

Advanced Concept Training Reinforced concrete (EN 1992) – 1D members

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Introduction

1D concrete design is available in the Concept Edition of SCIA Engineer.

Both beam and column design are part of the module esacd.01.01 (1D concrete design for EN1992). Practical reinforcement on 1D members is part of the module esacdt.01.

Both modules are part of the Concept Edition of SCIA Engineer.

All topics that will be treated in this training document about basic concrete calculation for 1D members are available in the modules described above.

This manual is handling the practical approach in SCIA Engineer in accordance with EN1992 for the concrete menu available since SCIA Engineer 17. For more theoretical background, reference is made to "Topic Training: New Concrete".

For 2D members and advanced concrete calculations reference is made to the respective training documents "Advanced Concept Training: Reinforced concrete (EN1992) – 2D members" and "Advanced Concept Training: Reinforced concrete (EN1992) – Adv. modules".

Materials

Verification by the partial factor method

Design values (art. 2.4.2)

Partial factors for materials (art. 2.4.2.4)

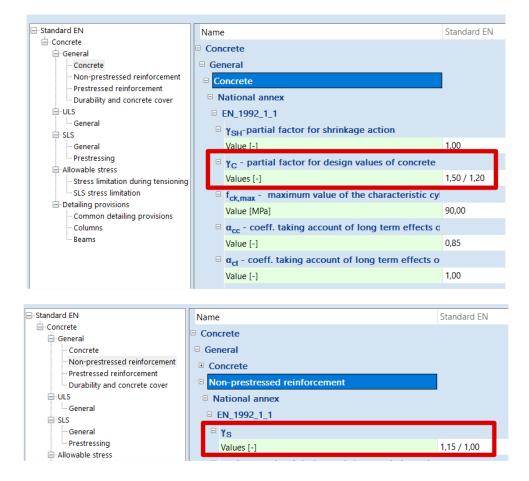
Partial factors for materials for ultimate limit states, γ_c and γ_s should be used.

The recommended values of γ_c and γ_s for 'persistent & transient' and 'accidental, design situations are given in the following table. These are not valid for fire design for which reference should be made to EN 1992-1-2.

For fatigue verification the partial factors for persistent design situations given in this table are recommended for the values of $\gamma_{c,fat}$ and $\gamma_{s,fat}$.

Design situations	$\gamma_{\rm C}$ for concrete	$\gamma_{\rm S}$ for reinforcing steel	$\gamma_{\rm S}$ for prestressing steel
Persistent & Transient	1,5	1,15	1,15
Accidental	1,2	1,0	1,0

These values can also be found in the Concrete setup of the National Annex:



All factors related to the code are shown in green on the screen. By default, the values of the chosen code are taken.

The values for partial factors for materials for serviceability limit state verification should be taken as those given in the particular clauses of this Eurocode.

The recommended values of γ_c and γ_s in the serviceability limit state for situations not covered by particular clauses of this Eurocode is 1,0.

Lower values of γ_c and γ_s may be used if justified by measures reducing the uncertainty in the calculated resistance.

Concrete

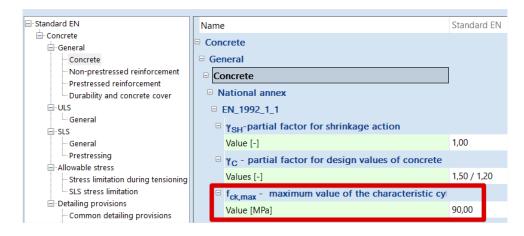
The following clauses give principles and rules for normal and high strength concrete.

Strength (art 3.1.2)

The compressive strength of concrete is denoted by concrete strength classes which relate to the characteristic (5%) cylinder strength f_{ck} , or the cube strength $f_{ck,cube}$.

The strength classes in this code are based on the characteristic cylinder strength f_{ck} determined at 28 days with a maximum value of C_{max} .

The recommended value of C_{max} is C90/105.



In certain situations (e.g. prestressing) it may be appropriate to assess the compressive strength for concrete before or after 28 days, on the basis of test specimens stored under other conditions than prescribed in EN 12390.

All values can also be found in the material library of SCIA Engineer:

	Materials		×	
🔎 🗄 🖋 🕼 🕸	I 요. 요 총 I 📽 🗭 🛃 🛛	• 7		
C12/15	Name	C50/60		
C16/20	Code independent	-		
C20/25	Material type	Concrete		
C25/30 C30/37	Thermal expansion [m/mK]	0.00		
C30/37 C35/45	Unit mass [kg/m^3]	2500.0		
C40/50	Time dependency of unit mass	None		
C45/55	E modulus [MPa]	3.7300e+04		
C50/60	Poisson coeff.	0.2		
C55/67	Independent G modulus			
C60/75 C70/85	G modulus [MPa]	1.5542e+04		
C80/95	Log. decrement	0.2		
C90/105	Colour			
B 400A	Specific heat [J/gK]	6.0000e-01		
B 500A	Temperature dependency of specific heat	None		
B 600A B 400B	Thermal conductivity [W/mK]	4.5000e+01		
B 500B	Temperature dependency of thermal conductivity	None		
B 600B	Order in code	9		
B 400C	EN 1992-1-1			
B 500C	Characteristic compressive cylinder strength fck(28) [MPa]	50.00		
B 600C C12/15(EN1992-2)	Calculated depended values			
C12/15(EN1992-2) C16/20(EN1992-2)	Mean compressive strength fcm(28) [MPa]	58.00	Measured values Measured values of mean compressive strength (influence of ageing)	
C20/25(EN1992-2)	fcm(28) - fck(28) [MPa]	8.00		1
C25/30(EN1992-2)	Mean tensile strength fctm(28) [MPa]	4.10	Measured values I	_
C30/37(EN1992-2)	fctk 0,05(28) [MPa]	2.90		.0
C35/45(EN1992-2)	fctk 0,95(28) [MPa]	5.30	mout faile of completence of mater energing [mits]	4.12
C40/50(EN1992-2) C45/55(EN1992-2)	Design compressive strength - persistent (fcd = fck / gamma c_p) [MPa]	33.33	mucht con fruid 1	4342.2
C50/60(EN1992-2)	Design compressive strength - accidental (fcd = fck / gamma c_a) [MPa	41.67	Measured values II	
C55/67(EN1992-2)	Strain at reaching maximum strength eps c2 [1e-4]	20.0	- go	8.0
C60/75(EN1992-2)	Ultimate strain eps cu2 [1e-4]	35.0	induit funde of compressive symbol and ign [in a]	0.00
C70/85(EN1992-2)	Strain at reaching maximum strength eps c3 [1e-4]	17.5	Emod, sec [MPa] 3	5654.4
C80/95(EN1992-2) C90/105(EN1992-2)	Ultimate strain eps cu3 [1e-4]	35.0	Measured values III	
Ca0/103(EI41992-2)	Stone diameter (dg) [mm]	32	Age of concrete [day] 0	.0
	Cement class	N (normal hardening - CEM 32,5 R, CEM 42,5 N)	Mean value of compressive cylinder strength [MPa] 0	.00
	Cement type - for BS and French NA only	CEMI	 Emod, sec (MPa) 0 	.00
	Type of aggregate	Quartzite	 Standard deviation [MPa] 4 	.9
	Measured values		Characteristic compressive cylinder strength (28) (Fck) [MPa] 4	2.0
	Measured values of mean compressive strength (influence of ageing)		Graph	
	Stress-strain diagram			
	Type of diagram	Bi-linear stress-strain diagram	·	
	Picture of Stress-strain diagram			
New Insert Edit	Delete	Clos	e	

It may be required to specify the concrete compressive strength, $f_{ck}(t)$, at time *t* for a number of stages (e.g. demoulding, transfer of prestress), where:

$$\begin{array}{ll} f_{ck}(t) = f_{cm}(t) - 8 \; (MPa) & \mbox{for } 3 < t < 28 \; \mbox{days} \\ f_{ck}(t) = f_{ck} & \mbox{for } t \geq 28 \; \mbox{days} \end{array}$$

The compressive strength of concrete at an age *t* depends on the type of cement, temperature and curing conditions. For a mean temperature of 20°C and curing in accordance with EN 12390 the compressive strength of concrete at various ages $f_{cm}(t)$ may be estimated from:

$$f_{cm}(t) = \beta_{cc}(t) f_{cm}$$
(3.1)

with
$$\beta_{cc}(t) = e^{\left\{s\left[1-\left(\frac{28}{t}\right)^{\frac{1}{2}}\right]\right\}}$$

$$(3.2)$$

where:

fcm(t) fcm	is the mean concrete compressive strength at an age of t days is the mean compressive strength at 28 days according to Table 3.1
$\beta_{cc}(t)$	is a coefficient which depends on the age of the concrete t
t	is the age of the concrete in days
S	is a coefficient which depends on the type of cement:
=	= 0,20 for cement of strength Classes CEM 42,5 R, CEM 52,5 N and CEM 52,5 R (Class R)
=	= 0,25 for cement of strength Classes CEM 32,5 R, CEM 42,5 N (Class N)
=	= 0,38 for cement of strength Classes CEM 32,5 N (Class S)

The type of cement can be chosen in the material library:

	Materials	
(💁 🗠 😂 🖆 🗃 🖥 Concrete		• 7
Name	C30/3	37
Code independent		
Material type	Concre	ete
Thermal expansion [m/mK]	0.00	
Unit mass [kg/m^3]	2500.0	n
Time dependency of unit mass	None	-
E modulus [MPa]	3,2800	0++04
Poisson coeff.	0.2	00+04
Independent G modulus	0.2	
	1.3667	7.04
G modulus [MPa]		/e+U4
Log. decrement	0.2	
Colour		
Specific heat [J/gK]	6.0000	De-01
Temperature dependency of specific heat	None	
Thermal conductivity [W/mK]	4.5000	De+01
Temperature dependency of thermal conduct	vity None	
Order in code	5	
E EN 1992-1-1		
Characteristic compressive cylinder strength f	ck(28) [MPa] 30.00	
Calculated depended values		
Mean compressive strength fcm(28) [MPa]	38.00	
fcm(28) - fck(28) [MPa]	8.00	
Mean tensile strength fctm(28) [MPa]	2.90	
fctk 0,05(28) [MPa]	2.00	
fctk 0,95(28) [MPa]	3.80	
Design compressive strength - persistent (fcd		
Design compressive strength - persistent (cu Design compressive strength - accidental (co		
Strain at reaching maximum strength eps c2 [1e-4j 20.0 35.0	
Ultimate strain eps cu2 [1e-4]		
Strain at reaching maximum strength eps c3 [
Ultimate strain eps cu3 [1e-4]	35.0	
Stone diameter (dg) [mm]	32	
Cement class		mal hardening - CEM 32,5 R, CEM 42,5 N)
Cement type - for BS and French NA only		v hardening - CEM 32,5 N)
Measured values	N (non B (rapi	mal hardening - CEM 32,5 R, CEM 42,5 N) idl hardening - CEM 42,5 R, CEM 52,5 N, CEM 52,5 R)
Measured values of mean compressive stree		
Stress-strain diagram		
Type of diagram	Bi-linea	ar stress-strain diagram
Picture of Stress-strain diagram		

The tensile strength refers to the highest stress reached under concentric tensile loading.

The characteristic strengths for f_{ck} and the corresponding mechanical characteristics necessary for design, are given in Table 3.1:

Table 3.1 St	trength and deformation	characteristics	for concrete
--------------	-------------------------	-----------------	--------------

Analytical relation / Explanation			$f_{\rm cm} = f_{\rm ck}$ + 8(MP a)	$f_{cum}=0,30.xf_{ck}^{(223)} \le C50/60$ $f_{cum}=2,12\cdot\ln(1+(f_{cm}/10))$ > C50/60	$f_{citrious} = 0.7 \times f_{cim}$ 5% fractile	f _{etrose} = 1,3×f _{etm} 95% fractile	E _{am} = 22[(f _{am})/10] ⁰³ (f _{em} in MPa)	see Figure 3.2 _{&1} (⁷ ₀₀) = 0,7 f _{en^{0,31} < 2.8}	See Figure 3.2 for f _{6k} ≥ 50 Mpa _{6-ut} (⁰ /m)=2.8+271(98-f _{cm})/1001 ⁴	see Figure 3.3 for f _{6k} ≥ 50 Mpa <i>c</i> ₆₂ (⁰ / ₀₁)=2,0+0,085(f _{6k} -50) ⁰⁵³	see Figure 3.3 for f _{6k} ≥ 50 Mpa ε₀ωc(⁰ /₀₀)=2,6+35[(90-f ₆₄)/100] ⁴	for f₀i≥ 50 Mpa n=1,4+23,4[(90- f₄)/100]⁴	see Figure 3.4 for f ₄ ≥ 50 Mpa c ₅₃ (^{0,04})=1 ,75+0,55[(c ₆ +50)/40]	see Figure 3.4 for $f_{\alpha, \lambda} \ge 50$ Mpa $\mathcal{E}_{cuel}^{(\gamma_{(0)})=2, 6+35[(90-f_{\alpha})/100]^4}$
	06	105	<mark>88</mark>	5,0	3,5	6,6	44	2,8	2,8	2,6	2,6	1,4	2,3	2,6
	80	96	8	4,8	3,4	6,3	42	2,8	2,8	2,5	2,6	1,4	2,2	2,6
	70	85	78	4,6	3,2	6,0	41	2,7	2,8	2,4	2,7	1,45	2,0	2,7
	60	75	68	4,4	3,1	5,7	39	2,6	3,0	2,3	2,9	1,6	1,9	2,9
	55	67	<mark>63</mark>	4,2	3,0	5,5	38	2,5	3,2	2,2	3,1	1,75	1,8	3,1
Strength classes for concrete	50	8	8	4,1	2,9	5,3	37	2,45						
for col	45	55	53	3,8	2,7	4,9	36	2,4						
sses	40	8	48	3,5	2,5	4,6	35	2,3						
gth cla	35	45	43	3,2	2,2	4,2	34	2,25						
Strenç	30	37	88	2,9	2,0	3,8	33	2,2	3,5	2,0	3,5	2,0	1,75	3,5
	25	8	33	2,6	1,8	3,3	31	2,1						
	20	25	28	2,2	1,5	2,9	30	2,0						
	16	20	24	1,9	1,3	2,5	29	1,9						
	12	15	8	1,6	1,1	2,0	27	1,8						
	$f_{ m dc}$ (MPa)	f _{ck αube} (MPa)	f _{an} (MPa)	f _{cm} (MPa)	f _{ak 0.05} (MPa)	f _{ek.095} (MPa)	E _{cm} (GPa)	$\mathcal{E}_{\mathrm{Cl}}$ (%)	Eart (‰)	Ea (‰)	Eu2 (‰)	Ľ	Ec3 (%0)	Eau3 (%o)

Design compressive and tensile strengths (art 3.1.6)

1) The value of the design compressive strength is defined as

$$f_{cd} = \alpha_{cc} f_{ck} / \gamma_C \tag{3.15}$$

where:

- $\gamma_{\rm C}$ is the partial safety factor for concrete.
- α_{cc} is the coefficient taking account of long term effects on the compressive strength and of unfavourable effects resulting from the way the load is applied.

The value of α_{cc} should lie between 0,8 and 1,0. The recommended value is 1,0.^[1]

2) The value of the design tensile strength, fctd, is defined as

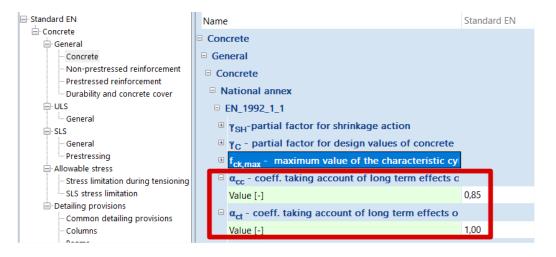
$$f_{ctd} = \alpha_{ct} f_{ctk,0,05} / \gamma_{C}$$
(3.16)

where:

- γc is the partial safety factor for concrete.
- α_{ct} is a coefficient taking account of long term effects on the tensile strength and of unfavourable effects, resulting from the way the load is applied.

The recommended value of α_{ct} is 1,0.

The values of the coefficients taking account of long term effects can be found in the Concrete setup of the National Annex:



If the concrete strength is determined at an age t > 28 days the values α_{cc} and α_{ct} should be reduced by a factor k_t .

The recommended value of k_t is 0,85.

^[1] Remark: the Belgian National Annex recommends the use of the value 0,85.

Elastic deformation (art 3.1.3)

The elastic deformations of concrete largely depend on its composition (especially the aggregates). The values given in this Standard should be regarded as indicative for general applications. However, they should be specifically assessed if the structure is likely to be sensitive to deviations from these general values.

The modulus of elasticity of a concrete is controlled by the moduli of elasticity of its components. Approximate values for the modulus of elasticity E_{cm} , secant value between $\sigma_c = 0$ and $0.4f_{cm}$, for concretes with quartzite aggregates, are given in Table 3.1.

For limestone and sandstone aggregates the value should be reduced by 10% and 30% respectively. For basalt aggregates the value should be increased by 20%.

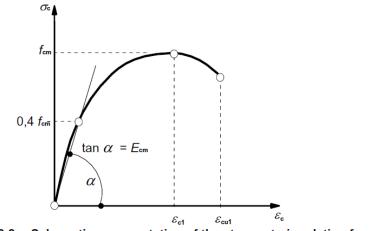


Figure 3.2: Schematic representation of the stress-strain relation for structural analysis (the use $0.4f_{cm}$ for the definition of E_{cm} is approximate).

Variation of the modulus of elasticity with time can be estimated by:

$$E_{cm}(t) = (f_{cm}(t) / f_{cm})^{0,3} E_{cm}$$

(3.5)

where $E_{cm}(t)$ and $f_{cm}(t)$ are the values at an age of t days and E_{cm} and f_{cm} are the values determined at an age of 28 days. The relation between $f_{cm}(t)$ and f_{cm} follows from Expression (3.1).

Poisson's ratio may be taken equal to 0,2 for uncracked concrete and 0 for cracked concrete.

Creep and shrinkage (art 3.1.4)

Creep and shrinkage of the concrete depend on the ambient humidity, the dimensions of the element and the composition of the concrete. Creep is also influenced by the maturity of the concrete when the load is first applied and depends on the duration and magnitude of the loading.

The value of the creep coefficient can be set in the concrete settings by using 'Advanced level' or in the 1D member data (advanced mode is ON) if it is defined. If the type input of the creep coefficient is **"Auto"**, the creep coefficient can be calculated automatically by inputting the age of concrete and the relative humidity (see annex B.1. in EN 1992-1-1).

If the type input of the creep coefficient is "User value", the creep coefficient can be inputted directly by the user.

ncrete s	ettings									
ational ar	nnex:				Fi	ind V	iew 🚽 A	dvanced	Default	t
Descr	iption	Symbol	Value	Default	Unit	Chapter	Code	Struct	Check	^
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Solve	er setting									
🗏 Ge	eneral									
	Limit value of unity check	Lim.check	1.0	1.0			Independ	All (Be	Solver s	
	Value of unity check for not calculated unity check	Ncal.che	3,0	3,0			Independ	All (Be	Solver s	
	The coefficient for calculation effective depth of cr	Coeff _d	0,9	0,9			Independ	All (Be	Solver s	
	The coefficient for calculation inner lever arm	Coeffz	0,9	0,9			Independ	All (Be	Solver s	
_	The coefficient for calculation force, where memb	Coeff	0,1	0,1			Independ	All (Be	Solver s	
	Сгеер									
	Type input of creep coefficient	Туре ф	Auto	Auto		Annex B.1	EN 1992-1-1	All (Be	Solver s	
	Relative humidity	RH	50	50	%	Annex B.1	EN 1992-1-1	All (Be	Solver s	
	Age of concrete at loading	to	28,00	28,00	day	Annex B.1	EN 1992-1-1	All (Be	Solver s	
	Age of concrete at the moment considered	t	1825,00	1825,00	day	Annex B.1	EN 1992-1-1	All (Be	Solver s	

CMD

Name	CMD1	
Member	B1	
Member type	Column	·
Advanced mode		
Solver setting		
□ General		
∃ Creep		
Type input of creep coefficient	Auto	-
Relative humidity [%]	50	
Age of concrete at loading [day]	28,00	
Age of concrete at loading [day]		

 \times

(1) The creep coefficient $\varphi(t,t_0)$ may be calculated from:

$$\varphi(t,t_0) = \varphi_0 \cdot \beta_c(t,t_0) \tag{B.1}$$

where:

 φ_0 is the notional creep coefficient and may be estimated from:

$$\varphi_{0} = \varphi_{\mathsf{RH}} \cdot \beta(f_{\mathsf{cm}}) \cdot \beta(t_{0}) \tag{B.2}$$

 φ_{RH} is a factor to allow for the effect of relative humidity on the notional creep coefficient:

$$\varphi_{\text{RH}} = 1 + \frac{1 - \text{RH}/100}{0.1 \cdot \sqrt[3]{h_0}}$$
 for $f_{\text{cm}} \le 35 \text{ MPa}$ (B.3a)

$$\varphi_{\mathsf{RH}} = \left[1 + \frac{1 - \mathsf{RH}/100}{0.1 \cdot \sqrt[3]{h_0}} \cdot \alpha_1\right] \cdot \alpha_2 \quad \text{for } f_{\mathsf{cm}} > 35 \text{ MPa}$$
(B.3b)

- *RH* is the relative humidity of the ambient environment in %
- β ($f_{\rm cm}$) is a factor to allow for the effect of concrete strength on the notional creep coefficient:

$$\beta(f_{\rm cm}) = \frac{16.8}{\sqrt{f_{\rm cm}}} \tag{B.4}$$

 f_{cm} is the mean compressive strength of concrete in MPa at the age of 28 days $\beta(t_0)$ is a factor to allow for the effect of concrete age at loading on the notional creep coefficient:

$$\beta(t_0) = \frac{1}{(0, 1 + t_0^{0.20})} \tag{B.5}$$

 h_0 is the notional size of the member in mm where:

$$h_0 = \frac{2A_c}{u} \tag{B.6}$$

- A_c is the cross-sectional area
- *u* is the perimeter of the member in contact with the atmosphere
- $\beta_{c}(t,t_{0})$ is a coefficient to describe the development of creep with time after loading, and may be estimated using the following Expression:

$$\beta_{c}\left(t,t_{0}\right) = \left[\frac{\left(t-t_{0}\right)}{\left(\beta_{H}+t-t_{0}\right)}\right]^{0.3} \tag{B.7}$$

t is the age of concrete in days at the moment considered

*t*₀ is the age of concrete at loading in days

 $t - t_0$ is the non-adjusted duration of loading in days

 $\beta_{\rm H}$ is a coefficient depending on the relative humidity (*RH* in %) and the notional member size (h_0 in mm). It may be estimated from:

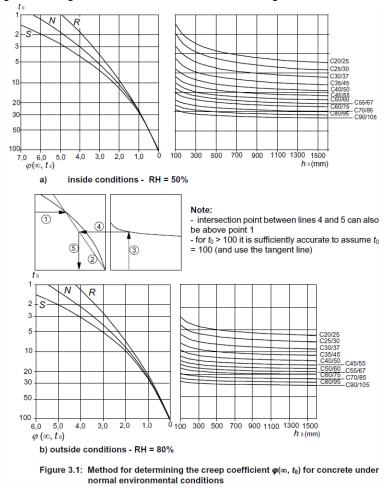
$$\beta_{\rm H} = 1.5 \left[1 + (0.012 \, RH)^{18}\right] h_0 + 250 \le 1500$$
 for $f_{\rm cm} \le 35$ (B.8a)

$$\beta_{\rm H} = 1.5 \left[1 + (0.012 \text{ RH})^{18}\right] h_0 + 250 \alpha_3 \le 1500 \alpha_3 \qquad \text{for } f_{\rm cm} \ge 35 \qquad (B.8b)$$

 $\alpha_{1/2/3}$ are coefficients to consider the influence of the concrete strength:

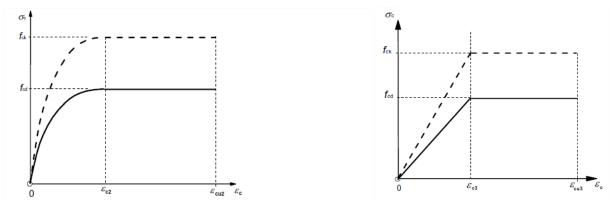
$$\alpha_1 = \left[\frac{35}{f_{\rm cm}}\right]^{0.7} \quad \alpha_2 = \left[\frac{35}{f_{\rm cm}}\right]^{0.2} \quad \alpha_3 = \left[\frac{35}{f_{\rm cm}}\right]^{0.5} \tag{B.8c}$$

Where great accuracy is not required, a value found from a figure (Figure 3.1) may be considered as the creep coefficient, provided that the concrete is not subjected to a compressive stress greater than 0,45 fck (t_0) at an age t_0 , the age of concrete at the time of loading.



Stress-strain relations for the design of cross-sections (art 3.1.7)

For the design of cross-sections, the following stress-strain relationship may be used:

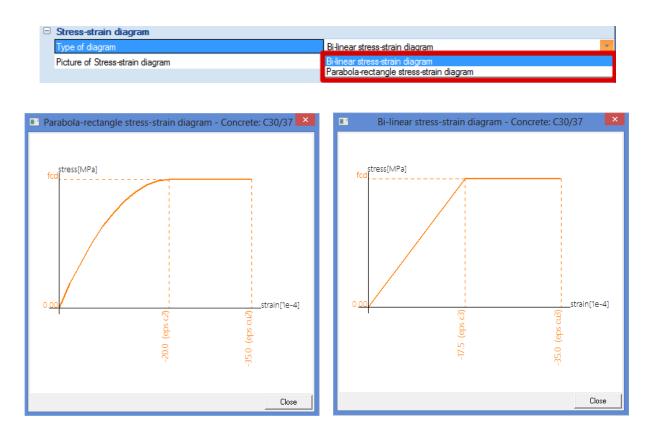




Ec2	is the strain at reaching the maximum strength in the parabola-rectangle diagram
Ecu2	is the ultimate strain in the parabola-rectangle diagram

- ϵ_{c3} is the strain at reaching the maximum strength in the bi-linear diagram
- ϵ_{cu3} is the ultimate strain in the bi-linear diagram

The user can choose in the material library which one of the diagrams should be used for the calculation:



Reinforcing steel

The following clauses give principles and rules for reinforcement which is in the form of bars, de-coiled rods, welded fabric and lattice girders. They do not apply to specially coated bars.

