term deflection. Curvatures are not integrated along the member, span-to-depth ratios (7.4.2) are not used, and shrinkage curvature is not available in this version.

Crack width and minimum steel

> $$h_{c,ef} = \min[2.5 \cdot (h - d) \; ; \; (h - x) / 3 \; ; \; h / 2] \; ; \; \rho_{p,eff} = A_s / A_{c,eff} \; ; \; \varphi_{eq} = \Sigma\varphi^2 / \Sigma\varphi$$
>
> EN 1992-1-1 7.3.2(3), 7.3.4 (7.12) · kernel `concrete/ConcreteBeamSlsVerifier.kt:276-290`

> $$s_{r,max} = 3.4 \cdot c + 0.8 \cdot 0.5 \cdot 0.425 \cdot \varphi / \rho_{p,eff}, \text{ or } 1.3 \cdot (h - x) \text{ when the bar spacing exceeds } 5 \cdot (c + \varphi / 2)$$
>
> EN 1992-1-1 7.3.4(3) (7.11), (7.14) · kernel `concrete/ConcreteBeamSlsVerifier.kt:291-297`

> $$\varepsilon_{sm} - \varepsilon_{cm} = \max\{[\sigma_s - 0.4 \cdot f_{ctm} / \rho_{p,eff} \cdot (1 + \alpha_e \cdot \rho_{p,eff})] / E_s \; ; \; 0.6 \cdot \sigma_s / E_s\} \; ; \; w_k = s_{r,max} \cdot (\varepsilon_{sm} - \varepsilon_{cm})$$
>
> EN 1992-1-1 7.3.4 (7.8), (7.9) · kernel `concrete/ConcreteBeamSlsVerifier.kt:298-311`

σ_s is the stress in the tension bars of the long-term cracked section under the quasi-permanent moment, using $E_s / E_{c,eff}$. $\alpha_e = E_s / E_{cm}$. The check passes when $w_k \le$ your limit w_{max} and the tension steel is at least:

> $A_{s,min} = (0.4 \cdot k \cdot A_{ct,web} + k_{c,fl} \cdot k_{fl} \cdot A_{ct,fl}) \cdot f_{ctm} / f_{yk}$; $k_{c,fl} = \max(0.9 \cdot F_{cr} / (A_{ct} \cdot f_{ct,eff})$; $0.5)$
>
> EN 1992-1-1 7.3.2(2) (7.1), (7.2), (7.3) · kernel `concrete/minimumCrackReinforcement.kt:6-41`

k is 1.0 up to 300 mm and 0.65 from 800 mm, interpolated in between, for the web depth and the flange width. The minimum is checked even when the section is uncracked (7.3.2(1)).

What you see and the limits

The concrete checks show bending in both directions (x, M_{Rd}, bar strains and failure mode), shear ($V_{Rd,c}$ or $V_{Rd,s}$ and $V_{Rd,max}$ with cot θ), torsion, detailing, SLS stresses, crack width, and short-term and long-term deflection with the stiffness assumption named. Each check carries its clause, governing combination and position, intermediate values and state. The report prints the same result.

- Persistent and transient design situations only; rectangle, solid circle and T; normal-weight, conventionally reinforced concrete.
- Uniaxial bending without axial force. Punching, prestress, deep beams, strut-and-tie, redistribution, restraint cracking and fatigue are not available in this version.
- A required check that is Unsupported, Unavailable or failed never counts as a pass.

Source: spec/beam/concrete-calculation.md rules 16, 17 and 23.

CHAPTER 21

Serviceability

This chapter explains the serviceability checks Statiko runs for steel and timber beams: the instantaneous deflection, the final deflection of timber with creep, and the natural frequency. You learn which combinations feed each check, how the limits you set are applied, and how the frequency is found as the lowest eigenvalue of $K \cdot \varphi = \omega^2 \cdot M \cdot \varphi$. Concrete deflection and crack width have their own method, described in Chapter 20.

Kernel paths in this chapter are under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/`; paths starting with `verification/BeamServiceability`, `verification/BeamDeflection`, `verification/TimberFinal` or `design/` are under `engineering/src/commonMain/kotlin/statiko/engineering/`.

The limits you set

Each beam stores its own serviceability limits. There are four deflection ratios: span instantaneous, cantilever instantaneous, span final and cantilever final. There is also a frequency limit in hertz. The **Design code** card shows them read-only in its **Deflection** row as **L/ · L/<cantilever> · <f> Hz**, and you change them through the card's **Edit**. A new beam starts with the app's preset, L/400 · L/200 · 8 Hz, for both the instantaneous and the final ratios.

> Eurocode leaves serviceability limits to the project. Agree the ratios and the frequency limit with your client, and enter them before you rely on the checks.

Source: spec/beam/design-code-member-combinations.md rules 5 and 21; kernel `design/DesignCodePresets.kt:18-20`, `:45-50`; `project/src/commonMain/kotlin/statiko/project/domain/design/DeflectionLimitsInput.kt:3-8`.

Instantaneous deflection

Every characteristic combination (EN 1990 6.14b, and its variant with G_{inf} when wind leads) gives one deflection row. The deflection δ(x) at every station comes from the linear-elastic finite-element solution of that combination with the mean modulus (Chapter 16). It includes everything in the combination, permanent and variable. For each span between supports, and for each cantilever, Statiko takes the largest absolute deflection in that span:

> $$\delta_{max} = \max |\delta(x)| \text{ over the span} \; ; \; w_{lim} = L_{span} \,/\, \text{ratio} \; ; \; \eta = \delta_{max} \,/\, w_{lim}$$
>
> EN 1990 6.5.3 (6.14b) · kernel `verification/BeamServiceabilityChecks.kt:46-70`

A span uses the span instantaneous ratio, and a cantilever uses the cantilever instantaneous ratio. The check passes when $\delta_{max} \le w_{lim} + 0.000001$ m, a tolerance of one micrometre for rounding. The governing span over all characteristic combinations is shown with its combination and position.

Frequent and quasi-permanent combinations do not give a deflection row. Precamber is not available in this version, so the deflection is never reduced by a precamber.

> The deflection comes from Euler–Bernoulli elements and leaves out shear deformation, as the old Statiko did. For steel the difference is small. Timber and glulam have a low shear modulus, so a Timoshenko beam deflects more: for a GL 140×360 beam over 5 m about 0.8 mm, or 9 %. EN 1995-1-1 sets no method; where a timber deflection is close to its limit, allow for that difference.

Source: kernel `verification/BeamServiceabilityChecks.kt:79-83`, `:107`; `verification/BeamVerificationCalculator.kt:74-91`, `:180-184`.

Final deflection of timber

Timber creeps under sustained load. For a timber or glulam beam, Statiko rebuilds every characteristic combination with creep coefficients from the deformation factor k_{def}, then solves it again with the mean stiffness. Steel beams have no final deflection row.

Service class	1	2	3
k_{def}, solid timber and glulam	0.60	0.80	2.00

Source: EN 1995-1-1 3.1.4, Table 3.2; kernel `verification/TimberFinalCombination.kt:20-25`.

> $$c_{G,fin} = 1 + k_{def}\,;\, c_{Q,fin} = c_{Q,char} + \psi_2 \cdot k_{def}$$
>
> EN 1995-1-1 2.2.3(5) (2.2)–(2.5) · kernel `verification/TimberFinalCombination.kt:30-38`

$c_{Q,char}$ is the action's coefficient in the characteristic combination: 1.0 for the leading action and ψ_0 for an accompanying one. An action left out of the combination stays at 0. This is $u_{fin} = u_{inst} + u_{creep}$, with the creep part equal to $k_{def} \cdot u_{inst}$ for permanent actions and $\psi_2 \cdot k_{def} \cdot u_{inst}$ for variable ones. It assumes that all parts of the beam creep equally and the behaviour stays linear, as 2.2.3(5) states.

The final deflection is then checked like the instantaneous one, with the span final ratio or the cantilever final ratio. The check detail shows k_{def}. An invalid service class makes the final deflection Unavailable.

