USER MANUAL SIKA® CARBODUR® SOFTWARE
BASED ON TR 55 AND EC2

OCTOBER 2025 V. 1.0 / SIKA SERVICES TH

DOCUMENT FOR THAILAND

BUILDING TRUST

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1 INTRODUCTION

This software assists consultants in designing CFRP for flexural strengthening, shear strengthening, and column confinement. The next sections detail the theoretical background for these calculations.

This program uses calculation procedures from the Concrete Society's Technical Report No55, third edition (2012), *"Design guidance for strengthening concrete structures using fibre composite materials"*.

Additional and auxiliary calculation methods are taken from the following codes:

- Eurocode 2: Design of concrete structures.
- EMPA report 116/7.

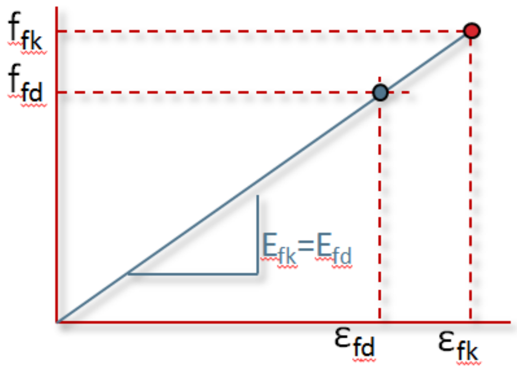
2 THEORETICAL BACKGROUND

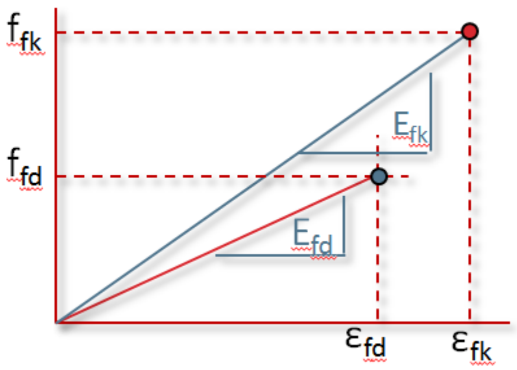
2.1 GENERAL DESIGN CONSIDERATIONS

2.1.1 PARTIAL FACTORS FOR FRP COMPOSITES (TR55, §5.6.3, §5.6.4 AND §5.6.5)

TR55 takes into account a combination of safety factors according to the following parameters, which apply over the characteristic values to determine the design values. The determination of the safety factors is based on the following issues:

- Type of FRP material.: Table 1 & 3
- Type of FRP system (method of application/manufacture: Table 2





Most alternative FRP guidelines recommend using ultimate strength and deformation values when performing design calculations. However, when it comes to the design E-modulus, these standards usually specify the use of either the characteristic or average value.

The TR55 approach differs from other existing FRP guidelines in that the safety factors not only limit the ultimate strength and deformation for design but also result in a reduced design E-modulus.

The safety factors can be taken from the following tables:

TABLE 1

Factor of safety for Young´s modulus at the ultimate limit state (all design situations), $\gamma_{FRP,E}$	
Carbon FRP	1.1
Aramid FRP	1.1
AR-Glass FRP	1.6
E-Glass FRP	1.8
Basalt FRP	1.8

TABLE 2

Additional partial safety factor according to the manufacture/application method, $\gamma_{FRP,m}$	
Plates	
Pultruded	1.05
Prepreg	1.05
Preformed	1.1
Sheets or tapes	
Machine-controlled application	1.05
Vacuum infusion	1.1
Wet lay-up	1.2
Prefabricated (factory-made) shells	
Filament winding	1.05
Resin transfer molding	1.1
Hand lay-up	1.2
Hand-held spray application	1.5

TABLE 3

Additional partial safety factor for strain at the ultimate limit state, $\gamma_{FRP,\varepsilon}$	
Carbon FRP	1.25
Aramid FRP	1.35
AR-Glass FRP	1.85
E-Glass FRP	1.95
Basalt FRP	1.95

By applying the appropriate safety factors, the design values for the FRP are determined as:

Equations from TR55

$$E_{fd} = \frac{E_{fk}}{\gamma_{FRP,mE}} = \frac{E_{fk}}{\gamma_{FRP,E} \cdot \gamma_{FRP,m}} \quad (2.1.a)$$

where E_{fd} is the design E-modulus of the FRP and E_{fk} is its characteristic value,

$$\varepsilon_{fd} = \frac{\varepsilon_{fk}}{\gamma_{FRP,m\varepsilon}} = \frac{\varepsilon_{fk}}{\gamma_{FRP,\varepsilon}\ \gamma_{FRP,m}} \quad (2.1.b)$$

where ε_{fd} is the design ultimate deformation of the FRP and ε_{fk} is its characteristic value, therefore the design strength f_{fd} is calculated as:

$$f_{fd} = E_{fd} \cdot \varepsilon_{fd} \quad (2.1.c)$$

2.1.2 STRENGTHENING LIMITS (TR55, §6.2.2)

Before strengthening, the designer must evaluate the potential impact of accidental loss, of strengthening so that such failure does not compromise the structure.

Due to this, the member should be only considered for the strengthening if the ultimate resistance of the unstrengthened (existing) member under an accidental situation, as defined in *Eurocode 2, Part 1-1,* is at least as great as the frequent combination of actions as indicated in *Eurocode 0 , sections A.1.4.1 and A.1.4.2*. This check is intended to limit any extra loads that can be applied to the strengthened member, regardless of how well the FRP system performs.

$$R_d \geq E_d \quad (2.1.d)$$

2.1.3 DESIGN OF FRP IN CASE OF FIRE (TR55, §5.7.1)

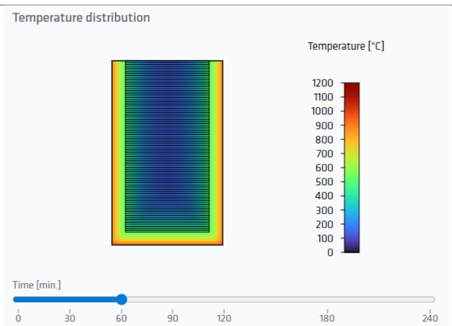
Fire is an accidental situation that involves exceptional design conditions of the structure and the acting loads.

In case of fire, unprotected CFRP is expected to be lost due to the high temperatures. Hence, the unstrengthened member is subjected to reduced design load combination, such as the quasi-permanent combination of service loads as indicated in *Eurocode 1 , Part 1-2: General actions – Actions on structures exposed to fire, section 4.3.1.*

The software includes a preliminary determination of the resistance of the un-strengthened member in case of fire. The ultimate strength of the member is determined according to the real strength of the concrete and steel, assuming a partial factor for those materials $\gamma_{M,fi} = 1$ *(Eurocode 2 , Part 1-2: General rules – Structural fire design, section 2.3)*, and must exceed the load combination under a fire scenario (*Eurocode 1 , Part 1-2: General actions – Actions on structures exposed to fire, section 4.3.1.).*

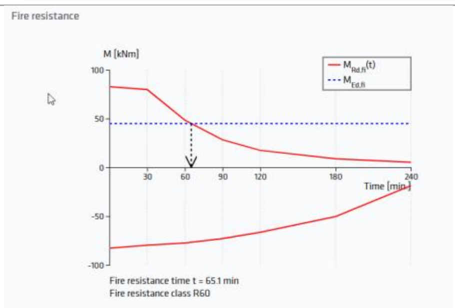
$$R_{d,fi} \geq E_{d,fi} \qquad (2.1.e)$$

Under this condition, the CFRP is no longer required in case of fire; hence no specific fire protection for FRP will be required. However, a certain protection for the RC member may be required to achieve a necessary fire rating. The software also includes an optional detailed calculation which allows determination of the fire resistance of the member without the additional contribution of the FRP, according to the temperature profiles for slabs, beams and columns and the 500 °C Isotherm Method (*Eurocode 2 , Part 1-2: General rules – Structural fire design, Annex A and Annex B).*



In case of fire, the member´s section will be progressively heated. Due to this, different temperature gradients will be produced in the section, leading to a reduced mechanical performance of the concrete and the steel reinforcement bars.

The 500 °C Isotherm Method is a simplified, non-tabulated method that does not take into account the mechanical contribution of the concrete section which exhibits a temperature beyond 500ºC.



The reduced effective section must maintain enough strength to withstand fire load combinations. The fire rating is the duration this condition is met.

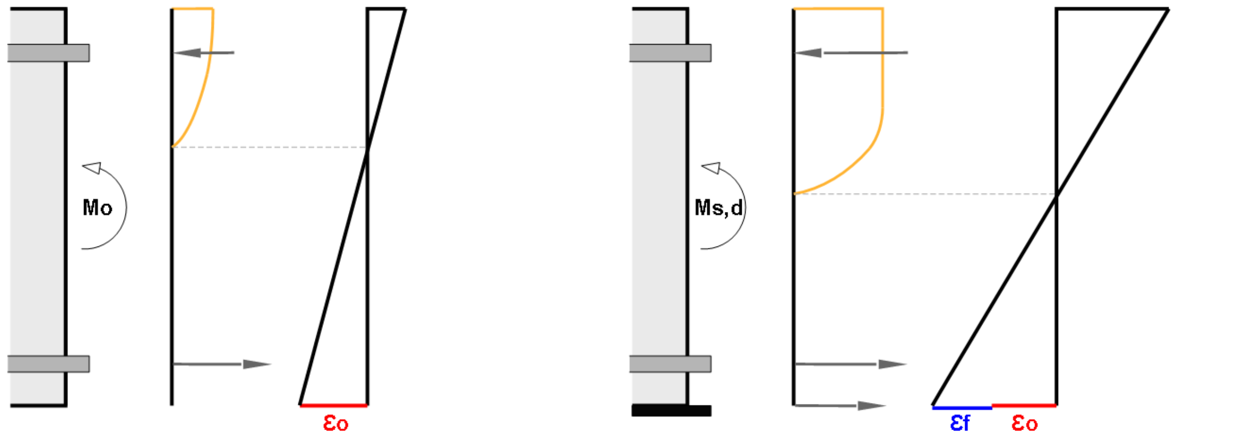
The Sika® CarboDur® software evaluates the strength of the un-strengthened member in case of fire, calculating the anticipated temperature profiles in the concrete section and the real fire resistance according to the fire loads, as shown in *TR55, section 5.7.1.*

2.2 FLEXURAL STRENGTHENING

Reinforced concrete components, including beams, slabs, and columns, can be enhanced in flexural capacity by applying FRP composites bonded with epoxy to the tension zones, aligning the fibres parallel to the direction of maximum tensile stresses (member axis). The following calculations address both the Ultimate Limit State (ULS) and the Serviceability Limit State (SLS).

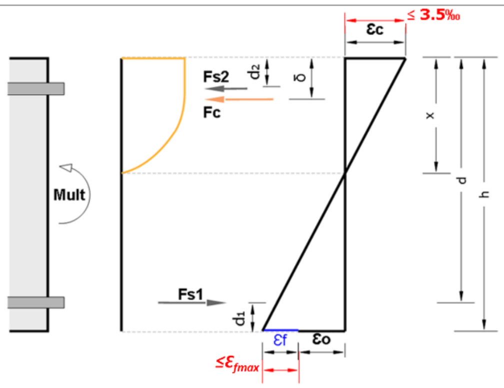
For members strengthened in flexure, the following aspects must be considered:

- Determinations of the existing deformation of the section under flexure at the moment of strengthening, taking into account the effects of the creep in the E-Modulus of the concrete. The software establishes the E-modulus for this verification as $\frac{E_{cm}}{1+\varphi_{ef}}$, where φ_{ef} is the effective creep coefficient.



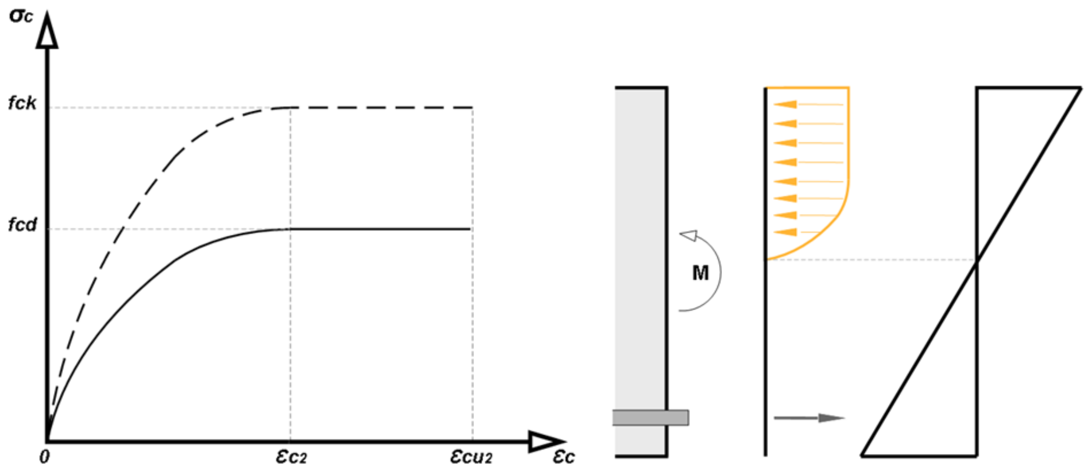
Determination of the initial strain at the extreme fiber (left), and its influence on the loaded, strengthened member (right)

- Strain compatibility and forces equilibrium in the strengthened section must be satisfied, considering the existing deformation of the extreme concrete fibre at the moment of strengthening, ε_0



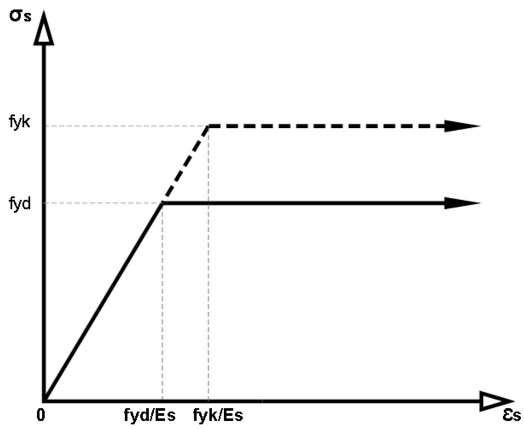
Stress and strain profiles for the ultimate limit state, strengthened member. Note that strains are limited (in red) by the maximum compressive strain of the concrete (3,5% for concrete class ≤50MPa), and the limiting strain of the CFRP, ε_{fmax}, which can be taken as 0.8% (TR55, 6.3.3C)

- The ultimate resistance of the strengthened section can be limited by the concrete crushing under compression (corresponding to 3.5 ‰ deformation) or the debonding of the CFRP laminate (shear-crack-induced separation, excessive longitudinal shear stress along the FRP or an insufficient end-anchorage for the laminate). In the case of NSM applications, additional failure mechanisms (e.g. adhesive splitting failure, concrete splitting failure and concrete cover separation) must be evaluated.
- Ductility of the strengthened member
- Compliance with the stress limitations for the different materials (concrete, steel and FRP) under relevant serviceability limit states.