Properties (art 3.2.2)

The behaviour of reinforcing steel is specified by the following properties:

- yield strength (f_{yk} or $f_{0,2k}$)
- maximum actual yield strength (fy,max)
- tensile strength (ft)
- ductility (Euk and ft/fyk)
- bendability
- bond characteristics (fR)
- section sizes and tolerances
- fatigue strength
- weldability
- shear and weld strength for welded fabric and lattice girders

The steel properties can be found in the material library:

치 👬 🏹 99 🎬	5 K 1	Ω 🗠 🎒 🗃 🛱 📕 Reinforcement steel	• 7	
400A		Name	B 500A	
500A	E	Code independent		
600A		Material type	Reinforcement steel	
400B 500B		Thermal expansion [m/mK]	0.00	
600B		Unit mass [kg/m^3]	7850.0	
400C		E modulus [MPa]	2.0000e+05	
500C		Poisson coeff.	0.2	
600C		Independent G modulus		
		G modulus [MPa]	8.3333e+04	
		Log. decrement	0.2	
		Colour		
		Specific heat [J/gK]	6.0000e-01	
		Thermal conductivity [W/mK]	4.5000e+01	
		Bar surface	Ribbed	
		Order in code	2	
	E	EN 1992-1-1		
		Characteristic yield strength fyk [MPa]	500.0	
		Calculated depended values		
		Characteristic maximum tensile strength ftk [MPa]	525.0	
		Coefficient k = ftk / fyk [-]	1.05	
		Design yield strength - persistent (fyd = fyk / gamma s_p) [MPa]	434.8	
		Design yield strength - accidental (fyd = fyk / gamma s_a) [MPa]	500.0	
		Maximum elongation eps uk [1e-4]	250.0	
		Class	A	
		Reinforcement type	Bars	
		Fabrication	Hot rolled	
		Stress-strain diagram		
		Type of diagram	Bi-linear with an inclined top branch	

The mean value of density may be assumed to be 7850 kg/m³. The design value of the modulus of elasticity $E_{\rm s}$ may be assumed to be 200 GPa.

This Eurocode applies to ribbed and weldable reinforcement, including fabric.

The application rules for design and detailing in this Eurocode are valid for a specified yield strength range, $f_{yk} = 400$ to 600 MPa.

Table C.1 gives the properties of reinforcement suitable for use with this Eurocode:

Table C.1:	Properties	of reinforcement
	110001000	

Product form	Bars and de-coiled rods Wire Fabrics				Requirement or quantile value (%)		
Class	А	в	с	А	В	с	-
Characteristic yield strength f_{yk} or $f_{0,2k}$ (MPa)			5,0				
Minimum value of $k = (f_t/f_y)_k$	≥1,05	≥1,08	≥1,15 <1,35	≥1,05	≥1,08	≥1,15 <1,35	10,0
Characteristic strain at maximum force, <i>ɛ</i> uk (%)	≥2,5	≥5,0	≥7,5	≥2,5	≥5,0	≥7,5	10,0
Bendability	Ber	nd/Rebend	i test		-		
Shear strength	- 0,3 A f _{vk} (A is area of wire)						Minimum
Maximum Nominal deviation from bar size (mm) nominal mass ≤ 8 (individual bar > 8 or wire) (%)		- 0,3 <i>A f</i> _{vk} (<i>A</i> is area of wire) ± 6,0 ± 4,5					5,0

Design assumptions (art 3.2.7)

For normal design, either of the following assumptions may be made:

- B1) an inclined top branch with a strain limit of ε_{ud} and a maximum stress of kf_{yk} / γ_s at ε_{uk} , where $k = (f_i/f_y)_k$.
- B2) a horizontal top branch without the need to check the strain limit.

The recommended value of ε_{ud} is 0,9 ε_{uk} . The value of $(f_t/f_y)_k$ is given in Table C.1.

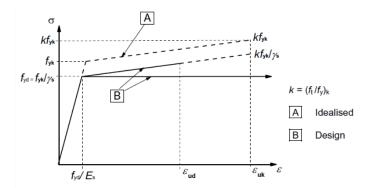
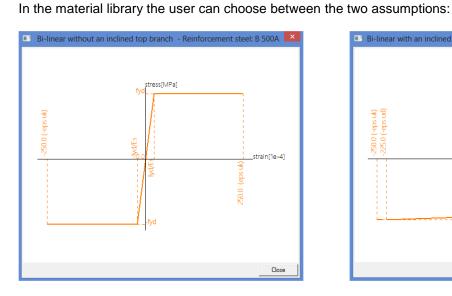
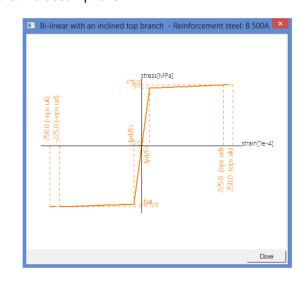


Figure 3.8: Idealised and design stress-strain diagrams for reinforcing steel (for tension and compression)





Durability and cover to reinforcement

Environmental conditions (art 4.2)

Exposure conditions are chemical and physical conditions to which the structure is exposed in addition to the mechanical actions.

Environmental conditions are classified according to Table 4.1:

Class	Description of the environment	Informative examples where exposure classes
designation		may occur
1 No risk o	f corrosion or attack	-
X0	For concrete without reinforcement or embedded metal: all exposures except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidit
2 Corrosio	n induced by carbonation	
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high ai humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2
3 Corrosio	n induced by chlorides	
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools Concrete components exposed to industrial water containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs
4 Corrosio	n induced by chlorides from sea water	
XS1	Exposed to airborne salt but not in direct contact with sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5. Freeze/Th		
XF1	Moderate water saturation, without de-icing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with de-icing agent	Vertical concrete surfaces of road structures exposed to freezing and airborne de-icing agents
XF3	High water saturation, without de-icing agents	Horizontal concrete surfaces exposed to rain and freezing
XF4	High water saturation with de-icing agents or sea water	Road and bridge decks exposed to de-icing agent Concrete surfaces exposed to direct spray containing de-icing agents and freezing Splash zone of marine structures exposed to freezing
6. Chemical	attack	
XA1	Slightly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA2	Moderately aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA3	Highly aggressive chemical environment	Natural soils and ground water

In the Concrete settings the user can choose the desired exposure class. All items with a blue background colour can be overwritten in the 1D member data.

itional annex:			Find		View 👻	Leve (advand		Default	
Description	Symbol	Value	Default	Unit	Chapter	Code	Struc	Chec	^
ب ااد	<all> 🔎</all>	<all></all>	o <all> 🔎</all>		<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	
Design defaults									
Minimal concrete cover									
Desian workina life		50.00	50.00	vear	4.4.1.2(5	EN 1992	All (Be	Desian	
Risk of corrosion attack			1.000			-			
Corrosion induced by carbonation		XC3	XC3			EN 1992		-	
Corrosion induced by chlorides Corrosion induced by chlorides from sea water		None None	None None			EN 1992 EN 1992		-	
Freeze / thaw attack		None	None			EN 1992		_	
Chemical attack		None	None			EN 1992		-	
Risk of abrasion attack		None	None			EN 1992			
Possibility of special control								-	
Risk of casting on atypical surface		Standard	Standard		4.4.1.3(4)	EN 1992	. All (Be	Design	
Design defaults		CMD							
Minimal concrete cover									
Different surfaces									
Different surfaces Design working life [vear]		50,00							
Desian working life [year]									
Desian working life [year]									-
Design working life [vear] Risk of corrosion attack		50,00							Ŧ
Design working life [vear] Risk of corrosion attack Corrosion induced by carbonation		50,00 XC3							+ + +
Besign working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides		50.00 XC3 None							
Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides from sea water		50,00 XC3 None None							
Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides from sea water Freeze / thaw attack		50.00 XC3 None None None							+ + + + +
Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides from sea water Freeze / thaw attack Chemical attack Risk of abrasion attack		50,00 XC3 None None None							* * * *
Design working life [vear] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides from sea water Freeze / thaw attack Chemical attack		50,00 XC3 None None None							* * * *

Methods of verification (art 4.4)

Concrete cover (art 4.4.1)

General (art 4.4.1.1)

The concrete cover is the distance between the surface of the reinforcement closest to the nearest concrete surface (including links and stirrups and surface reinforcement where relevant) and the nearest concrete surface.

The nominal cover shall be specified on the drawings. It is defined as a minimum cover, c_{\min} , plus an allowance in design for deviation, Δc_{dev} :

$$C_{nom} = c_{min} + \Delta c_{dev}$$

(4.1)

Minimum cover, c_{min} (art 4.4.1.2)

Minimum concrete cover, *c*_{min}, shall be provided in order to ensure:

- the safe transmission of bond forces
- the protection of the steel against corrosion (durability)
- an adequate fire resistance

The greater value for c_{min} satisfying the requirements for both bond and environmental conditions shall be used:

$$C_{min} = max \{C_{min,b}; C_{min,dur} + \Delta C_{dur,\gamma} - \Delta C_{dur,sdd}; 10 \text{ mm}\}$$
(4.2)

where:

Cmin,b	minimum cover due to bond requirement
Cmin,dur	minimum cover due to environmental conditions
$\Delta \mathbf{C}$ dur, γ	additive safety element
$\Delta \mathbf{C}$ dur,st	reduction of minimum cover for use of stainless steel
$\Delta \mathbf{C}$ dur.add	reduction of minimum cover for use of additional protection

The recommended value of $\Delta c_{dur,y}$, $\Delta c_{dur,st}$ and $\Delta c_{dur,add}$, without further specification, is 0 mm.

- In order to transmit bond forces safely and to ensure adequate compaction of the concrete, the minimum cover should not be less than *c*_{min,b} given in table 4.2.

Table 4.2: Minimum cover, c_{min,b}, requirements with regard to bond

Bond Requirement	
Arrangement of bars	Minimum cover c _{min,b} *
Separated	Diameter of bar
Bundled	Equivalent diameter (ϕ_n)(see 8.9.1)
*: If the nominal maximur	n aggregate size is greater than 32 mm, c _{min,b} should be increased by 5 mm.

- The minimum cover values for reinforcement and prestressing tendons in normal weight concrete taking account of the exposure classes and the structural classes is given by *c*_{min,dur}.

The recommended Structural Class (design working life of 50 years) is S4 for the indicative concrete strengths (given in Annex E of EN 1992-1-1). The recommended minimum Structural Class is S1.

The recommended modifications to the structural class is given in Table 4.3N:

Structural Class												
Criterion	Exposure Class according to Table 4.1											
Citterion	X0	XC1	XC2/XC3	XC4	XD1	XD2/XS1	XD3/XS2/XS3					
Design Working Life of	increase	increase	increase	increase	increase	increase	increase class					
100 years	class by 2	class by 2	class by 2	class by 2	class by 2	class by 2	by 2					
Strength Class 1) 2)	≥ C30/37	≥ C30/37	≥ C35/45	≥ C40/50	≥ C40/50	≥ C40/50	≥ C45/55					
	reduce	reduce	reduce	reduce	reduce	reduce	reduce class by					
	class by 1	class by 1	class by 1	class by 1	class by 1	class by 1	1					
Member with slab	reduce	reduce	reduce	reduce	reduce	reduce	reduce class by					
geometry (position of reinforcement not affected by construction process)	class by 1	class by 1	class by 1	class by 1	class by 1	class by 1	1					
Special Quality	reduce	reduce	reduce	reduce	reduce	reduce	reduce class by					
Control of the concrete production ensured	class by 1	class by 1	class by 1	class by 1	class by 1	class by 1	1					

Table 4.3N: Recommended structural classification

The design working life and the special quality control can be defined in the concrete settings or in the 1D member data:

	Cond	crete settir	ngs					-	
tional annex:			Find		View 👻	Leve (advan		Default	
Description	Symbol	Value	Default	Unit	Chapter	Code	Struc	Chec	^
> ,	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>		<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	
Design defaults									
Minimal concrete cover		50.00	50.00			E 11 4000	411.40		
Design working life		50,00	50,00	year	4.4.1.2(5	. EN 1992	. All (Be	. Design	
Corrosion induced by carbonation		XC3	XC3		4 4 1 2(5)	EN 1992	All (Re	Design	
Corrosion induced by chlorides		None	None			EN 1992		-	
Corrosion induced by chlorides from sea water		None	None			EN 1992		_	
Freeze / thaw attack		None	None			EN 1992		-	
Chemical attack		None	None		4.4.1.2(12)) EN 1992	. All (Be	Design	
Risk of abrasion attack		None	None		4.4.1.2(13)) EN 1992	. All (Be	Design	
Possibility of special control			NO						
Special geometric control		NO				ENI 1000		Design	1
Special concrete quality control Risk of casting on atypical surface		NO Standard	NO Standard			EN 1992 EN 1992			
hisk of casting on atypical surface		Standard	Standard		4.4.1.3(4)	EIN 1332	. All (De	. Design	
Concrete characteristics									
Concrete characteristics Type of concrete		In-situ	In-situ			. EN 1992			
Type of concrete		In-situ CMD	In-situ						
			In-situ						
Type of concrete Design defaults Minimal concrete cover			In-situ						
Type of concrete Design defaults Minimal concrete cover Different surfaces		CMD	In-situ						
Type of concrete Design defaults Minimal concrete cover Different surfaces Design working life [year]		CMD	In-situ						
Type of concrete Design defaults Minimal concrete cover Different surfaces Design working life [year]		CMD	In-situ						
Type of concrete		CMD	In-situ						
Type of concrete		CMD 50,00 XC3	In-situ						
Type of concrete Pesign defaults Minimal concrete cover Different surfaces Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides		CMD 50,00 XC3 None	In-situ						
Type of concrete cover Type of cover Type of c		CMD 50,00 XC3 None None	In-situ						
Type of concrete		CMD 50,00 XC3 None None None	In-situ						
Type of concrete		CMD 50,00 XC3 None None None None	In-situ						
Type of concrete		CMD 50,00 XC3 None None None None	In-situ						
Type of concrete		CMD 50,00 XC3 None None None None	In-situ						
Type of concrete		CMD 50,00 XC3 None None None None							

The recommended values of $c_{\min,dur}$ are given in Table 4.4N (reinforcing steel):

Environment	Environmental Requirement for c _{min,dur} (mm)												
Structural	tructural Exposure Class according to Table 4.1												
Class	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2 / XS2	XD3 / XS3						
S1	10	10	10	15	20	25	30						
S2	10	10	15	20	25	30	35						
S3	10	10	20	25	30	35	40						
S4	10	15	25	30	35	40	45						
S5	15	20	30	35	40	45	50						
S6	20	25	35	40	45	50	55						

Table 4.4N: Values of minimum cover, c_{min,dur}, requirements with regard to durability for reinforcement steel in accordance with EN 10080.

- The concrete cover should be increased by the additive safety element $\Delta c_{dur,\gamma}$.

Where stainless steel is used or where other special measures have been taken, the minimum cover may be reduced by $\Delta c_{dur,st}$. For such situations the effects on all relevant material properties should be considered, including bond.

For concrete with additional protection (e.g. coating) the minimum cover may be reduced by $\Delta c_{dur,add}$.

For concrete abrasion special attention should be given on the aggregate. Optionally concrete abrasion may be allowed for by increasing the concrete cover (sacrificial layer). In that case, the minimum cover c_{min} should be increased by k_1 for Abrasion Class XM1, by k_2 for XM2 and by k_3 for XM3.

Abrasion Class XM1 means a moderate abrasion like for members of industrial sites frequented by vehicles with air tyres. Abrasion Class XM2 means a heavy abrasion like for members of industrial sites frequented by fork lifts with air or solid rubber tyres. Abrasion Class XM3 means an extreme abrasion like for members industrial sites frequented by fork lifts with elastomer or steel tyres or track vehicles.

The recommended values of k_1 , k_2 and k_3 are respectively: 5 mm, 10 mm and 15 mm.

The abrasion class can be inputted in the concrete settings or the 1D member data:

		C	onc	crete se	ettir	ngs					-	
ational annex:						Find		View 👻		vel inced)	Default	:
Description		Symb	ol	Value		Default	Unit	Chapter	Code	Struc	Chec	^
all>	Q	<all></all>	2	<all></all>	Q	<all> 🔎</all>		<all> 🔎</all>	<all></all>	o 🛛 🖉	<all> 🔎</all>	-
Risk of corrosion attack												
Corrosion induced by carbonation				XC3		XC3		4.4.1.2(5)	EN 1992-	All (Be	Design	
Corrosion induced by chlorides				None		None		4.4.1.2(5)	EN 1992-	All (Be	Design	
Corrosion induced by chlorides from sea wat	ter			None		None		4.4.1.2(5)	EN 1992-	All (Be	Design	
Freeze / thaw attack				None		None		4.4.1.2(12)	EN 1992-	All (Be	Design	
Chemical attack				None		None		A A 1 2(12)	EN 1992	All (Re	Design	
Risk of abrasion attack				None		None		4.4.1.2(13)	EN 1992-	All (Be	Design	
Possibility of special control												•
Special geometric control				NO		NO		4.4.1.3(3)	EN 1992-	All (Be	Design	
Special concrete quality control				NO		NO		4.4.1.2(5)	EN 1992-	All (Be	Design	
Risk of casting on atypical surface				Standar	d	Standard		4.4.1.3(4)	EN 1992-	All (Be	Design	
Concrete characteristics												
											_	

Design defaults		
Minimal concrete cover		
Different surfaces		
Design working life [year]	50,00	
Risk of corrosion attack		
Corrosion induced by carbonation	XC3	
Corrosion induced by chlorides	None	
Corrosion induced by chlorides from sea water	None	
Freeze / thaw attack	None	
Chemical attack	None	
Risk of abrasion attack	None	
Possibility of special control		
Special geometric control		
Special concrete quality control		

The values of k_1 , k_2 and k_3 are available in the National Annex:

Standard EN	Name	Standard EN
i General	Concrete	
Concrete	General	
Non-prestressed reinforcement Prestressed reinforcement	E Concrete	
Durability and concrete cover	Non-prestressed reinforcement	
ULS	Prestressed reinforcement	
General	Durability and concrete cover	
General	National annex	
Prestressing	Clause 4.4.1.2(5)	
 Allowable stress Stress limitation during tensioning 	\oplus $\Delta c_{dur,\gamma}$ - additive safety element for concrete cover 4.4.1.2(6)	
SLS stress limitation	\oplus $\Delta c_{dur,st}$ - reduction of minimum concrete cover for use of stainle	SS S
Detailing provisions Common detailing provisions	Δc _{dur.add} - reduction of minimum concrete cover for use of addit determine the second	ion
- Columns	k _{XM} - values of abrasion for classes XM 1,2,3 4.4.1.2(13)	
Beams	Values [mm]	5,0 / 10,0 / 15,0

Allowance in design for deviation (art 4.4.1.3)

To calculate the nominal cover, c_{nom} , an addition to the minimum cover shall be made in design to allow for the deviation (Δc_{dev}). The required minimum cover shall be increased by the absolute value of the accepted negative deviation.

The recommended value of Δc_{dev} is 10 mm.

In certain situations, the accepted deviation and hence allowance, Δc_{dev} , may be reduced.

The recommended values are:

- where fabrication is subjected to a quality assurance system, in which the monitoring includes measurements of the concrete cover, the allowance in design for deviation Δc_{dev} may be reduced:

 $10 mm \ge \Delta c_{dev} \ge 5 mm$

 where it can be assured that a very accurate measurement device is used for monitoring and non conforming members are rejected (e.g. precast elements), the allowance in design for deviation Δc_{dev} may be reduced:

 $10 mm \ge \Delta c_{dev} \ge 0 mm$

The special geometric control can be checked in the concrete settings or the 1D member data:

ational annex:	co		rete se		Find] [View 🔻	Leve (advanc		Default	
Description	Symbol		Value		Default	Unit	Chapter	Code	Struc	Chec	^
(all)	<all></all>	ρ	<all></all>	ρ	<all> 🔎</all>		<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	
Design defaults											
Minimal concrete cover											
Design working life			50,00		50,00	year	4.4.1.2(5	EN 1992	All (Be	Design	
Risk of corrosion attack											
Corrosion induced by carbonation			XC3		XC3		4.4.1.2(5)	EN 1992	All (Be	Design	
Corrosion induced by chlorides			None		None			EN 1992		-	
Corrosion induced by chlorides from sea water			None		None			EN 1992		-	
Freeze / thaw attack			None		None			EN 1992		-	
Chemical attack			None		None			EN 1992		-	
Risk of abrasion attack			None		None		4.4.1.2(13)	EN 1992	All (Be	Design	
- Pessibility of epocial control		-								-	
Special geometric control			NO		NO			EN 1992		-	
Special concrete quality control			NO		NO			EN 1992	AII (Be	Design	
Del 6 de la color 6								EN1 4000	AUL (17)	D .	
Risk of casting on atypical surface			Standard	1	Standard		4.4.1.3(4)	EN 1992	All (Be	Design	
Risk of casting on atypical surface Concrete characteristics Ture of accounts			Standard	1	Standard			EN 1992		Design	>
Concrete characteristics			CMD							Design	
Concrete characteristics Tupo of concrete Different surfaces			CMD							Design	
Concrete characteristics			CMD							Design	
Concrete characteristics Type of concrete Different surfaces Design working life [year]			CMD	00						Design	
Concrete characteristics Type of concrete Different surfaces Design working life [year]			CMD	00						Design	*
Concrete characteristics Time of concrete Different surfaces Design working life [year] Risk of corrosion attack			CMD	00						Design	*
Concrete characteristics Time of concrete Different surfaces Design working life [year] Risk of corrosion attack Corrosion induced by carbonation			CMD 50,0	00 3 ne						Design	
Concrete characteristics Time of concrete Different surfaces Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides			CMD 50,0 XC3 Nor	00 3 ne						Design	•
Concrete characteristics Time of concrete Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides from sea water			CMD 50,0 XC3 Nor Nor	00 3 ne ne						Design	
Concrete characteristics Time of concrete Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides Freeze / thaw attack			CMD CMD 50,0 XC3 Nor Nor Nor	00 3 ne ne ne						Design	
Concrete characteristics Ture of concrete Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides freeze / thaw attack Chemical attack			CMD CMD 50,0 XC3 Nor Nor Nor Nor	00 3 ne ne ne						Design	
Concrete characteristics Ture of concrete Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides Freeze / thaw attack Chemical attack Risk of abrasion attack			CMD CMD 50,0 XC3 Nor Nor Nor Nor	00 3 ne ne ne						Design	
Concrete characteristics Ture of concrete Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides from sea water Freeze / thaw attack Chemical attack Risk of abrasion attack Possibilty of special control			CMD 50,0 XC3 Nor Nor Nor Nor	00 3 ne ne ne						Design	
Concrete characteristics Ture of concrete Design working life [year] Risk of corrosion attack Corrosion induced by carbonation Corrosion induced by chlorides Corrosion induced by chlorides Corrosion induced by chlorides from sea water Freeze / thaw attack Chemical attack Risk of abrasion attack Possibilty of special control Special geometric control			CMD 50,0 XC3 Nor Nor Nor	00 3 ne ne ne	In all.					Design	

The values of Δc_{dev} can be found in the National Annex:

E-Standard EN	Name	Standard EN
i General	Concrete	
Concrete Non-prestressed reinforcement	General	
Prestressed reinforcement Durability and concrete cover	Concrete Non-prestressed reinforcement	
- ULS - General	Prestressed reinforcement	
	Durability and concrete cover National annex	
- General - Prestressing	Clause 4.4.1.2(5)	
 Allowable stress Stress limitation during tensioning 		(6)
SLS stress limitation	 Δc_{dur,st} - reduction of minimum concrete cover for use of s Δc_{dur,add} - reduction of minimum concrete cover for use of 	
 Common detailing provisions Columns 	■ k _{XM} - values of abrasion for classes XM 1,2,3 4.4.1.2(13)	addition
Beams	$\Box \Delta c_{dev}$ - value of deviation for concrete cover 4.4.1.3(3)	
	Values [mm]	5,0 / 10,0 / 5,0

Analysis models

Eurocode

Structural models for overall analysis (art 5.3.1)

The elements of a structure are classified, by consideration of their nature and function, as beams, columns, slabs, walls, plates, arches, shells etc. Rules are provided for the analysis of the commoner of these elements and of structures consisting of combinations of these elements.

For buildings the following provisions are applicable:

- 1) A beam is a member for which the span is not less than 3 times the overall section depth. Otherwise it should be considered as a deep beam.
- 2) A slab is a member for which the minimum panel dimension is not less than 5 times the overall slab thickness.
- 3) A slab subjected to dominantly uniformly distributed loads may be considered to be one way spanning if either:
 - it possesses two free (unsupported) and sensibly parallel edges.
 - it is the central part of a sensibly rectangular slab supported on four edges with a ratio of the longer to shorter span greater than 2.
- 4) Ribbed or waffle slabs need not be treated as discrete elements for the purposes of analysis, provided that the flange or structural topping and transverse ribs have sufficient torsional stiffness.