Source: kernel `verification/BeamServiceabilityChecks.kt:47-52`, `verification/BeamDeflectionCriterion.kt:16-19`, `verification/BeamVerificationCalculator.kt:252-292`.

Natural frequency: the model

The frequency check uses the same beam line, meshed by default with 50 nodes, refined at supports and loads. Each node has a vertical displacement and a rotation.

- **Stiffness K.** Euler–Bernoulli bending elements with $EI = E \cdot I_{xx}$ (mean modulus, centroidal second moment of area), continuous or hinged at an internal hinge.
- **Mass M.** The mass comes from the loads of the combination being analysed, divided by $g = 9.81\ m/s^2$. For each element, the point mass is $\Sigma|P| / g$. The distributed mass is $\Sigma|w|$ over the element, divided by g and multiplied by the element length L_e. Both are added to the vertical displacement of the element's first node. Rotations carry no mass, and moment loads carry no mass. An upward load adds mass in the same way as a downward one.
- **Self-weight.** With **Include self-weight** on, self-weight is a uniform load $\rho \cdot A \cdot g$, multiplied by the combination's coefficient for the dead action. It becomes mass through the same rule.
- **Supports.** Restrained degrees of freedom are removed from K and M.

> $m_{point} = \Sigma|P_i| / g$; $m_{uniform} = \Sigma|w| / g \cdot L_e$
>
> kernel `fem/element/FemElement.kt:19-20`, `fem/vibration/VibrationMatrixAssembly.kt:56-76`, `core/Config.kt:4`

The element routine also has a consistent mass matrix, m·L / 420 times the standard 4 × 4 Hermite matrix. Statiko gives it no mass per length, so all the mass is the load-derived mass above.

Source: kernel `fem/vibration/VibrationCalculator.kt:18-37`, `fem/matrix/BeamBendingMatrices.kt:15-25`, `calculation/StaticBeamCalculationService.kt:264-273`, `:340-351`, `calculation/BeamKernelModel.kt:21-51`.

Natural frequency: the eigenvalue problem

> $K \cdot \varphi = \omega^2 \cdot M \cdot \varphi$; $f = \omega / (2\pi) = \sqrt{\lambda} / (2\pi)$
>
> kernel `fem/vibration/VibrationCalculator.kt:40-47`, `linalg/LinAlgImpl.kt:8-70`

The problem is symmetric-definite and is solved with LAPACK `dsygvd` through OpenBLAS:

1. Both matrices are scaled by $s_i = 1 / \sqrt{K_{ii}}$. K must be positive definite, and both matrices must be exactly symmetric.
2. Because M has no mass on the rotations, it is singular. `dsygvd` therefore solves the swapped problem $\tilde{M} \cdot x = \mu \cdot \tilde{K} \cdot x$, where $\mu = 1 / \lambda$.
3. Modes with $\mu \approx 0$, the massless rotational modes, are dropped. Each remaining $\lambda = 1 / \mu$ is refined by the Rayleigh quotient $\lambda = \varphi^T K \varphi / \varphi^T M \varphi$, using compensated summation.
4. Eigenvalues not above 10^{-9} are dropped, the rest are sorted ascending, and $f_i = \sqrt{\lambda_i} / 2\pi$.

The mode shapes are normalised and drawn on the result graphs (Chapter 11).

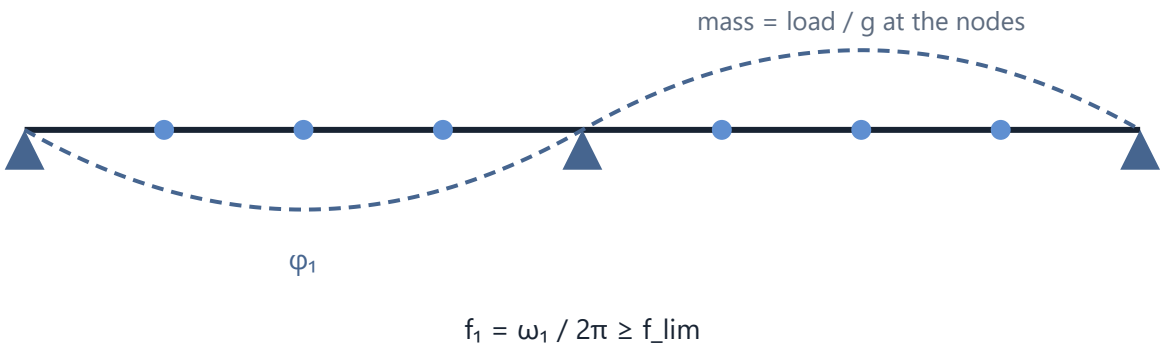


Figure 21.1 · The first mode shape φ_1 of a two-span beam, with the load-derived masses at the nodes.

Natural frequency: the check

Statiko analyses the beam once for every serviceability combination (characteristic, frequent and quasi-permanent), each with its own load-derived mass, and takes that combination's lowest frequency. The smallest of these over all

combinations is checked, and its combination is named. When the beam has no serviceability combination, the unfactored loads are used.

> $\eta = f_{lim} / f_1$; Passed when $\eta \leq 1.0$, i.e. $f_1 \geq f_{lim}$
>
> kernel `verification/BeamServiceabilityChecks.kt:92-105` , `calculation/StaticBeamCalculationService.kt:294-306`

Because the mass is the load of the combination divided by g, the frequency depends on which loads you model and on their combination coefficients. Check that your loads represent the mass that is really present when the beam vibrates.

If the native linear-algebra library is missing, the check reads Unavailable. A numerical failure reads Calculation failed, never a pass.

What you see and the limits

The **Displacements** group of the checks column shows **Deflection (instantaneous)**, for timber also **Deflection (final)** with k_{def}, and **Frequency**. Each deflection check lists δ_{max}, w_{lim}, the ratio, the span and the governing combination; the span deflections are listed per span. The frequency check lists f_1 and f_{lim}. The report prints the same values.

- Deflection is linear elastic with the mean modulus, from the beam elements of Chapter 16.
- Creep uses one service class for all actions. The 3.1.4(4) increase for timber installed near fibre saturation is not available in this version.
- The floor vibration criteria of EN 1995-1-1 7.3 are not available in this version; only the frequency limit is checked.
- Precamber is not available in this version.

CHAPTER 22

Fire resistance

This chapter explains how Statiko verifies the fire resistance of a beam once you have entered its fire design (Chapter 13). Steel follows EN 1993-1-2, with heating under the standard fire and two verification methods. Timber and glulam follow EN 1995-1-2 with the reduced cross-section method. Concrete follows the tabulated data of EN 1992-1-2. Fire is the accidental design situation: it never governs the normal checks, the governing summary or the report's governing check.

Kernel paths in this chapter are under `engineering/src/jvmAndAndroidMain/kotlin/statiko/engineering/`, except `combinations/`, which is under `engineering/src/commonMain/kotlin/statiko/engineering/`. Rules are from spec/beam/fire.md.

Fire actions and combinations

The design effects in fire come from the generated fire combinations, one for each leading variable action, plus a variant with G_{inf} when wind leads. Each fire combination is verified with its own moments and shears, and the result shows the governing one with its combination identity. You never type $E_{fi,d}$, and Statiko does not use the η_{fi} shortcut.

> $$E_{d,fi} = \Sigma\, G_{k,j} + \psi_{1,1} \cdot Q_{k,1} + \Sigma_{i>1}\, \psi_{2,i} \cdot Q_{k,i}$$
>
> EN 1990 6.4.3.3 (6.11b) · kernel `combinations/calculateCombination.kt:68-86`

Statiko applies ψ_1 to the leading variable action and ψ_2 to every other variable action, for every design country. The variant with G_{inf} contains only the permanent load and wind. A beam with fire input but no fire combination reads Unavailable with its reason.

Source: spec/beam/fire.md rules 15 to 19.