Parabola-rectangle stress block for concrete under compression (left) and section of a beam under flexure (right)

Reinforced concrete elements, such as beams, slabs and columns, may be strengthened in flexure through the use of FRP composites bonded with structural epoxy adhesives in their tension zones, with the direction of fibres parallel to that of the high tensile stresses (member axis).



Simplified design stress-strain diagram for reinforcing steel (tension and compression)

For the design, the parabola-rectangular method is used by the software to determine the compressive strain and stress ratio of the concrete across the section´s height. The design strength of the concrete is determined as:

$$f_{cd} = \frac{\alpha_{cc} f_{ck}}{\gamma_c} \qquad (2.2.a)$$

Where γ_c is the partial factor for the concrete, and α_{cc} is the coefficient taking account of long term effects on the compressive strength according to Eurocode 2.

The design values for the reinforcing steel are derived from the characteristic values, f_{yk}. In the case of ULS verifications, the software uses a simplified bilinear diagram, with a horizontal branch extending from the point where f_{yd} is achieved.

$$\sigma_s = E_s \, \varepsilon_s \qquad (2.2b)$$

For the design the value of the modulus of elasticity, E_s , is assumed to be 200 GPa as default.

The calculation of the FRP strengthening for flexural strengthening follows the principles exposed in **Eurocode 2** and **TR55(2012), Section 6** with the following modification:

- In case of post-tensioned Sika® CarboDur® S plates, the maximum effective strain for the CFRP laminate will be limited to 1.26% (value experimentally validated for the Sika® CarboStress system)

$$\varepsilon_{fd,postensioned} \leq 1.26\%$$

2.2.1 STRENGTHENING LIMITS

Refer to section 2.1.2.

2.2.2 SERVICEABILITY (TR55, §6.9)

Stress rupture:

Under the characteristic combination of actions, if the FRP carries a sustained stress, the maximum stress level at the laminate must not exceed the following:

Maximum stress in FRP under service loads, with respect to the design strength.	
Carbon FRP	65% x f_{fd}
Aramid FRP	40% x f_{fd}
Glass FRP	45% x f_{fd}
Basalt FRP	35% x f_{fd}

Strengthening under dynamic loads:

If the hardening of the adhesive is expected to occur under dynamic loads, the performance of the adhesive may be affected (TR55, 6.9.4). Under these circumstances, if the reduced adhesive strength is less than the design axial tensile strength of the concrete, then the live load during adhesive curing must be restricted.

Live load strains at FRP-concrete interface during curing (10^{-6})	**Reduction in tensile bond strength of adhesive**
20	10%
50	12%
100	16%
150	22%
200	32%

Reinforced concrete members (Eurocode 2, Part 1-1, section 7.2):

The effective tensile stress in the steel in the FRP-strengthened member under the characteristic combination of loads is being limited to:

$$\leq 0.80\ f_{yk} \text{ in case of reinforcing steel}$$
$$\leq 0.75\ f_{pk} \text{ in case of prestressed steel}$$

The compressive stress in concrete (FRP strengthened member) under the quasi-permanent combination of loads should be limited to 0.45 f_{ck} when the structural element is exposed to chlorides or freeze/thaw attack.

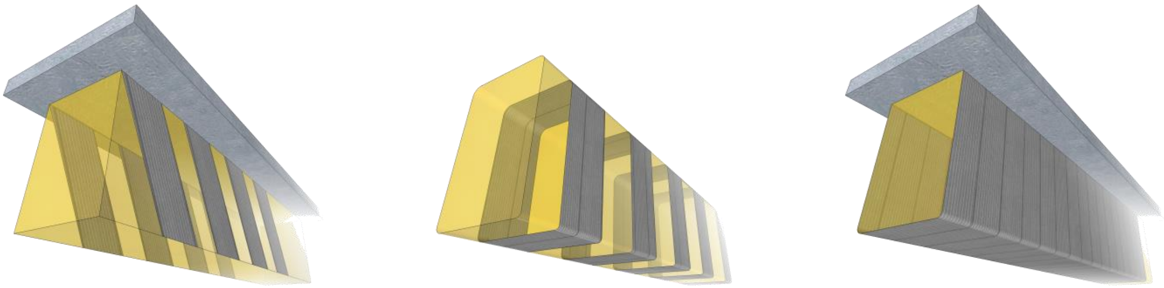
Post-tensioned CFRP laminates:

The effective strain for the CFRP laminate under service loads will be limited to 0.92% (value experimentally validated for the Sika® CarboStress system).

2.3 SHEAR STRENGTHENING

Shear strengthening of RC members using FRP may be provided through bonding the external reinforcement with the principal fibre direction as parallel as practically possible to that of maximum principal tensile stresses, so that the effectiveness of the FRP is maximized. For the most common case of structural members subjected to shear loads, the maximum principal stress trajectories in the shear-critical zones form an angle with the member axis that may be taken roughly equal to 45°, which is possible in those situations where the FRP is applied to both sides of the beam.

However, for complete wrapping or U-wrapping schemes, it is normally more practical to attach the external FRP reinforcement with the principal fibre direction perpendicular to the member axis.



Closed jackets or properly anchored strips are always preferable compared to open jackets, as in the latter case FRP premature debonding is usually expected; hence the effectiveness of the FRP is reduced. 2-sided configuration provides the least effective performance due to the risk of debonding and the smaller effective depth.

For discrete strip configuration, the maximum centre-to-centre spacing between consecutive strips is limited to the least of:

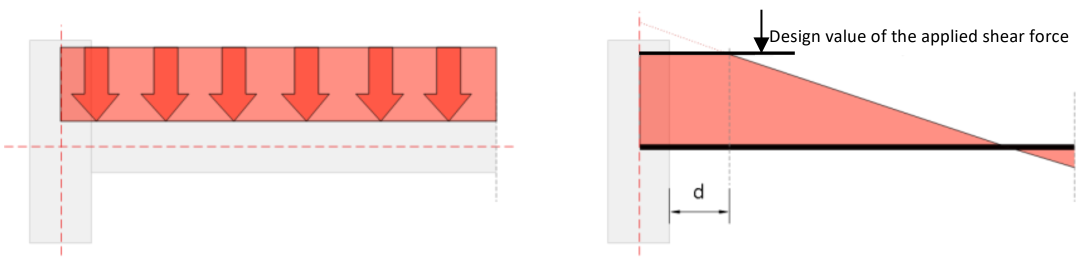
- $0.8d_f$
- $d_f - (n_s/3) l_{t,max} \cos \boldsymbol{\beta}$
- $b_f + d_f/4$

Where:

- d_f is the effective depth of FRP shear reinforcement
- n_s is the factor for anchorage of shear strengthening (TR55, section 7.2.). Its value equals:
  - 0 for a fully wrapped beam,
  - 1.0 when FRP is bonded continuously to the sides and bottom of a beam (U-wrapped) and
  - 2.0 when it is bonded to only the sides of a beam
- $l_{t,max}$ is the maximum anchorage length for the FRP scheme (TR55, Section 6.3).
- b_f is the width of FRP laminate, and
- $\boldsymbol{\beta}$ is the angle between the principal fibres of the FRP and a line perpendicular to the longitudinal axis of the member

Note these limitations disallow the use of discrete strips in the case of beams with a limited available height and/or wide FRP fabrics.

For members subjected primarily to uniformly distributed loading, the design shear force used to determine the required FRP section does not need to be evaluated at distances less than *d* from the face of the support.

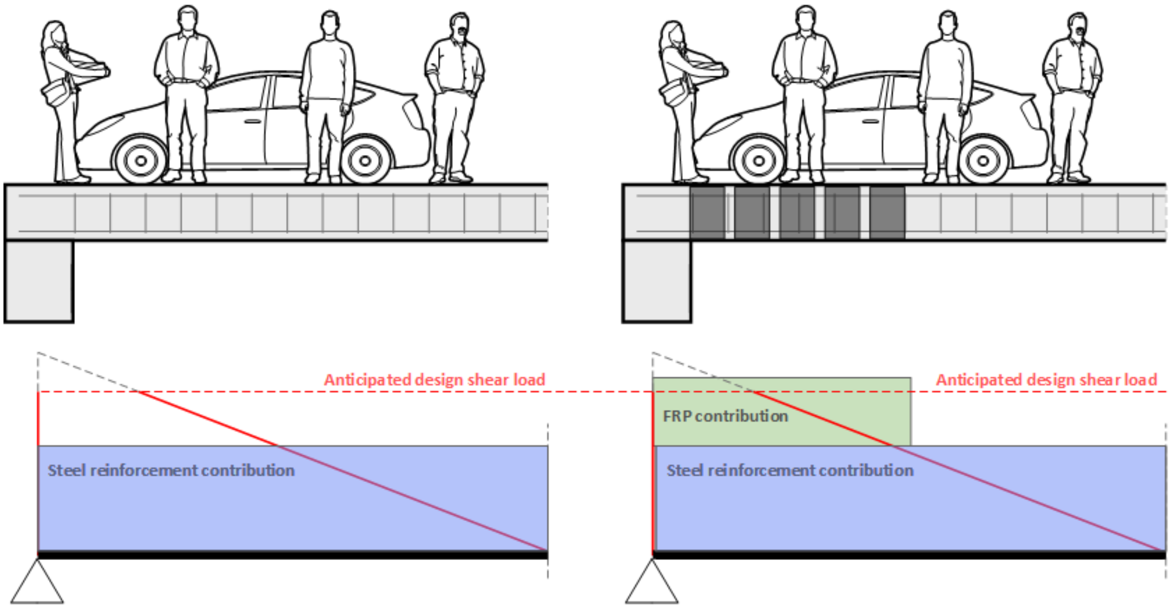


The external FRP reinforcement may be treated in analogy to the internal steel (accepting that the FRP carries only normal stresses in the principal FRP material direction), assuming that at the ultimate limit state in shear the FRP develops an effective strain in the principal material direction ε_{fse} which must not exceed:

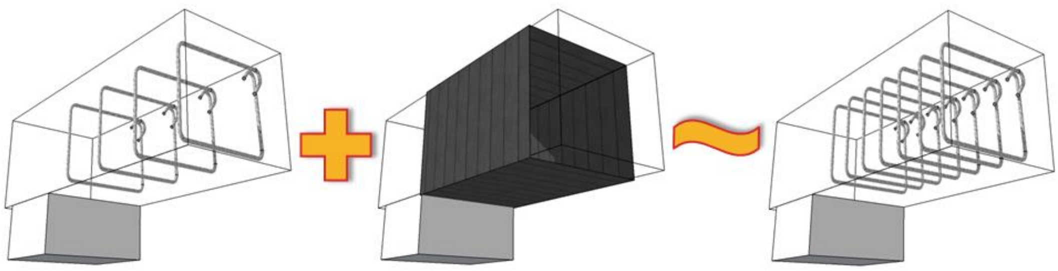
- $\varepsilon_{fd}/2$, where ε_{fd} corresponds to the design ultimate strain of the FRP.
- $0.5\sqrt{\frac{f_{ck}}{E_{fd} t_f}}$, where E_{fd} is the design E-modulus of the FRP and t_f is the total thickness of the FRP system.

- 0.4%

The shear resistance of the strengthened member is found by superposing the FRP and steel contribution under shear forces, and limiting the stresses in the steel, concrete and FRP to ensure that they do not exceed their design values.



Un-strengthened member *FRP-strengthened member*



Additionally, it must also be verified that the shear force can be sustained by the member, limited by the inclined compression failure of the concrete (Clause 6.2.3 of Eurocode 2, Part 1-1).

According to Eurocode, the resistance of a concrete section is the minimum between the resistance of the concrete compression strut $\mathbf{V_{Rd,c}}$ and the maximum resistance of the internal reinforcement $\mathbf{V_{Rd,s}}$ for a given angle of the compression strut.

$$\boldsymbol{V_{Rd}} = \mathbf{min}\ (\boldsymbol{V_{Rd,c}}; \boldsymbol{V_{Rd,s}})$$

The method for the design resistance of an unstrengthened reinforced concrete section allows the truss angle to be chosen by the designer to be either at the lower limit of 21.8° (cot θ = 2.5) or increased if desired up to a maximum value of 45° (cot θ = 1), to maximise the resistant shear resistance until a balanced equilibrium is found. When FRP shear reinforcement is introduced, this typically has the effect of steepening the effective truss angle at ULS. This effect can be modelled using the principle of superposition, considering the total effect to be the superposition of two truss systems, one relating to the steel reinforcement, with a truss angle θ limited to be between 21.8° and 45° (i.e. 1 < cot θ < 2.5), and another associated with the FRP, with a truss angle equal to 45°. The shear resistance is found by superposing these systems, and limiting the stresses in the steel, concrete and FRP to ensure that they do not exceed their design values. This is equivalent to considering a single truss system with a truss angle that is a weighted mean of the truss angles for the steel and FRP systems.