This may be assumed provided that:

- the rib spacing does not exceed 1500 mm
- the depth of the rib below the flange does not exceed 4 times its width.
- the depth of the flange is at least 1/10 of the clear distance between ribs or 50 mm, whichever is the greater.
- transverse ribs are provided at a clear spacing not exceeding 10 times the overall depth of the slab.

The minimum flange thickness of 50 mm may be reduced to 40 mm where permanent blocks are incorporated between the ribs.

5) A column is a member for which the section depth does not exceed 4 times its width and the height is at least 3 times the section depth. Otherwise it should be considered as a wall.

SCIA Engineer

Assignment of analysis model

In SCIA Engineer several types of analysis models are available. It is up to the user to decide which model should be used for which element.

For 1D members, there is the choice between Beam, Beam slab and Column calculation. Each element has a property 'Type' assigned to it, to determine which type of calculation will be used:

Properties	4 ×
Member (1)	🖃 Va V/ 🖉
	😤 🙈
Name	B1
Туре	beam (80) 🔹 🔹
Analysis model	general (0)
CrossSection	beam (80) column (100)
Alpha [deg]	gable column (70)
Member syste	secondary column (60) rafter (90)
ey [mm]	purlin (0)
ez [mm]	roof bracing (0) wall bracing (0)
LCS	girt (0)
LCS Rotation	truss chord (95)
FEM type	truss diagonal (90) beam slab (99)

The Beam calculation is used for the Types 'General', 'Beam, 'Rafter', 'Purlin', 'Roof bracing', 'Wall bracing', 'Girt', 'Truss chord' and 'Truss diagonal'.

The Beam slab calculation is used only for the Type 'Beam slab'. For this type, by default no shear reinforcement is added (unless necessary in case of a slab thickness of 200 mm or more, as defined in the Concrete Setup for slabs). As diameter for the longitudinal reinforcement, the default diameter for 2D structures – and not for beams! – is taken from the Concrete Setup.

The Column calculation is used for the Types 'Column', 'Gable column' and 'Secondary column'.

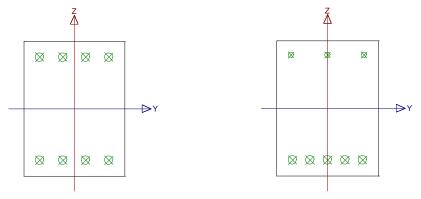
Be careful when 1D member data are added to an element, via Concrete menu > Setting per member > 1D member data. Also there, the user has the choice for the 3 different analysis models, by means of the option "Member type":

	CMD	×
Member	B2	^
Member type	Beam	
Advanced mode	Beam	
Solver setting	Column Beam slab	
🗆 General	Dealth slab	
🗆 Creep		
Type input of creep coefficient	Auto	· · · · · · · · · · · · · · · · · · ·
Internal forces		
Internal forces ULS		
Take into account additional tensile force caused by shear (shift rule)		
Interaction diagram		
Interaction disgram mathed	NRAMRA	

These 1D member data *overwrite* both the element properties and the default settings in the Concrete settings.

Difference between Beam and Column analysis model

The most important difference between Beam and Column calculation is the difference in reinforcement area per direction. A beam has an upper reinforcement area that differs from the lower reinforcement area. A column always has the same reinforcement configuration for the parallel sides, per direction.



These configurations are obvious, and caused by the difference in dominant internal forces per calculation type. For a beam calculation the bending moment is dominant, while for a column calculation the axial compression force + bending moments (if present).

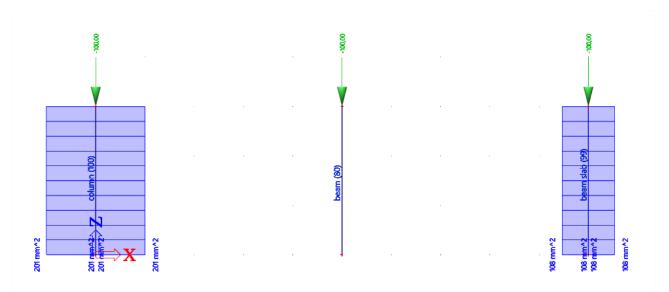
So in fact, when the axial pressure on a beam is too high, the user should choose to calculate the element as a column. In the concrete settings an option is available to consider if the member is in compression or not. If the member is compressed, the second order effect is taken into account. Go to Concrete > Concrete settings (structure) > Solver setting > General:

ational annex:	1	Cor	ncrete setting	JS				Find] [View 🗸		Level				
Description	Symbol		Value	_	Default	Ur	nit	Chapter	JL	Code		(advanc		CheckT		^
<al> ho</al>	<all></all>	Q	<all></all>	>	<all> 🔎</all>) <a< th=""><th><i>p</i></th><th><all></all></th><th>Q</th><th><all></all></th><th>Q</th><th><al></al></th><th>P</th><th><al></al></th><th>Q</th><th></th></a<>	<i>p</i>	<all></all>	Q	<all></all>	Q	<al></al>	P	<al></al>	Q	
Solver setting																
General																
Limit value of unity check	Lim.check		1,0		1,0					Independent		All (Bean	n,	Solver se	etti	
Value of unity check for not calculated unity check	Ncal.check		3,0		3,0					Independent		All (Bean	n,	Solver se	etti	
The coefficient for calculation effective depth of cross-section	Coeffd		0,9		0,9					Independent		All (Bean	n,	Solver se	etti	
The coefficient for calculation inner lever arm	Coeff-		0.9		0.9					Independent	_	All (Rean	n	Solver s	atti	
The coefficient for calculation force, where member as under compression	Coeff _{com}		0,1		0,1					Independent		All (Bean	n,	Solver se	etti	
- creep	_															
Type input of creep coefficient	Туре ф		Auto		Auto			Annex B.1		EN 1992-1-1		All (Bean				
Relative humidity	RH		50		50	%		Annex B.1		EN 1992-1-1		All (Bean	n,	Solver se	etti	
Age of concrete at loading	to		28,00		28,00	da	у	Annex B.1		EN 1992-1-1		All (Bean	n,	Solver se	etti	
Age of concrete at the moment considered	t		1825,00		1825.00	da	v	Annex B.1		EN 1992-1-1		All (Bean	n	Solver se	etti	

This option 'The coefficient for calculation force, where member as under compression' will check how important the contribution of the axial compression force is:

- If the axial compression load $N_{Ed} < 0.1^*A_c^*f_{cd}$, the member is not considered to be in compression, which means the type 'Beam' is the right choice.
- If the axial compression load N_{Ed} > 0,1*Ac*f_{cd}, the member is considered to be in compression, which means the beam has to be modelled as type 'Column' and the second order effect will be taken into account.

Example



Overall Design (ULS)

Linear calculation Load case: LC2 Coordinate system: Member Extreme 1D: Member Selection: All Longitudinal required reinforcement

Name	dx	Case	Member	Asz req+	A _{sz req} -	A _{sy req+}	A _{sv} req-	A _{sz req}	A _{sy req}	A _{s req}	ReinfReq
	[m]			[mm ²]	[mm ²]	[mm²]	[mm²]	[mm²]	[mm ²]	[mm ²]	
				A _{sz req bar+}	Asz reg bar-	A _{sy req bar+}	A _{sy req bar-}	A _{sz req bar}	A _{sy req bar}	A _{s req bar}	
				[mm ²]	[mm ²]	[mm²]	[mm²]	[mm²]	[mm ²]	[mm ²]	
B1	0,000	LC2	Column	201	201	201	201	402	402	804	[z]4ф16*,
				201	201	201	201	402	402	804	[y]4 φ16 *
B2	0,000	LC2	Beam	0	0	0	0	0	0	0	
				0	0	0	0	0	0	0	
B3	0,000	LC2	Beam slab	108	108	108	108	215	215	430	[z+]2 φ 16*,
				201	201	201	201	402	402	804	[z-]2 φ 16*,
											[y+]2 φ 16*,
											[y-]2 φ 16*

Shear reinforcement

Name	dx [m]	Case	Member	A _{swm req} [mm²/m]	A _{swm prov} [mm²/m]	ShearReinf
B1	0,000	LC2	Column	0	0	
B2	0,000	LC2	Beam	0	0	
B3	0,000	LC2	Beam slab	0	0	Not required

Under internal forces, a warning will be displayed in the detailed output whether it is necessary to calculate an element as column, to take into account the compression forces. If needed, the type has to be changed manually to column in the member properties or via 1D member data.

Compression member

Limit axial force to consider member as compression:

 $N_{com} = -Coeff_{com} \cdot (f_{cd} \cdot A_c) = -0.1 \cdot (6.4 \cdot 10^6 \cdot 0.09) = -57.6 \text{ kN}$

Check condition:

 N_{Ed} < N_{com} = -100 kN < -58 kN ... compression member

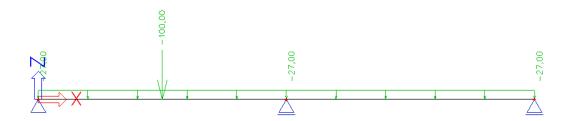
Warning: First and second order eccentricities should be taken to account, member should be evaluated as column (significant compressive normal force). Change type of member to Column.

Beam design

Description of used example

The example that will be used to explain reinforcement calculation in a beam is called 'beam.esa'.

The beam reinforcement calculation is explained by means of the following two span beam:



The length of the total beam is 10 m and it has a dimension of 500x300mm.

The inputted loads are:

- 1) BG1: self weight
- 2) BG2: permanent load
 - Line load: -27 kN/m
 - Point load: -100 kN at position x = 0.25
- 3) BG3: variable load
 - Line load: -15 kN/m
 - Point load: -150 kN at position x = 0

Recalculated internal forces

Reinforcement calculation in SCIA Engineer is based on recalculated internal forces. The pure internal forces calculated by the mechanical FEM calculation are transformed according to code regulation into 'recalculated internal forces' to design the reinforcement.

These recalculated internal forces can be viewed in the Concrete menu of SCIA Engineer.

Shifting of bending moments (art 9.2.1.3)

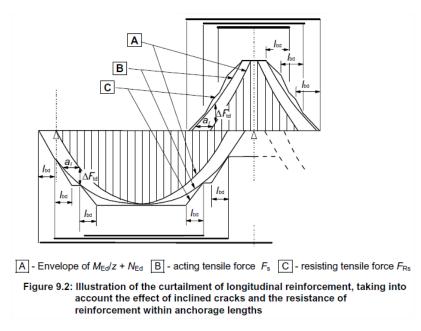
Sufficient reinforcement should be provided at all sections to resist the envelope of the acting tensile force, including the effect of inclined cracks in webs and flanges.

Additional tensile forces caused by shear and torsion are taken into account in SCIA Engineer by using the simplified calculation based on shifting of bending moments according to clause 9.2.1.3(2). Shifting of bending moments is calculated only for beams and beams as slab.

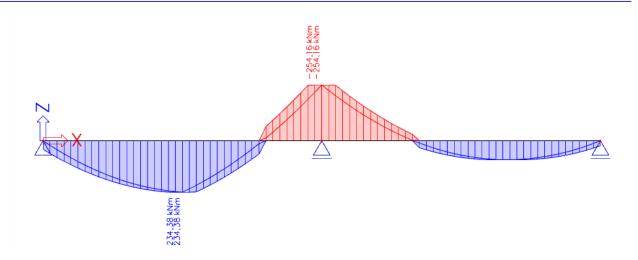
For members with shear reinforcement the additional tensile force, ΔF_{td} , should be calculated. For members without shear reinforcement, ΔF_{td} may be estimated by shifting the moment curve a distance $a_I = d$ (for beams as slab). This "shift rule" may also be used as an alternative for members with shear reinforcement, where:

$$a_l = z \left(\cot \theta - \cot \alpha \right) / 2 \quad \text{(for beams)} \tag{9.2}$$

The additional tensile force is illustrated in Figure 9.2:



In SCIA Engineer the user can review the recalculated internal forces. In the Concrete menu it is possible to view the internal forces and recalculated internal forces. In the figure below the difference is clearly visible:



The shifted moment line is taken into account for recalculated internal forces and by this also for the calculation of longitudinal reinforcement, if activated in the concrete settings (for the global structure) or in the 1D member data (individually per member):

Internal forces ULS					
Take into account additional tensile force caused by shear (shi	V	V		9.2.1.3(2)	EN 1992-1-1
Use minimum value of eccentricity	V	V		6.1(4)	EN 1992-1-1
Use geometric imperfection	V	V		5.2(5)	EN 1992-1-1
Use second order effect	V	V		5.8.8	EN 1992-1-1
Estimation ratio of longitudinal reinforcement for recalculation in μ_{S}	2,00	2,00	%	5.8.3.1	EN 1992-1-1
Shear force reduction above supports				6.2.1(8)	EN 1992-1-1
Moment reduction above supports				5.3.2.2 (4)	EN 1992-1-1
Internal forces ULS					
Take into account additional tensile force caused by shear (shift rule)					
Shear force reduction above supports					
Moment reduction above supports					

Reduction of bending moment (art 5.3.2.2 (3) & 5.3.2.2 (4))

Another typical case of recalculated internal forces is the moment capping at supports.

Where a beam or slab is monolithic with its supports, the critical design moment at the support should be taken as that at the face of the support. The design moment and reaction transferred to the supporting element (e.g. column, wall, etc.) should be generally taken as the greater of the elastic or redistributed values.

Regardless of the method of analysis used, where a beam or slab is continuous over a support which may be considered to provide no restraint to rotation (e.g. over walls), the design support moment, calculated on the basis of a span equal to the centre-to-centre distance between supports, may be reduced by an amount ΔM_{Ed} as follows:

$$\Delta M_{Ed} = F_{Ed,sup} t / 8$$

(5.9)

where:

t

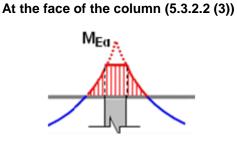
F_{Ed,sup} is the design support reaction

is the width of the support

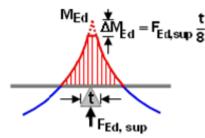
In SCIA Engineer this reduction of bending moment is only taken into account if it is activated in the concrete settings (for the global structure) or in the 1D member data (individually per member):

nternal forces ULS					
Take into account additional tensile force caused by shear (shi	\checkmark	V		9.2.1.3(2)	EN 1992
Use minimum value of eccentricity	\checkmark	V		6.1(4)	EN 1992
Use geometric imperfection	\checkmark	V		5.2(5)	EN 1992
Use second order effect	\checkmark	V		5.8.8	EN 1992
Estimation ratio of longitudinal reinforcement for recalculation in μ_{S}	2,00	2,00	%	5.8.3.1	EN 1992
Shear force reduction above supports				6.2.1(8)	EN 1992
Moment reduction above supports	V			5.3.2.2 (4)	EN 1992
Internal forces ULS					
Internal forces ULS Take into account additional tensile force caused by shear (shi	ít rule)				
	ft rule)				

The way in which the moment reduction is performed, is based on the type of support. If a standard support is defined, the reduction will be done following formula 5.9. If a column is defined the, reduction at the face of the column is used.



Using formula 5.9 (5.3.2.2 (4))



In SCIA Engineer the width t used for the moment reduction at supports can be set in the properties of that support:

Properties			Ψ×
Support in node (1)	🗖 Vã	1 🏹 🖉
			8
Name	Sn2		
Туре	Standard		*
Angle [deg]			
Constraint	Sliding		· •
x	Free		*
Z	Rigid		*
By	Free		
Default size [m]	0.200		
Node	K2		

In the bottom of the 1D member data there is an action button "Update support width". This button collects all linked members or supports of the selected member and reads their support widths.

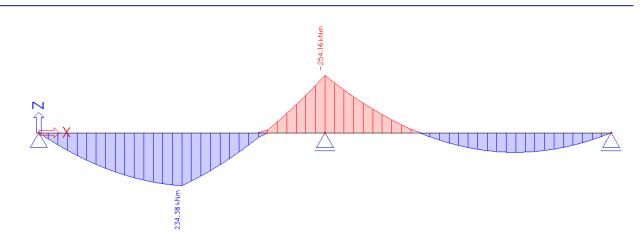
3	CMD	
Name	CMD1	^
Member	S1	
Member type	Beam	•
Advanced mode		
Solver setting		
General		
Creep		
Type input of creep coefficient	Auto	*
Internal forces		
Internal forces ULS		
Take into account additional tensile force caused by shear	🔽	
Interaction diagram		
Interaction diagram method	NRdMRd	*
Shear		
Type calculation/input of angle of compression strut	User(angle)	*
Angle of compression strut [deg]	40,00	
Cotangent angle of compression strut	1,19175359259421	
Crack width		
Type of maximal crack width	Auto	-
Deflections		
Maximal total displacement L/x; x =	250	
Maximal additional displacement L/x; x =	500	×
Actions		_
Update support width		>>>
Concrete Setup		>>>

2 9	Sn1 Sn2	0,000 5,000	0,200	V	V
_	Sn2	5.000			
3 9		5,000	0,200		\checkmark
	Sn3	10,000	0,200		
		ded from construction witho			

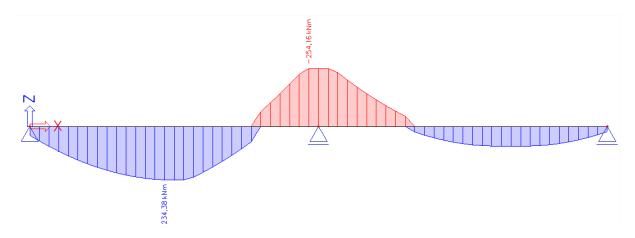
The reduction of moment by moment capping at supports is illustrated for our example below:

- t = 0.2 m
- $F_{Ed,sup} = 477.5 \text{ kN}$
- $\Delta M_{Ed} = 477.5*0.2 / 8 = 11.94 \text{ kNm}$

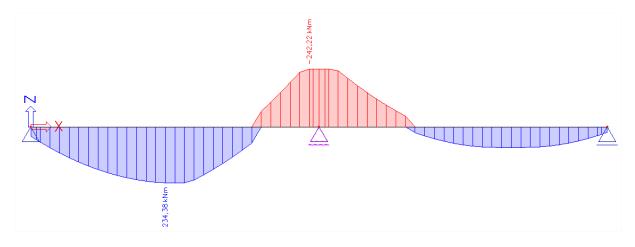
The original moment My at the support was 254.16 kNm.



The recalculated moment clearly shows the shifting of the moment line.



With moment capping at support taken into account the recalculated moment is 242.22 kNm.



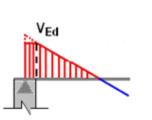
Reduction of shear forces (art 6.2.1 (8))

For members subject to predominantly uniformly distributed loading, the design shear force does not need to be checked at a distance less than d from the face of the support. Any shear reinforcement required should continue to the support. In addition it should be verified that the shear at the support does not exceed $V_{Rd,max}$.

In SCIA Engineer this reduction of shear forces is only taken into account if it is activated in the concrete settings (for the global structure) or in the 1D member data (individually per member):

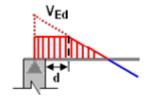
Determination or unitavourable direction	AULO	AULO		J.O.J	EN 1332-1-
Internal forces ULS					
Take into account additional tensile force caused by shear (shi		V		9.2.1.3(2)	EN 1992-1-
Use minimum value of eccentricity	V	V		6.1(4)	EN 1992-1-
Use geometric imperfection	V	V		5.2(5)	EN 1992-1-
Use second order effect	V	V		5.8.8	EN 1992-1-
Estimation ratio of longitudinal reinforcement for recalculation in µs	2,00	2,00	%	5.8.3.1	EN 1992-1-
Shear force reduction above supports	V			6.2.1(8)	EN 1992-1-
Reduce shear forces	On the face (su	upport/cOn the fa		6.2.1(8)	EN 1992-1-
Moment reduction above supports	On the face (su	upport/column)			992-1-
Internal forces SLS	On the face (su	upport/column) + effecti	ve depth	of cross-se	ection
Internal forces ULS					
Take into account additional tensile force caused by shear (shift rule)					
Shear force reduction above supports					
		On the face (support/col	umn)		
Reduce shear forces		On the face (support/con	anning		
Reduce shear forces Moment reduction above supports		On the face (support/cold On the face (support/cold On the face (support/cold	umn)		

It is possible to choose the type of reduction of shear forces at the face of the support or at a distance d from the face of the support:



At the face of the column

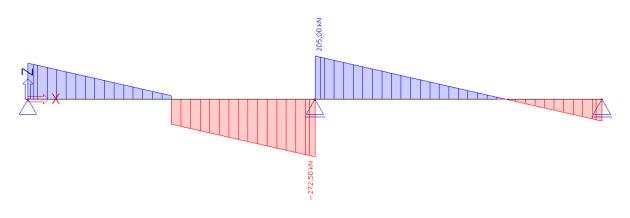
At the face of the column + effective depth of the cross-section (based on 6.2.1 (8))



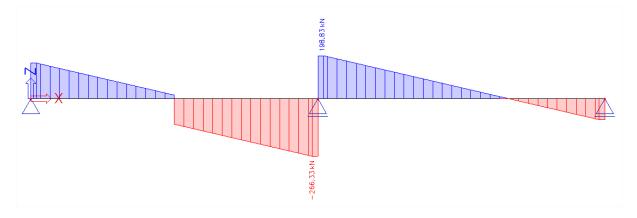
Also for the reduction of shear forces, the support width t is taken into account, which is taken from the properties of the support or the 1D member data.

The reduction of shear forces at supports is illustrated for our example below with t = 0.2 m:

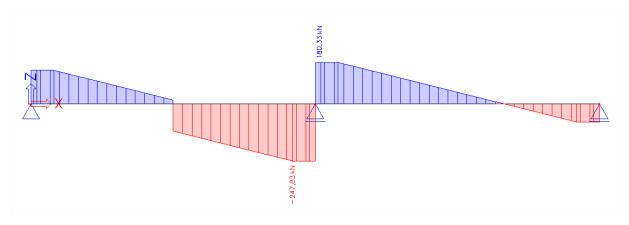
The first image displays the original Vz :



The second image shows the reduction at the face of the support:



The last image shows the reduction at the effective depth from the face:



Theoretical reinforcement

Configuration

The theoretical reinforcement is calculated out of the recalculated internal forces. It gives the amount of reinforcement needed to resist the internal forces induced by ULS loads. Since there are several workflows possible to design concrete beam elements, the theoretical reinforcement design is not mandatory to perform. Experienced users can directly jump to practical reinforcement to perform the checks on, but this theoretical approach gives a good idea of how this practical reinforcement should look like.

The configuration of this theoretical reinforcement can be found in the Design defaults under Reinforcement design. Templates of longitudinal reinforcement for different shapes of beam are available. The concrete cover can be set for upper, lower and side faces. For the stirrups, diameter, number of cuts and angle can be adapted. Note that for the practical reinforcement and checks, only vertical stirrups ($\alpha_s = 90^\circ$) are supported.

Concrete # ×	Design defaults								_
Concrete settings (structure) I Reinforcement drawing setting E Setting per member	National annex:					Find		√iew ▼	Adv
= 10 member data	Description	Symb	ol	Value	Default	Unit	Chapter	Code	
	<al></al>	Q <al></al>	ρ	<all></all>	<al></al>	<u>م </u>	<all></all>	Q < all >	Ω
10 buckling data	Design defaults								
E Reinforcement design	Beam (Rib)								
Design defaults	Longitudinal								
□ ID members	Use a template of provided reinforcement			V				Independe	ent
	Rectangular section			Beam_Rec	Beam_Rec			Independe	ent
Slenderness	T section			Beam_Tse	Beam_Tse			Independe	ent
TReinforcement design	L section			Beam_Lse	Beam_Lse			Independe	ent
⊞	I section			Beam_lsec	Beam_Isec			Independe	ent
⊞ Reinforcement check (ULS+SLS) - 1D members	Other and general			Beam_Oth	Beam_Oth			Independe	ent
Section Check - results	Upper								
	Type of cover of upper reinforcement			Auto	Auto		4.4.1	EN 1992-1	1-1
	Lower								
	Type of cover of lower reinforcement			Auto	Auto		4.4.1	EN 1992-1	1-1
	□ Side								
	Type of cover of side reinforcement			Upper	Upper		4.4.1	EN 1992-1	1-1
	Stirrups								
	Diameter of stimups	dss		8.0	8.0	mm		EN 1992-1	
	Number of cuts	ns		2,0	2,0			Independe	
	Angle	αs		90,00	90,00	deg		Independe	ent

Several default templates for longitudinal reinforcement are available for the different section types. These can be adapted or new ones can be made.

🔎 🦆 🏒 📫	🖌 🗠 🗠 🚔 🔒				
Beam_Rect_Empt Beam_Rect_Basic, Beam_Rect_Basic, Beam_Rect_Basic, Beam_Rect_Basic, Beam_Rect_Basic, Beam_Rect_Basic,	Vertic Horiz _Add_Vertic _Add_Horiz _AddList_Vertic		Upper		
Name	Beam_Rect_Basi	Side		Side	
Description	Basic and fix add				
Member type	Beam				
Cross-section	Rectangle				
Mode	Standard				
			Lower		
New Insert	Edit Delete				ОК

This template exists of basic and additional reinforcement for the upper, lower and side faces. The exact use of these templates will be elaborated under next paragraph on longitudinal reinforcement. However, the purpose is to compare these templates with the required reinforcement, to model the longitudinal reinforcement that should be introduced later on. The basic reinforcement is present along the whole length of the beam; the additional reinforcement is present only at the zones where basic reinforcement is not sufficient to withstand (recalculated) internal forces. A choice can be made between fixed additional bars (diameter and number) or a list with different numbers of bars with a fixed

diameter. SCIA Engineer uses the least amount of necessary additional bars, or places the maximum if this template is still not sufficient to resist the (recalculated) internal forces.

ement mber Are [mm^2 402 0 402	
nber Are [mm^2 402 0	2] both corners no corners
[mm^2 402 0	2] both corners no corners
402 0	both corners no corners
0	no corners
402	both corners
	0

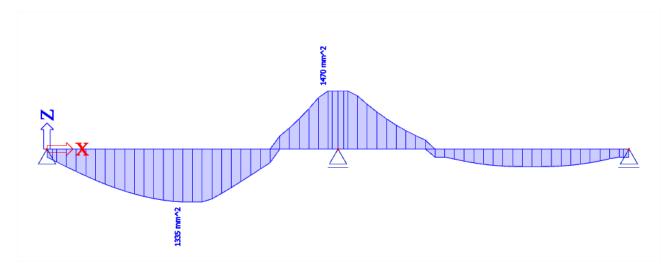
Calculation of longitudinal reinforcement As

The longitudinal reinforcement calculation is based on My,recalc represented in the previous chapter.