Steel: heating in the standard fire

Standard fire curve

> $$\theta_g = 20 + 345 \cdot \log_{10}(8 \cdot t + 1), \text{ t in minutes}$$
>
> EN 1991-1-2 3.2.1 (3.4) · kernel `eurocode/fire/Iso834StandardFireCurve.kt:5-7`

Section factor and shadow effect

A_m/V is the perimeter of the exposed faces divided by the steel area; $[A_m/V]_b$ uses the box perimeter. An unprotected member heats with $\max(A_m/V\ ;\ 10\ m^{-1})$ (4.2.5.1(5)). A contour-protected member uses $A_p/V = A_m/V$, and a box-protected member uses $[A_m/V]_b$.

> $k_{sh} = 0.9 \cdot [A_m/V]_b / [A_m/V]$ (I and H sections) ; $[A_m/V]_b / [A_m/V]$ (other open sections) ; 1.0 (hollow sections and protected members)
>
> EN 1993-1-2 4.2.5.1(2) (4.26a), (4.26b) · kernel `eurocode/fire/steel/SteelFireShadowFactor.kt:7-21`, `eurocode/fire/steel/SteelFireSectionFactor.kt:20-49`

k_{sh} uses the section's real A_m/V, not the floored value.

Thermal properties

> $c_a = 425 + 0.773 \cdot \theta - 1.69{\cdot}10^{-3} \cdot \theta^2 + 2.22{\cdot}10^{-6} \cdot \theta^3$ (20–600 °C) ; $666 + 13\,002 / (738 - \theta)$ (600–735 °C) ; $545 + 17\,820 / (\theta - 731)$ (735–900 °C) ; 650 (900–1200 °C) J/kgK
>
> EN 1993-1-2 3.4.1.2 (3.2a)–(3.2d) · kernel `eurocode/fire/steel/SteelFireSpecificHeat.kt:10-20`

ρ_a = 7850 kg/m³ (3.2.2(1)), and the initial steel temperature is 20 °C unless you change it. With **Custom c_a and ρ_a** your constant values are used instead.

Unprotected members

> $\dot{h}_{net} = \alpha_c \cdot (\theta_g - \theta_a) + \Phi \cdot \varepsilon_{res} \cdot \sigma \cdot [(\theta_g + 273)^4 - (\theta_a + 273)^4]$; $\alpha_c = 25$ W/m²K, $\Phi = 1.0$, $\varepsilon_{res} = 0.7$, $\sigma = 5.67{\cdot}10^{-8}$ W/m²K⁴
>
> EN 1991-1-2 3.1 (3.1)–(3.3) · kernel `eurocode/fire/steel/SteelFireUnprotectedHeatingStep.kt:6-36`

> $\Delta\theta_{a,t} = k_{sh} \cdot (A_m/V) / (c_a \cdot \rho_a) \cdot \dot{h}_{net} \cdot \Delta t$, $\Delta t = 5$ s
>
> EN 1993-1-2 4.2.5.1 (4.25) · kernel `eurocode/fire/steel/SteelFireUnprotectedHeatingStep.kt:36`, `eurocode/fire/steel/SteelFireStandardFireHeating.kt:58-95`

Protected members

> $\varphi = (c_p \cdot \rho_p) / (c_a \cdot \rho_a) \cdot d_p \cdot A_p/V$
>
> EN 1993-1-2 4.2.5.2 · kernel `eurocode/fire/steel/SteelFireProtectedHeatingStep.kt:41-42`

> $\Delta\theta_{a,t} = (\lambda_p / d_p) \cdot (A_p/V) / (c_a \cdot \rho_a) \cdot (\theta_g - \theta_a) / (1 + \varphi/3) \cdot \Delta t - (e^{\varphi/10} - 1) \cdot \Delta\theta_g$, not below 0, $\Delta t = 30$ s
>
> EN 1993-1-2 4.2.5.2 (4.27) · kernel `eurocode/fire/steel/SteelFireProtectedHeatingStep.kt:43-47`

Each time step takes θ_g at the end of the step and c_a at the current steel temperature. Intumescent coatings are outside Eq. (4.27) and read Unavailable.

Steel: verification

Reduction factors

$k_{y,\theta}$ and $k_{E,\theta}$ are interpolated linearly in Table 3.1 (3.2.1(1)):

θ_a (°C)	20–100	200	300	400	500	600	700	800	900	1000	1100	1200
$k_{y,\theta}$	1.000	1.000	1.000	1.000	0.780	0.470	0.230	0.110	0.060	0.040	0.020	0
$k_{E,\theta}$	1.000	0.900	0.800	0.700	0.600	0.310	0.130	0.090	0.0675	0.0450	0.0225	0

A zero factor means the section has no resistance, and the check reads Failed.

Source: kernel `eurocode/fire/steel/SteelFireYieldReductionFactor.kt:7-19`, `eurocode/fire/steel/SteelFireElasticModulusReductionFactor.kt:7-19`, `eurocode/fire/steel/SteelFireReductionTable.kt:4-11`.

Critical temperature method

$\gamma_{M,fi}$ = 1.0. Its provenance is "CEN recommended" for Eurocode, "DK NA:2007" for Denmark, and "CEN value · national annex not verified" for Sweden and Serbia. A Custom design country leaves steel fire Unavailable.

> $$\mu_0 = E_{fi,d} / R_{fi,d,0} \; ; \; \mu_{0,mod} = \mu_0 \cdot \kappa_1 \cdot \kappa_2, \text{ not less than } 0.013$$
>
> EN 1993-1-2 4.2.4(2), (3) (4.23) · kernel `eurocode/fire/steel/SteelFireDegreeOfUtilisation.kt:5-16`, `eurocode/fire/steel/SteelFireModifiedUtilisation.kt:21`, `eurocode/fire/steel/SteelFireCriticalTemperature.kt:7-13`

> $$\theta_{a,cr} = 39.19 \cdot \ln[1 / (0.9674 \cdot \mu_0^{3.833}) - 1] + 482 \; ; \; 350 \text{ °C for Class 4}$$
>
> EN 1993-1-2 4.2.4 (4.22), 4.2.3.6 · kernel `eurocode/fire/steel/SteelFireCriticalTemperature.kt:10-23`

$R_{fi,d,0}$ is the section's resistance in fire at time zero, capped at M_{Rd}. κ_1 is 0.70 (unprotected) or 0.85 (protected) when a slab covers the top flange and the top face is not exposed, otherwise 1.0. κ_2 is 0.85 only at stations over an intermediate support or a fixed end of a statically indeterminate beam with the box ticked, otherwise 1.0. The method passes when θ_a at the required time is at most $\theta_{a,cr}$. Where the beam's restraint does not hold the compressed flange, this method reads Unavailable, because it cannot rule out instability.

Source: kernel `eurocode/fire/steel/SteelFireAdaptationFactors.kt:7-23`, `eurocode/fire/steel/SteelFireMechanicalPartialFactor.kt:5-31`, `steel/SteelFireBeamResistance.kt:58-74`; spec/beam/fire.md rules 21, 25, 27, 28 and 34.