The final strengthened shear resistance of the member under shear forces is determined as:

$$V_{Rd,s,f} = \frac{A_{sw}}{s} z f_{ywd} cot\theta + \frac{A_{fw}}{s_f}\left(d_f - \frac{n_s}{3} \cdot l_{t,max} \cdot cos\beta\right) E_{fd}\varepsilon_{fse}(sin\beta + cos\beta) \quad \text{(eq. 7.1 TR 55)}$$

where:

- $\frac{A_{sw}}{s} z f_{ywd} cot\theta = \boldsymbol{V_{Rd,s}}$
- $\frac{A_{fw}}{s_f}\left(d_f - \frac{n_s}{3} \cdot l_{t,max} \cdot cos\beta\right) E_{fd}\varepsilon_{fse}(sin\beta + cos\beta) = \boldsymbol{V_{Rd,f}}$
- **A_{sw}** is the cross-sectional area of steel shear reinforcement;
- **s** is the longitudinal spacing of the steel shear reinforcement stirrups;
- **z** is the lever arm between the longitudinal steel reinforcement and the centroid of the compression in the section;
- **f_{ywd}** is the design yield strength of the steel shear reinforcement;
- **θ** is the angle between the concrete compression strut and the beam axis perpendicular to the shear force;
- **A_{fw}** is the area of FRP (mm^2) for shear strengthening measured perpendicular to the direction of the fibres. When FRP laminates are applied symmetrically on both sides of a beam, A_{fs} is the sum of the areas of both laminates;
- **s_f** corresponds to longitudinal spacing of the FRP laminates used for shear strengthening (mm). For continuous FRP sheet, s_f is taken as 1.0;
- **d_f** is the effective depth of the FRP strengthening, measured from the top of the FRP shear strengthening to the steel tension reinforcement (mm);
- **n_s** is 0 for a fully wrapped beam, 1.0 when FRP is bonded continuously to the sides and bottom of a beam (U-wrapped) and 2.0 when it is bonded to only the sides of a beam;
- **$l_{t,max}$** is anchorage length required to develop full anchorage capacity;
- **β** is the angle between the principal fibres of the FRP and a line perpendicular to the longitudinal axis of the member. β is positive when the principal fibres of the FRP are rotated away from the direction in which a shear crack will form;
- **E_{fd}** is the design tensile modulus of the FRP laminate (MPa);
- **ε_{fse}** is the effective strain in the FRP for shear strengthening;
- **b_f** is the width of the FRP laminate (mm) measured perpendicular to the direction of the fibres. For continuous FRP sheet, b_f is taken as cos β;
- **t_f** is the thickness of the FRP laminate (mm).

<u>This means that the additional contribution of the FRP (**$V_{Rd,f}$**) is not always added arithmetically to the original shear resistance of the un-strengthened section, because adding the FRP could change the angle of the truss θ (steepening it) and reducing the value of **$V_{Rd,s}$**.</u>

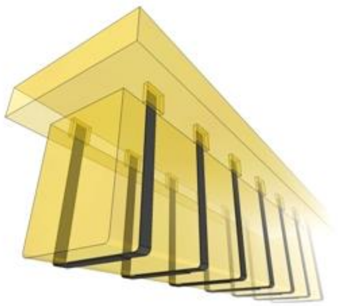
<u>The strengthened shear resistance will be:</u> $\boldsymbol{V_{Rd}} = \mathbf{min}\,(\boldsymbol{V_{Rd,c}}; \boldsymbol{V_{Rd,s}} + \boldsymbol{V_{Rd,f}})$

Additionally, the Sika CarboDur® software can also calculate other strengthening options, not based on externally bonded FRP laminates:

Near-surface-mounted FRP reinforcement for shear strengthening.

The NSM bars are mounted in slots cut into the sides of the beam to be strengthened

For shear strengthening using NSM bars mounted to the sides of a beam, a similar approach of combining the contribution from the steel (assuming a variable angle truss) and that from the NSM bars (assuming a 45° truss) can be performed. Additional information can be found in TR55, Section 7.5.



Sika CarboShear® L

The CarboShear® L profiles are carbon fibre shear links for high performance shear strengthening. The L-shaped profiles are bonded onto the beam and anchored into the top slab/flange.

Additional information can be found at the following tests report from the Swiss Federal Laboratories for Materials Testing and Research (EMPA):

- EMPA Test Report 169´219
- EMPA Test Report 116/7

2.3.1 STRENGTHENING LIMITS

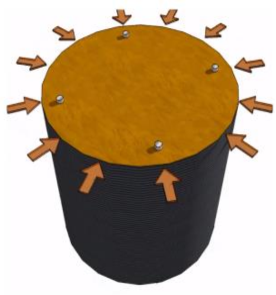
Refer to section 2.1.2.

2.4 COLUMN CONFINEMENT

The main objectives of confinement are:

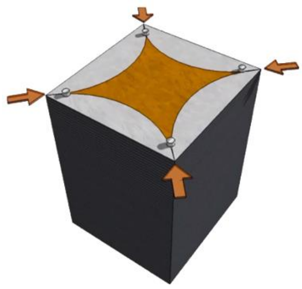
a. to enhance concrete strength and deformation capacities,
b. to provide lateral support to the longitudinal reinforcement and
c. to prevent the concrete cover from spalling.

For circular columns, these goals can be achieved by applying external FRP jackets. For rectangular columns, confinement can be provided with rectangular-shaped reinforcement, with corners rounded before application. Note that rectangular confining reinforcement is less effective as the confinement action is mostly located at the corners and a significant jacket thickness needs to be used between corners to restrain lateral dilation.



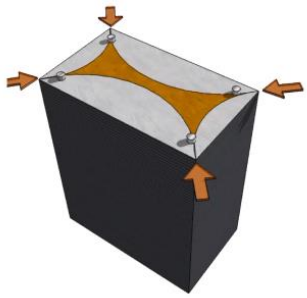
Circular columns

The concrete section effectively confined by the externally bonded FRP jacket equals the net section of the structural member.



Square/rectangular columns

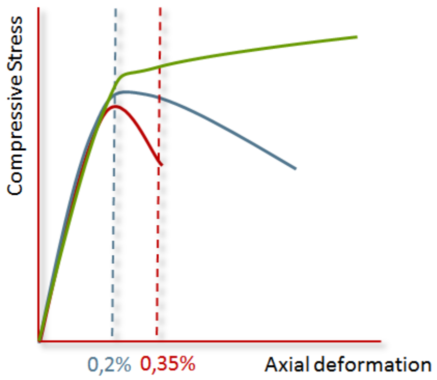
Confinement is concentrated at the corners rather than around the entire perimeter and thus the level of confinement varies throughout the cross-section, with much of the section having low levels of confinement



Long-shaped rectangular columns

The efficiency decreases further with columns that exhibit long-shaped cross-sections. The benefit provided by the confinement in case of 2:1 aspect ratios or greater is almost negligible.

The stress-strain response of CFRP-confined concrete is illustrated schematically as follows:



- Heavily confined concrete. Its strength at 0.2% deformation is enhanced. However, the concrete is still capable to assume additional loads. The ultimate load is higher than the peak load. This scheme corresponds to the confinement model adopted by the TR55.
- Confined concrete. The peak stress remains at ~0.2% deformation. The ductility is significantly enhanced.
- Original concrete. The peak stress corresponds to a deformation of 0.2%, and the ultimate strain is located at ~0.35%.

The figure displays a nearly bilinear response with a sharp softening and a transition zone at a stress level that is near the strength of unconfined concrete, f_{c0}. After this stress the tangent stiffness changes, until the concrete reaches its ultimate strength f_{ccd} when the jacket reaches tensile strain at failure $\varepsilon_{h,rup}$.

The limiting rupture strain is calculated as:

- $0.6\ \varepsilon_{fd}$ for circular columns
- $\varepsilon_{fd}\left(0.46\left(\frac{2R_c}{h}\right)+0.14\right)$, where h is the length of long side and R_c is the radius of corner.

The determination of the design strength of the confined column is carried out according to TR55, sections 8.3 and 8.5.

The software determines column strength under axial loads and bending moments in both directions, employing the TR55 (Section 8.4) method for single-direction bending. Consequently, it produces Mx-My interaction diagrams (Diagram 2) instead of the simpler 2D diagrams illustrated in TR55 Figure 34 (Diagram 1).

DIAGRAM 1

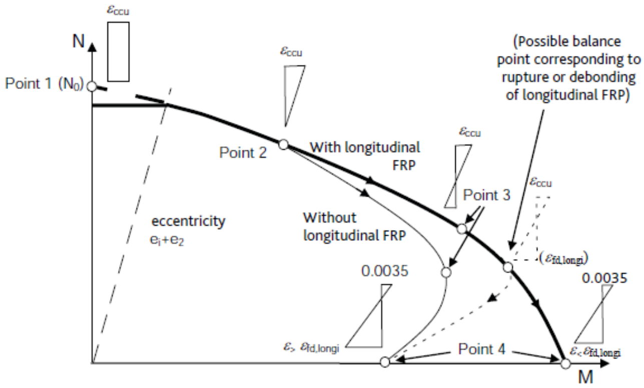
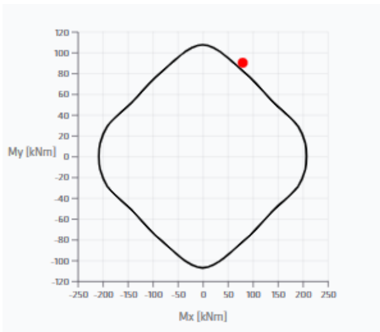


DIAGRAM 2



2.4.1 STRENGTHENING LIMITS

Refer to section 2.1.2.

2.4.2 SERVICEABILITY (TR55, SECTION §8.8)

<u>The limitations as indicated in Eurocode 2, Part 1-1, section 7.2 must be fulfilled as follows:</u>

The effective tensile stress in the steel in the FRP-strengthened member under the characteristic combination of loads is limited to$0.80\ f_{yk}$.

The compressive stress in concrete (FRP strengthened member) under the quasi-permanent combination of loads should be limited to 0.45 f_{ck} when the structural element is exposed to chlorides or freeze/thaw attack.

3 USE OF SIKA® CARBODUR® CALCULATION SOFTWARE

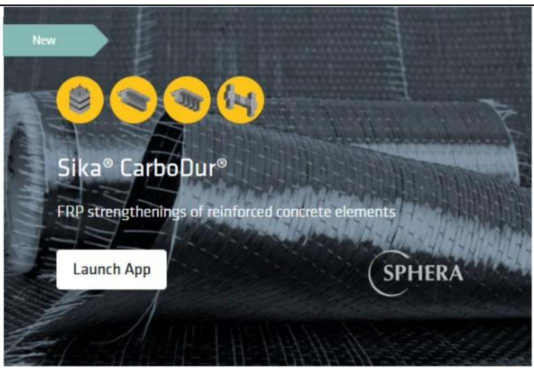
3.1 INTRODUCTION

Sika® CarboDur® Calculation Software is an advanced solution for FRP design and assessment on reinforced concrete structures. Following the most used and reliable FRP design guidelines worldwide, this powerful tool enables engineers to efficiently identify optimal FRP products that meet specific structural requirements. The software streamlines the design process, ensuring reliability, compliance, and enhanced project performance.

The software gives the possibility of access from any PC, laptop, tablet with an active internet connection. It is compatible with all web browsers, and it offers an interface designed for modern use and ease of navigation.

3.2 REGISTRATION

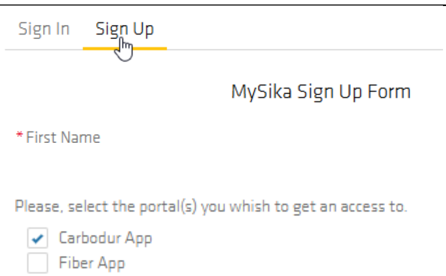
Being a cloud-based software, before start using the software, it is necessary to complete a registration process and to setup the access credentials.



The software is accessible at:
https://software.sika.com/structural

From this page click “Launch App”

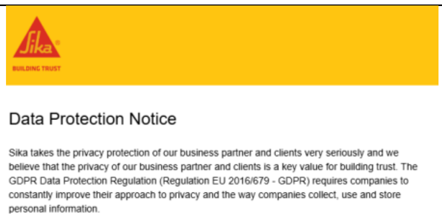
***NOTE**: The language of the page can be changed by selecting the language button located in the top yellow bar.*



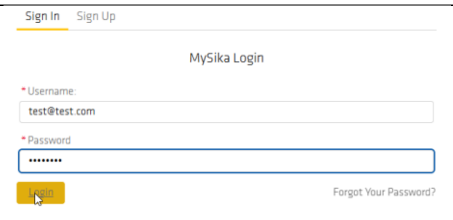
Click “Sign up” and complete the form with your name, surname, email, company, language, city, and country.

Choose whether to access only the CarboDur® Software or both the CarboDur® Software and SikaFiber software.

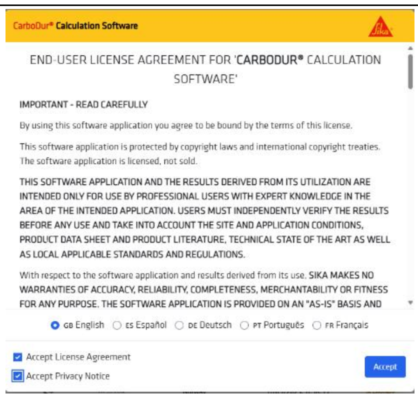
Read and accept the Privacy Notice and Submit



Check your inbox for two emails: one to set your portal password, and one with the Sika Data Protection Notice.



Once the password is set, it is possible to login and start to use the software

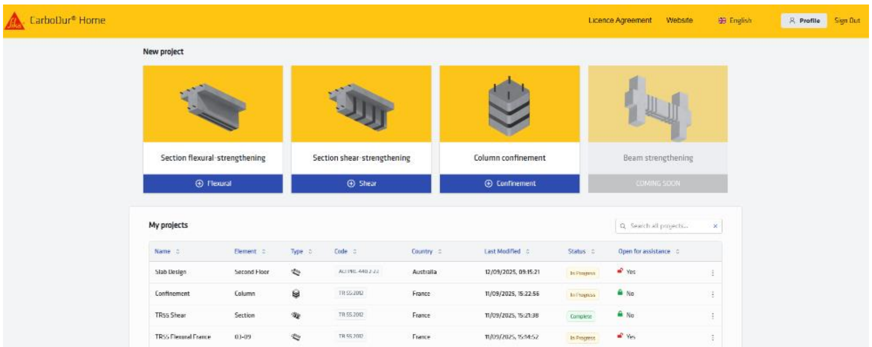


At the first login the user will be required to accept the EULA (End-user Licence Agreement) and the privacy notice

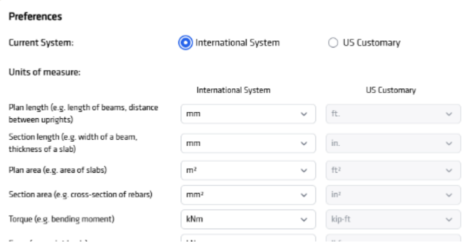
NOTE*: This popup will appear at each login, but only if the "My projects" section is empty. Once the user creates any projects, the popup will no longer be displayed. The End User License Agreement (EULA) always remains accessible via the "License Agreement" link in the top yellow bar.*

3.3 HOME PAGE

Home page offers an overview displaying the icons for creating a new project, the list of existing projects, the access to preferences, etc

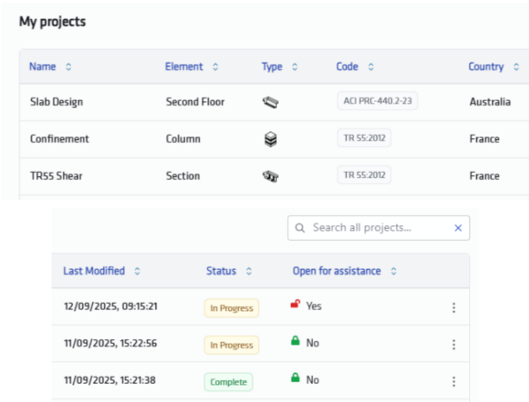


The yellow bar at the top allows you to view the License Agreement (EULA), go to **sika.com webpage**, switch languages of the software, edit your profile or log out.