The only thing left to be set in the concrete setup is the material quality and default diameter:

- Material quality is set to B 500A. This can be changed in the project data or concrete 1D member data.
- The default diameter is set to 16mm. This parameter is taken from the additional reinforcement diameter of the reinforcement template under Design defaults, or from 1D member data.

The following results are obtained with these settings:



In the following image you can see the brief output in the preview:

Longitudinal required reinforcement

Name	dx [m]	Case	Member	Asz_req+ [mm ²] Asz_req_bar+ [mm ²]	Asz_req- [mm ²] Asz_req_bar- [mm ²]	A _{sy_req+} [mm ²] A _{sy_req_bar+} [mm ²]	Asy_req- [mm ²] Asy_req_bar- [mm ²]	Asz_req [mm ²] Asz_req_bar [mm ²]	A sy_req [mm ²] A _{sy_req_bar} [mm ²]	As_req [mm ²] A _{s_req_bar} [mm ²]	ReinfReq
S1	2,333-	ULS	Beam	0	1335	0	0	1335	0	1335	[z-]7φ16
				0	1407	0	0	1407	0	1407	
S1	4,833-	ULS	Beam	1470	0	0	0	1470	0	1470	[z+]8¢16
				1608	0	0	0	1608	0	1608	

You can also ask a standard or a more detailed output where you can find more information about certain parameters used in the calculation, for example:

d: lever arm of reinforcement.

 $d = h - cover - \Phi_{stirrup} - \Phi_{longitudinal beam} / 2 = 500 - 35 - 8 - 16/2 = 449 mm$

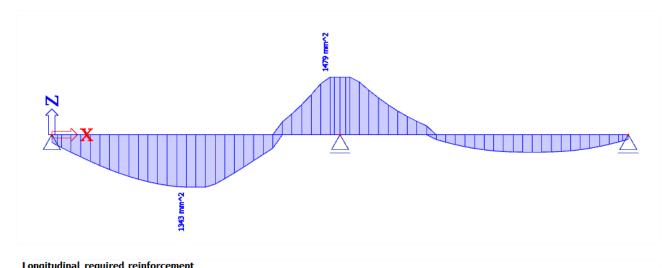
(the cover is defined by the environmental class and is 35 mm for XC3)

The only internal force working on this beam is M_{yd} . N_d and T_d are zero.

 $A_{sy_req} = 0$ because there is no torsion on this beam.

Note that the detailing provisions are deactivated. Otherwise no reinforcement of $\phi = 16$ mm could be proposed, since the detailing provisions are not met (bar distance too small).

If the default diameter is set to 20mm, the following results are obtained:



Longitua	ongitudinal required reinforcement													
Name	dx	Case	Member	Asz_req+	Asz_req-	Asy_req+	Asy_req-	Asz_req	Asy_req	As_req	ReinfReq			
	[m]			[mm²]	[mm²]	[mm²]	[mm²]	[mm²]	[mm ²]	[mm²]				
				Asz_req_bar+	A sz_req_bar-	A _{sy_req_bar+}	A _{sy_req_bar} -	Asz_req_bar	A _{sy_req_bar}	As_req_bar				
				[mm²]	[mm²]	[mm²]	[mm²]	[mm²]	[mm ²]	[mm ²]				
S1	2,333-	ULS	Beam	0	1343	0	0	1343	0	1343	[z-]5 ф 20			
				0	1571	0	0	1571	0	1571				
S1	4,833-	ULS	Beam	1479	0	0	0	1479	0	1479	[z+]5¢20			
				1571	0	0	0	1571	0	1571				

If you take a close look at these results, you can see that also the value for A_{s,req} has changed.

This is because the lever arm d has decreased:

d = h -cover - Φ_{stirrup} - $\Phi_{\text{longitudinal beam}}/2$ = 500 - 35 - 8 - **20**/2 = 447 mm

As you can see, the default diameter has also a slight effect on the amount of reinforcement that is required, because of the changed lever arm.

Note that 1D member data can be used to change the default diameter for the bar to which these data are assigned. It is obvious that the 1D member data have higher priority than the Concrete settings.

1	CMD	
Type of concrete	In-situ	- ^
Beam (Rib)		
Longitudinal		
Material	B 500A	×
🗆 Upper		
Diameter of upper reinforcement [mm]	20,0	· · · · · · · · · · · · · · · · · · ·
Type of cover of upper reinforcement	Auto	· · · · · · · · · · · · · · · · · · ·
🗆 Lower		
Diameter of lower reinforcement [mm]	20,0	· · · · · · · · · · · · · · · · · · ·
Type of cover of lower reinforcement	Auto	· · · · · · · · · · · · · · · · · · ·
Side		
Type of cover of side reinforcement	Upper	· · · · · · · · · · · · · · · · · · ·
Stirrups		
Material of stirrups	B 500A	💌
Diameter of stirrups [mm]	8,0	*

Next to the required reinforcement area, also the unity check UC can be viewed to check for maximum reinforcement area and $A_{s,req}(\phi)$ for the reinforcement translated into bars.

Properties	4	×	Pr	roperties				Ч×
Overall Design (ULS) (1)	🧧 Va V/ 🖉	1	0	verall Design (ULS) (1)		-	Va V	40
	S 🐔 🛎						s 🗸	
Name	Overall Design (ULS)			Name	Overall Design (ULS)			
Selection				Selection				
Type of selection	All	-		Type of selection	All			-
Filter	No	-		Filter	No			-
Results in sections	All	-		Results in sections	All			-
□ Result case				Result case				
Type of load	Combinations	-		Type of load	Combinations			-
Combination	ULS	-		Combination	ULS			-
Extreme 1D				Extreme 1D				
Extreme 1D	Global	-		Extreme 1D	Global			-
Type of values	Required	-		Type of values	Provided			-
Values	As,req			Values	As, add, req			1
	As, req	h		Output settings	As, add, req			- L
	Aswm,req UC (As,max)			Output	As,prov UC (As,req)			
	UC (Asymax)			Print combination key	UC (As, max)			
	As,req (φ)		Đ	Drawing Setup 1D	As,prov (φ)			
	Aswm,req (φ/s) Components		Đ	Errors, warnings and notes se	As,add,req (φ) Components			
Run using Model Data files (Debug)				Run using Model Data files (Debug)				

The provided reinforcement $A_{s,prov}$ gives the amount of reinforcement or in bars ($A_{s,prov}$), determined by the template. $A_{s,add, req} = A_{s,req} - A_{s,prov}$, thus the amount of reinforcement which still has to be added to the template to resist the (recalculated) internal forces. If $A_{s,prov} > A_{s,req}$, $A_{s,add, req} = 0$. Also unity checks can be performed on the provided reinforcement.

Calculation of shear reinforcement Aswm

Name	dx [m]	Case	Member	A _{swm_req} [mm²/m]	A _{swm_prov} [mm²/m]	ShearReinf
S1	7,333-	ULS	Beam	298	309	ф8/325mm, (ns=2)
S1	4,900	ULS	Beam	1315	1340	ф8/75mm, (ns=2)

Shear reinforcement

V_{Ed} = design shear force resulting from external loading

- $V_{Rd,c}$ = design shear resistance of the member without shear reinforcement
- $V_{Rd,s}$ = design value of the shear force which can be sustained by the yielding shear reinforcement
- **V**_{Rd,max} = design value of the maximum shear force which can be sustained by the member, limited by crushing of the compression struts

In general we can have three cases:

- V _{Ed} > V _{Rd,max}	Concrete strut failure
- $V_{Ed} \leq V_{Rd,c}$	Shear force carried by concrete. No shear reinforcement necessary (minimum shear reinforcement according to detailing provisions)
- $V_{Ed} > V_{Rd,c}$ and $V_{Ed} < V_{Rd,max}$	Shear reinforcement necessary in order that: $V_{Ed} \leq V_{Rd}$

Members NOT requiring design shear reinforcement: VEd < VRd,c (art 6.2.2)

$$V_{Rd,c} = [C_{Rd,c} \, k (100 \, \rho_l \, f_{ck})^{1/3} + k_1 \, \sigma_{cp}] \, b_w \, d \tag{6.2.a}$$

with a minimum of

$$V_{Rd,c} = (v_{min} + k_1 \sigma_{cp}) b_w d$$
 (6.2.b)

where:

fck	= characteristic concrete compressive strength [MPa]
k	= size factor: k = 1 + $\sqrt{(200/d)}$ ≤ 2,0 (with d in mm)
ρι	= longitudinal reinforcement ratio: $\rho_{I} = A_{sI}/b_{w}d \le 0.02$
bw	= smallest web width of the cross-section in the tensile area [mm]
σ_{cp}	= concrete compressive stress due to loading: $\sigma_{cp} = N_{Ed}/A_c < 0.2 f_{cd}$ [MPa]
d	= effective height of cross section

The recommended value for $C_{Rd,c}$ is 0,18/ γ_c , that for k_1 is 0,15 and that for v_{min} is given by expression:

$$v_{min} = 0,035 \ k^{3/2}. \ f_{ck}^{1/2} \tag{6.3N}$$

The shear force V_{Ed} , calculated without reduction by β , should always satisfy the condition:

 $V_{Ed} \leq 0.5 b_w d v f_{cd}$

(6.5)

where v is a strength reduction factor for concrete cracked in shear.

The recommended value for v follows from:

$$V = 0.6 \left[1 - \frac{f_{ck}}{250} \right] \tag{6.6N}$$

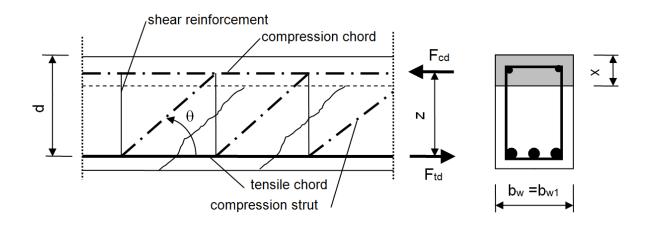
In SCIA Engineer, it is possible to input the following parameters:

itandard EN	Name	Standard EN
🖻 Concrete	Concrete	
🚍 General		
Concrete	General	
··· Non-prestressed reinforcement		
···· Prestressed reinforcement	🗆 General	
Durability and concrete cover	\oplus $\theta_n = 1/x$ - basic value of inclination 5.2(5)	
General		
⊡- SLS	Type of simplified method for analysis second order effect	
···· General	C _{Rd,c}	
Prestressing		0.10
- Allowable stress	Value [-]	0,18
Stress limitation during tensioning	k _{1,shear} - coeff. for calculation Vrd, c 6.2.2(1)	
SLS stress limitation	Value [-]	0,15
Detailing provisions Common detailing provisions	□ v _{min} - coeff. for calculation Vrd, c for shear 6.2.2(1)	
- Columns		Formula
Beams	Formula	Formula
beams	v - strength reduction factor for concrete cracked in shear 6.2.2(6)	
	Formula	Formula

Note that the green values are according to EN code.

Members requiring design shear reinforcement: VEd > VRd,c (art 6.2.3)

The design of members with shear reinforcement is based on the theory of the concrete truss-model. In this theory, a virtual truss-model is imagined in a concrete beam. This truss-model has a set of vertical (or slightly diagonal), horizontal and diagonal members. The vertical bars are considered to be the stirrups, the horizontal bars are the longitudinal reinforcement bars and the diagonal bars are the concrete struts.



The angle θ should be limited.

The recommended limits of $\cot \theta$ are given:

$$1 \leq \cot \theta \leq 2,5$$

The angle θ can be inserted in SCIA Engineer:

		Co	ncrete sett	ings									-	
lational annex:							Find		View	•	Leve (advand		Defau	It
Description	Symbo	bl	Value		Default	Unit	Chapter		Code		Structur	e	CheckType	^
<all></all>	🔎 <all></all>	Q	<all></all>	Q	<al></al>	o (allo 🔎	<al></al>	Q	<al></al>	Q	<al></al>	2	(all) 🔎	ē.,
- Shear														1
Type calculation/input of angle of compression strut	Type 6	1	User(angle)		User(angle)		6.2.3		EN 1992-1-	1	All (Bear	n, \$	Solver settin.	
Angle of compression strut	θ		40,00		40,00	deg	6.2.3		EN 1992-1-	1	All (Bear	n, \$	Solver settin.	
Cotangent angle of compression strut	cot(θ)		1,2		1,2		6.2.3		EN 1992-1-	1	All (Bear	n, \$	Solver settin.	
Shear between web and flanges														•
Type input of angle of compression strut	Туре)f	User(angle)		User(angle)		6.2.4(4)		EN 1992-1-	1	Beam,Be	ea (Solver settin.	
Angle of compression strut	θf		40,00		40,00	deg	6.2.4(4)		EN 1992-1-	1	Beam,Be	ea (Solver settin.	
Cotangent of angle of compression strut	cot(0f		1,2		1,2		6.2.4(4)		EN 1992-1-	1	Beam,Be	ea S	Solver settin.	

For members with vertical shear reinforcement, the shear resistance V_{Rd} is the smaller value of:

$$V_{Rd,s} = \frac{A_{SW}}{s} z f_{ywd} \cot \theta$$
(6.8)

and

$$V_{Rd,max} = \alpha_{cw} b_w z v_1 f_{cd} / (\cot \theta + \tan \theta)$$
(6.9)

where:

Asw	= cross-sectional area of the shear reinforcement
S	= spacing of the stirrups
f _{ywd}	= design yield strength of the shear reinforcement
V 1	= strength reduction factor for concrete cracked in shear
α_{cw}	= coefficient taking account of the state of the stress in the compression chord

The recommended value of v_1 is v (see Expression 6.6N)

If the design stress of the shear reinforcement is below 80% of the characteristic yield stress f_{yk} , v_1 may be taken as:

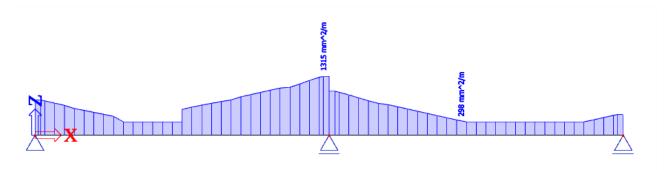
$V_1 = 0, 6$	for $f_{ck} \leq 60 MPa$	(6.10.aN)
$v_1 = 0.9 - f_{ck}/200 > 0.5$	for $f_{ck} \ge 60 MPa$	(6.10.bN)

The recommended value of α_{cw} is 1 for non-prestressed structures.

These code related parameters can be found in the Concrete setup:



If we go back to our example in SCIA Engineer, we find the following $A_{swm,req}$ for the whole beam:



Shear reinforcement

Name	dx [m]	Case	Member	A _{swm_req} [mm²/m]	A _{swm_prov}	ShearReinf
S1	7,333-	ULS	Beam	298	309	ф8/325mm, (ns=2)
<mark>S1</mark>	4,900	ULS	Beam	1315	1340	ф8/75mm, (ns=2)

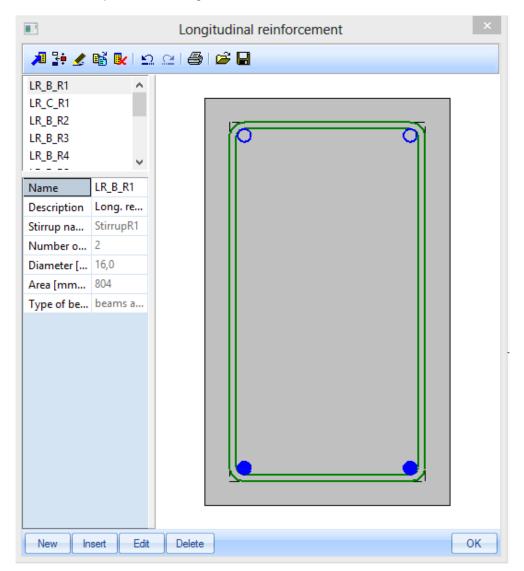
The maximum value of 1315 mm² corresponds to a two section stirrup of ϕ = 8mm every 75 mm.

Practical reinforcement

We will now pass on to the level of practical reinforcement. This will allow us to specify the reinforcement locally over the beam.

In the theoretical reinforcement design, we have calculated where reinforcement is needed. This allows us to input manually the practical reinforcement by adding New reinforcement for the whole length of the beam.

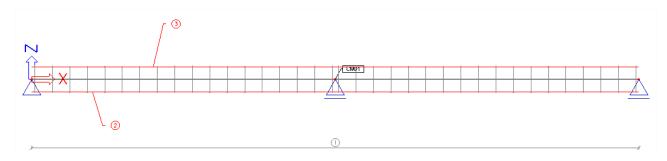
We can first select a template for the longitudinal reinforcement:



Next, we have to decide where the parameters of reinforcement are coming from:

Reinforcement parameters	Х
Do you want to use parameters of reinforcement (diamater of long.reinforcement, stirrup and concrete cover) from the Concrete member data from the Concrete setup (Design default)	
If from the defined template	
ОК	

The practical reinforcement is shown graphically on the screen:

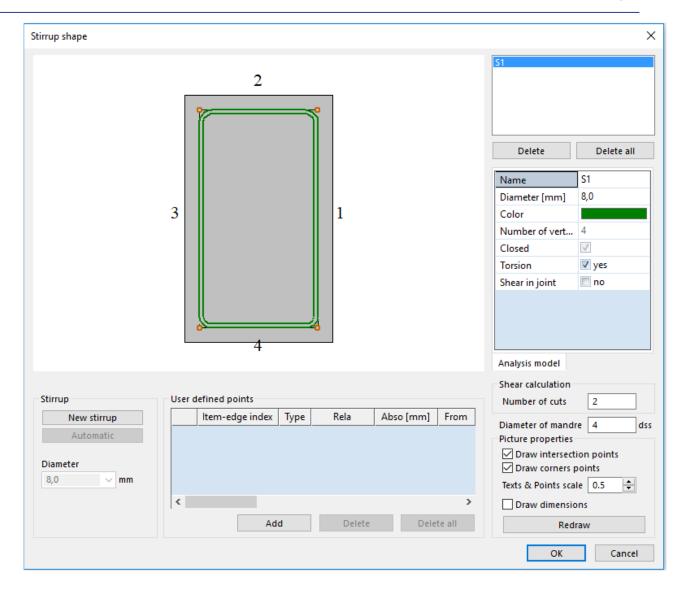


As a user, you can add locally New stirrups or New longitudinal bars.

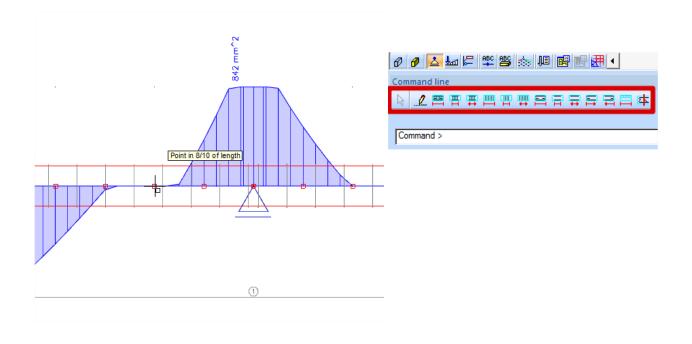
For the stirrups, you can select a certain stirrup shape:

		Stirrup shape manager	×
× 🕫 🖉	📽 🔛 🖸	요 종 62 🔒	
StirrupR1 StirrupR2 StirrupR3 StirrupR4 StirrupR5	^		
Name	StirrupR1		
Description	Stirrups		
Number o	1		
Diameter [8,0		
Number o	2		
New	sert Edit	Delete	ОК

The stirrup shape can be edited or a new one can be made. Therefore user points may be added.



For the longitudinal reinforcement, we can define precisely where the extra practical reinforcement needs to be putted:



The configuration for the selected zone of the member is shown:

	Member S	1, Zone from 0,	500 m to 4,000 m(0.05	0 - 0.400)	
		2		Filter All L1-51E4 L2-51E2	
				Delete	Delete all
				Name	L2-S1E2 ^
			1	Position num	3
	3		1	Material	B 500A 👻
				Diameter [mm]	20,0
				Number of b	2
				Area [mm^2]	628
				Layer type	Uniform 💌
				Cover type	Surface to 💌
				Cover [mm]	0,0
				Left bar	Before the 💌
		4		Right bar	Before the 💌
				Stirrup name	S1 🔻 🗸
				Analysis model	Automatic design
ongitunidal reinforcement	New reinforcemen	t parameters	Type of beam	Reinforcement I	ayers area
New layer	Number of bars	2 🗸	beams and ribs	Selected layers	628 mm/
Add bars to corners	Diameter [mm]	8,0 🗸		All layers	1257 mm/
	Stirrup name	51 V	Stirrups	Picture propertie	
Province it is not	Edge index	2 🗸	Edit stirrups	Draw dimen	
Bars positions Collision of bars			Edit cover	Texts scale	0.5 🜩
Collision	Between existin Move layer	ng bars	Save to template	Re	draw

Here can be set on which face extra reinforcement needs to be added:

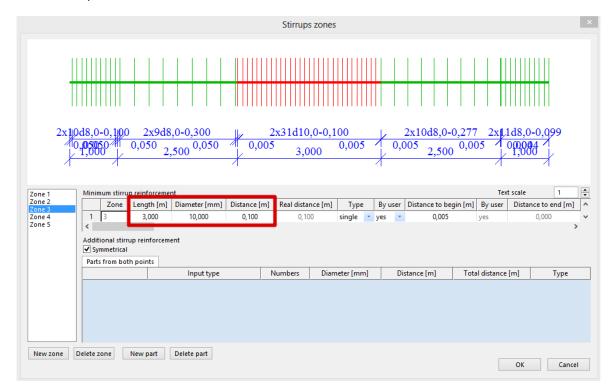
	Member S1	, Zone from 0	,500	m to 4,000 m(0.050 - 0.400	0		2
	P	2			Filter All L1-S1E4 L2-S1E2 L3-S1E4		~
					Delete	Delet	e all
					Name	L3-S1E4	^
			1		Position num	5	
	3				Material	B 500A 🝷	
					Diameter [mm]	20,0	
					Number of b	3	
					Area [mm^2]	942	
					Layer type	No corner	*
					Cover type	Surface to	•
					Cover [mm]	0,0	
					Stirrup name	S1	*
		4			Edge index	4	*
					Detailing	🗖 no	~
					Analysis model	Automatic	design
Longitunidal reinforcement	New reinforcement	parameters		Type of beam	- Reinforcement la	ayers area	
New layer	Number of bars	3 🗸		beams and ribs 🗸 🗸	Selected layers	942	mm^
Add bars to corners	Diameter [mm]	20,0 ¥			All layers	2199	mm^
	Stirrup name	S1 ♥	i I I	Stirrups	Picture propertie	5	
	Edge index	4 v		Edit stirrups	Draw dimens		
Bars positions	Logement	- · ·		Edit cover	Texts scale	0.5	÷
Collision of bars			Т	Save to template	Rei	draw	
Collision	 Between existing Move layer 	g bars					

For reasons of simplicity we will add 3 bars of 20mm that are still needed over the whole area where extra reinforcement is required. This can of course be done more detailed.

The same procedure will be repeated for the upper reinforcement over the support.

Also the shear reinforcement needs to be increased in the zones over the support. This can be done by increasing the diameter of the stirrups or by decreasing the distance between the stirrups.

Different stirrup zones can be created:

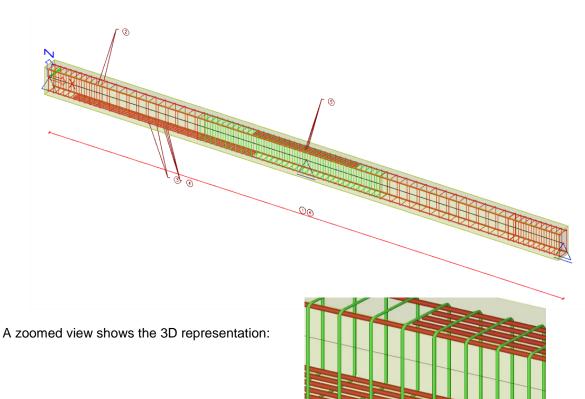


To check if there is enough shear reinforcement, a capacity check needs to be performed. This will be explained in the next chapter.

By selecting the reinforcement it is always possible to change the parameters afterwards through the property window.