Resistance method

> $V_{fi,t,Rd} = k_{y,\theta} \cdot V_{pl,Rd}$ (with $\gamma_{M,fi}$) ; $M_{fi,\theta,Rd} = k_{y,\theta} \cdot W \cdot f_y / \gamma_{M,fi}$; $M_{fi,t,Rd} = \min(M_{fi,\theta,Rd} ; M_{Rd}) / (\kappa_1 \cdot \kappa_2)$
>
> EN 1993-1-2 4.2.3.3 (4.8), (4.10), (4.16); 4.2.3.4 (4.17), (4.18), (4.20) · kernel `steel/SteelFireBeamResistance.kt:106-170`

W is plastic for Class 1 and 2 and elastic for Class 3, and the bending resistance is reduced for high shear as in EN 1993-1-1 6.2.8. For lateral-torsional buckling in fire:

> $\bar{\lambda}_{LT} = \sqrt{(W \cdot f_y / M_{cr})}$; $\bar{\lambda}_{LT,\theta} = \bar{\lambda}_{LT} \cdot \sqrt{(k_{y,\theta} / k_{E,\theta})}$; $\alpha = 0.65 \cdot \sqrt{(235 / f_y)}$
>
> EN 1993-1-2 4.2.3.3(5) (4.12), (4.13) · kernel `eurocode/fire/steel/SteelFireBucklingCurve.kt:8-23`, `steel/SteelFireBeamResistance.kt:214-244`

> $\varphi = 0.5 \cdot (1 + \alpha \cdot \bar{\lambda}_{LT,\theta} + \bar{\lambda}_{LT,\theta}^2)$; $\chi_{LT,fi} = 1 / (\varphi + \sqrt{(\varphi^2 - \bar{\lambda}_{LT,\theta}^2)})$; $M_{b,fi,t,Rd} = \chi_{LT,fi} \cdot k_{y,\theta} \cdot W \cdot f_y / \gamma_{M,fi}$
>
> EN 1993-1-2 4.2.3.3(4) (4.11), (4.14), (4.15); 4.2.3.4(3) (4.19) · kernel `eurocode/fire/steel/SteelFireBucklingCurve.kt:16-17`, `steel/SteelFireBeamResistance.kt:238-244`

M_{cr} is the ambient critical moment of Chapter 17, and the compression flange is taken at the uniform steel temperature. The steel fire verdict is the worse of the two methods. When the critical temperature method is Unavailable for instability, the resistance method gives the verdict.

Torsion in fire

EN 1993-1-2 gives no torsion rule. When the fire combination has torsion, for example from an eccentric load, Statiko verifies it with the normal-temperature rules of Chapter 18 at the steel temperature, as a reading of EN 1993-1-2 4.2.1(2), and the report says so beside the check. The critical temperature method then reads Unavailable and the resistance method gives the verdict, because the critical temperature formula presumes a resistance proportional to $k_{y,\theta}$.

> $\tau_{fi,Rd} = k_{y,\theta} \cdot f_y / (\sqrt{3} \cdot \gamma_{M,fi})$; $T_{fi,t,Rd} = W_t \cdot \tau_{fi,Rd}$; $M_{z,fi,Ed} = (\varphi / k_{E,\theta}) \cdot M_{y,fi,Ed}$; $k_\alpha = 1 / (1 - M_{y,fi,Ed} / (k_{E,\theta} \cdot M_{cr}))$
>
> EN 1993-1-2 4.2.1(2) with EN 1993-1-1 6.2.7 (6.23), (6.25) to (6.28) and SCI P385 3.1, 3.2 · kernel `steel/SteelFireBeamTorsionResistance.kt`

The torques and the warping moment $M_{w,Ed}$ are those of the analysis, because E and G drop together; the twist φ grows by $1 / k_{E,\theta}$ and M_{cr} drops by $k_{E,\theta}$. Shear with torsion uses $\tau_{fi,Rd}$ as its limit. In the warping interactions M_y takes $M_{fi,t,Rd}$ and $M_{b,fi,t,Rd}$, while $M_{z,Rd}$ and the flange resistance $M_{w,Rd}$ take $k_{y,\theta} \cdot f_y / \gamma_{M,fi}$ without κ_1 and κ_2. As at normal temperature, a coexistent shear above half its resistance leaves bending Not supported, and lateral-torsional buckling with torsion is covered for a single span on two pinned or roller supports only.

Timber and glulam: reduced cross-section

> $\beta_0 = 0.65$ mm/min ; $\beta_n = 0.80$ mm/min (solid softwood), 0.70 mm/min (softwood glulam)
>
> EN 1995-1-2 3.4, Table 3.1 · kernel `eurocode/fire/timber/TimberFireCharringRates.kt:4-17`

> $d_{char,n} = \beta_n \cdot t$; $k_0 = t / 20$ for $t < 20$ min, 1.0 from 20 min ; $d_{ef} = d_{char,n} + k_0 \cdot d_0$, $d_0 = 7$ mm
>
> EN 1995-1-2 3.4 (3.2), 4.2.2 (4.1), Table 4.1 · kernel `eurocode/fire/timber/TimberFireZeroStrengthLayer.kt:4-12`, `eurocode/fire/timber/TimberFireEffectiveCharringDepth.kt:5-19`

Under gypsum plasterboard type A, charring starts at $t_{ch} = 2.8 \cdot h_p - 14$ (EN 1995-1-2 (3.11)). From t_{ch} to $t_a = \min(2 \cdot t_{ch} ; t_{ch} + 25 / (2 \cdot \beta_n))$ the charring rate is $2 \cdot \beta_n$. After t_a, $d_{char} = 25 + \beta_n \cdot (t - t_a)$. Under plasterboard $k_0 = 1.0$ throughout, so before t_{ch} $d_{ef} = 7$ mm with no charring (`eurocode/fire/timber/TimberFireEffectiveCharringDepth.kt:58-66`). The kernel cites JRC EUR 26698 6.1 for this part.

Source: kernel `eurocode/fire/timber/TimberFireCladdingStartTime.kt:4-9`, `eurocode/fire/timber/TimberFireEffectiveCharringDepth.kt:34-67`.

The residual section loses d_{ef} from each exposed face. Each exposed left or right face reduces the width, and each exposed top or bottom face reduces the depth. A section consumed by charring, or timber with a density below 290 kg/m³, reads Unavailable.

> $b_{fi} = b - n_{left,right} \cdot d_{ef}$; $h_{fi} = h - n_{top,bottom} \cdot d_{ef}$
>
> EN 1995-1-2 4.2.2 · kernel `eurocode/fire/timber/TimberFireEffectiveSection.kt:23-26`

> $f_{d,fi} = k_{mod,fi} \cdot k_{fi} \cdot f_k / \gamma_{M,fi}$; $k_{mod,fi} = 1.0$; $k_{fi} = 1.25$ (solid), 1.15 (glulam) ; $\gamma_{M,fi} = 1.0$
>
> EN 1995-1-2 2.3 (2.1), Table 2.1, 4.2.2(5) · kernel `eurocode/fire/timber/TimberFireDesignStrength.kt:4-17`, `eurocode/fire/timber/TimberFireFractileFactor.kt:4-11`, `eurocode/fire/timber/TimberFireMechanicalPartialFactor.kt:5-14`

> $\sigma_{m,d} = M / W_{fi}$; $\tau_d = 1.5 \cdot V / A_{fi}$; $\eta = \sigma_{m,d} / f_{m,d,fi}$ and $\tau_d / f_{v,d,fi}$
>
> EN 1995-1-1 6.1.6, 6.1.7 · kernel `eurocode/fire/timber/TimberFireBendingStress.kt:11`, `eurocode/fire/timber/TimberFireShearStress.kt:4-12`

Lateral-torsional buckling in fire runs for solid timber only; glulam reads Unavailable. Statiko first finds an effective length from the ambient critical moment, then the critical stress of the residual section:

> $l_{ef} = 0.78 \cdot b^2 \cdot E_{0,05} / (h \cdot \sigma_{m,crit})$, with $\sigma_{m,crit} = M_{cr} / W$; $\sigma_{m,crit,fi} = 0.78 \cdot b_{fi}^2 \cdot E_{0,05} / (h_{fi} \cdot l_{ef})$
>
> EN 1995-1-1 6.3.3 (6.32) · kernel `timber/TimberFireLtbEffectiveLength.kt:6-24`, `eurocode/fire/timber/TimberFireCriticalBendingStress.kt:4-28`

k_{crit} then follows the branches of EN 1995-1-1 (6.34) from the relative slenderness $\lambda_{rel,m} = \sqrt{(k_{fi} \cdot f_{m,k} / \sigma_{m,crit,fi})}$, which the kernel computes with k_{fi} inside the root and for which no clause is cited, and the check is $\sigma_{m,d} / (k_{crit} \cdot f_{m,d,fi})$ (`eurocode/fire/timber/TimberFireKCrit.kt:5-26`, `eurocode/fire/timber/TimberFireReducedCrossSectionVerification.kt:166-203`). A top flange restrained by a slab makes this check Not evaluated with the timber reason **Top flange laterally restrained: k_{crit} = 1.0 (EN 1995-1-1 6.3.3(5)).**, the sentence the ambient timber check uses.