Accessing the profile and Preferences opens a window where the selection between SI (International System) and US Customary Units measurement units can be done.

***NOTE**: Every single units of measure can be customized*



The "**My Projects**" section appears in the centre of the home page, showing a list of your projects. The columns in these table can be easily rearranged clicking on the symbols.

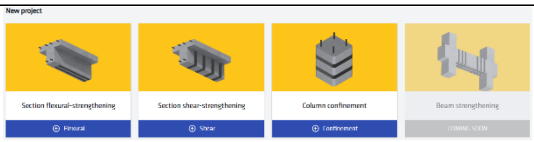
The columns of the table represents:

- Name: name assigned to the project
- Element: name or position of the element designed
  Type of design: confinement, flexural, shear, beam
  Design code: (ACI 440, TR 55, CNR-DT 200 SIA 166)
- Country: It shows the country product catalogue used for that specific design
- Date of last modification
- Status or the project: It shows if the project is complete or still in progress
- Open for assistance: It shows if the project is locked or unlocked (see below)

Projects are private and locked by default; only the owner has access.

To request support from Sika on a specific project, open it and use the "Open the project for assistance" slider. Click "Copy Current URL" to share direct access with others. When finished, turn off the slider.

NOTE: *Access to projects opened for assistance is restricted* ***ONLY*** *to members of the Sika organization. Any shared link will not be accessible to external users.*



The "**New Projects**" section enables users to create new projects by selecting the appropriate button, based on the required type of FRP strengthening.

<u>Flexural strengthening of the critical section in a beam.</u>

The Flexural module includes the dimensioning of the necessary FRP, based on the anticipated bending moments acting on the critical section of a RC / Prestressed beam, subjected to both positive and negative bending moments, including scenarios involving also axial loads

<u>Shear strengthening of the critical section in a beam/column.</u>

The calculation determines the required FRP based on anticipated shear forces at the critical section of an RC beam or column. Axial loads on the section can also be considered in the design.

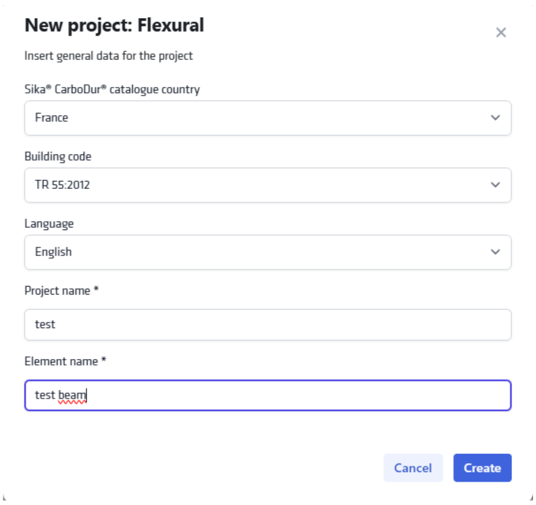
<u>Column strengthening by means of CFRP confinement.</u>

The Confinement module will comprise of the mechanical enhancement of a RC member under axial loads and bending moments. It allows the design of structural strengthening through confinement for reinforced concrete (RC) sections subjected to biaxial bending moments, using SikaWrap® FRP systems. This module facilitates the analysis of columns subjected simultaneously to axial loads and bending moments acting in two orthogonal directions.

<u>Flexural/Shear strengthening of beam</u>

Software determines the distribution of the anticipated bending moments/shear forces for the RC/prestressed member, and calculates the necessary FRP flexural and shear sections and the arrangement along the beam.

NOTE: *This module will be released soon*



When starting a new project, the user must select the country catalogue, the design guideline, the language, the project name and the element name or position.

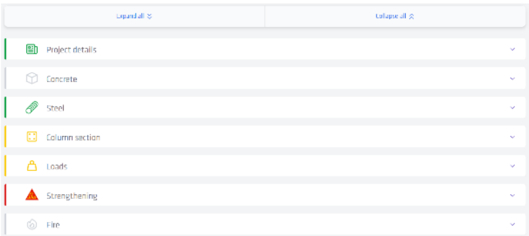
The country catalogue restricts FRP strengthening products to those listed within that specific catalogue/country.

The country catalogue and design guideline cannot be modified after the project is created.

***NOTE**: Be sure that the chosen FRP design guideline is consistent with the general concrete design code.*

General Concrete Building Code	***FRP Design Guideline***
ACI 318	*ACI 440 PRC-440.2-23*
Eurocode 2	*TR 55*
NTC 2018	*CNR-DT 200 R1/2013*
SIA 262	*SIA 166*

3.4 GENERAL INFORMATION



Each project, when opened, displays an interface consisting of panels that can be expanded or collapsed.

At the top, there are two buttons ("Expand all" and "Collapse all") that allow the user to expand or collapse all panels simultaneously.

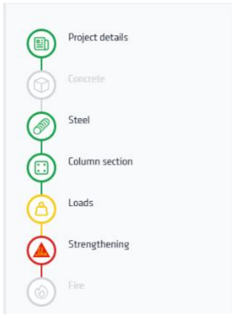
Each panel features a coloured icon, where the colour indicates the progress status of the individual project section.

See below for the explanation of the colours

The side bar is always displayed.

The top of the sidebar shows the project title, the current design element, last save date, FRP guideline used for this specific project and chosen product catalogue.

NOTE*: The country catalogue restricts FRP strengthening products to those listed within that specific catalogue/country.*



The central part of the sidebar displays all icons, each representing different section of the project.

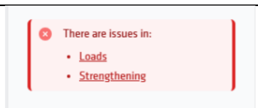
Green means that panel is complete

Grey means that panel has not been opened yet

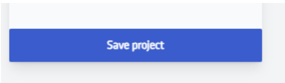
Yellow means there's a warning in that panel

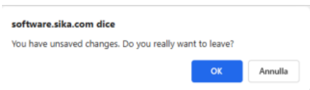
Red means there is an issue or some data are missing in that panel

NOTE*: In this way the user has always a complete overview of the full project parts*



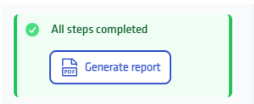
If there are any problems or warnings, they'll appear beneath the icons so users can easily review them.



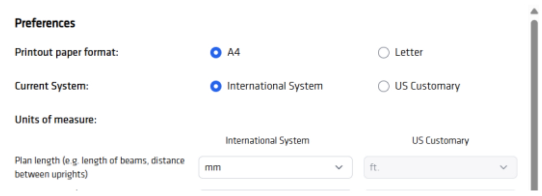


The lower part of the sidebar features a button labelled "Save project." This button remains grey when the project has been saved and turns blue if there are any unsaved changes requiring the user to save the project.

NOTE*: Most web browsers display a popup warning about unsaved changes if you try to refresh, go back, or close the browser window.*

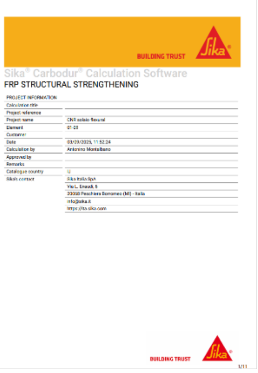


When all sections are completed and all the sidebar icons display green, a button will appear at the bottom of the sidebar, allowing the user to generate the print-out report



Users are able to specify the desired paper size for printouts. The document can be printed in either A4 or Letter size.

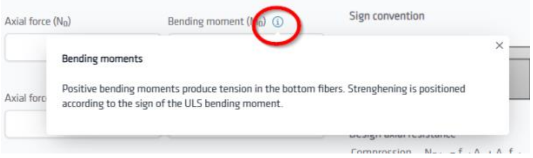
The selection can be made prior to clicking the "**Generate report**" button by accessing your profile in the upper right corner of the page **Profile** and on the prefrences **Preferences** .



A full printout in PDF is generated after the project is completed.

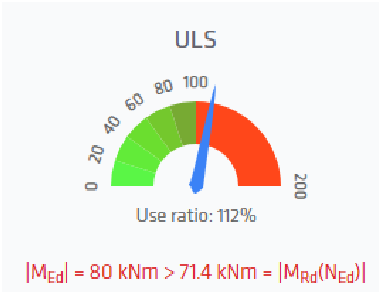
Print out contains:

- Design data
- Element data
- Loads
- Strengthening details
- Results



In many parts of the software this symbol ⓘ is displayed.

Clicking on it will allow the user to access additional and useful information

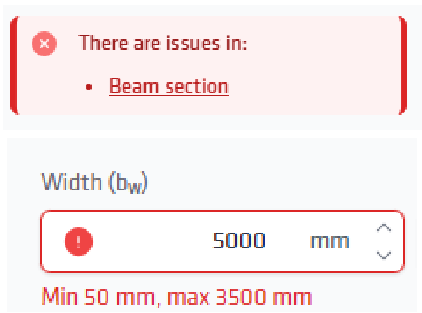


In "Loads", "Strengthening" and "Fire" panels these indicators called "**Use ratio**" are shown.

These indicators represent the usage ratio for a specific load combination or verification. They are defined as the ratio of the design condition to the resistant condition.

The use ratio indicator in the left picture displays the proportion of the design ULS bending moment (**M_{Ed}**) to the ULS resistant bending moment (**M_{Rd}**).

Use ratio= M_{Ed} / M_{Rd}



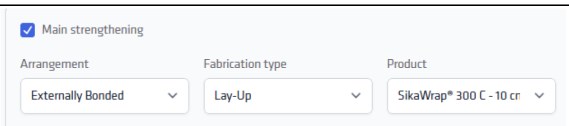
Some conditions or logical parameters may not satisfy certain limitations during calculation.

This information will be displayed on the main screen and in the lateral bar too.

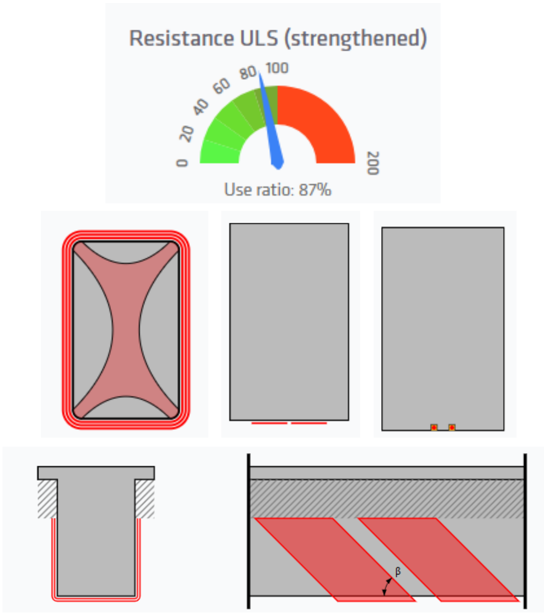
NOTE:

This symbol indicates that the condition is not satisfied. However, the user is allowed to complete the calculation.

This symbol indicates that some critical or logical condition is not satisfied. The calculation cannot be completed unless it is corrected.



The software, across all modules (Flexural, Shear, Confinement, Beam) and for all supported design guidelines (TR 55, ACI 440, CNR-DT 200, SIA 166), applies a **verification approach** rather than a **design approach**.



Once the geometry and loading conditions are defined, the user can select, using some dropdown menus:

- The strengthening arrangement (Externally Bonded or Near-Surface Mounted),
- The fabrication type (Wet Lay-Up or Prefabricated),
- the specific product (from the available products listed in the Country Catalogue),
- and the geometry of the strengthening system (width, number of layers, position).

Based on these inputs, the **use ratio** indicator is updated in real time, providing immediate feedback on whether the design satisfies the selected verification criteria.

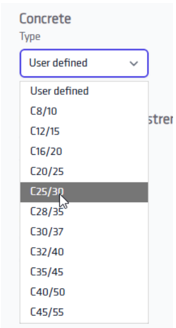
The layout of the chosen strengthening products is always displayed graphically in the screen.

NOTE*: This approach provides the user with full flexibility in defining the strengthening system, including the choice of products, positioning, number of strips, number of layers, spacing, and inclination. The adequacy of the configuration is always verified by monitoring the section status through the use ratio indicator.*

3.5 COLUMN CONFINEMENT

The Confinement module will comprise of the mechanical enhancement of a RC member under axial loads and bending moments. It allows the design of structural strengthening through confinement for reinforced concrete (RC) sections subjected to biaxial bending moments, using SikaWrap® FRP systems. This module facilitates the analysis of columns subjected simultaneously to axial loads and bending moments acting in two orthogonal directions.

3.5.1 CONCRETE

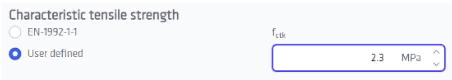


In this panel, the characteristic cylinder compressive strength of concrete (**f_{ck}**) is specified by the user. This value can be selected from a dropdown menu, or, if "user defined" is chosen, it may be entered manually. Once **f_{ck}** is provided, the software calculates the design compressive strength using the following formula:

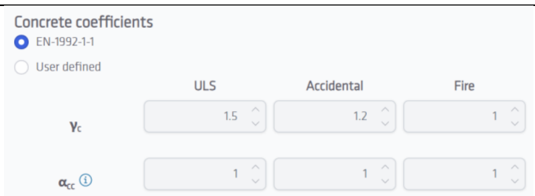
$$f_{cd} = \alpha_{cc} \frac{f_{ck}}{\gamma_c}$$

and the Characteristic tensile strength. This value is calculated with the Eurocode formula:

$$f_{ctk} = 0.70 f_{ctm} \quad f_{ctm} = 0.30 f_{ctm}^{(\frac{2}{3})}$$

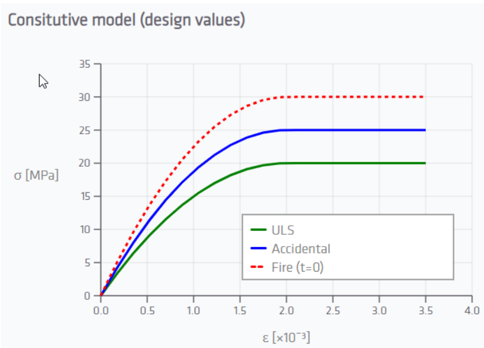


Additionally, the user can define manually the characteristic tensile strength of the concrete (derived from in-situ pull-off tests), clicking on “user defined”



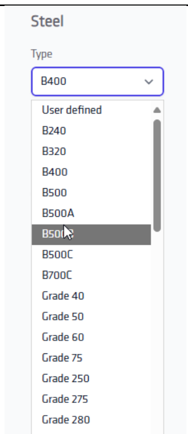
Coefficients α_{cc}e γ_c are defined according to Eurocode 2, for ULS, Accidental and Fire conditions.