Through view parameter settings a 3D representation of the reinforcement can be obtained:

	View parameters	setting
	Check / Uncheck group	Lock position
4	🖻 😐 🛃 🛃 🔟 📓) 🖉 🔍 🕨
	Check / Uncheck all	
E	Service	
	Display on opening the service	
E	Concrete + reinforcement	
	Display	
	Member data	
	SaT detail data	
	Drawing directions for design	
	Main reinforcement	V
	Style of main reinforcement	all 🔹
	Stirrups	
	Style of stirrups	all 🔹
	Number of stirrups	all 🔹
	Color of reinforcement	colour by diameters 🔹
	Scheme of reinforcement	
	Reinforcement drawing type	3D 🔹
	Rounded bends	✓
E	Concrete labels	
	Display label	✓
	Name	✓



The total practical reinforcement of the beam is shown below:

Checks

In SCIA Engineer, checks can be performed in three different ways:

- 1. With practical reinforcement inputted on the member, checks can be done one by one for all sections of the member
- 2. With practical reinforcement inputted on the member, overall ULS or SLS checks can be done for a specific section of the member with the tool "Section check"
- 3. Without practical reinforcement, overall ULS or SLS checks can be done for a specific section of the member with the tool "Section Check". Reinforcement will then be added locally in the Section check tool to be able to perform the various available checks.

First you get an overview of the input data for the checks:

- Internal forces: displaying the characteristic and design values
- Slenderness: determining if 2nd order effects need be considered (for member type 'column')
- Stiffnesses: displaying the values EA, El_y and El_z

Available checks at the Ultimate Limit State are:

- **Capacity check:** for N-My-Mz interaction based on resistance calculated from interaction diagram
- Response check: based on check of ultimate stresses and strains for N-My-Mz interaction
- Check of shear and torsion
- Check of interaction of shear, torsion, bending and normal force

Available checks at the Serviceability Limit State are:

- Stress limitation (for concrete as well as reinforcing steel)
- Crack width limitation
- **Simple check for deflection:** based on calculation of stiffness ratio, without necessity to calculate Code Dependent Deflection (CDD)

The capacity, response and shear + torsion check should be okay if no additional reinforcement is required.

However, these checks give interesting information on the efficiency of reinforcement. For instance, if in a section only 50% of reinforcement is used, then we can conclude that here less reinforcement would have been sufficient.

The detailing provisions and the crack limitation are extra checks that are not accounted in the reinforcement design. If these checks are not okay, then the practical reinforcement needs to be changed.

In the following chapters, we will explain the checks one by one when practical reinforcement is inputted. It corresponds to the 1st method to perform a check (see above).

Example 1: 'beam_practical reinforcement.esa'

The last chapter will be focused on the Section check tool, corresponding to 2nd and 3rd methods to perform a check (see above).

Example 2: 'beam_without practical reinforcement.esa'

Capacity response

The Capacity - response is based on the calculation of strain and stress in a particular component (concrete fibre or reinforcement bar).

The check consists of the comparison of those strains and stresses with the limited values according to EN 1992-1-1 requirements.

However, this method does not calculate extremes (capacities of the cross-section) like the interaction diagram, but calculates the state of equilibrium for that section (response). For capacities of the member, please refer to the "Capacity – diagram" check.

The following checks are performed:

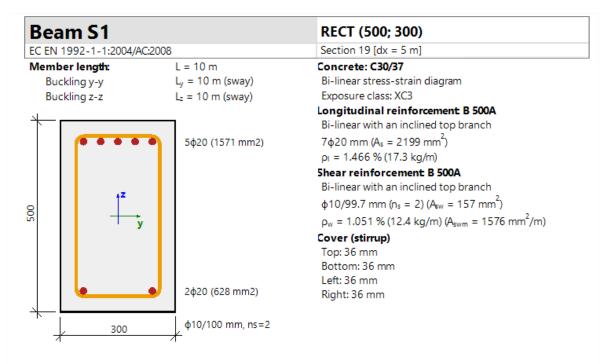
- Check of compressive concrete (cc)
- Check of compressive reinforcement (sc)
- Check of tensile reinforcement (st)

The Unity Check, UC, displayed on the screen will be the maximum value of those 3 checks.

Example: 'beam_practical reinforcement.esa'

Run the Capacity – Response check in Concrete menu > Reinforcement check (ULS+SLS) > Capacity – Response (ULS)

The maximum value of the check is given on the middle support. The Standard output gives:



Summary of check

Type of component	Fibre / Bar		σ _{extr} [MPa]	Check strain [-]	Check stress [-]	UC [-]	Limit [-]	Status
Concrete	1	-1.63	-18.7	0.47	0.93	0.95	1	ОК
Reinf.	1	2.17	434	0.10	0.95			

In the Standard output you can read the UC, and the extreme strain and stress in the studied section.

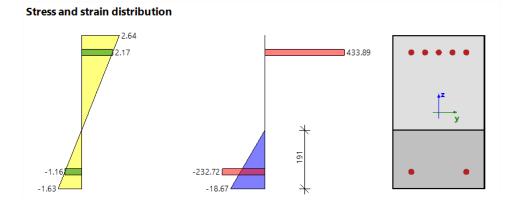
In the Detailed output you will get all the strains and stresses and the limit strains and stresses:

Type of component	Fibre /	ε	ε _{lim}	σ	σ _{lim}	UC [-]	Status
	Bar	[‰]	[‰]	[MPa]	[MPa]		
Concrete - compression	1	-1.63	-3.5	-18.7	-20	0.93	ОК
Concrete - tension	3	2.64	0	0	0	0.00	ОК
Reinforcement - compression	3	-1.16	-22.5	-233	-454	0.51	ОК
Reinforcement - tension	1	2.17	22.5	434	454	0.95	ОК

Extreme values of stress/strain in component

Note that the tensile stress in concrete is not considered, therefore the corresponding UC is 0.

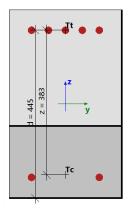
Stress and strain diagrams are also available in the Detailed output:



Settings that might influence the check:

• Effective depth of cross-section - d

It is usually defined as distance of the most compressive fibre of concrete to centre of gravity of tensile reinforcement. In SCIA Engineer, the effective depth of cross-section is defined as distance of the most compressive fibre of concrete to position resultant of forces in tensile reinforcement.



The effective depth d cannot be calculated in the following cases:

- The most compressive fibre cannot be determined (the whole cross-section is in tension)
- Resultant of forces in tensile reinforcement cannot be determined (whole section is in compression)
- Equilibrium is not found
- Distance of the most compressive fibre and Resultant of forces in tensile reinforcement is less than 0,5·h

In those cases, the effective depth is calculated according to formula: $d = Coeff_d * h_I$ Coeff_d by default 0.9 in Concrete settings > Solver settings > General

h height of cross-section perpendicular to neutral axis

	Conc	rete setting	js				_ □
National annex:				Find	View 🔻	Advanced	Default
Description	Symbol	Value	Default Unit	Chapter	Code	Structure	CheckTy
<all></all>	<all></all>	<all></all>	<all></all>	<all></all>	<all></all>	<all> 🔎</all>	<all> 🔎</all>
Solver setting							
General							
Limit value of unity check	Lim.check	1.0	1.0		Independent	All (Bea	Solver se
Value of unity check for not calculated unity check	Ncal.check	3.0	3.0		Independent	All (Bea	Solver se
The coefficient for calculation effective depth of cross-s	Coeff _d	0.9	0.9		Independent	All (Bea	Solver se
The coefficient for calculation inner lever arm	Coeffz	0.9	0.9		Independent	All (Bea	Solver se
The coefficient for calculation force, where member as	Coeff _{com}	0.1	0.1		Independent	All (Bea	Solver se

• Inner lever arm

z is defined in EN 1992-1-1, clause 6.2.3 (3) as the distance between position resultant of tensile force (tensile reinforcement) and position of resultant of compressive force (compressive reinforcement and compressive concrete).

The inner lever arm cannot be calculated in the following cases:

- The most compressive fibre cannot be determined (the whole cross-section is in tension)
- Resultant of forces in tensile reinforcement cannot be determined (whole section is in compression)
- Equilibrium is not found

In those cases, it is calculated according to formula: $z = \text{Coeff}_z * d$ Coeff_z by default 0.9 in Concrete settings > Solver settings > General

	Cone	crete	setting	S								-		1
National annex:							F	ind	View	- A	dvano	ed	Defa	ult
Description	Symbol	Valu	е	Defaul	t	Unit	Chapte	r	Code	S	tructu	ire (heckT	<u>y</u>
<all></all>	<all></all>) <all< td=""><td>ς Ω</td><td><all></all></td><td>ρ</td><td></td><td><all></all></td><td>ρ</td><td><all></all></td><td><u>ہ</u></td><td>all></td><td>ρ</td><td><all></all></td><td>ρ</td></all<>	ς Ω	<all></all>	ρ		<all></all>	ρ	<all></all>	<u>ہ</u>	all>	ρ	<all></all>	ρ
Solver setting														
General														
Limit value of unity check	Lim.check	1.0		1.0					Independe	ent A	l (Bea	a S	olver s	е
Value of unity check for not calculated unity check	Ncal.check	3.0		3.0					Independe	ent A	l (Bea	a S	olver s	е
The coefficient for calculation effective depth of cross-s	Coeff.	0.9		0.9					Independe	ent A	l (Bea	a S	olver s	е
▶ The coefficient for calculation inner lever arm	Coeff _z	0.9		0.9					Independe	ent A	l (Bea	a S	olver s	е
The coefficient for calculation force, where member as	Coeff _{com}	0.1		0.1					Independe	ent A	l (Bea	a S	olver s	е

For additional information about this check and the theoretical background, please refer to our web help.

Capacity diagram

Capacity - diagram services uses the creation of interaction diagram (graph presenting the capacity of a concrete member to resist a set of N+My+Mz).

This check calculates the extreme allowable interaction between the normal force N and bending moments My and Mz.

Example: 'beam_practical reinforcement.esa'

Run the Capacity – Diagram check in Concrete menu > Reinforcement check (ULS+SLS) > Capacity – diagrapm (ULS)

The standard output gives the summary result of the check:

Summary of check

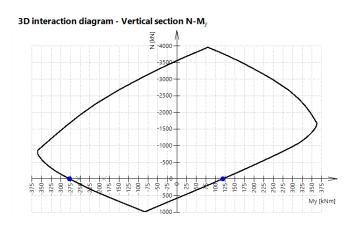
Ν	N _{Ed}	\mathbf{N}_{Rd+}	My	M _{Edy}	M _{Rdy+}	M _{Rdy-}	UC	Status
		N _{Rd-}	Mz	M _{Edz}	M _{Rdz+}	M _{Rdz-}		
[kN]	[kN]	[kN]	[kNm]	[kNm]	[kNm]	[kNm]	[-]	
0	0	0	-261	-261	119	-278	0.939	OK
		0	0	0	0	0		${\rm M}_{\rm Edz}/{\rm M}_{\rm Rdz}$

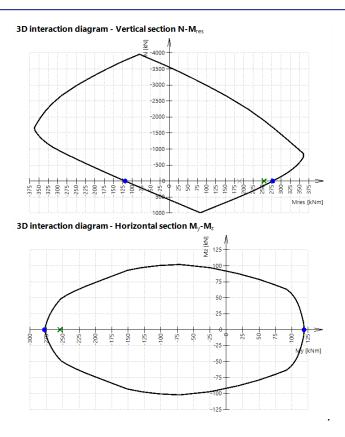
The Detailed output gives additional info about how the check is performed:

Summary of check

Forces: $N_{Ed} = 0 \text{ kN}$ $M_{Edy} = -261 \text{ kNm}$ $M_{Edz} = 0 \text{ kNm}$ Resistance: $N_{Rd} = 0 \text{ kN}$ $M_{Rdy} = -278 \text{ kNm}$ $M_{Rdz} = 0 \text{ kNm}$ Calculation of unity check $UC = \frac{\sqrt{N_{Ed}^2 + M_{Edy}^2 + M_{Edz}^2}}{\sqrt{N_{Rd}^2 + M_{Rdy}^2 + M_{Rdz}^2}} = \frac{\sqrt{0^2 + -261^2 + 0^2}}{\sqrt{0^2 + -278^2 + 0^2}} = 0.939 \quad <= 1$ OK

Interaction diagrams are also drawn in the Detailed output:





Settings that might influence the check:

- Interaction diagram method
- Division of strain
- Number of points in vertical cuts

For additional information about this check and the theoretical background, please refer to our web help.

Shear + Torsion

Check of Interaction shear and torsion consists of three checks according to clause 6.1 - 6.3 in EN 1992-1-1:

- check of shear
- check of torsion
- check of interaction of shear and torsion

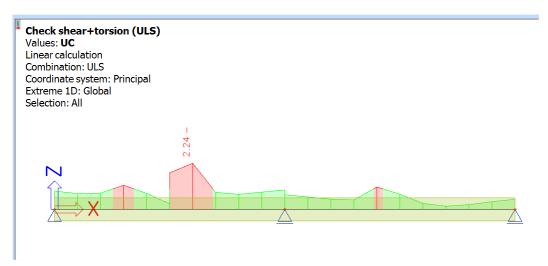
This check can be performed if the following conditions are met:

- The material of all reinforcement bars and stirrups are the same
- The angle between gradient of the strain plane and the resultant of shear forces is not greater than 15°
- Cross-section with one polygon and one material

Example: 'beam_practical reinforcement.esa'

Run the Shear + Torsion check in Concrete menu > Reinforcement check (ULS+SLS) > Shear + Torsion (ULS)

Some parts of the beam do not satisfy:



The Standard output allows us to identify which specific check is not satisfied:

Forces

Content of combination: 1.35*LC1+1.35*LC2+1.50*LC3	
$N_{Ed} = 0 \ kN M_{Edy} = 203 \ kNm M_{Edz} = 0 \ kNm V_{Edy} = 0 \ kN$	V_{Edz} = -152 kN T_{Ed} = 0 kNm
Resultant of shear force	Difference between angles $\alpha_{\!M}$ and $\alpha_{\!V}$
$V_{Ed} = \sqrt{V_{Edy}^2 + V_{Edz}^2} = \sqrt{0^2 + -152^2} = 152 \text{ kN}$	$\alpha_{MV} = abs(\alpha_M - \alpha_V) = abs(90 - 90) = 0^{\circ}$

Summary of check

Summary of check

Interaction check Vy+Vz+T (concrete)

Interaction check Vy+Vz+T (long. reinf.) 0.0 kN

Interaction check Vy+Vz+T (shear)

 d = 445 mm
 z = 383 mm
 b_w = 300 mm
 V_{Rdc} = 87.8 kN
 V_{Rds} = 66.5 kN
 V_{Edmax} = 705 kN
 V_{Rdmax} = 598 kN

 Type of check
 Forces
 Resistances
 UC [-]
 Status

 Check shear Vy+Vz
 151.7 kN
 66.5 kN
 2.28
 Not OK

 Check torsion
 0.0 kNm
 0.0 kNm
 0.00
 OK

0.0 kN

0.0 kN

0.0 kN

0.00

0.00

0.00

2.28

OK

ОК

ОК

Not OK

Here the shear forces cause a unity check >1.

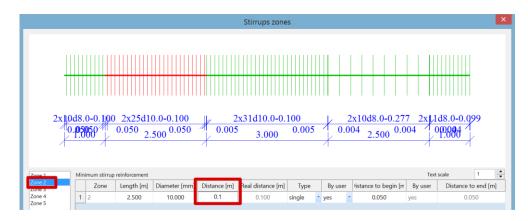
In the Detailed output we can read notes, warning and errors about the design. For example, for the shear forces check not satisfied, the report clearly explains that the shear reinforcement is not sufficient and that we have to increase it.

Shear c	heck
Chec <mark>k</mark> V	Rdmax
	V_{Ed} = 152 kN \leq V_{Rdmax} + V_{ccd} + V_{td} = 598 kN
Note:	The check satisfies for crushing of the compression strut ($V_{Ed} \le V_{Rd,max} + V_{td} + V_{ccd}$).
Check V	Edmax
	V_{Ed} = 152 kN \leq V_{Edmax} + V_{ccd} + V_{td} = 705 kN
Note:	The check satisfies for shear force near the support ($V_{Ed} \leq V_{Ed,max} + V_{td} + V_{ccd}$).
Check V	R _{dc} and V _{Rds}
	V_{Ed} = 152 kN > V_{Rdc} = 87.8kN and V_{Ed} = 152 kN > V_{Rds} + V_{ccd} + V_{td} = 66.5 kN
	The check does not satisfy, because of shear reinforcement ($V_{Ed} > V_{Rds} + V_{ccd} + V_{td}$). It is necessary to increase of shear reinforcement or to increase dimensions of the cross-section or quality of shear reinforcement.
Unity cl	neck
-	$UC = \frac{abs(V_{Ed})}{V_{ed}} = \frac{abs(152 \text{ kN})}{66.5 \text{ kN}} = 2.28$

Various actions can be done to fix this issue. In this example, we choose to decrease the spacing of the stirrups in the section where there is an issue.

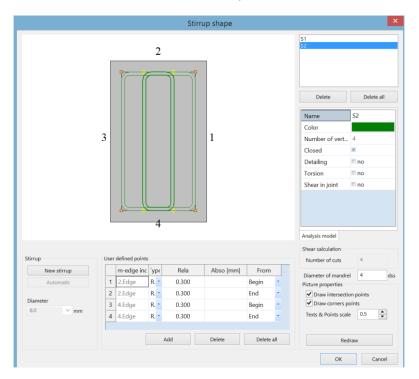
Select stirrups and click on "Edit stirrups distances" at the bottom of the Properties of the stirrup layers:

Properties		4 ×
Stirrups layer (1)		V/ /
	Ś	* *
Name	RL	^
Type of zone	stirrups	
Detailing	🗖 no	
Material	B 500A	·
Calculation of cuts n	User	-
Number of cuts	2	
Diameter of mandrel	4	
Anchorage		
Туре	Α	-
Torsion type	D	-
Anchorage L [mm]	0	
Keep formwork	🗹 yes	
B Geometry		
Test of overlapping	🖻 no	
Whole length beam	🗷 yes	
Member	S1	
Position x1	0.000	
Position x2	1.000	~
Actions		
Edit stirrup shape		>>>
Edit covers		>>>
Edit stirrups distances		>>>



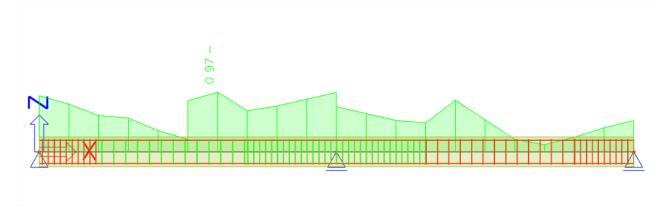
Select "Zone 2" and change the distance between stirrups from 0.3m to 0.1m:

We could also have added more stirrups like below:



Changing the stirrup shape allows us to keep a bigger distance of 0.2m between stirrups in "Zone 2".

After modification, the shear + torsion check is satisfied:



Settings that might influence the check:

• Coefficient for calculation of effective depth of cross-section

Default value 0.9 in Concrete settings > Solver settings > General

• Coefficient for calculation of inner lever arm

Default value 0.9 in Concrete settings > Solver settings > General

• Angle of concrete compression strut

3 types of input in Concrete settings > Solver settings > Shear:

- User (angle) user input of the angle by default
- User (cotangent) user input of the cotangent
- Auto automatic calculation of the angle fulfilling equation 6.29

	nex:									-ind			lvanced		
Descrip	ption	Sy	mbol	Value		Default	t	Unit	Chapte	er	Code	St	ructure	CheckT	
all>		P <a< th=""><th>all> 🖌</th><th>) <all></all></th><th>Q</th><th><all></all></th><th>ρ</th><th></th><th><all></all></th><th>ρ</th><th><all></all></th><th>Q <</th><th>all> 🔎</th><th><all></all></th><th>Q</th></a<>	all> 🖌) <all></all>	Q	<all></all>	ρ		<all></all>	ρ	<all></all>	Q <	all> 🔎	<all></all>	Q
Solver	setting														
🗄 Ge	eneral														
🗄 Int	ernal forces														
🕂 De	esign As														
🗄 Int	eraction diagram														
🗏 Sh	ear														
•	Type calculation/input of angle of compression strut	Тур	beθ	User(angle	User(ar	ngl		6.2.3		EN 1992-	1-1 All	(Bea	Solver s	e
	Angle of compression strut	θ		Auto		00		deg	6.2.3		EN 1992-	1-1 All	(Bea	Solver s	e
•	Cotangent angle of compression strut	cot	i(θ)		angle) cotange	nt)			6.2.3		EN 1992-	1-1 All	(Bea	Solver s	e
	Shear between web and flanges														
	Type input of angle of compression strut	Тур	be θ _f	User(angle)	User(ar	ngl		6.2.4(4)	EN 1992-	1-1 Be	am,B	Solver s	e
	Angle of compression strut	θ _f		40.00		40.00		deg	6.2.4(4)	EN 1992-	1-1 Be	am,B	Solver s	e
	Cotangent of angle of compression strut	cot	:(θ _t)	1.2		1.2			6.2.4(4)	EN 1992-	1-1 Be	am,B	Solver s	e

The angle should be between θ_{min} and θ_{max} defined in the NA for EN1992-1-1.

	Concrete setup	
Standard EN Concrete General	 □ General □ θ_n=1/x - basic value of inclination 5.2(5) 	
Oncrete Non-prestressed reinforcement Prestressed reinforcement	Value [-] 200.00 □ λ _{lim} 5.8.3.1(1)	
□ Durability and concrete cover □ ULS □ General	Formula Formula Image: Type of simplified method for analysis Image: Type of simplified method for analysis	
General Prestressing Allowable stress	Formula Method based on nominal curvature (5.8.8) CRd,c Value [-] 0.18	
Stress limitation during tensioning SLS stress limitation Detailing provisions	Value [] k _{1,shear} - coeff. for calculation Vrd,c 6.2.2 Value [] 0.15	
Common detailing provisions Columns Beams	vmin coeff. for calculation Vrd,c for shear Formula Formula	
	v - strength reduction factor for concret Formula E k - Coefficient for calculation of longitu	
	Value [-] 0.40 θ _{min} - min. angle between the concrete cor	
	Value [deg] 21.80 □ θ _{min,prestressed} - min, angle between the cc Value [deg] 21.80	
	Value [dec] 21.00 Ømax - max. angle between the concrete co Value [deg] Value [deg] 45.00	
2	emin,c - Minimal angle between the concret Value [deg] 0.00	

• Angle of shear reinforcement

Practical reinforcement can only be introduced at 90°.

• Type for determination equivalent thin-walled cross-section

For additional information about this check and the theoretical background, please refer to our web help.

Stress limitation

Stress limitation is based on the verification of:

- **compressive stress in concrete** the high value of compressive stress in concrete could lead to appearance of longitudinal cracks, spreading of micro-cracks in concrete and higher values of creep (mainly nonlinear). This effect can lead to a state where the structure is unusable.
- **tensile stress in reinforcement** stress in reinforcement is verified due to limitation of unacceptable strain existence and thus appearance of cracks in concrete.

Example: 'beam_practical reinforcement.esa'

The stress limitation check is done according to the following steps:

- 1. Verification of crack appearance
- 2. Verification of the stresses

The Standard output shows those 2 steps:

Verification of cracks in cross-section

Load	Type of module	-	Combi.		M _{Edy}	M _{Edz}	σ _{ct} [MPa]	h [mm]	- count	Cracks appear
Short			Char.	0	-188	0	12.6		2.9	YES

Stress limitation in concrete

Check type	Load		M _{Edy} [kNm]			z _i [mm]	σ _c [MPa]	2,000	σ _c /σ _{c,lim} [-]	Status
§7.2(2) Char.	Short	0	-188	0						OFF
§7.2(3) QP.	Short	0	-188	0	0.15	-0.25	-21.2	-13.5	1.57	Not OK

Stress limitation in non-prestressed reinforcement

Check type	Load			M _{Edz} [kNm]			-	-	3° 3,000	Status
§7.2(5) Char.	Short	0	-188	0	0.09	0.2	300	400	0.75	ОК

Verification of crack appearance

Crack appearance is verified for characteristic load combination in accordance to chapter 7.1(2) in EN1992-1-1:

- $\sigma_{ct} \leq f_{ct,eff}$ no crack appears
- $\sigma_{ct} > f_{ct,eff}$ crack appears

 σ_{ct} maximal tensile stress in concrete fibre f_{ct,eff} effective concrete tensile strength

Verification of stresses

There are 3 stress limitations checked:

- $\sigma_{c,char,lim} \le k_1 \times f_{ck}$ concrete stress under Char. load 7.2(2) exposure classes XD, XF, XS
- $\sigma_{c,qp,lim} \le k_2 \times f_{ck}$ concrete stress under Quasi Perm. load chapter 7.2(3)
- $\sigma_{s,char,lim} \le k_3 \times f_{yk}$ reinforcement stress under Char. Load chapter 7.2(5)

Values of k1, k2, k3, are defined in the NA, standard values are respectively 0.6, 0.45, 0.8

Additionally, when the stress in the reinforcement is caused by an imposed deformation, then the maximal strength is increased to $k_4 \times f_{yk}$, where k_4 is NA parameter with standard value $k_4 = 1,0$. This option can be activated in Concrete settings > Stress limitations:

					Concre	te set	tings					_ □ ×
ational annex:							Find	View -	Advanced	Default		Remark
Description	Symbol		Value		Default	Unit	Chapter	Code	Structu	CheckT		
all>	<all></all>	ρ	<all></all>	ρ	<all> 🔎</all>)	<all> 🔎</all>	<all></all>	0 <all> 🗘</all>) <all> 🔎</all>		
Solver setting												
General												
Internal forces												
Design As												
H Interaction diagram												
H Shear												k ₃ ×f _{yk}
H Torsion												
Stress limitations	-	-	_									×
Indirect load (imposed deformation)							7.2(5)	EN 1992-	I-1 All (Bea.	Solver s		
Eracking forces											<<	k ₄ × f _{yk}
Deflections												
Detailing provisions												
<i>€</i> -												When the stress in reinforcement is caused by the indirect load (imposed deformation) then the stress should not exceed different maximal value
												OK Cancel

By default, stress limitation check is done for short-term state.