Timber fire uses the CEN values only: for any other design country the timber fire result reads Unavailable. A result with an Unavailable part, such as glulam lateral-torsional buckling, is shown as partial, never as a pass.

Concrete: tabulated data

A single span on two hinged supports uses Table 5.5. A beam with more than one span uses Table 5.6, because Statiko does not redistribute moments. A cantilever, or a single span with a fixed end, reads Unavailable. The check compares the beam width b with b_{min}, the smallest width of the row (column 2), and the axis distance a with a_{min}, for the required resistance. a_{min} is read from the column your width reaches; the check detail names it in the row **Column for the axis distance**.

Table 5.5	**b_{min} / a_{min} (mm), columns 2 to 5**			
R30	80 / 25	120 / 20	160 / 15	200 / 15
R60	120 / 40	160 / 35	200 / 30	300 / 25
R90	150 / 55	200 / 45	300 / 40	400 / 35
R120	200 / 65	240 / 60	300 / 55	500 / 50
R180	240 / 80	300 / 70	400 / 65	600 / 60
R240	280 / 90	350 / 80	500 / 75	700 / 70

Source: EN 1992-1-2 5.6.2, Table 5.5; kernel `eurocode/fire/concrete/ConcreteFireBeamTables.kt:6-14` (Table 5.6 at `:16-24`).

> $a = c_{nom} + \varphi_{link} + \varphi / 2$; $a_m = \Sigma A_{s,i} \cdot a_i / \Sigma A_{s,i}$ (several layers) ; $a_{sd} = a + 10$ mm (corner bars of a single layer, when the beam width is at most the width of the corner-bar column)
>
> EN 1992-1-2 5.2(14), 5.2(15) (5.5), 5.6.1(8) · kernel `eurocode/fire/concrete/ConcreteFireTabulatedBeam.kt:12-36`

a_{min} is interpolated linearly between columns (5.2(12)). Custom minutes use the next table row at or above; above R240 the check reads Unavailable. Each bar must also meet the R30 value for its width (single layer) or half the average (several layers), as 5.2(17) requires. The tables hold for three-sided exposure at the reference load level η_{fi} = 0.7 (5.2(3)), for the Eurocode design country only. Four-sided exposure, other design countries, circular sections, concrete above C50/60 and density above 2600 kg/m³ read Unavailable. A continuous beam at R90 and above that needs the top-reinforcement rule of 5.6.3(3), or Table 5.7 at R120 and above, reads Unavailable, never Pass. The 500 °C isotherm method is not available in this version.

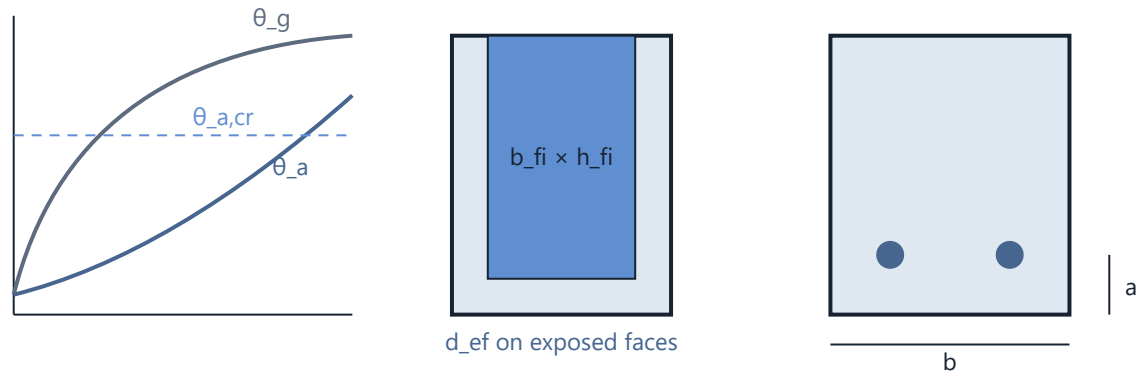


Figure 22.1 · Steel heating against the critical temperature, the timber residual section, and the concrete width b and axis distance a.

What you see

Fire results appear in the window's **Fire verification** group and in the report. With fire input, steel, timber, glulam and concrete beams also list **Fire verification** at the end of their checks column, marked as the fire design situation.

- **Steel** shows both methods side by side, then the steel fire verdict. The critical temperature method shows μ_0, κ_1, κ_2, $\gamma_{M,fi}$ with its provenance, $\theta_{a,cr}$, A_m/V, θ_a at the required time and the margin. The resistance method shows $M_{fi,t,Rd}$, $V_{fi,t,Rd}$ and $M_{b,fi,t,Rd}$ with $\chi_{LT,fi}$.
- **Timber** shows $k_{mod,fi}$, $d_{char,n}$, d_{ef}, b_{fi}, h_{fi}, the charring phase, $f_{m,d,fi}$ and $f_{v,d,fi}$, the bending and shear ratios, and $\sigma_{m,crit}$, $\lambda_{rel,m}$ and k_{crit}.
- **Concrete** shows b, b_{min}, a, a_{min}, the table, row and column, and the verdict.

Every fire result is Available, Unavailable with its reason, Invalid input, or Calculation failed. It is never a faked pass.

Source: spec/beam/fire.md rules 18, 33, 35, 38, 42, 43, 46 and 50.

PART V

Reference

CHAPTER 23

AI agents: the Statiko MCP server

Statiko includes a Model Context Protocol (MCP) server, so an AI agent such as Claude can work with your beam projects: create or open a project, read and edit the beam, undo and redo, save, read the result with every check and the moment, shear and deflection lines, and export the PDF report. The agent uses the same project, calculation and report code as the app, so its numbers, verdicts and PDF are the app's. This chapter shows how to switch the server on, how to connect an agent and what the agent can do.

How it works

The installed Windows app starts the server when an agent's client runs `Statiko.exe mcp`. It opens no window and talks to the client over standard input and output on your own computer. The server is named `statiko` and carries the app's version.

- The server has its own open project and never talks to a running Statiko window. If you save a file in the app after the agent opened it, the agent's save answers `conflict` instead of overwriting your work.
- Calculation follows every edit, as in the app; there is no calculate tool.
- Your licence decides every call exactly as it does in the app. A refused call answers `denied` with the reason.

Not available in this version: a hosted remote server, Android and macOS, any transport other than stdio, per-agent permission levels, and fire design through the server.

Source: spec/mcp/server.md rules 3, 8, 11–13 and Scope; spec/beam/fire.md Scope.

Switching the server on

Open **Settings** › **General**. On the Windows desktop the area **AI agents (MCP)** sits after Interface language and Theme. Android has no such area.

Control	What it does
Let AI agents use Statiko	Switches the server on. Off by default.
Project folder	The only folder the agent may read and write. Shows “No folder chosen” until you pick one.
Choose folder…	Opens a folder chooser; cancelling keeps the current folder.
Copy configuration	One button per client: Claude Desktop, Claude Code, Cursor, Codex, Gemini CLI, VS Code (Copilot). Copies that client's configuration with the installed `Statiko.exe` path filled in and shows “Copied”.

The Copy configuration buttons need the installed app; on a development build they are disabled with “Install Statiko to copy a configuration”. If another program holds the clipboard you see “The configuration could not be copied to the clipboard.” **Settings** › **Reset** switches the server off and clears the folder.

The server reads these settings when it starts. A change applies at the server's next start; a running server keeps its folder.

Source: spec/mcp/server.md rules 10, 40–47.

Connecting an agent

1. Install Statiko with the Windows installer.
2. In **Settings › General › AI agents (MCP)**, tick **Let AI agents use Statiko** and click **Choose folder...** to pick your project folder.
3. Click the **Copy configuration** button for your client.
4. Paste the configuration where the client reads it (table below) and start the client. The client starts `Statiko.exe mcp` itself.