User can click on “User defined” to customize the values



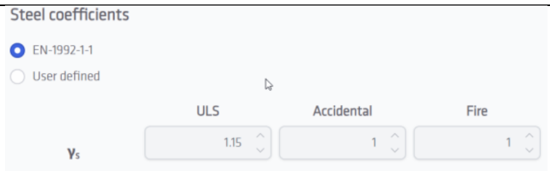
Stress-strain constitutive model (design values) are visualized in ULS, Accidental and Fre conditions

3.5.2 STEEL



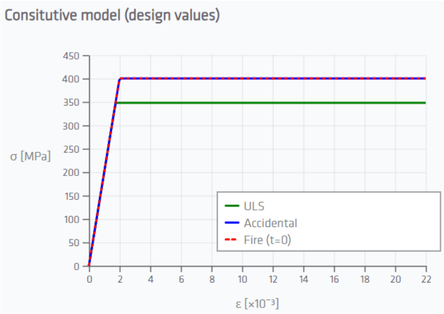
In this panel, the characteristic tensile strength of the steel (**f_{yk}**) is specified by the user. This value can be selected from a dropdown menu, which contains a list of the most used steel types all around the world, or, if "user defined" is chosen, it may be entered manually. From the input of **f_{yk}**, the software calculate the design tensile strength with the formula:

$$f_{yd} = \frac{f_{yk}}{\gamma_s}$$



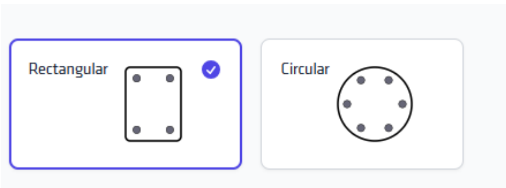
Coefficient γ_s is defined according to Eurocode 2, for ULS, Accidental and Fire conditions.

User can click on “User defined” to customize the values



Stress-strain constitutive model (design values) are visualized in ULS, Accidental and Fre conditions

3.5.3 COLUMN SECTION

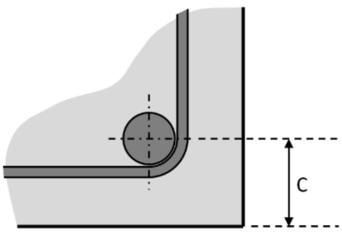


It is possible to select rectangular or circular concrete section

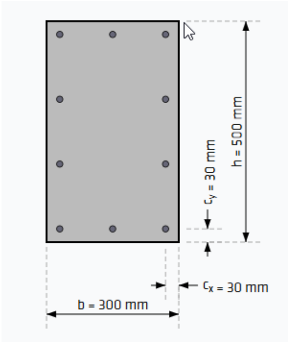
In case of rectangular, width and height need to be selected.

In case of circular section, just the diameter of the section

NOTE*: Although the TR55, for rectangular sections, does not specify a precise geometric limitation for the width-to-height ratio, it has been decided—following other international design guidelines—to limit the B/H (or H/B) ratio to a maximum value of 2.*



Mechanical covering is the distance from the centre of the longitudinal rebar to the outer edge of the concrete, calculated as the sum of the concrete cover, stirrup diameter, and half the longitudinal bar diameter.

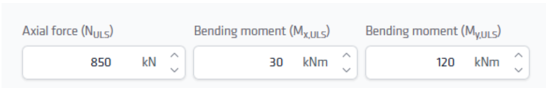


For rectangular section, reinforcing bars are defined in 3 groups:

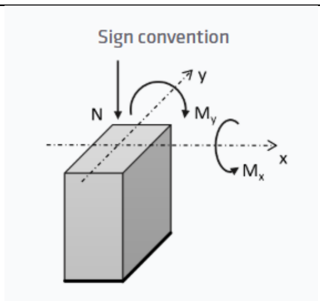
- **Corner bars**: bars at the 4 corners of the section
- **Horizontal bars**: additional bars located on the horizontal sides
- **Vertical bars**: additional bars located on the vertical sides

For a circular section, reinforcing bars are defined as the total number of bars evenly placed around the perimeter.

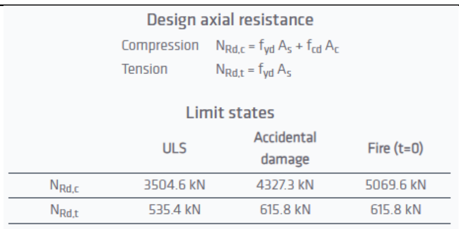
3.5.4 LOADS



Each load combination is specified by an axial load value and two bending moment values acting simultaneously in two perpendicular directions.



Each load can be assigned as positive or negative according to the convention shown in the figure on the left. It is possible to analyse conditions of combined bending and compression (biaxial bending), tension and bending, or pure axial force.


Design axial resistance

Compression $N_{Rd,c} = f_{yd} A_s + f_{cd} A_c$

Tension $N_{Rd,t} = f_{yd} A_s$

Limit states

	ULS	Accidental damage	Fire (t=0)
$N_{Rd,c}$	3504.6 kN	4327.3 kN	5069.6 kN
$N_{Rd,t}$	535.4 kN	615.8 kN	615.8 kN

In this table the limit values of the axial load, in compression and in tension, for ULS, Accidental damage and Fire (T=0) are showed

Ultimate limit state (ULS) loads
Combination loads for strength checks.

This represents the design values of the axial load (**N_{ULS}**) and the two design bending moments (**$M_{x,ULS}$** and **$M_{y,ULS}$**), for the ULS loads combination

Characteristic loads
Combination loads for serviceability limit state.

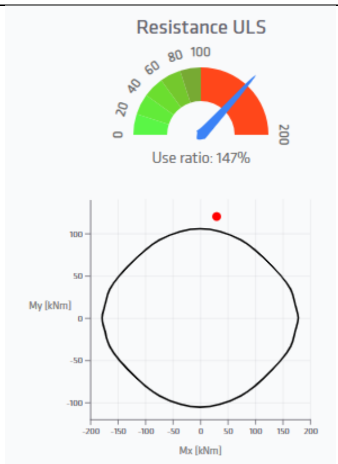
This represents the design values of the axial load (**N_C**) and the two design bending moments (**$M_{x,c}$** and **$M_{y,c}$**), for the characteristic combination of actions in serviceability conditions

Fire loads
Combination loads for fire limit state.

This represents the design values of the axial load (**N_{fl}**) and the two design bending moments (**$M_{x,fl}$** and **$M_{y,fl}$**) acting in serviceability limit state (see section 2.1.3), using the quasi-permanent combination of actions as defined in BS EN 1990. For the verification, the partial safety factors of the materials for accidental design situation are assumed.

Accidental damage loads
Combination loads for accidental damage.

This preliminary verification is required (see section 2.1.2). It represents the design values of the axial load (**N_{damage}**) and the two design bending moments (**$M_{x,damage}$** and **$M_{y,damage}$**) acting in serviceability limit state, using the frequent combination of actions as defined in BS EN 1990. Material partial safety factors for accidental design are assumed in the verification.



For each combination, the use ratio (see section 3.4) is displayed.

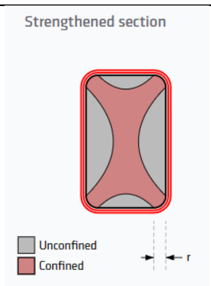
Below, a graphic visualization of the interaction diagram of the section, in the plane Mx-My, shows the diagram and the position of the combination (red point).

***NOTE**: Use ratio > 100% means that the combination is out of the interaction diagram.*

3.5.5 STRENGTHENING

Define the following parameters:

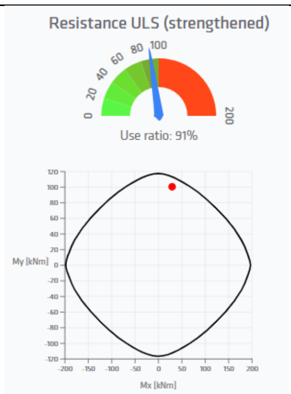
- **SikaWrap® fabric**: select from the products available in the Country Catalogue.
- **Number of layers**: specify the required number of fabric layers.
- **Fillet radius**: define the corner radius for the columns.



The software provides a visual representation of the applied strengthening and the effect of confinement.

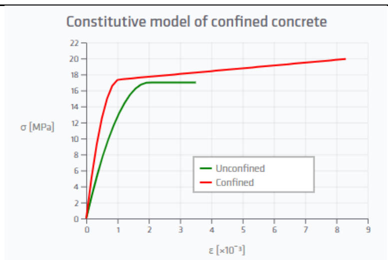
The confined area of the concrete is highlighted in red.

As the height-to-width (or width-to-height) ratio increases, the confined zone becomes smaller, resulting in reduced confinement efficiency.



The software shows the use ratio indicator for the strengthened section in ULS combination. Use ratio <100% means that verification is ok and with the chosen strengthening system and FRP quantity the section is OK.

A graphic visualization of the interaction diagram for the strengthened section , in the plane Mx-My, shows the diagram and the position of the combination (red point).



A comparison between the stress-strain diagrams for unconfined and confined concrete is displayed

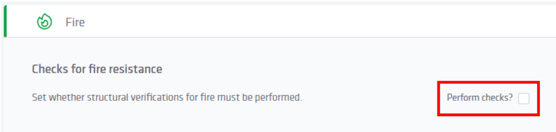
Product details

Product	SikaWrap® 300 C - 10 cm
Type of fibers	C
Width (w_f)	100 mm
Single layer thickness (t_f)	0.167 mm
Characteristic elastic modulus (E_f)	220 GPa
Characteristic ultimate strain (ε_{fu}^*)	14.5 ‰
Characteristic strength (f_{fu}^*)	3190 MPa
Partial safety factor on strain ($\gamma_{FRP,\varepsilon}$)	1.25
Partial safety factor on elastic modulus ($\gamma_{FRP,E}$)	1.10
Partial safety factor on material ($\gamma_{FRP,m}$)	1.20

For the chosen SikaWrap® system, all the relevant physical and mechanical properties are displayed.

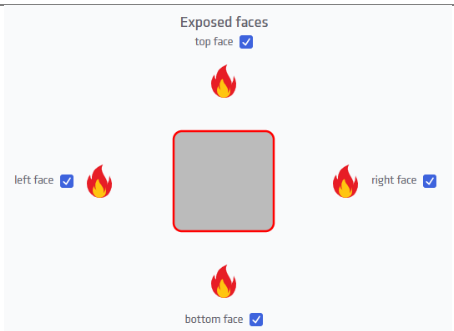
3.5.6 FIRE

The software evaluates the strength of the un-strengthened member in case of fire, calculating the anticipated temperature profiles in the concrete section and the real fire resistance according to the fire loads, as shown in *TR55, section 5.7.1*.

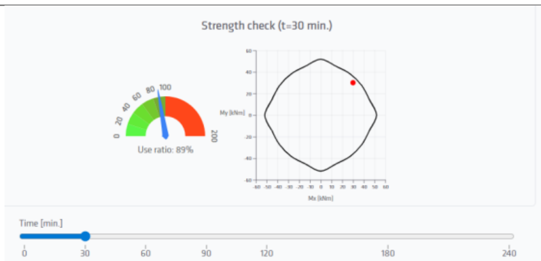


The user can verify the member's fire resistance, assuming FRP strengthening fails immediately at high temperatures (see section 2.1.3 for details).

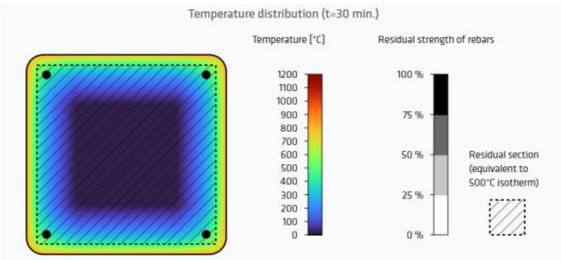
This option can be enabled is enabled by clicking the box located in Fire panel.



The sides of the column that may be directly exposed to fire can be flagged and selected by the user.

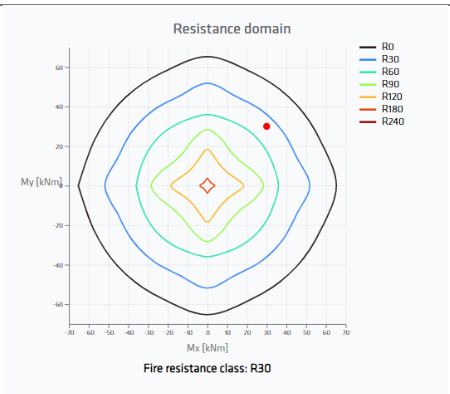


At the bottom of the Fire panel, a slider indicates the minutes of fire exposure. By adjusting the slider, users can view in real time the use ratio in case of fire and the interaction diagram in the Mx-My plane.



A coloured graphical representation illustrates the temperature distribution within the section. The black dashed line denotes the location of the 500°C isotherm at the specified exposure time, which delineates the portion of the concrete section considered for residual strength assessment.

Residual strength of the steel rebar is indicated on a grey scale (black = 100%, white = 0%).



The chart illustrates the evolution of the interaction domains in the Mx-My plane over time. It is clearly visible the contraction of the interaction diagram as temperatures increase. The design load combination under fire conditions is indicated on the chart by a red dot.

3.5.7 PRINTOUT

A full printout in PDF is generated after the project is completed.

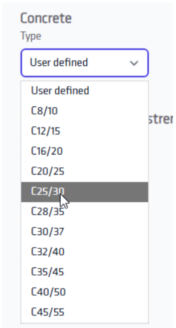
Print out contains:

- Design data
- Element data
- Loads
- Strengthening details
- Results

3.6 SECTION FLEXURAL STRENGTHENING

The Flexural module includes the dimensioning of the necessary FRP, based on the anticipated bending moments acting on the critical section of a RC / Prestressed beam, subjected to both positive and negative bending moments, including scenarios involving also axial loads.