It is possible to perform a long-term state. Effective E modulus of elasticity is calculated as follows, using the creep coefficient:

 $E_{c,eff} = E_{cm} / (1 + \phi)$

Long-term behaviour can be activated in Concrete Setting > Solver settings > General > SLS > Use effective modulus of elasticity.

The creep coefficient can whether be calculated by the software or inputted manually in the Concrete settings.

onal annex:					Find	View 🔻	Advanc	ed Default		Remark
Description	Symbol	Value	Default	Unit	Chapter	Code	Struct	CheckT		
> O	<all> 🔎</all>	<all></all>) <all> 🔎</all>)	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>		
Solver setting										
General										
Limit value of unity check	Lim.check	1.0	1.0			Independe	All (Bea	Solver s		
Value of unity check for not calculated unity check	Ncal.check	3.0	3.0			Independe	All (Bea	Solver s		
The coefficient for calculation effective depth of cr	Coeff _d	0.9	0.9			Independe	All (Bea	Solver s		
The coefficient for calculation inner lever arm	Coeffz	0.9	0.9			Independe	All (Bea	Solver s		E _{cm}
The coefficient for calculation force, where membe	Coeff _{com}	0.1	0.1			Independe	All (Bea	Solver s		
Creep										
Type input of creep coefficient	Туре ф	Auto	Auto		Annex B.1	EN 1992-1-1	All (Bea	Solver s		
Relative humidity	RH	50	50	%	Annex B.1	EN 1992-1-1	All (Bea	Solver s	<<	E _{cm}
Age of concrete at loading	t _o	28.00	28.00	day	Annex B.1	EN 1992-1-1	All (Bea	Solver s		1+φ
Age of concrete at the moment considered	t	1825.00	1825.00	day	Annex B.1	EN 1992-1-1	All (Bea	Solver s		
SLS										
Use effective modulus of concrete					7.1(2)	EN 1992-1-1	All (Bea	Solver s		
Default sway type										
Minimal concrete cover										Possibility to use effective E modulus of
Internal forces										concrete. It means the longterm
Design As										behaviour of concrete is covered in the analysis of the crack width and stiffnes
Interaction diagram										calculation
Shear										
Torsion								~		

Note: Scia Engineer is not able to use characteristic or quasi-permanent combinations together in one step. Therefore, the same forces (load combination) are used for crack appearance and final stress values.

Crack width

The crack width is calculated according to clause 7.3.4 in EN 1992-1-1.

The following preconditions are used for calculation:

- The crack width is calculated for beams and columns and for general loads (N+My+Mz)
- Cross-section with one polygon and one material is considered in version SEN 17
- The material of all reinforcement bars must be the same in SEN 17
- Appearance of cracks should be calculated for a characteristic combination according to EN 1992-1-1, clause 7.2(2). A simplification is made in SEN 17 that the normal stress is calculated for the same type of combination as used for the calculation of crack width, inputted in service Crack control.

Example: 'beam_practical reinforcement.esa'

First a determination whether the section is cracked or un-cracked is performed by comparing:

- $\sigma_{ct} \leq \sigma_{cr}$ Uncracked
- $\sigma_{ct} > \sigma_{cr}$ Cracked

Value for σ_{cr} can be set in the Concrete settings > Cracking forces. Two options can influence this value:

ional annex:							Find		View 🔻	Advanced	Default	Remark Value of strength which is used for
Description	Symbol		Value		Default		Chapter	0	Code	Structu	CheckT	calculation of first crack. It is possible
ll> 🔎	<all></all>	ρ	<all></all>	ρ	<all></all>	С	<all></all>	Q	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>	select between 1) 0 MPa - the first crack appears whe
Solver setting												tensile stress occurs in the cross-sect
General												 fct,eff - the first crack appears whe tensile effective strength of concrete in
Internal forces												reached in the cross-section
Design As												
Interaction diagram												
E Shear												
H Torsion												
Stress limitations												
Cracking forces												
Type of strength for calculation of cracking force	f _{ct,eff}		f _{ctm}		ctm		7.1(2)	E	EN 1992-1-1	All (Bea	Solver s	<<
Value of strength for calculation cracking force			f _{ct,eff}	*	ct,eff		7.1(2)	E	EN 1992-1-1	All (Bea	Solver s	
Detailing provisions												

Value of strength for calculation of cracking forces:

- $\sigma_{cr} = 0$ Mpa cracks appear when tensile stress occurs in the section
- $\sigma_{cr} = f_{ct,eff}$ cracks appear when tensile effective strength of concrete is reached in the section

Type of strength for calculation of cracking forces:

If previous option is set on $\sigma_{cr} = f_{ct,eff}$, which is the default value then:

- f_{ct,eff} = f_{ctm} mean tensile strength of concrete at 28 days set in the material properties.
- f_{ct,eff} = f_{ctm,fl} mean flexural tensile strength (EN 1992-1-1,clause 3.1.8(1)). This value should be used if restrained deformations such as shrinkage or temperature movements are considering for calculation crack width.

	Materials		×
🚚 🤮 🗶 👪 💕	💽 🗠 🖉 🖉 📽 🖬		
C12/15	Colour		^
C16/20	Specific heat [J/gK]	6.0000e-01	
C20/25 C25/30	Temperature dependency of specific h	None	·
C30/37	Thermal conductivity [W/mK]	4.5000e+01	
C35/45	Temperature dependency of thermal c	None	·
C40/50	Order in code	5	
C45/55	B Material behaviour for nonlinear		
C50/60	Material behaviour	Elastic	-
C55/67 C60/75	⊟ EN 1992-1-1		
C70/85	Characteristic compressive cylinder str	30.00	
C80/95	Calculated depended values		
C90/105	Mean compressive strength fcm(28) [38.00	
	fcm(28) - fck(28) [MPa]	8.00	
	Mean tensile strength fctm(28) [MPa]	2.90	
	fctk 0,05(28) [MPa]	2.00	
	fctk 0,95(28) [MPa]	3.80	

Note: The value presented in material properties (picture above) is the mean tensile strength at 28 days. If cracking is expected earlier than 28 days, it is necessary to input this value $f_{ctm}(t)$ into the material properties (EN 1992-1-1, clause 3.1.2(9)).

Css cracked

0 -0.117

0.0533

1.91·10⁻³

370·10⁻⁶

The check of crack appearance, with values of cracking forces (Ncr, Mcry, Mcrz) can be read in the Detailed output:

Material characteristics

Effective strength of concrete:

 $f_{ct,eff} = f_{ctm} = 2.9 \text{ MPa}$

Strength in concrete, when crack is appeared: σ_{cr} = 2.9 MPa

Forces

Modulus of elasticity of concrete: $E_c = E_{cm} = 33 \text{ GPa}$

Cross-section characteristics

Content of combination:	Туре	Css-uncracked	
LC1+LC2+LC3	t _{iy} [m]	0	
Characteristic values	t _{iz} [m]	6.82·10 ⁻³	
N _{char} = 0 kN M _{y,char} = -188 kNm M _{z,char} = 0 kNm	A _i [m ²]	0.163	
Quasi-permanent values	l _{iy} [m ⁴]	3.63·10 ⁻³	
$N_{qp} = 0 \text{ kN}$ $M_{y,qp} = -188 \text{ kNm}$ $M_{z,qp} = 0 \text{ kNm}$	l _{iz} [m ⁴]	1.19·10 ⁻³	
Angle of bending moment resultant			

Angle of bending $\alpha_{M} = -90^{\circ}$

Calculation of cracking forces (uncracked section)

Maximal stress in concrete $\sigma_{ct} = 12.6 \text{ MPa}$ Cracking forces Ncr = 0 kN Mcry = -43.3 kNm Mcrz = 0 kNm σ_{ct} = 12.6 MPa > σ_{cr} = 2.9 MPa => Cracks appear Note: The crack is appeared, because maximal tensile stress is greater than cracking strength.

Here, modulus E is taken for short-term state. As mentioned previously, long-term state with an effective modulus E_{eff} can be chosen in Concrete settings > General > SLS > Use effective modulus E.

In this example, cracks appear. Crack width is then calculated according to EN 1992-1-1, formula 7.8: $W = S_{r,max} \cdot (\epsilon_{sm} - \epsilon_{cm})$

For further details about the calculation, the Detailed output can be analysed. The following picture shows only a part of the report:

Maximum crack spacing

$$s_{max}$$
 = 45 mm \le 5*(c+0.5* ϕ_{eq}) = 275 mm or $\rho_{p,eff}$ = 0, therefore:

$$s_{r,max} = k_3 \cdot c + \frac{k_1 \cdot k_2 \cdot k_4 \cdot \phi_{eq}}{\rho_{p,eff}} = 3.4 \cdot 0.045 + \frac{0.8 \cdot 0.5 \cdot 0.425 \cdot 0.02}{0.0428} = 232 \text{ mm}$$
(7.11)

Mean strain in the reinforcement

$$\varepsilon_{sm_cm} = \max\left(\frac{\sigma_{s} - k_{t} \cdot \left(\frac{f_{ct.eff}}{\rho_{p.eff}}\right) \cdot \left(1 + \alpha_{E} \cdot \rho_{p.eff}\right)}{E_{s}}, \frac{0.6 \cdot \sigma_{s}}{E_{s}}\right)$$

$$= \max\left(\frac{300 \cdot 10^{6} - 0.46 \cdot \left(\frac{2.9 \cdot 10^{6}}{0.0428}\right) \cdot \left(1 + 6.06 \cdot 0.0428\right)}{200 \cdot 10^{9}}, \frac{0.6 \cdot 300 \cdot 10^{6}}{200 \cdot 10^{9}}\right) = 1.3 \%$$
(7.9)

Calculated crack width

 $w = \epsilon_{sm_cm} \cdot s_{r,max} = 1.3 \cdot 232 = 0.303 \text{ mm}$

Limit value of crack width

w_{max} = 0.4 mm

Unity check

Calculation unity check

$$UC = \frac{W}{W_{max}} = \frac{0.303 \text{ mm}}{0.4 \text{ mm}} = 0.757$$

Check crack width

$$w = 0.303 \text{ mm} = < w_{max} = 0.4 \text{ mm}$$

Note: Check crack width satisfies, because the crack width is lesser than limit value.

Standard output will give the summary values:

Summary of check

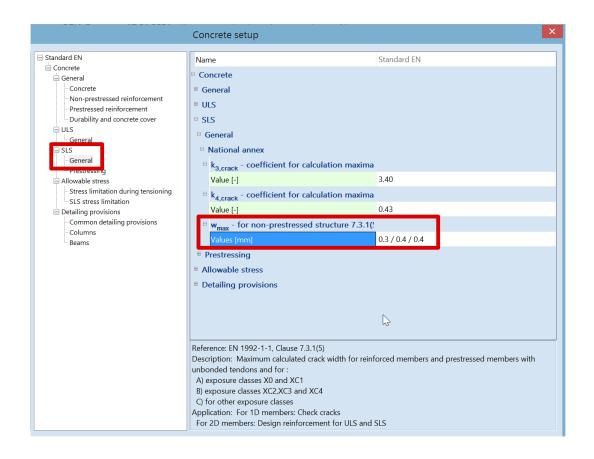
 $N_{cr} = 0 \ kN \ M_{cry} = -43.3 \ kN \ M_{crz} = 0 \ kN \ \sigma_s = 300 \ MPa \ s_{r.max} = 232 \ mm \ \epsilon_{sm_cm} = 1.3 \ \%$

σ _{ct} [MPa]	σ _{cr} [MPa]	Cracked	w [mm]	w _{lim} [mm]	UC [-]	Limit check [-]	Status
12.6	2.9	YES	0.303	0.4	0.76	1	ОК

(7.8)

The limit value of the crack width w_{max} is by default automatically calculated according to EN 1992-1-1 (Table 7.1N). The allowable crack width can be seen in the NA setup:

Manager for National annexes	X
계 밝 ℓ 땅 및 의 은 문 🖉 🖬 📶 🔹	
Standard EN	^
Austrian ÖNORM-EN NA	
Belgian NBN-EN NA	
British BS-EN NA	
Cypriot CYS-EN NA	
Czech CSN-EN NA	~
References	^
B EN 1990: Basis of structural design	
EN 1990 (Basis of structural design)	
[⊕] EN 1991: Actions of structures	
EN 1992: Design of concrete structures	
EN 1992-1-1 (General rules and rules for buildings)	ĸ
EN 1992-1-2 (General rules -Structural fire design)	
EN 1992-2 (Concrete bridges - Design and detailing rules)	
EN 1168 (Precast concrete products – Hollow core slab)	
[⊕] EN 1993: Design of steel structures	
B EN 1994: Design of composite steel and concrete structures	
EN 1994-1-1 (General rules and rules for buildings)	
EN 1994-1-2 (General rules - Structural fire design)	
EN 1995: Design of timber structures	~
New Insert Edit Delete	ОК



The user can manually input the limiting crack width in Settings per member > 1D member data:

Concrete 4 ×	•	CMD	×
Concrete settings (structure) Reinforcement drawing setting Setting per member 10 member data D buckling data Pr D buckling data	Name Member Member type Advanced mode Solver setting	CMD1 S1 Beam	•
G Reinforcement input+edit G Reinforcement check (ULS+SLS) - 1D membe Section Check - results			
	 Crack width Type of maximal crack width User defined crack width [mm] Deflections Actions Update support width Load default values 	User 0.300	× × >>> >>>
			OK Cancel

Deflection

The calculation of deflection is done according to chapter 7.4.3 from EN 1992-1-1. Two kinds of deflection calculations are possible in the software:

- Simplified method where the calculation is done twice, assuming the whole member to be uncracked and fully cracked, and then interpolating formula 7.18 according to clause 7.4.3(7). This is the default used method.
- Code dependent deflection. This is the most rigorous method to calculate deflection by computing the calculation of curvatures at frequent sections along the member and then calculate the deflection by numerical integration. This method is available if additional functionalities are activated.

Simplified method

The calculation procedure for the simplified method can be described in the following steps:

- 1. Calculation of short-term stiffness using E modulus at 28 days.
- 2. Calculation of long-term stiffness using effective E modulus based on creep coefficient.

In the current version of the software, 17.1, it is not possible to distinguish between the short-term and long-term part of the load in a combination. Therefore, some preconditions have been established for determination of the long-term part of the load. The long-term part of the load (LongTermPercentage) is estimated based on the type of combination. There are three main SLS combinations:

SLS characteristics - LongTermPercentage = 70 % SLS frequent - LongTermPercentage = 85 % SLS guasi-permanent- LongTermPercentage = 100 %

The creep-factor is calculated by the software depending on the relative humidity, outline of the crosssection, reinforcement percentage, concrete class, etc. It can also be manually inputted in the Concrete setup > General > Creep:

ational anr	nex:					Find	View -	Advanc	ed Defau
Descrip	tion	Symbol	Value	Default	Unit	Chapter	Code	Struct	Check
all>	Q	<all> 🔎</all>	<all> 🔎</all>	<all> 🔎</all>		<al> 🔎</al>	<all> 🔎</all>	<a th="" 🔎<=""><th><all> 🔎</all></th>	<all> 🔎</all>
Solver	setting								
🗏 Ge	neral								
	Limit value of unity check	Lim.check	1.0	1.0			Independe	All (Bea	Solver s
	Value of unity check for not calculated unity check	Ncal.check	3.0	3.0			Independe	All (Bea	Solver s
	The coefficient for calculation effective depth of cr	Coeff _d	0.9	0.9			Independe	All (Bea	Solver s
	The coefficient for calculation inner lever arm	Coeffz	0.9	0.9			Independe	All (Bea	Solver s
	The coefficient for calculation force, where memb	Coeff _{com}	0.1	0.1			Independe	All (Bea	Solver s
	Creep								
) Type input of creep coefficient	Туре ф		Auto		Annex B.1	EN 1992-1	All (Bea	Solver s
	Relative humidity	RH	Auto User value	50	%	Annex B.1	EN 1992-1	All (Bea	Solver s
	Age of concrete at loading	t _o	28.00	28.00	day	Annex B.1	EN 1992-1	All (Bea	Solver s
	Age of concrete at the moment considered	t	1825.00	1825.00	day	Annex B.1	EN 1992-1	All (Bea	Solver s
	SLS								
	Use effective modulus of concrete					7.1(2)	EN 1992-1	All (Bea	Solver s
=	Default sway type								
=	Minimal concrete cover								
🗄 Int	ernal forces								
🗄 De	sign As								
🗄 Int	eraction diagram								
🗄 Sh	ear								
	rsion								

 Calculation of stiffness ratios between each state, short and long term. It is the ratio of linear stiffness of the concrete component divided by the resultant stiffness taking cracks into account. The calculation of resultant stiffness is based on clause 7.4.3 (3), formula 7.18. For additional information about the resultant stiffness, please refer to our webhelp or to the Concrete menu > Reinforcement check > Stiffnesses.

ratio = Stiffness_{lin} / Stiffness_{res}, for example ratio_{uz} = $EI_{z,lin}$ / $EI_{z,res}$

4. Calculation of deflection components

Several components are needed to calculate the total and additional deflection.

In the following part we will note "s" for short term and "l" for long term.

The components are:
$$\begin{split} &\delta_{\text{lin}} \text{ linear (elastic) deflection, } \delta_{\text{lin}} = \delta_{\text{lin,s}} + \delta_{\text{lin,l}} \\ &\delta_{\text{imm}} \text{ immediate deflection, } \delta_{\text{imm}} = \delta_{\text{lin,l}} \cdot \text{ ratios} \\ &\delta_{\text{s}} \text{ short-term deflection, } \delta_{\text{s}} = \delta_{\text{lin,s}} \cdot \text{ ratios} \\ &\delta_{\text{l,creep}} \text{ long-term deflection + creep, } \delta_{\text{l,creep}} = \delta_{\text{lin,l}} \cdot \text{ ratiol} \\ &\delta_{\text{creep}} \text{ creep deflection, } \delta_{\text{creep}} = \delta_{\text{lin,l}} \cdot (\text{ ratiol} - \text{ ratios}) \\ &\delta_{\text{l}} \text{ long-term deflection, } \delta_{\text{l}} = \delta_{\text{l,creep}} - \delta_{\text{creep}} \\ &\delta_{\text{add}} \text{ additional deflection, } \delta_{\text{add}} = \delta_{\text{s}} + \delta_{\text{l,creep}} - \delta_{\text{imm}} \\ &\delta_{\text{tot}} \text{ total deflection, } \delta_{\text{tot}} = \delta_{\text{s}} + \delta_{\text{l,creep}} \end{split}$$

5. Check of deflections

Two deflections are checked: *Total deflection:* The appearance and general utility of the structure could be impaired when the calculated sag of a beam, slab or cantilever subjected to quasi-permanent loads exceeds span/250. $\delta_{tot,lim} = L / 250$

Additional deflection: Deflections that could damage adjacent parts of the structure should be limited.

 $\delta_{add,lim} = L / 500$

L is the buckling length multiplied by a β factor of the member in the corresponding direction.

Final unity check is:

Unity check = max {
$$\frac{\delta tot}{\delta tot, lim}$$
; $\frac{\delta add}{\delta add, lim}$ }

Concrete settings Find View - Advanced Default National anne Description Symbol Value Default Unit Chapter Code Struct... CheckT. salls Q <all> Q <al> Q Q Q Q Q Q Solver setting H General Internal forces H Design As Interaction diagram E Shear H Torsion Stress limitations E Cracking forces Deflections Coefficient for increasing the amount of reinforcem... Coeff... 1.0 1.0 Independent All (Bea... Solver s... 50.0 Maximal total deflection L/x; x = x_{tot} 250.0 7.4.1(4) EN 1992-1-1 1D (Be... Solver s. Maximal additional deflection L/x; x = 500.0 00.0 7.4.1(5) EN 1992-1-1 1D (Be... Solver s... X_{add} Type of variable load coefficient for the automatic g. Independent All (Bea... Solver s... Use Psi2 fa Use Psi2. Detailing provisions

The limits of deflection can be changed in Concrete setup > Deflections:

Example: 'beam_practical reinforcement.esa'

Look at deflection check for the "SLS qp" combination. Various results can be displayed on the screen: UC, total and additional deflection or limits for total and additional deflection.

Open the Standard output for the UC. At position dx = 2.5m we have the following result:

Basic values of deflections

Type of	Ratio	Ratio	δlin	δ _{imm}	δ add	δ _{short}	δlong	δ _{long+creep}	δ _{creep}
deflection	short [-]	long [-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
u _y	2.88	5.22	0	0	0	0	0	0	0
Uz	2.5	3.38	-3.08	-7.7	-2.69	0	-7.7	-10.4	-2.69

Check of additional and total deflections

Type of deflection	L [m]	δ _{add} [mm]	δ _{add,lim} [mm]	UC _{add} [-]	δ _{tot} [mm]	δ _{tot,lim} [mm]	UC _{tot}	UC [-]	Limit [-]	Status
Uy	10	0	0	0	0	0	0	0	1	ОК
Uz	10	-2.69	-20	0.13	-10.4	-40.1	0.26	0.26	1	ОК

List of errors/warnings/notes: NO

All ratio of stiffnesses and deflection components are resumed in a table.

Open the Detailed output, for the same position dx = 2.5m. All previously mentioned steps for the calculation of the deflections can be found here.

For example for the long-term stiffness, we can obtain the long-term part of the loads and the calculated creep coefficient:

Long-term stiffnesses and curvatures under total load

Settings

Long-term part of applied load = 100%Creep coefficient $\varphi = 2.21$

Uncracked (state I) and cracked (state II) cross section properties are also shown in a table:

Cross-section characteristics

Type of component	t _y [m]	t _z [m]	A [m ²]	l _y [m ⁴]	l _z [m ⁴]	x _i [m]	A _{st} [m ²]	A _{sc} [m ²]	Α _s [m ²]
Linear	0	0	0.15	3.13·10 ⁻³	1.13·10 ⁻³	0.25	-	-	-
Uncracked	0	-0.019	0.193	4.69·10 ⁻³	1.35·10 ⁻³	0.27	1.57·10 ⁻³	628·10 ⁻⁶	2.2·10 ⁻³
Cracked	0	0.053	0.102	2.89·10 ⁻³	667·10 ⁻⁶	0.197	1.57·10 ⁻³	628·10 ⁻⁶	2.2·10 ⁻³

Check of concrete stresses and calculation of cracking forces

Maximal tensile stress in concrete fibre	
σ_{ct} = 7.76 MPa	
Cracking status	
$\sigma_{ct} > f_{ct,eff} = 7.76 \text{ MPa} > 2.9 \text{ MPa} => \text{Cracks appear.}$	
Stress in reinforcement for cracking load	
σ _{sr} = 99.3 MPa	
Stress in reinforcement for acting load	
σ _s = 262 MPa	
Distribution coefficient	
$\zeta = \max\left(0; 1 - \beta \cdot \left(\frac{\sigma_{sr}}{\sigma_s}\right)^2\right) = \max\left(0; 1 - 0.5 \cdot \left(\frac{99.3}{262}\right)^2\right) = 0.928$	(7.19)

N _{cr,} [kN]	M _{y,cr} [kNm]	M _{z,cr} [kNm]	σ _{ct} [MPa]	f _{ct,eff} [MPa]	Cracked section	σ _{sr} [MPa]	σ _s [MPa]	β [-]	ζ [-]	E _c [GPa]
0	59.6	0	7.76	2.9	YES	99.3	262	0.5	0.928	33

Which allows to calculate the stiffness's ratio, for example the bending stiffness's ratio:

Bending stiffness Ely	
$El_{y,lin} = E_c \cdot l_y = 33 \cdot 3.13 \cdot 10^9 = 103 \text{ MNm}^2$	
$EI_{y,l} = E_{c,eff} \cdot I_{y,l} = 10.3 \cdot 4.69 \cdot 10^9 = 48.1 \text{ MNm}^2$	
$EI_{y,II} = E_{c,eff} \cdot I_{y,II} = 10.3 \cdot 2.89 \cdot 10^9 = 29.7 \text{ MNm}^2$	
$\frac{EI_{y}}{EI_{y, }} = \frac{1}{\frac{\zeta}{EI_{y, }}} + \frac{1-\zeta}{EI_{y, }} = \frac{1}{\frac{0.928}{29.7}} + \frac{1-0.928}{48.1} = 30.5 \text{ MN} \cdot \text{m}^{2}$	(7.18)
$RatioEly = \frac{El_y}{El_{y,lin}} = \frac{30.5}{103} = 0.296$	
Bending stiffness Elz	
$EI_{z,lin} = E_c \cdot I_z = 33 \cdot 1.13 \cdot 10^9 = 37.1 \text{ MNm}^2$	
$EI_{z,1} = E_{c,eff} \cdot I_{z,1} = 10.3 \cdot 1.35 \cdot 10^9 = 13.8 \text{ MNm}^2$	
$EI_{z,II} = E_{c,eff} \cdot I_{z,II} = 10.3 \cdot 667 \cdot 10^{6} = 6.85 \text{ MNm}^{2}$	
$EI_{z} = \frac{1}{\frac{\zeta}{EI_{z, }} + \frac{1-\zeta}{EI_{z, }}} = \frac{1}{\frac{0.928}{6.85} + \frac{1-0.928}{13.8}} = 7.11 \text{ MN} \cdot \text{m}^{2}$	(7.18)
RatioEiz = $\frac{El_z}{El_{z,lin}} = \frac{7.11}{37.1} = 0.191$	

And final the short and long-term ratios:

Short-term ratios	Long-term ratios
Bending stiffness Ely	Bending stiffness Ely
RatioElys = $\frac{El_{y,s}}{El_{y,lin}} = \frac{41.2 \cdot 10^6}{103 \cdot 10^6} = 0.4$	RatioElyl = $\frac{El_{y,l}}{El_{y,lin}} = \frac{30.5 \cdot 10^6}{103 \cdot 10^6} = 0.296$
Bending stiffness Elz	Bending stiffness Elz
RatioElzs = $\frac{El_{z,s}}{El_{z,lin}} = \frac{12.9 \cdot 10^6}{37.1 \cdot 10^6} = 0.347$	RatioElzI = $\frac{EI_{z,I}}{EI_{z,Iin}} = \frac{7.11 \cdot 10^6}{37.1 \cdot 10^6} = 0.191$
Ratios	Ratios
$ratio_{uys} = \frac{1}{RatioElzs} = \frac{1}{0.347} = 2.88$	$ratio_{uyl} = \frac{1}{RatioElzl} = \frac{1}{0.191} = 5.22$
$ratio_{uzs} = \frac{1}{RatioElys} = \frac{1}{0.4} = 2.5$	$ratio_{uzl} = \frac{1}{RatioElyl} = \frac{1}{0.296} = 3.38$

Then all deflection components are calculated together with the limit deflections:

Deflections

Linear deflection

$$\begin{split} \delta_{Iin,y} &= u_{ys} + u_{yl} = 0 + 0 = 0 \ mm \\ \delta_{Iin,z} &= u_{zs} + u_{zl} = 0 + -3.08 = -3.08 \ mm \end{split}$$

Immediate deflection

$$\begin{split} \delta_{imm,y} &= u_{y1} \cdot ratio_{uys} = 0 \cdot 2.88 = 0 \ mm \\ \delta_{imm,z} &= u_{z1} \cdot ratio_{uzs} = -3.08 \cdot 2.5 = -7.7 \ mm \end{split}$$

Short-term deflection

$$\begin{split} \delta_{short,y} &= u_{ys} \cdot ratio_{uys} = 0 \cdot 2.88 = 0 \ mm \\ \delta_{short,z} &= u_{zs} \cdot ratio_{uzs} = 0 \cdot 2.5 = 0 \ mm \end{split}$$

Long-term + creep deflection

$$\begin{split} \delta_{\text{long,creep,y}} &= u_{yl} \cdot ratio_{uyl} = 0 \cdot 5.22 = 0 \text{ mm} \\ \delta_{\text{long,creep,z}} &= u_{zl} \cdot ratio_{uzl} = -3.08 \cdot 3.38 = -10.4 \text{ mm} \end{split}$$

Creep deflection

$$\begin{split} \delta_{creep,y} &= u_{y1} \cdot \Big(\mbox{ ratio}_{uy1} - \mbox{ ratio}_{uys} \Big) = 0 \cdot \Big(\ 5.22 - 2.88 \Big) = 0 \ \mbox{mm} \\ \delta_{creep,z} &= u_{z1} \cdot \Big(\mbox{ ratio}_{uz1} - \mbox{ ratio}_{uzs} \Big) = -3.08 \cdot \Big(\ 3.38 - 2.5 \Big) = -2.69 \ \mbox{mm} \end{split}$$

Long-term deflection

$$\begin{split} \delta_{long,y} &= \delta_{long,creep,y} - \delta_{creep,y} = 0 - 0 = 0 \text{ mm} \\ \delta_{long,z} &= \delta_{long,creep,z} - \delta_{creep,z} = -10.4 - -2.69 = -7.7 \text{ mm} \end{split}$$

Additional deflection

$$\begin{split} \delta_{add,y} = \delta_{short,y} + \delta_{long,creep,y} - \delta_{imm,y} = 0 + 0 - 0 = 0 mm \\ \delta_{add,z} = \delta_{short,z} + \delta_{long,creep,z} - \delta_{imm,z} = 0 + -10.4 - -7.7 = -2.69 mm \end{split}$$

Limit additional deflection

 $\delta_{add,lim,y} = 0 \text{ mm}$

 $\delta_{add,lim,z} = \frac{-l_{0z}}{Lim_{add}} = \frac{-10}{500} = -20 \text{ mm}$

Total deflection

$$\begin{split} \delta_{tot,y} &= \delta_{short,y} + \delta_{long,creep,y} = 0 + 0 = 0 \text{ mm} \\ \delta_{tot,z} &= \delta_{short,z} + \delta_{long,creep,z} = 0 + -10.4 = -10.4 \text{ mm} \end{split}$$

Limit total deflection

 $\delta_{tot,lim,y} = 0 mm$

 $\delta_{tot,lim,z} = \frac{-I_{0z}}{Lim_{tot}} = \frac{-10}{250} = -40 \text{ mm}$

Limitations of the deflection check:

- Deformation caused by shrinkage is not automatically considered.
- Verification based on limiting span / depth ratio according to 7.4.2 is not implemented.
- Calculation of deflection depends on the internal forces used for the reduced stiffness. Therefore, the check of deflection doesn't work for cases where the internal forces are equal to zero but deflections are not zero. Typically, this is the case for a cantilever structure with free overhang.

Code dependent deflection CDD

The CDD calculation is a more rigorous calculation of the deflection. The calculation procedure is the same as for the simplified method, but with following differences:

- 3 types of combinations are used to calculate the deflections
- Calculation of stiffness is more precise

To be able to use this method in SCIA Engineer, the following settings should be set beforehand:

~

1. Use the post processing environment v17 in the Project menu:

	– Data –		Material	_
	Name:	•	Concrete	
			Material	C30/37 🔽
No.	Part:	-	Reinforcement	B 500A 🛛 🖌
			Steel	
	Description:		Timber	
			Masonry	
	Author:	-	Other	
			Aluminium	
	Date:	03. 01. 2007		
KIRAN	Structure:	Post processing environment	National Code:	
ALL	💭 Frame XZ	💌 🚳 v17 💽	EC - EN	····
	Model:		National annex:	
	🕅 One	-	Standard El	N 💌

2. Activate functionality « Code dependent deflection » :

		Project da	ata		
Basic data Fur	nctionality Actions Protection				
	Dynamics	· ^		Concrete	
	Initial stress			Fire resistance	
	Subsoil			Hollow core slab	
	Nonlinearity			Code dependent deflection	V
	Stability				
(PIRES)	Climatic loads				
		[area]			

3. In the Concrete menu > Reinforcement check, you will then see a new check named Code dependent deflection:



Types of combinations

Three different combinations are automatically created by the software in the background to calculate the deflection:

1. Combination for calculation of total deflection

Generated directly from the user choice of combination in the CDD check, properties window:

Properties		դ	×
Code dependent deflect			0
	8	6	*
Name	Code dependent d.		^
Selection			
Type of selection	All	*	
Filter	No	*	
Automatic combinati	V		
■ Result case for d			
Type of load	Combinations	*	L
Combination	SLS	¥	
Envelope (for 2D dr	Absolute extreme	٣	
Type of reinforcement	User	-	
Extreme 1D			
 Extreme 1D Direction (local) 	z (1D/2D)	•	
	z (1D/2D) UC	•	
Direction (local)		*	
Direction (local) Values	UC	*	

2. Combination for calculation of immediate deflection

Uses the generated combination for total deflection and removes variable load cases with duration type Medium, Short or Instantaneous. Duration type is defined in the Load cases prop . .

uration type	is defined in	n the Load cas	ses properties:	

Load cases							
🦊 🔆 🖌 📽 🔽 🏷 🕰 🥌 🖉 🖬 🛛	All 🗸 🗸						
LC1 - SW	Name	LC3					
LC2 - per	Solver index	(3)					
LC3 - var	Description	var					
	Action type	Variable					
	LoadGroup	LG2 🔹					
	Load type	Static					
	Specification	Standard -					
	Duration	Short *					
	Master load case	Long Medium					
		Short Instantaneous					

3. Combination for calculation of deflection due to creep

Uses the generated combination for total deflection and multiplies variable load cases by a coefficient defined in Concrete settings > Deflections:

lation	al annex:								F	ind	View 🔻	Advanced	Defa	aı
D	escription	Symbol		Value		Default		Unit	Chapte	r	Code	Structure	Check	τ
<all></all>	Ω	<all></all>	ρ	<all></all>	ρ	<all></all>	ρ		<all></all>	ρ	<all></all>	<all> 🔎</all>	<9 >	,
S	olver setting													
Ŧ	General													
H	Internal forces													
Ŧ	Design As													
H	Interaction diagram													
H	Shear													
H	Torsion													
H	Stress limitations													
H	Cracking forces													
	Deflections													
	Coefficient for increasing the amount of reinforcement	Coeff _{reir}	nf,	1.0		1.0					Independent	All (Bea	Solver	1
	Maximal total deflection L/x; x =	x _{tot}		250.0		250.0			7.4.1(4)		EN 1992-1-1	1D (Bea	Solver	1
	Maximal additional deflection L/x; x =	x _{add}		500.0		500.0			7.4.1(5)		EN 1992-1-1	1D (Bea	Solver	-
	Type of variable load coefficient for the automatic gener.			Use Psi2 fa	•	U e Psi	i2				Independent	All (Bea	Solver	
+	Detailing provisions			Use Psi2 fac User input	ctor	r I								

Additional characteristic combinations are generated for each previously mentioned combination to determine if the section is cracked or uncracked.

Types of reinforcement

For the CDD method, it is possible to calculate the deflection with required, provided or user inputted reinforcement. This choice is done in the Properties window of the CDD check:

Properties	4	×
Code dependent deflect	tion (1) 🛛 🔽 🔽	0
	& 😎	*
Name	Code dependent d	^
Selection		
Type of selection	All	
Filter	No	
Automatic combinati	V	
■ Result case for d		
Type of load	Combinations •	
Combination	SLS 🗸	
Envelope (for 2D dr	Absolute extreme	
Type of reinforcement	User 🔹	
Extreme 1D	Required Provided	
Direction (local)	User	
Values	UC 🔹	
Output	Brief	
Print combination key	V	
Print explanation of s	8	

Calculation of deflection

The following deflections are calculated in the CDD check:

 δ_{lin} linear (elastic) deflection, calculated for the total combination and for linear stiffness.

 δ_{imm} immediate deflection, the deflection after applying permanent and long-term variable loads which means calculated for short-term stiffness and immediate combination

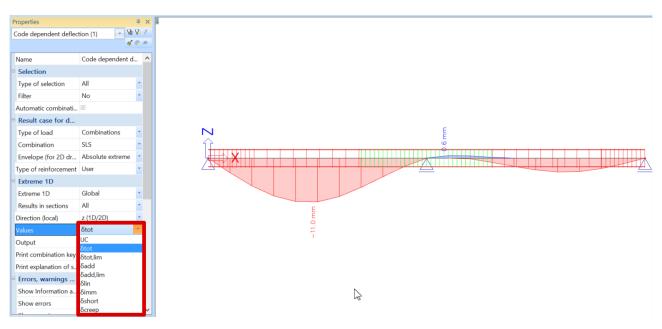
 δ_{short} short-term deflection, the deflection which considers cracking of cross-section calculated for short-term stiffness and total combination

 δ_{creep} creep deflection, calculated as the difference between deflection calculated for long-term and short-term stiffness for the creep combination. $\delta_{creep} = \delta_{creep, long} - \delta_{creep, short}$

 δ_{add} additional deflection, the deflection after applying a variable load and considering creep calculated as the difference between total and immediate deflection. $\delta_{add} = \delta_{tot} - \delta_{imm}$

 δ_{tot} total deflection, the deflection which considers creep and cracking calculated as the sum of short-term deflection and deflection caused by creep. $\delta_{tot} = \delta_{short} + \delta_{creep}$

All those values can be displayed on the screen:



For the CDD check, only a brief output is available in 17.1:

For 1D member

Name	dx [m]	Case Type of reinf.		δ _{imm,y} [mm] δ _{imm,z} [mm]	δ _{short,y} [mm] δ _{short,z} [mm]	δ _{creep,y} [mm] δ _{creep,z} [mm]	[mm]	δ _{add,lim,y} [mm] δ _{add,lim,z} [mm]	δ _{tot,y} [mm] δ _{tot,z} [mm]	δ _{tot,lim,y} [mm] δ _{tot,lim,z} [mm]	UC [-] Check
S1	2.500-	SLS/1	0.0	0.0	0.0	0.0	0.0	20.0	0.0	40.0	0.55
		User	-3.4	-6.8	-8.0	-3.0	-4.2	10.0	-11.0	20.0	OK
S1	5.500-	SLS/2	0.0	0.0	0.0	0.0	0.0	20.0	0.0	40.0	0.03
		User	0.2	0.5	0.5	0.1	0.1	10.0	0.6	20.0	OK

Detailing provisions

Scia Engineer distinguishes three types of member with their detailing provisions:

- Beam verification of longitudinal and shear reinforcement
- Column verification of main and transverse reinforcement
- Beam slab verification of longitudinal reinforcement only

All detailing provisions are taken into account automatically in Concrete settings > Detailing provisions:

tional annex:										ind	View	- Advar	nced Defa	ult
Description	Syn	nbol	V	/alue		Default	Ur	nit (Chapter		Code	Structure	e CheckT	^
all>	C <al< td=""><td>> 🖌</td><td>)</td><td><all></all></td><td>ρ</td><td><all></all></td><td>С</td><td></td><td><all></all></td><td>ρ</td><td><all> 🔎</all></td><td><all> 🔎</all></td><td>) <all> 🔎</all></td><td></td></al<>	> 🖌)	<all></all>	ρ	<all></all>	С		<all></all>	ρ	<all> 🔎</all>	<all> 🔎</all>) <all> 🔎</all>	
Interaction diagram														
∃ Shear														
Torsion														
Cracking forces														
Deflections														
Detailing provisions														
Beam (Rib)														
Longitudinal														
Check min. bar distance			8	/		1		8	8.2(2)		EN 1992-1-1	Beam,Ri	b Solver s	
Minimal bar distance	s _{lb,n}	nin	2	0		20	mn	n 8	8. 2(2)		EN 1992-1-1	Beam,Ri	b Solver s	
Check max. bar distance			l								Independent	Beam,Ri	b Solver s	
Check max. bar distance (torsion)			5	/		1		Ş	9.2.3(4)		EN 1992-1-1	Beam,Ri	b Solver s	
Maximal bar distance (torsion)	s _{lbt,r}	nax	3	50		350	mn	n §	9.2.3(4)		EN 1992-1-1	Beam,Ri	b Solver s	
Check min. reinforcement area			8	7		1		ę	9.2.1.1(1)		EN 1992-1-1	Beam,Ri	b Solver s	
Check min. reinforcement area for secondary			5	/		1		Ş	9.2.1.1(1)		EN 1992-1-1	Beam,Ri	b Solver s	
Check max. reinforcement area			8	7		1		9	9.2.1.1(3)		EN 1992-1-1	Beam,Ri	b Solver s	
Stirrups			[
Check min. mandrel diameter								8	8.3(2)		EN 1992-1-1	Beam,Ri	b Solver s	
Check max. longitudinal spacing (shear)			8	7		1		9	9.2.2(6)		EN 1992-1-1	Beam,Ri	b Solver s	
Check max. longitudinal spacing (torsion)			8	/		1		ę	9.2.3(3)		EN 1992-1-1	Beam,Ri	b Solver s	
Check max. transverse spacing			5	/		1		Ş	9.2.2(8)		EN 1992-1-1	Beam,Ri	b Solver s	
Check min. percentage of stirrups				7		1		9	9.2.2(5)		EN 1992-1-1	Beam,Ri	b Solver s	
Check max. percentage of stirrups			5	/		1		e	6.2.3(3)		EN 1992-1-1	Beam,Ri	b Solver s	
🗄 Beam slab														
H Column														\mathbf{v}

Following table shows which checks of detailing provisions are performed:

Member type	Longitudinal (main)	Shear (transverse)
Beam	 8.2(2) - Minimal clear spacing of bars 9.2.1.1(1) - Minimal area of longitudinal reinforcement 9.2.1.1(3) - Maximal area of longitudinal reinforcement 9.2.3(4) - Maximal center-to-center bar distance based on torsion Code-Independent - Maximal clear spacing 	 6.2.3(3) - Maximal percentage of shear reinforcement 9.2.2(5) - Minimal percentage of shear reinforcement 9.2.2(6) - Maximal longitudinal spacing of stirrups (shear) 9.2.2(8) - Maximal transverse spacing of stirrups (shear) 9.2.3(3) - Maximal longitudinal spacing of stirrups (torsion)
Column	 8.2(2) - Minimal clear spacing of bars 9.5.2(1) - Minimal bar diameter of longitudinal reinforcement 9.5.2(2) - Minimal area of longitudinal reinforcement 9.5.2(3) - Maximal area of longitudinal 	 9.2.3(3) - Maximal longitudinal spacing of stirrups (torsion) 9.5.3(1) - Minimal diameter of transverse reinforcement 9.5.3(3) - Maximal longitudinal spacing of transverse reinforcement

Member type	Longitudinal (main)	Shear (transverse)
	reinforcement 9.5.2(4) - Minimal number of longitudinal reinforcement bars	
Beam Slab	8.2(2) - Minimal clear spacing of bars 9.3.1.1(3) - Maximal bar distance of longitudinal reinforcement	-

Section check

The Section check tools can be used in two different ways: with or without practical reinforcement inputted beforehand.

Section check can be launched:

• In the properties window for an individual check

Concrete 7 ×	Properties		д х	Check shear+torsion (ULS)
© Concrete settings (structure)	Check shear+torsion (U		1 🌾 /	Values: UC
Reinforcement drawing setting		4	· 6 .*	Linear calculation Combination: ULS
⊞ - Setting per member	Name	Check shear+torsi	o ^	Coordinate system: Principal
🖽 😽 Reinforcement design	Selection	-		Extreme 1D: Global
G Reinforcement input+edit	The College	All		Selection: All
Em Reinforcement check (ULS+SLS) - 1D membe				
Internal forces Slenderness	Filter	No	- ·	2.28
Sienderness Stiffnesses	Results in sections	All		
Capacity-response (ULS)	Result case			Section: 11
Capacity-diagram (ULS)	Type of load	Combinations	•	Sector: 12
in Shear + Torsion (ULS)	Combination	ULS	*	
-/' Stress limitation (SLS)	Extreme 1D			
Crack width (SLS)	Extreme 1D	Global		
Deflection (SLS)	Values	UC		
Detailing provision		00	- 84	
Section Check - results	Output settings		- 14	
	Output	Standard		
	Drawing Setup 1D			
	Errore worninge		~	
	Actions			
	Refresh		>>>	Ø ● △ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □
	New combination from	n Combination key	>>>	Command line 4
	Section Check		>>>	
	Table results		>>>	
New Close	Preview		>>>	Select an input for Section Check tool: a section on the member to define a new section >
	L			precedent input for becault check tool, a section on the member to define a new section 2

• In the properties window for the Section Check - results service

Concrete 7 ×	Properties	
	Section Check - results (1)	
Concrete settings (structure)	Section check results (1)	
Reinforcement drawing setting		
	Name Section Check - resu	ts
G Reinforcement input+edit	Result case	
□ II Reinforcement check (ULS+SLS) - 1D membe	Type of load Combinations	-
themal forces	Combination ULS	•
IS Slenderness	Selection	
Stiffnesses	Type of selection All	• N
Capacity-response (ULS)	.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Section : 9 Section : 10
4 Capacity-diagram (ULS)		
iii Shear + Torsion (ULS)	Print combination key	
Stress limitation (SLS) Crack width (SLS)	Print checks per secti 🗵	45
 Crack width (SLS) Deflection (SLS) 	Checks	
Detection (SLS) Detection (SLS)	Capacity-response (🗵	
Section Check - results	Capacity-diagram (🗵	
	Shear+Torsion (ULS)	
	Detailing provision	
	Actions	
	Refresh	Command line
	Section Check	
New Close	Table results	
New Close	Preview	>>> Select an input for Section Check tool: a section on the member to define a new section >

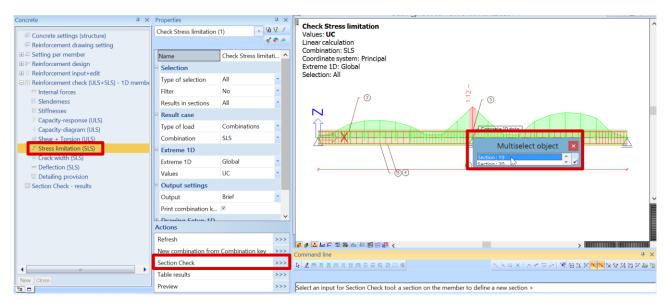
With practical reinforcement

Example 1: 'beam_practical reinforcement SC.esa'

Section check can be opened from all individual checks.

In this example, select Stress limitation check (SLS) and click on "Section check" in the Properties window:

Select the beam and then click on the position for which the check should be done. Choose section 19 at the middle of the beam:



The Section check tool opens:

										tion Check (tool)							
Home	e																
					× •						Save & close	Cancel & close					
		ngitudinal re	einforcemen	it				Stirrups		A	Applicatior						
Section				_				Report	Charles	itress limitation	(61.6)	Check			Che	Name	Value
	Grid siz	e: 100 n	nm / _ 4	1	-			Standard		: SLS/1 [SLS]	(SLS)	Check	value: 1.12	Ж.		Name Internal forces (check)	value
		20			8									-		Capacity-response (ULS)	
		ZÓ	••••	•	80				on SC1			ECT (500; 300)			H	Capacity-diagram (ULS)	
			Ŧ		10			Member		18 L = 10 m L _v = 10 m (sway)	Co	am S1 (dx = 5 m) hcrete: C30/37 linear stress-strain diagra				Shear+Torsion (ULS)	
		0	+5		4			Bucklin		$L_z = 10 \text{ m} (\text{sway})$ $L_z = 10 \text{ m} (\text{sway})$	Ex	ninear stress-strain diagra posure class: XC3 agitudinal reinforcemer				Crack width (SLS)	
		-100								5¢20 (1571 mm2)	Bi	linear with an inclined to 20 mm (A ₅ = 2199 mm ²)		-		Stress limitation (SLS)	1.12
		*	<u> </u>	•							She	= 1.466 % (17.3 kg/m) ar reinforcement: B 50				Deflection (SLS)	
		16 au	-10 0		W			8	ť		φ1	linear with an inclined to $0/99.7 \text{ mm} (n_s = 2) (A_{sw} = 1)$	= 157 mm ²)			Detailing provisions	
Reinfo	rcement (layout	Reinforce	ement (free)	Diameter			_	8	+-,		Con	= 1.050 % (12.4 kg/m) (A ver (stirrup)	A _{swm} = 1575 mm ² /m)		Ext	reme	
	Bar	Y [mm]	Z [mm]	Ø [mm]	Material	Detailing	1				Bo	p: 36 mm ttom: 36 mm ft: 36 mm				Name	Value
-	BO	90	195	20	B 500A				اسما	2ф20 (628 mm2)		ght: 36 mm			٠	SLS/1 (SLS)	1.12
-	B1	-90	195	20	B 500A		_	۲.	300	\$10/100 mm, ns=2							
-	B2	-90	-195	20	B 500A												
-	B3	90	-195	20	B 500A			Verificat		ombi. Nrd Mrde	Meda of ct	h fout Cra	icks				
-	B4	45	195	20	B 500A				odule [MPa]	[kN] [kNm]	[kNm] [M	Pa] [mm] [MPa] ap		Ŧ	•		•
-	B5	0	195	20	B 500A			•					-	•		all check status:	1 12 🍁
-	B6	-45	195	20	B 500A		-							- •	Not	satisfied	1.12 💢
Output	finished: Chec	k name: Ch	eck Stress li	mitation Co	ombi name	: CO0											

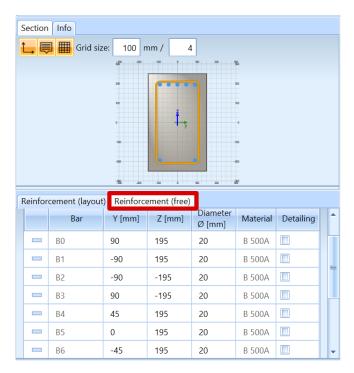
This window is composed of 3 mains parts:

- 1. Definition / modification of the reinforcement
- 2. Preview of the report
- 3. Checks to be performed according to the previous selected combinations or load cases. By default, only the individual selected check will be performed. The user can activate more checks if wanted.

When selecting a SLS combination in the Properties windows, only SLS checks will be available. When selecting a ULS combination in the Properties windows, only ULS checks will be available.

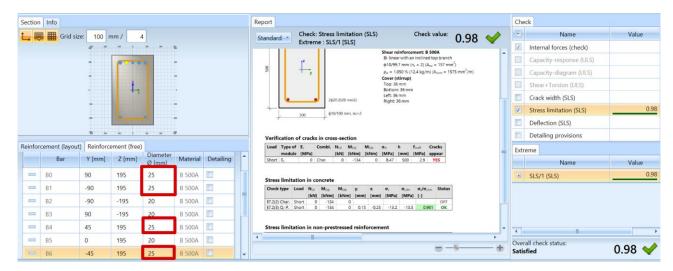
In this example, stress limitation in the concrete is not OK. One solution is to redesign the longitudinal reinforcement to satisfy the SLS stress limitations. We could then close the Section check tool and change the practical reinforcement for this beam or we can adapt locally the reinforcement in the studied section (Section 19). We will choose to adapt the reinforcement in the Section check tool itself.

When practical reinforcement was already inputted, it can be edited in the tab "Reinforcement (free)":



Each present bar, position and diameter, is listed in the table. They can be modified, deleted or new bars can be added.

Increase the diameter of top layer bars B0, B1, B4 and B6 from 20mm to 25mm:



The stress limitation check is now satisfied.