Client	Where to paste it (Windows)	Configuration
Claude Desktop	`%APPDATA%\Claude\claude_desktop_config.json`	`{"mcpServers": {"statiko": {"command": "<exe>", "args": ["mcp"]}}}`
Claude Code	`.mcp.json` in a project, or `claude mcp add-json`	`{"mcpServers": {"statiko": {"type": "stdio", "command": "<exe>", "args": ["mcp"]}}}`
Cursor	`%USERPROFILE%\.cursor\mcp.json` or `.cursor\mcp.json`	as Claude Code
Codex	`%USERPROFILE%\.codex\config.toml`	`[mcp_servers.statiko]`, `command = "<exe>"`, `args = ["mcp"]`, one per line
Gemini CLI	`%USERPROFILE%\.gemini\settings.json` or `.gemini\settings.json`	as Claude Desktop
VS Code (Copilot)	`.vscode\mcp.json` or the user `mcp.json`	`{"servers": {"statiko": {"type": "stdio", "command": "<exe>", "args": ["mcp"]}}}`

`<exe>` is the installed `Statiko.exe` path; the button fills it in, correctly escaped.

When the server will not start

The server refuses to start and writes one line to standard error when the settings file cannot be read ("Open Statiko once and check Settings › General › AI agents (MCP)."), when it is switched off, when no project folder is chosen, or when the folder no longer exists. Each message tells you which setting to fix.

Source: spec/mcp/server.md rules 10, 41–45 and Client configurations.

What the agent can do

The server offers fourteen tools. When a project has a single analysis and a single member, the agent does not need to name them.

Tool	Purpose
`list_projects`	Lists the `.statiko` files in the project folder or a subfolder
`create_project`	Creates a new beam project from Statiko's template and saves it; never overwrites an existing file
`open_project`	Opens a project and returns its summary
`close_project`	Closes the project; refuses with unsaved changes unless told to discard them
`get_project`	Returns the summary: name, input revision, unsaved changes, undo and redo, design code and analyses
`get_beam`	Returns the beam or column input: material, section, supports, loads, self-weight, combination and limits
`list_choices`	Lists allowed values: design countries, steel and timber grades, profile catalogues and profiles, support kinds, load actions and axes, combinations
`edit_beam`	Applies a batch of edits as one Undo step, with the same rules as the app's screens
`undo`, `redo`	Undo or redo the last edit, as in the app
`save_project`	Saves the project; a file changed since it was opened is a conflict and never overwritten
`get_results`	Waits for the calculation (30 s by default, at most 120 s) and returns the verdict, reactions and every check with title, clause, status, reason, utilisation and governing combination
`get_stations`	Waits as `get_results` does and returns the lines the app's graphs draw for the selected combination: position, deflection, rotation, moment and shear at every station, and the final deflection line where the app draws one. Beam analyses only
`export_report`	Writes the PDF report as the app's export does, in English, Danish or Serbian Cyrillic, and answers with the path it wrote

Two read-only resources are also offered: `statiko://project`, the project summary, and `statiko://results/{analysisId}`, the latest result without waiting.

The edits `edit_beam` accepts are: rename the project, set the profile, steel or timber grade, set, add or remove a support or load, self-weight, top flange restraint, combination, deflection limits, design code and load duration. The same tools work on a column analysis, with the edits a column allows.

Source: spec/mcp/server.md Tools table and rules 24–39e and 48; tool descriptions in mcp/.

Folder, units and answers

- **Folder.** The agent can only read and write inside the project folder you chose. Paths are relative to it; an absolute path, a `..` that leaves the folder or a link pointing outside answers `outside_root`. Projects end in `.statiko`, reports in `.pdf`.
- **Units.** Every quantity is a value with an SI unit, for example `{"value": 100000, "unit": "N"}`: m, m^2, m^3, m^4, N, N/m, Nm, Pa, Hz, kg/m^3, rad for a rotation, 1 for a ratio and % for profile slopes. Values are never rounded, and an input in another unit is refused rather than converted. A bare number is refused too. A force or line load is positive downward, in the direction of gravity, as `get_beam` reports it; a negative value lifts the beam.
- **States.** Every answer has a state: `success`, `denied`, `invalid_input`, `unsupported`, `running`, `outdated`, `failed`, `outside_root`, `conflict`, `busy`, `unsaved_changes` or `no_project`. Anything but success comes with a reason.
- **Results.** A result names the input revision it belongs to. A result of an older input is `outdated`; a calculation not finished in time is `running`. Each check keeps its own status, and a check without a utilisation never reads as passed.

> The agent's answers are the engine's results, with the same scope limits as the app. Ask it for every check's status and reason, not only the overall verdict, and review the exported PDF before you rely on it.

Source: spec/mcp/server.md rules 15–23.

CHAPTER 24

Notation, units and glossary

This chapter is the reference for the symbols, units and words Statiko shows on screen and in the PDF report. Use it when a symbol in a check, a graph or the report is unfamiliar, when you want to change units, or when you need to know which direction counts as positive. Every symbol is drawn from one notation source shared by the app and the report, so a symbol means the same thing everywhere.

How symbols are written

- Symbols are typeset with real subscripts and superscripts, for example M_{Ed} or γ_{M0}, never with visible underscores.
- Negative numbers use the true minus "−"; there is no plus sign on positive values. Input fields accept both - and −.
- Green and red appear only with a real Pass or Fail and always with the word. Unsupported, Unavailable, Invalid input and Failed calculation stay neutral and distinct.
- Utilisation is shown as a percentage with the ratio η beside it, for example 86.2 % and η = 0.862.
- In the report, a label made of two parts is joined with " · ", for example "G_k · Dead Load".

Source: CODING_GUIDELINES.md, Engineering notation and reports; spec/beam/structural-system-drawing.md rules 11, 12; spec/beam/checks-column.md rule 7; spec/beam/report.md rules 34, 58.

Axes and sign convention

The report's Basis of design states the convention: "Loads and displacement are positive downward; moments are positive counter-clockwise; sagging moment is positive and drawn up. Positive shear is drawn up."

- x runs along the beam; y and z are the transverse directions. The structural model offers the "y–y elevation" (strong axis, z displacement) and the "z–z elevation" (weak axis, y displacement).
- In the drawing, reaction badges show magnitudes and the arrow shows the direction: a positive force points up and a positive moment turns anticlockwise. Tables and the report keep the signed components.
- Load values keep their sign, for example 24.50 kN/m and −16.20 kN/m.
- Supports restrain: fixed w and φ; pinned u and w; roller w.
- In the concrete flexure figure, sagging compresses the top face and hogging the bottom.

Source: resources ReportStringsEn axes and sign convention text; spec/beam/structural-system-drawing.md rules 11, 13; spec/beam/concrete-report.md rule 9; resources notation AnalysisNotation.kt.

Units

Choose units in **Settings › Units**. The **Defaults** tab holds the **Metric** or **Imperial** preset; the **Advanced** tab can "Override input, display and PDF units per app area. Unset fields use the Defaults tab." The report uses the same units and decimals (see Chapter 14).

Quantity	Metric default	Imperial default	Decimals	Choices
Length	m	ft	2	mm, cm, dm, m, in, ft, yd

Quantity	Metric default	Imperial default	Decimals	Choices
Displacement	mm	in	1	mm, cm, dm, m, in, ft, yd
Force	kN	kip	2	N, kN, lbf, kip
Force / Length	kN/m	lbf/ft	2	N/mm, N/m, kN/m, lbf/in, lbf/ft
Moment	kNm	kip·ft	2	Nmm, Nm, kNm, lbf·ft, lbf·in, kip·ft
Inertia	cm^4	in^4	0	mm^4, cm^4, m^4, in^4, ft^4
Self weight	kg/m	lb/ft	2	kg/m, g/m, lb/ft, oz/ft
Density	kg/m^3	lb/ft^3	0	kg/m^3, g/m^3, lb/ft^3, lb/in^3
Stress	MPa	ksi	1	Pa, kPa, MPa, psi, ksi
Time	min	min	0	s, min, h
Temperature	°C	°F	0	°C, K, °F
Rotation	rad	rad	8	mrad, rad, °
Area	cm^2	in^2	2	mm^2, cm^2, m^2, in^2, ft^2, yd^2
Warping constant	cm^6	in^6	2	m^6, cm^6, mm^6, in^6, ft^6
Section modulus	cm^3	in^3	2	mm^3, cm^3, m^3, in^3, ft^3
Frequency	Hz	Hz	2	Hz, kHz
Bending stiffness	MNm^2	$kip{\cdot}in^2$	2	Nm^2, kNm^2, MNm^2, $kip{\cdot}in^2$

The Advanced tab groups overrides by area: **Cross-section / detailing** (length, recommended mm or in), Supports (length), Loads (length, force, force per length, moment, self-weight) and **Results** (displacement, stress, rotation). The Results area sets rotation to mrad with 2 decimals, which is why the Rotation graph shows mrad.