3.6.1 CONCRETE

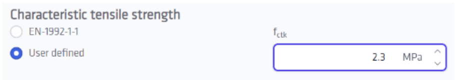


In this panel, the characteristic cylinder compressive strength of concrete (f_{ck}) is specified by the user. This value can be selected from a dropdown menu, or, if "user defined" is chosen, it may be entered manually. Once f_{ck} is provided, the software calculates the design compressive strength using the following formula:

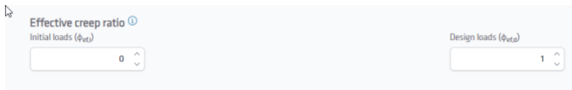
$$f_{cd} = \alpha_{cc}\frac{f_{ck}}{\gamma_c}$$

and the Characteristic tensile strength. This value is calculated with the Eurocode formula:

$$f_{ctk} = 0.70 f_{ctm} \quad f_{ctm} = 0.30 f_{ctm}^{(\frac{2}{3})}$$



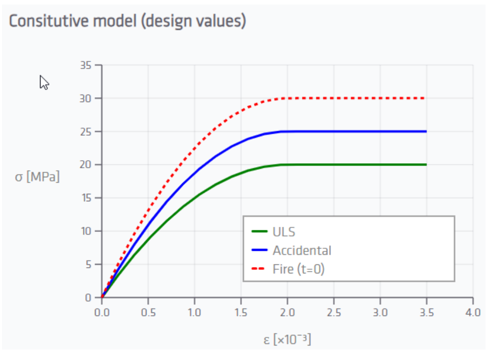
Additionally, the user can define manually the characteristic tensile strength of the concrete (derived from in-situ pull-off tests), clicking on “user defined”



Creep may be taken into account by multiplying all strain values in the concrete stress-strain diagram with a factor (1 + ϕ_{ef}). (EN 1992-1-1, 5.8.6(4))

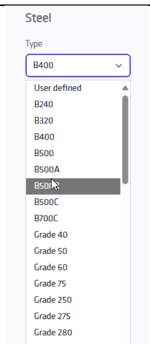
Coefficients α_{cc}e γ_c are defined according to Eurocode 2, for ULS, Accidental and Fire conditions.

User can click on “User defined” to customize the values



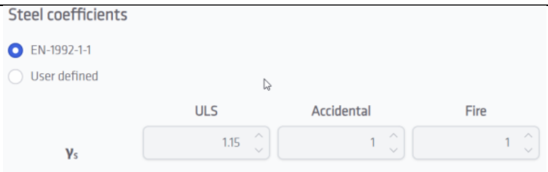
Stress-strain constitutive model (design values) are visualized in ULS, Accidental and Fre conditions

3.6.2 STEEL



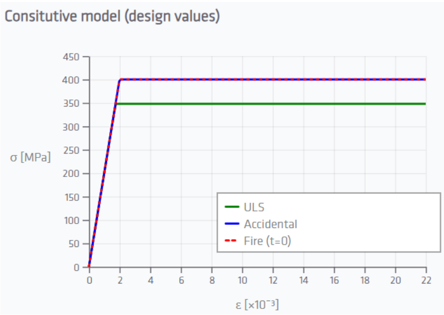
In this panel, the characteristic tensile strength of the steel (f_{yk}) is specified by the user. This value can be selected from a dropdown menu, which contains a list of the most used steel types all around the world, or, if "user defined" is chosen, it may be entered manually. From the input of f_{yk}, the software calculate the design tensile strength with the formula:

$$f_{yd} = \frac{f_{yk}}{\gamma_s}$$



Coefficient γ_s is defined according to Eurocode 2, for ULS, Accidental and Fire conditions.

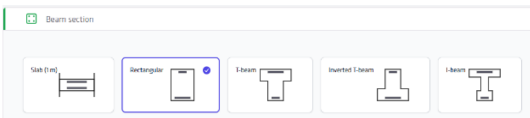
User can click on “User defined” to customize the values

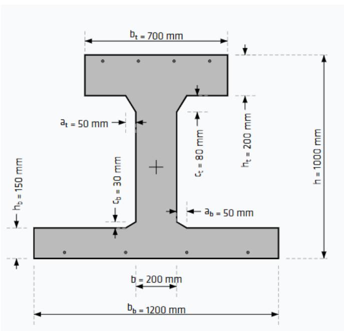


Stress-strain constitutive model (design values) are visualized in ULS, Accidental and Fre conditions

For designs involving bonded prestressed concrete sections, the Prestressed steel flag should be activated. This value can be selected from a dropdown menu, which contains a list of the most used prestressed steel types all around the world, or, if "user defined" is chosen, required values (Yielding strength, Ultimate strength, Elastic Modulus) need be entered manually

3.6.3 BEAM SECTION



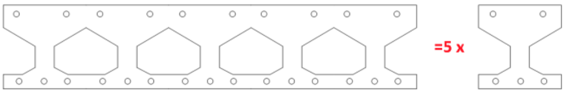


The user can select one of the following basic shapes for the element:

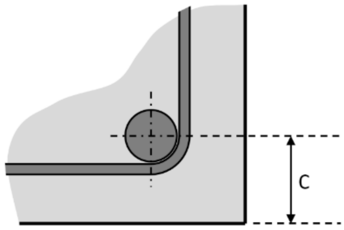
- Slab
- Rectangular
- T-beam
- Inverted T-beam
- I-beam

In case of slab section, the user needs to enter just the thickness of the slab.

Additionally, fillets (chamfers) can be displayed for certain shapes, providing the possibility of defining complex geometries.



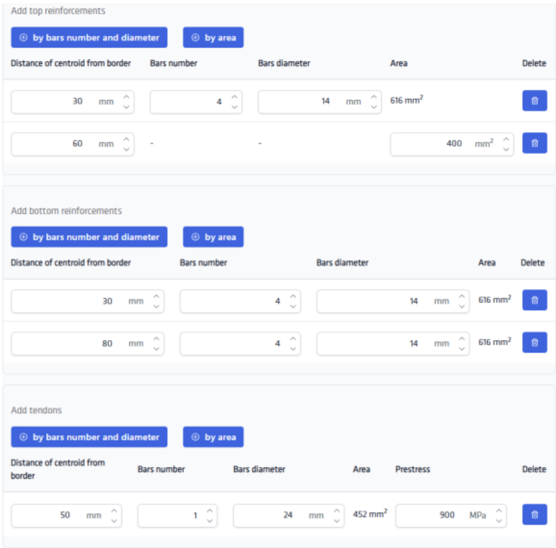
NOTE: *by selecting a suitable geometry profile, the user can create parts of complex elements and geometries*



In this panel the internal steel reinforcement of the section needs to be defined.

Internal steel reinforcement are divided in **Top Reinforcements**, **Bottom Reinforcement** and, in case of prestressed concrete section, **Tendons**

For each type of internal steel reinforcement the first parameter to define the mechanical covering (Distance of centroid from the border). This represents the distance from the centre of the longitudinal rebars to the outer edge of the concrete, calculated as the sum of the concrete cover, stirrup diameter, and half the longitudinal bar diameter.



The definition of the top and bottom steel bars is determined separately for each layer, consisting of the following parameters:

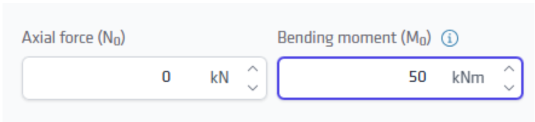
- Distance from the centroid to the concrete surface (see previous point).
- Steel section.

Each layer of steel section may be specified by providing the number of rebars, their diameter and position, or by assigning the total area of steel and its location.

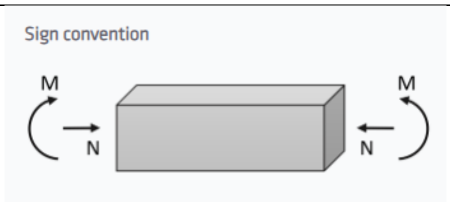
The quantity of steel layers is not restricted.

NOTE: *For prestressing steel, the user should confirm the mechanical properties of the steel and specify the actual stress in the steel at the time of strengthening (f_{se}). This value generally corresponds to the initial prestressing stress minus any prestressing losses up to the point of strengthening.*

3.6.4 LOADS



For the flexural strengthening design, it possible to consider an axial force acting on the section. This is helpful to design, for example, inclined beams or inclined roofs. Each load combination is specified by an axial load and a bending moment value.



Each load can be assigned as positive or negative according to the convention shown in the figure on the left. It is possible to analyse conditions of bending and compression, tension and bending, or pure bending moments.

Design axial resistance

Compression $N_{Rd,c} = f_{yd} A_s + A_c f_{cd}$

Tension $N_{Rd,t} = f_{yd} A_s$

Limit states

	ULS	Accidental	Fire (t=0)
$N_{Rd,c}$	8485.7 kN	10513.2 kN	12399.9 kN
$N_{Rd,t}$	-939 kN	-1079.9 kN	-1079.9 kN
$M_{Rd}^{+}(N_{Ed})$	1109.8 kNm	1292.9 kNm	1325.5 kNm
$M_{Rd}^{-}(N_{Ed})$	-354.2 kNm	-407.5 kNm	-409.5 kNm

In this table the limit values of the axial load, in compression and in tension, for ULS, Accidental damage and Fire (T=0) are showed

---

Initial loads

Combination loads at the time of the application of strengthening.

This represents the current values of the axial load (**N_0**) and the bending moment (**M_0**) acting on the section, at the time of the application of the FRP strengthening system.

This Initial loads can be due to: the self-weight of the beam, the dead loads (either in whole or in part), live loads (when applicable).

The software checks that those forces do not exceed the initial strength of the un-strengthened element. This condition must be fulfilled to continue with the calculation.

Ultimate limit state (ULS) loads

Combination loads for strength checks.

This represents the design values of the axial load (**N_{ULS}**) and the design bending moment (**M_{ULS}**), for the Ultimate State Loading (ULS) loads combination

---

Characteristic loads

Combination loads for serviceability limit state.

This represents the design values of the axial load (**N_C**) and the design bending moment (**M_C**), for the characteristic combination of actions in serviceability conditions

---

Fire loads

Combination loads for fire limit state.

This represents the design values of the axial load (**N_{fl}**) and the design bending moment (**M_{fl}**) acting in serviceability limit state (see section 2.1.3), using the quasi-permanent combination of actions as defined in BS EN 1990. For the verification, the partial safety factors of the materials for accidental design situation are assumed.

Checks for accidental damage

Set whether structural verifications for accidental damage must be performed.

This preliminary verification is required (see section 2.1.2). It represents the design values of the axial load (**N_{damage}**) and the design bending moment (**M_{damage}**) acting in serviceability limit state, using the frequent combination of actions as defined in BS EN 1990.For the verification, the partial safety factors of the materials for accidental design situation are assumed.

Prestress steel? ☑

Statically indeterminate scheme? ☐

Prestress loads

Statically indetererminate internal actions due to prestress

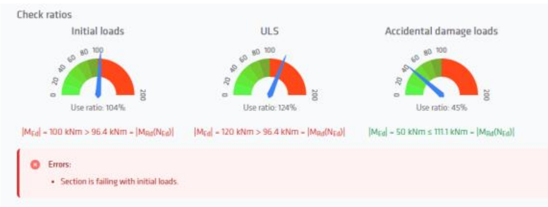
For prestressed concrete sections (where the “Prestressed Steel” option is selected in the Steel Panel), users must specify whether the static scheme is statically indeterminate.

A **statically determinate beam** is one where the support reactions can be found using only the equations of static equilibrium.

In this scenario, the values of axial load (**N_p**) and bending moment (**M_p**), due to prestressing steel, are automatically calculated by the software.

A **statically indeterminate beam**, on the other hand, requires additional compatibility and deformation conditions to be solved, since it has more supports or restraints than necessary.

In this scenario, the user is required to select the appropriate option and manually enter the values for axial load (N_p) and bending moment (**M_p**) attributable to prestressing steel.

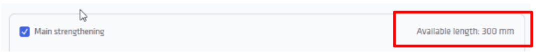


For the Initial, Accidental damage, and ULS loads, use ratio indicators for the unstrengthened section are shown (see section 3.4).

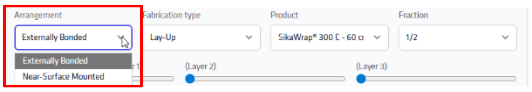
If the use ratio for either the "Initial loads" or the "Accidental damage loads" exceeds 100%, an error message will be displayed to notify the user that the preliminary verification has not been successful.

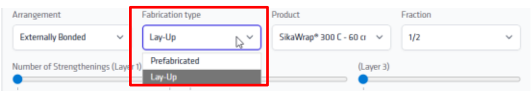
***NOTE**: In this situation, strengthening can be designed; however, generating the printout report is not possible due to this error. The error appears in the Loads panel and is indicated by a red icon in the lateral bar (see section 3.4).*

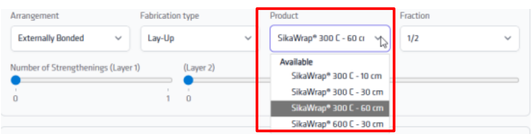
3.6.5 STRENGTHENING

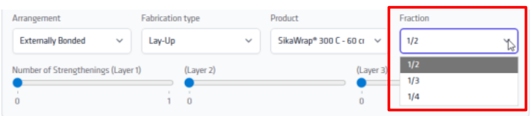


Typically, the strengthening system is located on the bottom side of the beam (on top for negative bending moments). This is called “**Main strengthening**” and the option is selected by default. The available width is displayed and it represents the maximum avaialble space to place the FRP strengthening system.