Other units you may see: ‰ for concrete strains, 1/m for the steel section factor A_m/V, W/(m·K) and J/(kg·K) for thermal properties. The AI agent interface uses SI base units only (see Chapter 23).

Source: reports/units UnitDisplayQuantity.kt and UnitPreferenceArea.kt; project unit MeasurementUnit.kt; resources UnitStringsEn.

Symbols: actions, combinations and results

Symbol	Meaning	Unit	Where
G_k, Q_k	Characteristic permanent and variable action	kN, kN/m, kNm	Loads, report 3.1
γ_G, γ_Q, $\gamma_{G,sup}$, $\gamma_{G,inf}$	Partial factors on actions	–	Design code, report 3.2

Symbol	Meaning	Unit	Where
$\xi \cdot \gamma_{G,sup}$	Reduced permanent factor of 6.10b	–	Report 3.2
ψ_0, ψ_1, ψ_2	Combination, frequent and quasi-permanent factors	–	Report 3.2
K_{FI}	Consequence-class factor	–	Basis of design
6.10a, 6.10b	EN 1990 ULS (STR/GEO) combinations	–	Combination names
6.10	EN 1990 ULS (STR/GEO) combination of the Serbian annex	–	Combination names
6.14b, 6.15b, 6.16b	Characteristic, frequent, quasi-permanent SLS combinations	–	Combination names
6.11a/b	Accidental (fire) combination	–	Fire
P, M, q	Point load, moment, distributed load	kN, kNm, kN/m	Load cards, report drawing
x, x_1, x_2	Position along the beam; start and end of a load	m	Loads, graphs
e_y, e_z	Load eccentricities	mm	Load cards, report 3.1
L	Span; L/n deflection limit	m	Drawing, Design code
V, M, θ, δ, T	Shear, moment, rotation, deflection, torsion	kN, kNm, mrad, mm, kNm	Result graphs
ϕ	Angle of twist	mrad	Torsion graph (Twist)
f_1, f_n	First and n-th natural frequency	Hz	Natural Frequency graph, Eigenfrequencies
f_{lim}	Frequency limit from the project settings	Hz	Eigenfrequencies
w, w_{lim}	Deflection and its limit	mm	Displacements
u_{inst}, u_{fin}	Instantaneous and final deflection (timber)	mm	Deflection graph, Displacements, report 6.1
M_{Ed}, V_{Ed}, T_{Ed}	Design moment, shear, torque	kNm, kN, kNm	Checks
M_{cr}	Elastic critical moment for lateral-torsional buckling	kNm	Moment graph header, LTB check
η	Utilisation ratio	–	Every check

Source: resources notation CombinationNotation.kt, ActionsNotation.kt, AnalysisNotation.kt, SectionNotation.kt, BeamCheckNotation.kt.

Symbols: steel and timber

Symbol	Meaning	Unit	Where
f_y, f_u	Steel yield and ultimate strength	MPa	Report 2.1, steel checks
γ_{M0}, γ_{M1}, γ_{M2}	Steel partial factors: cross-section, instability, fracture	–	Report 2.1; γ_{M1} in LTB
ε, c/t	Classification strain factor, plate slenderness	–	Report 2.2 classification
W_{pl}, $W_{el,min}$, W_{eff}	Plastic, minimum elastic and effective section modulus	cm^3	Bending check
$M_{c,Rd}$	Bending resistance	kNm	Bending check
$A_{v,z}$, $V_{pl,Rd}$, $V_{pl,T,Rd}$	Shear area, plastic shear resistance (with torsion)	cm^2, kN	Shear check
h_w, t_w, η, 72 ε/η	Web height and thickness, shear factor, web slenderness limit	mm, –	Shear Buckling Resistance
ρ, $M_{y,V,Rd}$	High-shear reduction and reduced moment resistance	–, kNm	Bending check, report 5.3
α_{LT}, $\bar{\lambda}_{LT}$, Φ_{LT}, χ_{LT}, $M_{b,Rd}$	LTB imperfection factor, relative slenderness, Φ, reduction factor, buckling resistance	–, kNm	LTB check
T_{Rd}, $\tau_{t,Ed}$, $\tau_{w,Ed}$	Torsion resistance, St Venant and warping shear stress	kNm, MPa	Torsion check
$M_{w,Ed}$, $M_{z,Ed}$	Warping moment, minor-axis moment	kNm	Bending and LTB cards
A, I_y, I_z, I_t, I_w, $W_{el,y}$, $W_{pl,y}$, i_y, i_z	Area, second moments, torsion and warping constants, section moduli, radii of gyration	cm^2, cm^4, cm^6, cm^3, cm	Report 2.2, Profile view
$f_{m,k}$, $f_{v,k}$, $f_{c,90,k}$	Timber characteristic bending, shear and perpendicular compression strength	MPa	Report 2.1
$E_{0,mean}$, $E_{0,05}$, ρ_{mean}	Timber stiffness and density	MPa, kg/m^3	Report 2.1
γ_M, γ_3	Timber partial factors	–	Report 2.1, Design code
k_{mod}, k_h, k_{sys}, k_{def}	Modification, size, system and deformation factors	–	Timber checks, report 2.1
$\sigma_{m,y,d}$, $f_{m,d}$	Design bending stress and strength	MPa	Timber Bending

Symbol	Meaning	Unit	Where
$\tau_{v,d}$, $f_{v,d}$, k_{cr}, b_{ef}	Design shear stress and strength, crack factor, effective width	MPa, –, mm	Timber Shear
$\tau_{tor,d}$, k_{shape}	Torsion stress, shape factor	MPa, –	Timber Torsion
$\sigma_{m,crit}$, $\lambda_{rel,m}$, k_{crit}	Critical bending stress, relative slenderness, LTB factor	MPa, –	Timber LTB
l_{ef}, A_{ef}, $k_{c,90}$, $\sigma_{c,90,d}$, $f_{c,90,d}$	Effective bearing length and area, bearing factor, stress and strength	mm, mm^2, –, MPa	Bearing check

Source: resources notation BeamCheckNotation.kt, SectionNotation.kt, TimberNotation.kt, DesignCodeNotation.kt.

Symbols: concrete and fire

Symbol	Meaning	Unit	Where
f_{ck}, E_{cm}, f_{cd}	Concrete characteristic and design strength, modulus	MPa	Concrete report 2.1, Bending
f_{yk}, f_{yd}	Reinforcement characteristic and design yield strength	MPa	Concrete report 2.1, Bending
γ_C, γ_S, α_{cc}, α_{ct}, cot θ	Concrete partial factors, coefficients, strut angle	–	Concrete Basis of design
d, $A_{s,t}$, $A_{s,c}$	Effective depth, tension and compression reinforcement	mm, mm^2	Concrete section properties
$c_{min,dur}$, Δc_{dev}	Durability cover, execution deviation	mm	Concrete report 2.1
x, ε_{cu}, $\varepsilon_{s,max}$, C_c, C_s, T_s	Neutral-axis depth, strains, internal forces	mm, ‰, kN	Bending + and −, flexure figure
$V_{Rd,c}$, $V_{Rd,s}$, $V_{Rd,max}$	Shear resistances without links, with links, strut	kN	Concrete Shear
σ_c, σ_s	Concrete and reinforcement stress	MPa	Stresses
w_k, $s_{r,max}$	Crack width, maximum crack spacing	mm	Crack width
l_{bd}, l_0	Anchorage and lap length	mm	Anchorage, Laps
$E_{fi,d}$, $R_{fi,d,0}$, μ_0	Fire design effect, resistance at time zero, degree of utilisation	kNm, –	Steel fire
κ_1, κ_2, $\gamma_{M,fi}$	Fire adaptation factors and partial factor	–	Steel fire

Symbol	Meaning	Unit	Where
θ_a, $\theta_{a,cr}$	Steel temperature and critical temperature	°C	Steel fire
A_m/V	Section factor	1/m	Steel fire
d_p, λ_p, c_p, ρ_p	Protection thickness, conductivity, specific heat, density	mm, W/(m·K), J/(kg·K), kg/m³	Steel fire protection
$M_{fi,t,Rd}$, $V_{fi,t,Rd}$, $M_{b,fi,t,Rd}$, $\chi_{LT,fi}$	Resistances in fire at time t	kNm, kN, –	Steel resistance method
$d_{char,n}$, d_{ef}, b_{fi}, h_{fi}	Notional and effective charring depth, residual width and height	mm	Timber fire
$k_{mod,fi}$, $f_{m,d,fi}$, $f_{v,d,fi}$	Fire modification factor and design strengths	–, MPa	Timber fire
h_p	Cladding thickness	mm	Timber fire cladding
b_{min}, a, a_{min}	Minimum width, axis distance and its minimum	mm	Concrete fire
R30 … R240	Required fire resistance class	min	Fire inputs

Source: resources notation ConcreteNotation.kt, SteelNotation.kt, TimberNotation.kt; spec/beam/concrete-report.md rules 4–9; spec/beam/fire.md rules 20–47.

State words

Word	Meaning
Results current · <combination>	The shown result belongs to the current input
Calculating…	A calculation is running; results update automatically
Results outdated	You changed the input after the shown result
Invalid input	A field holds a value that cannot be calculated
Not calculated	There is nothing to calculate yet, for example no loads and self-weight off
Calculation unsupported / failed / unavailable	The engine does not cover the model, broke on it or could not run
Pass / Fail	A real verdict with its utilisation
Governing	The evaluated check with the greatest utilisation
Not evaluated / Not relevant	The check does not apply to this beam; never a pass

Word	Meaning
Unsupported / Unavailable / Failed calculation	A check the engine does not cover, could not give, or broke on
Not checked	The report's word for a check without a verdict
Resistance satisfied / not satisfied; Partial result	Fire verdicts

Source: spec/beam/workspace-shell.md rules 20–25; spec/beam/checks-column.md rules 9, 12, 14; spec/beam/report.md rule 11; spec/beam/fire.md rules 10, 42.

CHAPTER 25

Scope, editions and limitations

This chapter states what Statiko designs, which Eurocode editions and National Annexes it uses, where it uses its own finite-element method and where it leaves Eurocode. Read it before you rely on a result for a member type or a country the chapter does not name. The **Eurocode references** tile on the hub's Documentation page opens this chapter.

What Statiko designs

Statiko designs single beams: steel (classes 1 to 3), timber, glulam and reinforced concrete, each with its normal design and its fire design. One beam is analysed as a line of beam elements on its supports, with its loads, combinations, checks and PDF report (Chapter 16).

Not in Statiko:

- 3D models: Statiko analyses one straight beam, never a spatial structure.
- Frames: no beam is connected to a column or to another beam.
- Connections: no bolts, welds, end plates or timber fasteners are designed.
- Foundations: the support reactions are reported, but no footing or soil is designed.

Source: statiko spec/guide.md › Scope; this guide's chapters 16 to 22.

Eurocode editions

Statiko calculates with the first generation of the Eurocodes, in the editions below. The report states the edition of the design code and of the basis of design on its Basis of design page (Chapter 14).

Part	Edition	Used for
EN 1990	EN 1990:2002 + A1:2005	Basis of design, load combinations (Chapter 15)
EN 1993-1-1	EN 1993-1-1:2005 + AC:2009	Steel checks (Chapter 18)
EN 1993-1-5	EN 1993-1-5:2006 + AC:2009	The shear factor η (Shear)
EN 1995-1-1	EN 1995-1-1:2004 + AC:2006 + A1:2008	Timber and glulam checks (Chapter 19)
EN 1992-1-1	EN 1992-1-1:2004 + A1:2014	Concrete checks (Chapter 20)
EN 1991-1-2	EN 1991-1-2:2002	Fire actions (Fire actions)
EN 1993-1-2	EN 1993-1-2:2005	Steel in fire
EN 1995-1-2	EN 1995-1-2:2004	Timber and glulam in fire
EN 1992-1-2	EN 1992-1-2:2004	Concrete in fire

Source: resources `localization/design/DesignStrings.kt:34,37,44`; resources `ConcreteStringsEn.kt:459`; engineering `SteelShearEtaProvenance.kt:3`; statiko `ai/eurocode/sources/register.tsv` (fire parts); reports `reportBasis.kt:74-75`.

National Annexes

A project has one design code (Chapter 5). The choices are:

- **Eurocode recommended values**: the values the Eurocode parts recommend.
- **Denmark (DS EN)**, **Sweden (SS EN)** and **Serbia (SRPS EN)**: the nationally determined parameters of that country's National Annexes.
- **Custom values**: values you enter yourself. Statiko does not check them against any National Annex; their source is yours to state.

Concrete beams do not calculate under **Sweden (SS EN)**, because the Swedish National Annex to EN 1992-1-1 is not in Statiko yet. Norway is not a design code choice, and there is no United Kingdom National Annex.

Source: project `domain/design/AnnexDesignCountry.kt:3-9`; resources `DesignStringsEn.kt:24,40,60-62`; spec/beam/concrete-workspace.md rule 4.

Where Statiko uses its own finite-element method

Where Eurocode leaves the method to the designer or gives no formula, Statiko uses its own finite-element method, and the guide names it each time:

- The static analysis of the beam: Eurocode prescribes no beam formulation (The beam model).
- The elastic critical moment M_{cr}: EN 1993-1-1 6.3.2.2(2) gives no formula, so Statiko solves a linear buckling eigenvalue problem over the whole member, with no effective-length table. Steel uses it for χ_{LT} (Critical moment as an eigenvalue), timber and glulam for k_{crit} (Timber).
- The natural frequency: an eigenvalue problem of the same beam model (Natural frequency).
- The section analysis: the torsion modulus W_t and, for some steel shapes, the shear area (Shear).

Source: statiko `ai/architecture/engineering-rules.md:5-9`; engineering `fem/ltb/CriticalBucklingCalculator.kt:39`.

Results beyond Eurocode

One result is marked beyond Eurocode in the check details and the report: **Finite-element shear area, beyond Eurocode**. Statiko uses it for zee and solid sections, welded channels and boxes with inclined webs, for which EN 1993-1-1 6.2.6(3) gives no shear area (Shear).

The steel torsion resistance $T_{Rd} = W_t \cdot (f_y / \sqrt{3}) / \gamma_{M0}$ is Statiko's own form; the utilisation follows $T_{Ed}/T_{Rd} \le 1$ of EN 1993-1-1 6.2.7 (Torsion).

Source: resources `ReportStringsEn.kt:57`; reports `steelReportCrossSection.kt:77`; engineering `steel/SteelShearArea.kt:12-151`, `steel/SteelTorsionCalculator.kt:33-36`.

Limits of this version

Each calculation chapter lists what this version does not check. A check outside these limits reads Unsupported or Unavailable, never Pass.

- Static analysis: Limits.
- Steel: Results and limits.
- Timber and glulam: Limits of this version.

- Concrete: What you see and the limits.

Source: this guide's chapters 16, 18, 19 and 20.