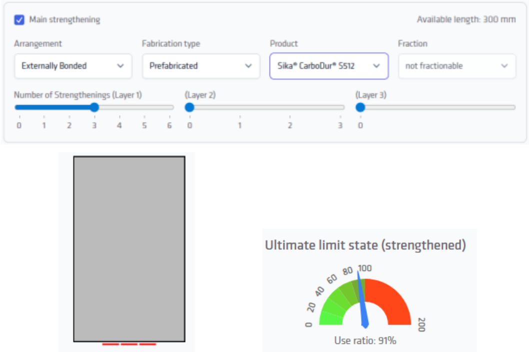




The user should define the following strengthening parameters:

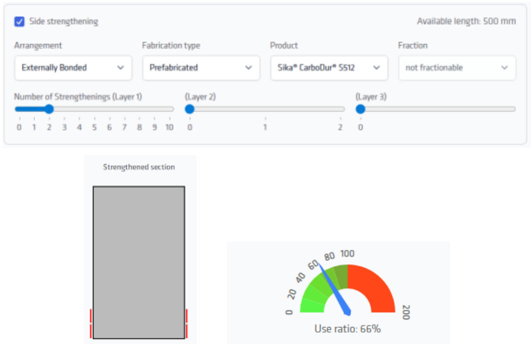
- **Arrangement**: Based on the chosen country catalogue, the user selects either an externally bonded system, a near surface mounted (NSM) system or Post-tensioned CFRP (Sika® CarboStress) for statically determinate beams, if locally available.
- **Fabrication type**: Based on the chosen country catalogue , the user selects either a Prefabricated system (Sika® CarboDur®) or a Lay-up system (SikaWrap®).
- **Product**: The user selects which product to use from a dropdown menu.
- **Fraction**: In certain Lay-up systems, it is possible to utilize a fraction of the fabric's original width. For example, when selecting SikaWrap®-300 C – 60 cm, users may opt to utilize the full width or choose from 1/2, 1/3, or 1/4 of the width. This results in corresponding fabric widths of 30 cm, 20 cm, or 15 cm.

***NOTE**: The software checks the available width against the chosen fabric's width and only shows options that* *fit within the available width. In case the available width is 300 mm, it won't be possible select the full 60 cm fabric width.*



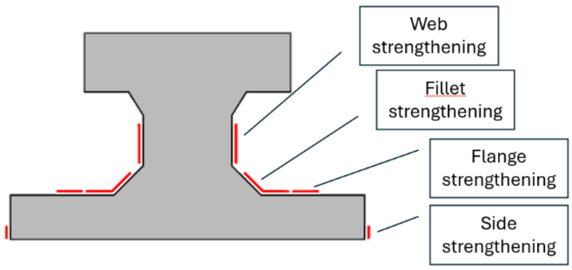
Number of strengthening layers: indicate the required number of fabric or plate strips and layers. If the width of the FRP matches the available section width, the software allows the addition of multiple strengthening strips. In the illustration, the user has chosen 3 strips of Sika® CarboDur® S512.

***NOTE**: As already written, the user needs to select the appropriate product, number of strips and layer to get the use ratio (M_{Ed} / M_{Rd}) below 100%*

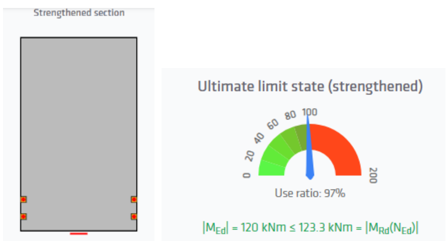


For rectangular, T-beam, inverted T-beam and I-beam sections, the software allows users to apply the strengthening system also to the beam's lateral sides (rectangular), called "**Side strengthening**." While the main application method is preferred, this option is useful when the soffit is inaccessible or insufficient for required strengthening, such as with narrow beams. Side strengthening can be used in addition to the main or as a replacement of it.

The choice of the strengthening follows the same logic of the main strengthening. User has to define the Arrangement, the Fabrication type, the Product, the fraction (if available) and the number of strips and layers.

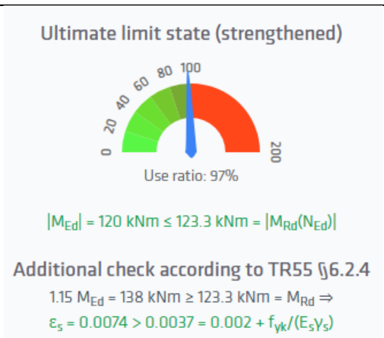


For I-beam sections, the software enables users to apply FRP strengthening to the vertical **Side**, the **Web**, the upper portion of the **Flange**, and the **Fillet**.



The software displays the reinforced section with the designed FRP systems and the use ratio indicator for the ULS combination. A ratio below 100% indicates that verification is successful and the section meets requirements with the selected strengthening system and FRP amount.

The values for the design bending moment (M_{Ed}) and the strengthened resistant bending moment (M_{Rd}) are compared.



In case **87% < Use Ratio < 100%** ($M_{Rd} < 1.15\ M_{Ed}$), the software performs the required verification at §6.2.4 of TR55, checking the tensile stress of the steel reinforcement.

"…if the ultimate moment of resistance,…, is less than 1.15 times the required value, the section should be proportioned such that the strain at the centroid of the tensile steel reinforcement is not less than $0.002 + f_{yk}/(E_s\gamma_s)$ *"*

Serviceability limit state (strengthened)

σ_c = 5.7 MPa ≤ 15 MPa = 0.6 f'_c

σ_s = 222 MPa ≤ 320 MPa = 0.8 f'_y

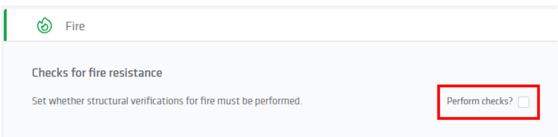
The software checks the characteristic serviceability limit state, by comparing concrete and steel stress levels to admissible values.

	Main	Side
Product	Sika® CarboDur® S512	SikaWrap® 300 C - 10 cm
Fraction	1/1	1/1
Type of fibers	[illegible]	[illegible]
Width (b_f) / Diameter (d_f)	50 mm	100 mm
Single layer thickness (t_f)	1.2 mm	0.167 mm
Characteristic elastic modulus (E_{fk})	165 GPa	220 GPa
Characteristic ultimate strain (ε_{fk})	17.6 ‰	14.5 ‰
Characteristic ultimate strength (f_{fk})	2904 MPa	3190 MPa
Arrangement	EBR	EBR
Number of plies	1	1
PSF for manufacture of FRP (γ_{mfm})	1.05	1.2
PSF for elastic modulus (γ_{mE})	1.1	1.1
PSF for ultimate strain ($\gamma_{m\varepsilon}$)	1.25	1.25
Serviceability limit state	σ_f = 28.7 MPa ≤ 1245.2 MPa = 0.65 f_{fk}	σ_f = 33.5 MPa ≤ 1047.2 MPa = 0.65 f_{fk}

For the selected FRP systems (SikaWrap®, Sika® CarboDur®, etc.), all relevant physical and mechanical properties are provided, including the partial safety factors used for the calculation and the serviceability limit state check for the strengthening systems.

3.6.6 FIRE

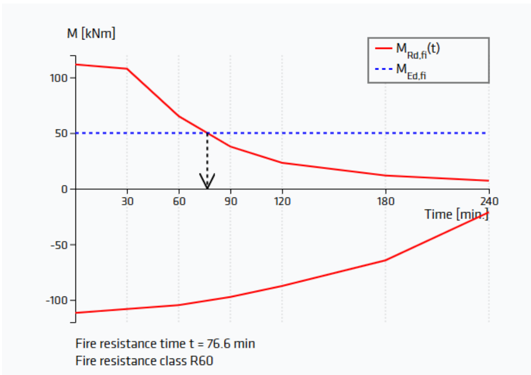
The software evaluates the strength of the un-strengthened member in case of fire, calculating the anticipated temperature profiles in the concrete section and the real fire resistance according to the fire loads, as shown in *TR55, section 5.7.1*.



The user can verify the member's fire resistance, assuming FRP strengthening fails immediately at high temperatures (see section 2.1.3 for details).

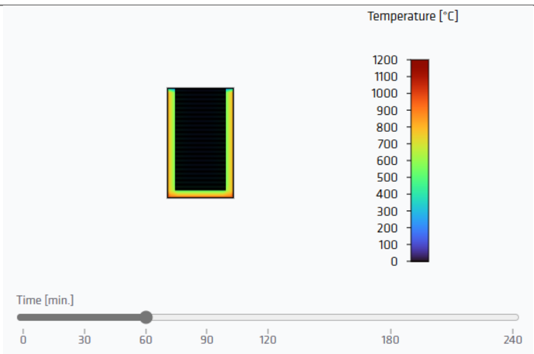
This option can be enabled is enabled by clicking the box located in Fire panel.

The sides of the beam that may be directly exposed to fire can be selected by the user.



The software displays a diagram. The horizontal axis represents time, while the vertical axis indicates the bending moment. The red lines indicate the positive and negative values of the resistant bending moment (M_{Rd}^+ and M_{Rd}^-) over time. These values are determined based on the temperature distribution in the concrete section and by applying the 500 °C Isotherm Method (section 2.1.3). The blue line represents the design value of the bending moment under fire conditions, denoted as M_{fi}.

The lower part of the diagram shows when the resistant bending moment equals the design value under fire conditions, which determines the Fire resistance class.



A slider enables the visualisation of temperature distribution within the section through a coloured graphical interface.

3.6.7 PRINTOUT

A full printout in PDF is generated after the project is completed.

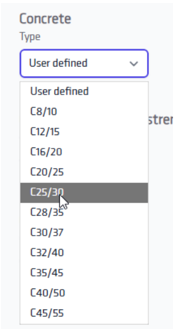
Print out contains:

- Design data
- Element data
- Loads
- Strengthening details
- Results

3.7 SECTION SHEAR STRENGTHENING

The Shear strengthening of the critical section in a beam/column calculation determines the required FRP based on anticipated shear forces at the critical section of an RC beam or column. Axial loads on the section can also be considered in the design.

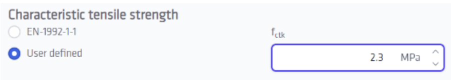
3.7.1 CONCRETE



In this panel, the characteristic cylinder compressive strength of concrete (f_{ck}) is specified by the user. This value can be selected from a dropdown menu, or, if "user defined" is chosen, it may be entered manually. Once f_{ck} is provided, the software calculates the design compressive strength using the following formula:

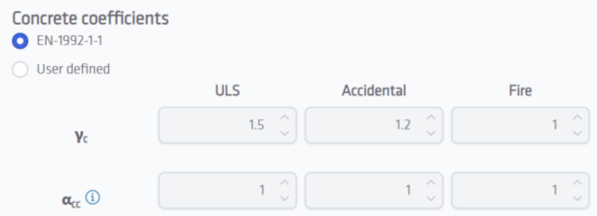
$$f_{cd} = \alpha_{cc} \frac{f_{ck}}{\gamma_c}$$

and the Characteristic tensile strength. This value is calculated with the Eurocode formula:



$$f_{ctk} = 0.70 f_{ctm} \quad f_{ctm} = 0.30 f_{ctm}^{\left(\frac{2}{3}\right)}$$

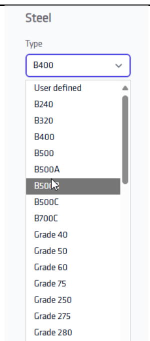
Additionally, the user can define manually the characteristic tensile strength of the concrete (derived from in-situ pull-off tests), clicking on “user defined”



Coefficients α_{cc}e γ_c are defined according to Eurocode 2, for ULS, Accidental and Fire conditions.

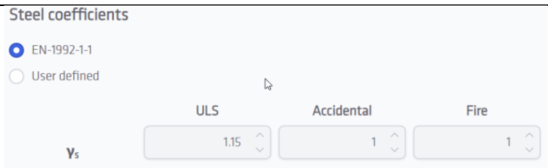
User can click on “User defined” to customize the values

3.7.2 STEEL



In this panel, the characteristic tensile strength of the steel (f_{yk}) is specified by the user. This value can be selected from a dropdown menu, which contains a list of the most used steel types all around the world, or, if "user defined" is chosen, it may be entered manually. From the input of f_{yk}, the software calculate the design tensile strength with the formula:

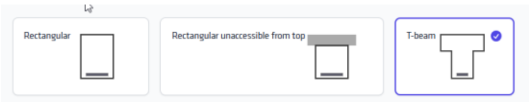
$$f_{yd} = \frac{f_{yk}}{\gamma_s}$$



Coefficient γ_s is defined according to Eurocode 2, for ULS, Accidental and Fire conditions.

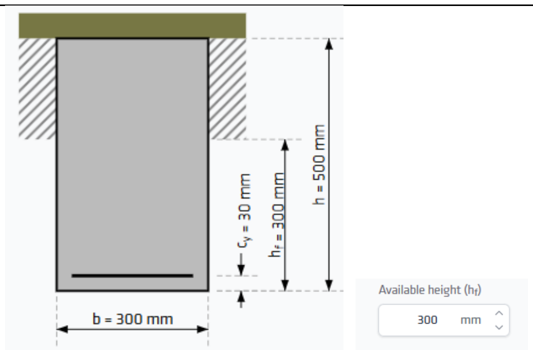
User can click on “User defined” to customize the values

3.7.3 BEAM SECTION

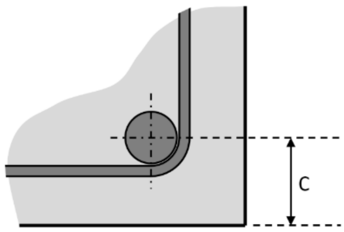


The user can select one of the following basic shapes for the element:

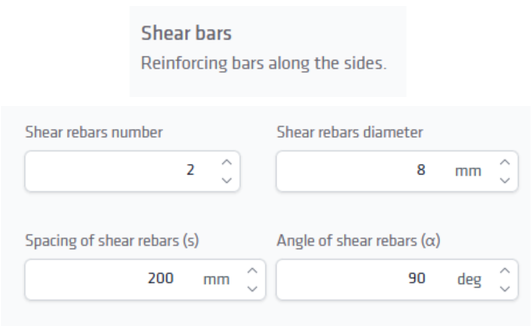
- Rectangular
- Rectangular not accessible from top
- T-beam



In the section "Rectangular not accessible from top" and for “T-Beam”, it is necessary to specify the dimensions of the section (Width and Height) and the available height (**hf**), which indicates the space available on the vertical sides of the beam for installing the FRP shear strengthening system. This takes into account the presence of a slab that can limit the space for the application of the U-shaped SikaWrap® fabrics.



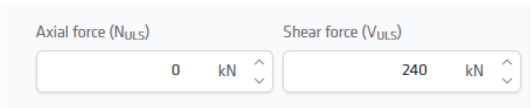
Mechanical covering (**c_y**) is the distance from the centre of the longitudinal rebar to the outer edge of the concrete, calculated as the sum of the concrete cover, stirrup diameter, and half the longitudinal bar diameter.



The definition of the internal shear reinforcement is determined defining the following parameters:

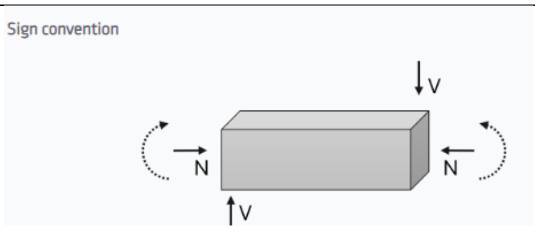
- **Shear rebars number**: This represents the number of arms of the internal stirrups (typically 2 for normal stirrups or 4 for double stirrups)
- **Shear rebars diameter**
- **Spacing of shear rebars**: This represents the spacing, centre-to-centre, of the stirrups
- **Angle of shear rebars**: is the angle of the stirrups with the axis of the beam. By default it is assumed 90° (vertical stirrups).

3.7.4 LOADS

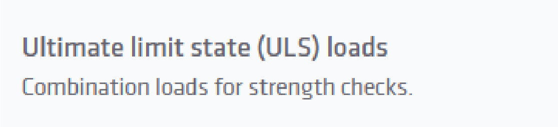


For the shear strengthening design, it possible to consider an axial force acting on the section. This is helpful to design shear strengthening, for example, for inclined beams or columns. Each load combination is specified by an axial load and a bending moment value.

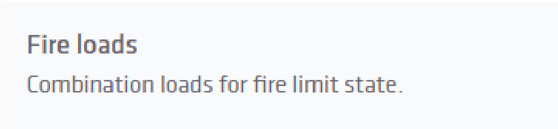
***NOTE**: The axial load exclusively affects the shear-compression component (**$V_{Rd,c}$**). When the failure mechanism is determined solely by the shear-tension mechanism (cot(θ)=2.50), the axial load does not affect the Resistant Shear (**V_{Rd}**).*



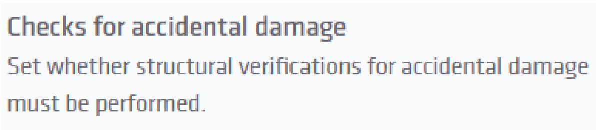
Each load can be assigned as positive or negative according to the convention shown in the figure on the left. It is possible to analyse conditions of shear-tension, shear-compression or pure shear.



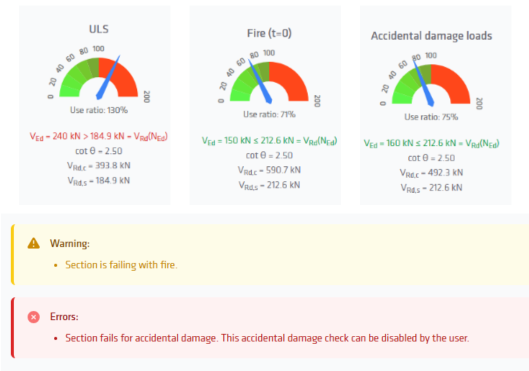
This represents the design values of the axial load (**N_{ULS}**) and the design shear force (**V_{ULS}**), for the Ultimate State Loading (ULS) loads combination



This represents the design values of the axial load (**N_{fi}**) and the design shear force (**V_{fi}**) acting in serviceability limit state (see section 2.1.3), using the quasi-permanent combination of actions as defined in BS EN 1990. For the verification, the partial safety factors of the materials for accidental design situation are assumed.



This preliminary verification is required (see section 2.1.2). It represents the design values of the axial load (**N_{damage}**) and the design shear force (**V_{damage}**) acting in serviceability limit state, using the frequent combination of actions as defined in BS EN 1990.For the verification, the partial safety factors of the materials for accidental design situation are assumed.



For the ULS , the Fire (t=0) and the Accidental damage loads, use ratio indicators for the unstrengthened section are shown (see section 3.4).

If the use ratio for either the "Fire loads" or the "Accidental damage loads" exceeds 100%, an error message will be displayed to notify the user that the preliminary verification has not been successful.

NOTE*: In this situation, strengthening can be designed; however, generating the printout report is not possible due to this error. The error appears in the Loads panel and is indicated by a red icon in the lateral bar (see section 3.4).*

3.7.5 STRENGTHENING

The possible FRP schemes are indicated in the upper-left corner of the panel Strengthening. The user must define the FRP wrapping scheme to be used in the calculation (refer to section 2.3 for additional information).

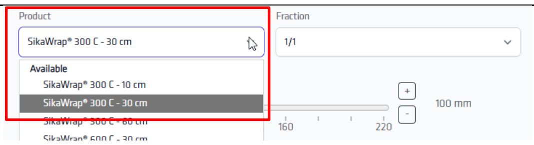
The available schemes are:

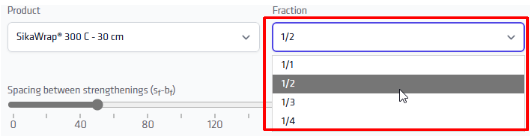
- **Full Wrapping** (SikaWrap® fabrics), in those cases where the 4 sides of a rectangular beam are accessible.
- **U-Wrapping** (SikaWrap® fabrics), valid for all the geometries.

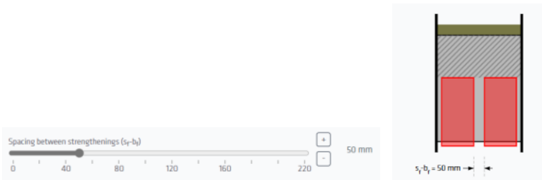
- **2-sided configuration** (SikaWrap® fabrics or Sika® CarboDur® plates), valid for all the geometries.
- **Sika CarboShear® L** plates (when locally available), displayed on one or 2 sides, valid for T-beams with a slab/flange height exceeding 100mm.
- **NSM profiles** mounted in slots (when locally available). Note that the calculation of this configuration may not be possible in case of beams with reduced height.

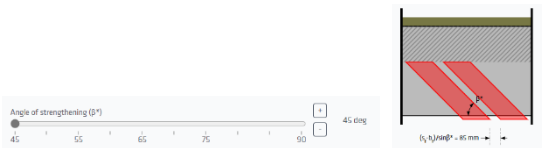
NOTE*: Availability of strengthening options may vary depending on the selected country catalogue. For instance, if NSM is unavailable in the selected country catalogue, the NSM option won't be displayed.*

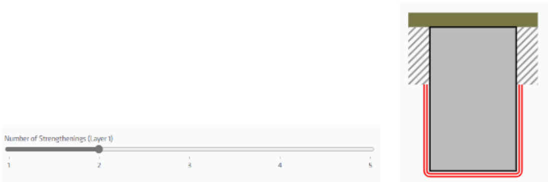
For Rectangular not accessible from top and T-beam sections, "Full Wrapping" option won't be available.

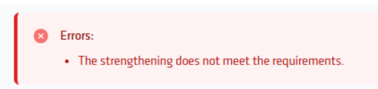








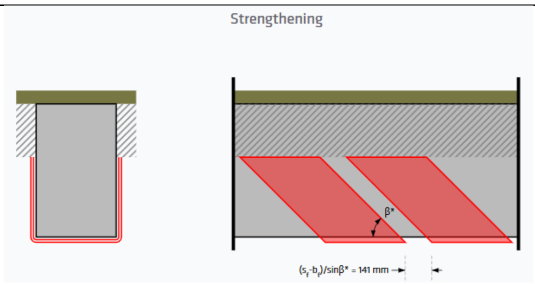




The user should define the following strengthening parameters:

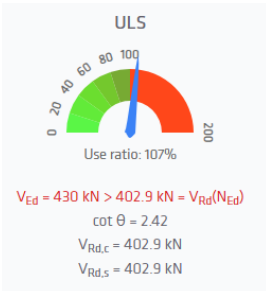
- **Product**: The user selects which product to use from a dropdown menu
- **Fraction**: For some products, it is possible to utilize a fraction of the fabric's original width. For example, when selecting SikaWrap®-300 C – 60 cm, users may opt to utilize the full width or choose from 1/2, 1/3, or 1/4 of the width. This results in corresponding fabric widths of 30 cm, 20 cm, or 15 cm.
- **Spacing between strengthening**: User can decide to apply the shear strengthening either continuous or discrete. This slider sets the spacing between the strips. Moving the slider to the left (Spacing =0), the strengthening will be considered continuous. Spacing is measured perpendicular to the strips.
- **Angle of strengthening**: The software allows users to design the stripes at an angle as required. The slider enables users to select the inclination angle of the strips relative to the beam's axis.
- **Number of Strengthening Layers:** This slider allows users to choose the desired number of shear strengthening layers.
-

NOTE*: The software checks automatically the geometrical limits of the strengthening, according to TR55. In case these limits are not fulfilled (see section 2.3) an error will be displayed .*

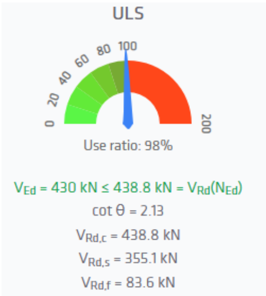


The software shows the reinforced section with FRP systems in two vertical views: one perpendicular and one parallel to the beam axis. This allows the user to view the number of layers, their arrangement, and the angle of the strips.

Unstrengthened section



Strengthened section



The Use ratio indicator for the ULS combination for the strengthened section (on the right), shows the final result of the calculation. A ratio below 100% indicates that verification is successful and the section meets requirements with the selected strengthening system and FRP amount.

Design shear force (**V_{Ed}**) is compared to strengthened resistant shear (**V_{Rd}**).

The value of Cot θ (always between 1 and 2.5) is displayed below the use ratio indicator, along with the individual values for each shear resistance component. For the strengthened section

$$\boldsymbol{V_{Rd}} = \min\left(\boldsymbol{V_{Rd,c}}; \boldsymbol{V_{Rd,s}} + \boldsymbol{V_{Rd,f}}\right)$$

NOTE*: in this example we can appreciate what is described in the section 2.3. The left side displays the ULS Use ratio for the unstrengthened section. In this case Cot θ = 2.42. This value maximises the resistant shear V_{Rd} by ensuring balanced failure between shear-tension and shear-compression, so* $\boldsymbol{V_{Rd,c}} = \boldsymbol{V_{Rd,s}}$.

On the right, the results for the strengthened section are shown, indicating a steepening effect on the compression strut (Cot θ = 2.13 < 2.42) that is associated with the presence of the FRP. In this case $\boldsymbol{V_{Rd,c}} = \boldsymbol{V_{Rd,s}} + \boldsymbol{V_{Rd,f}}$

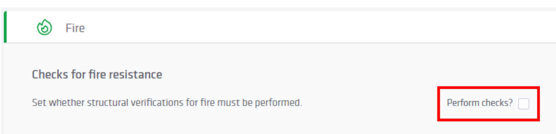
Product details

Product	SikaWrap® 300 C - 30 cm
Fraction	1/1
Type of fibers	C
Width (b_f)	300 mm
Single layer thickness (t_f)	0.167 mm
Characteristic elastic modulus (E_{fK})	220 GPa
Characteristic ultimate strain (ε_{fk})	14.5 ‰
Strength (f_{fk})	3200 MPa
Partial safety factor on strain ($\gamma_{FRP,\varepsilon}$)	1.25
Partial safety factor on elastic modulus ($\gamma_{FRP,E}$)	1.10
Partial safety factor on material ($\gamma_{FRP,m}$)	1.20
Effective strain (ε_{fse})	2.8 ‰

For the selected FRP systems (SikaWrap®, Sika® CarboDur®, etc.), all relevant physical and mechanical properties are provided, including the partial safety factors used for the calculation and the serviceability limit state check for the strengthening systems.

3.7.6 FIRE

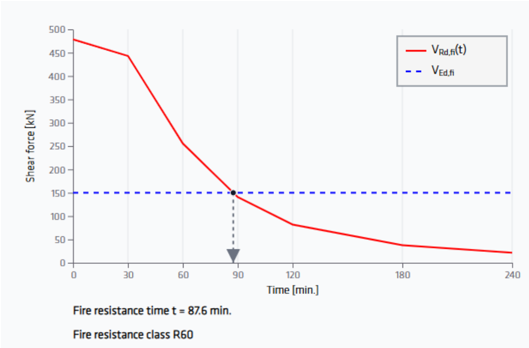
The software evaluates the strength of the un-strengthened member in case of fire, calculating the anticipated temperature profiles in the concrete section and the real fire resistance according to the fire loads, as shown in *TR55, section 5.7.1*.



The user can verify the member's fire resistance, assuming FRP strengthening fails immediately at high temperatures (see section 2.1.3 for details).

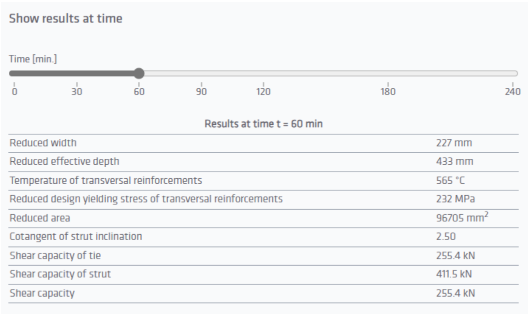
This option can be enabled is enabled by clicking the box located in Fire panel.

The sides of the beam that may be directly exposed to fire can be selected by the user.



The software displays a diagram. The horizontal axis represents time, while the vertical axis indicates the bending moment. The red lines indicate the values of the resistant shear force (**V_{Rd}**) over time. These values are determined based on the temperature distribution in the concrete section and by applying the 500 °C Isotherm Method (section 2.1.3). The blue line represents the design value of the shear force under fire conditions, denoted as **$V_{Ed,fl}$**.

The lower part of the diagram shows when the resistant bending moment equals the design value under fire conditions, which determines the Fire resistance class.

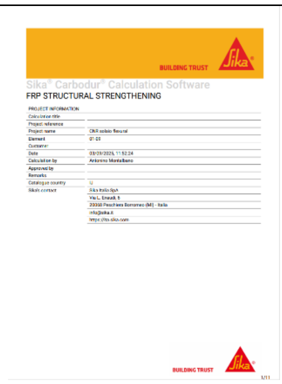


A slider enables the visualisation of several data used for the verification under fire conditions using the 500 °C Isotherm Method.

Changing the time of exposure to the fire the table shows:

- The **Reduced width** and **Effective depth** of the section(due to the position in that moment of the 500°C isotherm)
- The **Temperature of the transversal reinforcement** and the consequent **Reduced design yielding stress**
- The total **Shear capacity** and its components, together with the updated value of **Cot** *θ.*

3.7.7 PRINTOUT



A full printout in PDF is generated after the project is completed.

Print out contains:

- Design data
- Element data
- Loads
- Strengthening details
- Results

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