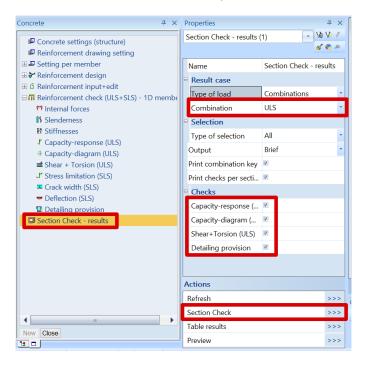
Without practical reinforcement

Example 2: 'beam_without practical reinforcement SC.esa'

When no practical reinforcement was inputted beforehand, it is possible to run the section check tool in order to check a specific section of a member with a local reinforcement on this specific section.

In the Concrete tree, select "Section check - results".

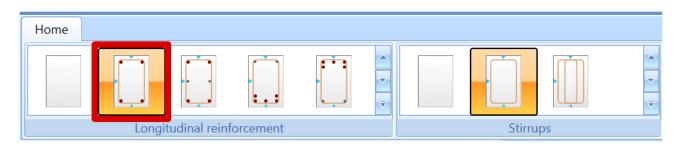
In the properties window, choose the ULS combination to perform all ULS checks:



Select Section 9, in the middle of the first span.

All checks are not satisfied, and the overall UC is 3. The value 3 means that the check could not be performed due to an error in the calculation. In this case, it is because there is no reinforcement yet.

We will start by inserting the reinforcement. First choose the reinforcement template:



Then change the diameter of the reinforcement template. For bottom longitudinal bars, change diameter to 20mm in the tab "Reinforcement (layout):

Section In	fo					
	Grid size:	100 mm /	4			
		300 - 200 - 100	° 10 20 25 Ø8/20	³⁰⁰ 300		
		20	2Ø16			
		100		100		
		25	Ť,			
		-100		-100		
		-20	2Ø20	-200		
		-300 -200 -100	25	300 -300		
Reinforcem			25	340 -300		
	ent (layout)	Reinforcement	25	30 -300		
Reinforcem Longitudi	ent (layout) inal	Reinforcement	zs _{xo} _{xo}	80		
	ent (layout)		25	Material	Detailing	
Longitudi	ent (layout) inal	Reinforcement Bars	(free) Diameter	80	Detailing	
Longitudi Layer	ent (layout) inal Position	Reinforcement Bars N x 2	z (free) Diameter Ø [mm]	Material		
Longitudi Layer L1 L2	ent (layout) inal Position top	Reinforcement Bars N x 2	Z5 to zo t (free) Diameter Ø [mm] 16	Material B 500A		
Longitudi Layer L1	ent (layout) inal Position top	Reinforcement Bars N x 2	Z5 to zo t (free) Diameter Ø [mm] 16	Material B 500A		

Note that it is also possible to define the shear reinforcement in this window.

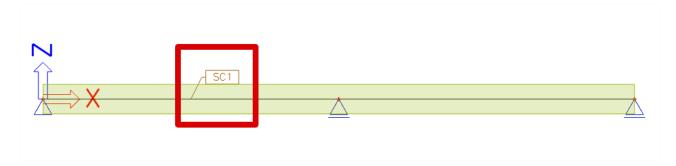
The results for all ULS checks are now:

ort				Che		
andard V	k: Capacity-response (ULS) Check value: 0.85			Name	Value
Extre	me : ULS/2 [ULS]	0.05		1	Internal forces (check)	
			Ē		Capacity-response (ULS)	0.8
Section SC1		RECT (500; 300)			Capacity-diagram (ULS)	0.8
EC EN 1992-1-1:2004/AC Member length:	L = 10 m	Beam S1 [dx = 2.5 m] Concrete: C30/37				
Buckling y-y	$L_y = 10 \text{ m} (\text{sway})$	Bi-linear stress-strain diagram		1	Shear+Torsion (ULS)	0.3
Buckling z-z	L _z = 10 m (sway)	Exposure class: XC3 Longitudinal reinforcement: B 500A			Crack width (SLS)	
	2ф16 (402 mm2)	Bi-linear with an inclined top branch 2φ16 mm + 2φ20 mm (A _s = 1030 mm ²)			Stress limitation (SLS)	
		ρ _l = 0.687 % (8.09 kg/m) Shear reinforcement: B 500A			Deflection (SLS)	
+z		Bi-linear with an inclined top branch	=		Detailing provisions	0.7
20		φ8/200 mm (n _s = 2) (A _{sw} = 101 mm ²) ρ _w = 0.335 % (3.95 kg/m) (A _{swm} = 503 mm ² /m)			Detailing provisions	
y		Cover (stirrup)		Exti	reme	
		Top: 25 mm Bottom: 25 mm			Name	Value
	2φ20 (628 mm2)	Left: 25 mm Right: 25 mm		÷	ULS/2 (ULS)	0.8
300	\$\$/200 mm, ns=2			±	ULS/1 (ULS)	0.5
				÷	ULS/3 (ULS)	0.4
Summary of check						
Type of Fibre /	ϵ_{extr} σ_{extr} Check	Check UC [-] Limit Status				
			-	•		
Type of Fibre /	ε _{extr} σ _{extr} Check [‰] [MPa] strain [-]		+	•	III check status:	

Once the section is reinforced and checks are satisfied, the user can save the design of this section with the option "Save and close":



A label will then be added on the beam:



It is possible to run the Section check for SLS combination as below:

Concrete	4 × Properties	4 ×
© Concrete settings (structure)	Section Check - results	
Reinforcement drawing setting		s 🗸 🖉 🛎
Setting per member	Name	Section Check - results
🗄 😽 Reinforcement design	Result case	Section encore results
🗄 🖞 Reinforcement input+edit	T (1)	Combinations •
Reinforcement check (ULS+SLS) -	membel	
th Internal forces	Combination	SLS *
Slenderness Stiffnesses	Selection	
Capacity-response (ULS)	Type of selection	All
 4 Capacity-diagram (ULS) 	Output	Brief 👻
m Shear + Torsion (ULS)	Print combination key	· •
-I' Stress limitation (SLS)	Print checks per secti	
Crack width (SLS)	Checks	
 Deflection (SLS) Detailing provision 	Stress limitation (SLS)	v
Section Check - results	Crack width (SLS)	2
By Section Check - results	Deflection (SLS)	v
	Detailing provision	
	Actions	
	Refresh	>>>
	Section Check	>>>
•	Table results	>>>
New Close		

If required, Section check tool can still be opened to redesign the section to satisfy the SLS checks by clicking on Section check in the Properties window.

Column Design

Reinforcement design methods

For column design, there are 3 types of calculation:

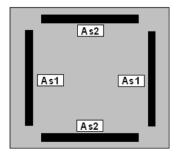
- Axial compression only
- Uniaxial bending
- Biaxial bending

When taking a closer look at the column calculation, 2 different approaches can be distinguished:

- For the 'Axial compression only' and 'Uniaxial bending' calculation, SCIA Engineer uses the same computing heart as for beams.
- For 'Biaxial bending' calculations, SCIA Engineer uses a combination of the computing heart for beams and the so-called interaction formulas.

Furthermore, the uniaxial bending calculation always has as result a 1-directional reinforcement configuration, with the same number of reinforcement bars at parallel sides.

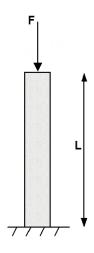
The biaxial bending calculation has as result a 2-directional reinforcement configuration. The number of bars may differ per direction, but is always the same for parallel sides:



The uniaxial bending calculation is a relatively simple calculation type, while the biaxial bending calculation requires an iterative process.

Keep this in mind as the reason why the uniaxial bending calculation will go a lot faster.

Design with axial compression only



No reinforcement required: N_{Ed} < N_{Rd}

Example: 'Axial compression only.esa'

Studied column: B1

Geometry

Column cross-section: RECT 350x350 mm² Height: 4,5 m Concrete grade: C45/55

Concrete Setup

Item Concrete settings > Internal forces ULS: 'eccentricities' are not taken in account.

	nex:							Find		View	,	Adv	anc	ed	Defau	lt
Descriptio	on	Sym	bol		Value		Defau	lt	Unit	Chapter		Code		Structure	Check	с Т
<all></all>	٨) <alb< th=""><th></th><th>ρ</th><th><all></all></th><th>ρ</th><th><all></all></th><th>ρ</th><th><q< th=""><th><all></all></th><th>ρ</th><th><all></all></th><th>ρ</th><th><all> 🔎</all></th><th><all></all></th><th>\$</th></q<></th></alb<>		ρ	<all></all>	ρ	<all></all>	ρ	<q< th=""><th><all></all></th><th>ρ</th><th><all></all></th><th>ρ</th><th><all> 🔎</all></th><th><all></all></th><th>\$</th></q<>	<all></all>	ρ	<all></all>	ρ	<all> 🔎</all>	<all></all>	\$
Solver s	etting															
H Gene	भव															
🗆 Interr	nal forces															
Ab	osolute limit ratio for modification of internal forces	Ratio)int,a	bs	5,00		5,00		kN			Independe	nt	1D (Bea	. Solver	S
Re	elative limit ratio for modification of internal forces	Ratio)int,re	el	0,10		0,10		-			Independe	nt	1D (Bea	. Solver	S
Mo	odification of internal forces				No		No					Independe	nt	1D (Bea	Solver	S
Us	se equivalent first order value				1		1			5.8.8.2(2)	EN 1992-1	-1	Column	Solver	S
De	etermination of unfavourable direction				Auto		Auto			5.8.9		EN 1992-1	-1	Column	Solver	S
🖃 Int	ternal forces ULS															
	Take into account additional tensile force caused by s.						V			9.2.1.3(2)	EN 1992-1	-1	Beam,Ri	. Solver	S
	Use minimum value of eccentricity						1			6.1(4)		EN 1992-1	-1	Column	Solver	S
•	Use geometric imperfection						V			5.2(5)		EN 1992-1	-1	Column	Solver	S
	Use second order effect						V			5.8.8		EN 1992-1	-1	Column	Solver	S
	Estimation ratio of longitudinal reinforcement for recalc.	. μs			2,00		2,00		%	6.2.3		EN 1992-1	-1	Column	Solver	S
	Shear force reduction above supports									6.2.1(8)		EN 1992-1	-1	Beam,B	Solver	S
	Moment reduction above supports									5.3.2.2 (4	4)	EN 1992-1	-1	Beam B	Solver	S

The Detailing provisions are not taken in account, in order to view the pure results (according to the Eurocode, always a minimum reinforcement percentage must be added).

latior	nal annex:							Find		View	Advan	ced	Default	t
De	escription		Symbol		Value		Defau	lt	Unit	Chapter	Code	Structure	Check	Т.
<all></all>		ρ	<all></all>	ρ	<all></all>	ρ	<all></all>	ρ	<q< th=""><th><all></all></th><th>) <all> 🔎</all></th><th><all> 🔎</all></th><th><all></all></th><th>1</th></q<>	<all></all>) <all> 🔎</all>	<all> 🔎</all>	<all></all>	1
= So	olver setting													
+	General													
+	Internal forces													
+	Design As													
+	Interaction diagram													
+	Shear													
+	Torsion													
+	Punching													
+	Stress limitations													
+	Cracking forces													
+	Deflections													
	🗄 Beam (Rib)													
	🗄 Beam slab													
	Column													
	Longitudinal													
	Check min. bar distance			L			\checkmark			8.2(2)	EN 1992-1-1		Solver	
	Check max. bar distance			L							Independent		Solver	_
	Check max. bar distance (torsion)						1			9.2.3(4)	EN 1992-1-1		Solver	-
	Check min. reinforcement area						V			9.5.2(2)	EN 1992-1-1		Solver	
	Check max. reinforcement area						V			9.5.2(3)	EN 1992-1-1		Solver	_
	Check min. bar diameter						V			9.5.2(1)	EN 1992-1-1		Solver	_
	Check min. number of bars						\checkmark			9.5.2(4)	EN 1992-1-1	Column	Solver	S

Loads

LC1: Permanent load > F = 1100 kN LC2: Variable load > F = 1000 kN This means the column is loaded with a single compression force.

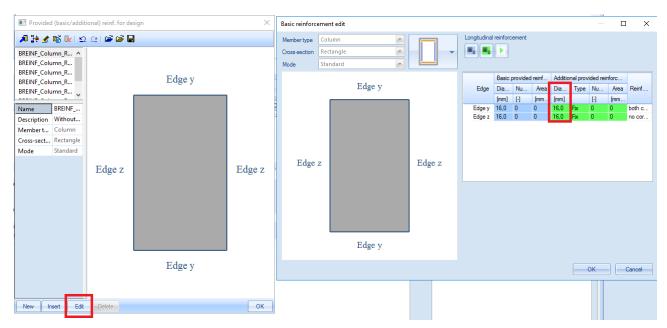
Combination according to the Eurocode: ULS Combination = $1,35 \times LC1 + 1,50 \times LC2$ Design normal force N_{Ed} = $1,35 \times 1100 + 1,50 \times 1000 = 2985$ kN

Bar diameter

The bar diameter is taken from the Reinforcement design > Design defaults > Tab Columns, or from 1D member data if applied (1D member data always overwrite the Concrete Setup data, for the specific member they are assigned to).

ioncrete 🛛 🕹 🗙				De	sign	n defaults	5							_ □)
Concrete settings (structure)	National annex:										Find	View -	Advance	d Defa	ult
Reinforcement drawing setting	Description			Symbol	V	'alue	Defa	ult	Unit	Chapter	r	Code	Structure	CheckTy	
■ ■ Setting per member	<all></all>		Q	<all></all>	<u>ہ</u> م	all> 🖌) <all></all>	ρ		<all></all>	Q	<all></all>	<all></all>) <all></all>	ρ
Reinforcement design	📄 Design def	aults	-					-				-			-
🛯 Design defaults	⊞ Beam (
⊞ m 1D members	⊞ Beam s														
d Reinforcement input+edit															-
Reinforcement check (ULS+SLS) - 1D															_
Section Check - results		gitudinal													_
		Use a template of provided reinforcement			2		v					Independent		Design o	l
		Rectangular section			Co	olumn	Colun	nn				Independent	Column	Design o	l
		Circular			C	olumn	Colun	nn				Independent	Column	Design o	l
		Oval			C	olumn	Colun	nn				Independent	Column	Design o	l
		Other and general			C	olumn	Colun	nn			1	Independent	Column	Design o	l
	8	Main													
		Type of cover			A	uto	Auto			4.4.1		EN 1992-1-1	Column	Design o	
	🗏 Stir	rups												0	
		Diameter of stirrups		d _{ss}	8.	0	8.0		mm			EN 1992-1-1	Column	Design o	
		Number of cuts			2.		2.0					Independent		Design o	
			_	n _s	2.	.0	2.0	_				maoponaem	Column	Designe	

By default, the diameter for the main column reinforcement is put to ϕ 16mm. Based on this diameter and the exposure class (by default XC3), the concrete cover is calculated. This information is necessary to be able to calculate the lever arm of the reinforcement bars.



Note: To change the default diameter from ϕ 16mm to ϕ 20mm for example, edit the template "Column_Rect_Empty" (or the corresponding empty template for the specific columns shape), and change the value of the diameter to be taken into account (additional provided reinforcement).

Results

Go to Reinforcement design > 1D members > Reinforcement design. Ask the value of $A_{s reg}$ for member B1, and click the action button [Refresh].

Concrete 4 ×		4 ×
Concrete settings (structure) Reinforcement drawing setting	Overall Design (OLS) (1)	V; /
 ➡ Setting per member ➡ Reinforcement design ➡ Design defaults ➡ 1D members ➡ Internal forces ➡ Slenderness ➡ Reinforcement design ➡ G Reinforcement input+edit ➡ In Reinforcement check (ULS+SLS) - 1D member ➡ Section Check - results 	Name Overall Design (ULS) Selection Type of selection Type of selection Current Filter No Results in sections All Result case Type of load Combination ULS Extreme 1D Global Type of values Required Values As,req Output Brief Print combination k Image: Combination section sec	
•	•	>>>
New Close	Table results Preview	>>> >>>

The graph appears to be null on the screen. The Brief output (Preview button), gives As, req = 0.

Overall Design (ULS)

Linear calculation Combination: CO1 Coordinate system: Principal Extreme 1D: Global Selection: All **Longitudinal required reinforcement**

Na	me dx [m]	Case	Member	Asz_req+ [mm ²] Asz_req_bar+ [mm ²]	Asz_req- [mm ²] Asz_req_bar- [mm ²]	Asy_req+ [mm ²] Asy_req_bar+ [mm ²]	A _{sy_req} - [mm ²] A _{sy_req_bar-} [mm ²]	A _{sz_req} [mm ²] A _{sz_req_bar} [mm ²]	A _{sy_req} [mm ²] A _{sy_req_bar} [mm ²]	As_req [mm ²] As_req_bar [mm ²]	ReinfReq
B1	0,000	CO1	Column	0	0	0	0	0	0	0	
				0	0	0	0	0	0	0	

Shear reinforcement

Name	dx [m]	Case	Member	A _{swm_req} [mm²/m]		ShearReinf
B1	0,000	CO1	Column	0	0	

If you set output settings on Detailed, you can see the explanation that reinforcement is not necessary.

Ρ	roperties		դ	×
C	Overall Design (ULS) (1)	- 10	7/	Ø
		5	8	*
	Name	Overall Design (ULS	5)	^
8	Selection			
	Type of selection	Current	•	
	Filter	No	•	
	Results in sections	All	•	
8	Result case			
	Type of load	Combinations	•	
	Combination	ULS	•	
8	Extreme 1D			
	Extreme 1D	Global	•	
	Type of values	Required	•	
	Values	As,req	•	
•	Output settings			
	Output	Detailed	•	
æ	Drawing Setup 1D			
⊞	Errors, warnings			
	Run using Model Da	n		~

Explanation errors/warnings and notes

Index	Туре	Description	Solution
N1/1	Note	Statically required reinforcement: The reinforcement is not neccessary.	
		Shear design: Design is not done, because	

<u>Remark:</u> this result is obtained only because **all detailing provisions are deactivated** in the Concrete Setup!

Check of reinforcement

 $\begin{aligned} N_{Rd} &= f_{cd} \cdot \alpha \cdot A_c \\ &= 30 \cdot 1 \cdot 350^2 \, / \, 1000 = 3675 \; kN \end{aligned}$

Since N_{Rd} = 3675 kN > N_{Ed} = 2985 kN, indeed no theoretical reinforcement is required.

Reinforcement required: NEd > NRd

Example: 'Axial compression only.esa'

Studied column: B2

For this example, the same configuration as above is used, only the permanent point load is increased to 2000 kN.

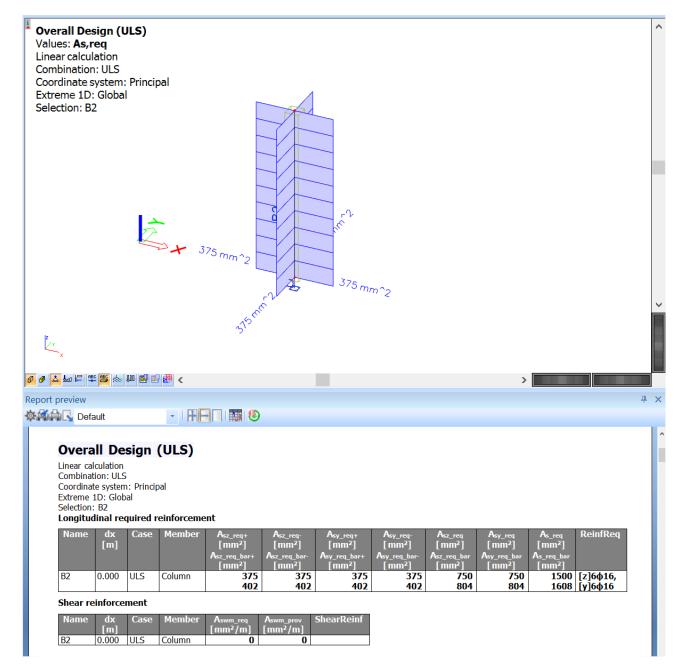
Loads

LC1: Permanent load > F = 2000 kNLC2: Variable load > F = 1000 kN

Combination according to the Eurocode: ULS Combination = 1,35 * LC1 + 1,50 * LC2Design normal force N_{Ed} = 1,35 * 2000 + 1,50 * 1000 = 4200 kN

Results

Remark that SCIA Engineer shows on the screen the reinforcement per direction. The total reinforcement area is in fact $750 + 750 = 1500 \text{ mm}^2$.



When asking for the Standard output for Reinforcement design, the proposed configuration can be found:

Overall Design (ULS)

Linear calculation Combination: CO1 Coordinate system: Principal Extreme 1D: Global Selection: All

Column B1		Rectangle (350; 350)								
EN 1992-1-1:2004/AC:2008		Section 0 [dx = 0	m]							
Member length	Ld = 4.5 m	Materials								
Buckling length y	Ly = 9.01 m	Concrete	C45/55							
Buckling length z	Lz = 9.01 m	Reinforcement	B 500B							

Longitudinal reinforcement

 φ = 16 mm, c = 30 mm,

Shear reinforcement

 n_{sreq} = 2, φ_{sreq} = 8 mm, α_{sreq} = 90 °

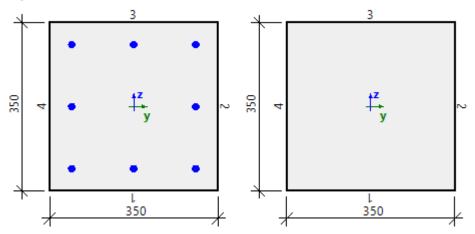
Design of longitudinal reinforcement A_s: 1.35*LC1+1.50*LC2 : N_{Ed} = -4200 kN, M_{Edy} = 0 kNm, M_{Edz} = 0 kNm

Required

Edge	Layer	y [m]	z [m]	A _{s.stat} [mm ²]	A _{s.det.min} [mm ²]	A _{s.det.max} [mm ²]		A _{s.req} [mm ²]	A _{s.req.bar} [mm ²]	Reinf
1	1	0	-0.129	375	0	0	0	375	402	3ф16
2	1	0.129	0	375	0	0	0	375	402	3ф16
3	1	0	0.129	375	0	0	0	375	402	3ф16
4	1	-0.129	0	375	0	0	0	375	402	3ф16

Required bars

Provided bars



Explanation of the number of reinforcement bars

Default bar diameter has been set to ϕ 16 in Design default. The table indicates that each edge needs 3ϕ 16. On the final picture, this leads to a total of 8ϕ 16 in the section of the column.

Design with bending moment and axial force

Four calculation methods are available in SCIA Engineer in concrete settings > Design As > Beam, Column, Rib, ... > Design method:

- Auto (by default)
- Uniaxial around y axis
- Uniaxial around z axis
- Biaxial (always used for circular and oval columns)

ional annex:							Find	Viev	w 🔻	Advand	ed Def	ault		Remark
Description	Symbol	Value	е	Defa	ult	Unit	Chapter	Code	5	Struct	CheckT	^		
⊳ Ω	<all></all>) <all></all>	Q	<all></all>	ρ		<all> 🔎</all>	<all></all>	S.	<all> 🔎</all>	<all> 🔎</all>	>		
Solver setting														
General														
Internal forces														
Design As														Ratio _{uni} < Ratio _{lim}
Coefficient for reduction of strength of the concrete	Red _{fcd}	0.85		0.85		-		EN 1992	-1-1 A	All (Bea	Solver s			Auto:
Beam, Column, Rib, Beam Slab														Ratio _{uni} > Ratio _{šm}
Limit ratio of bending moment for uniaxial method	$\rho_{M,lim}$	0.10		0.10		-		Independ	dent 1	ID (Be	Solver s			
Design method (beams)		Auto		Auto				Independ	dent E	Beam,B	Solver s			Uniax y: Uniax z:
Design method (columns)		Auto	-	Auto				Independ	dent C	Column	Solver s			
Coefficient increasing statically required reinforc	Coeff _{stat.u}	Auto		5		-		Independ	dent E	Beam,B	Solver s		<<	
Coefficient increasing statically required reinforc	Coeff _{stat.lo}		xial arour xial arour			-		Independ	dent E	Beam,B	Solver s			Biaxial:
Coefficient increasing statically required reinforc	Coeff _{stat}	Biaxi	al					Independ	dent C	Column	Solver s			
Design longitudinal and shear reinforcement du		V		V				Independ	dent 1	ID (Be	Solver s			
Interaction diagram														
E Shear														
H Torsion														Auto - Automatic determination of
Stress limitations														design method according to bending
Cracking forces														moments ratio rhoo,M Uniaxial around z - Design for uniaxial
Deflections														bending moment Mz only. Moment My
Detailing provisions														will not be taken into account (My = 0 kNm)
🗄 Beam (Rib)												\sim		Uniaxial around y - Design for uniaxial

The "Auto" selection of the design method is based on the limit ratio of bending moment for the uniaxial method. The program will automatically select the uniaxial or biaxial method depending on the values of bending moments around y and z axis.

Rule for automatic selection of the design method:

• If $\rho_M \le \rho_{M,lim}$ Uniaxial method

$$\rho_M = \frac{Min\{|MEd_{y,max}|, |MEd_{z,max}|\}}{Max\{|MEd_{y,max}|, |MEd_{z,max}|\}}$$

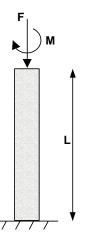
• If $\rho_M \ge \rho_{M,lim}$ Biaxial method

MEdy.maxmaximal design moment around y axis from all combinations in current sectionMEdz.maxmaximal design moment around z axis from all combinations in current sectionρ_{M,lim}limit ratio of bending moments for uniaxial method loaded from Concrete setting >Design As

Settings for limit ratio:

tional annex:							Fin	d View	 Advar 	iced Defa	ault	Remark
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Solver setting												
General												
Internal forces												
Design As												_
Coefficient for reduction of strength of the concrete in c.	Red _{fcd}	0.85		0.85	-			EN 1992-1-1	All (Bea	Solver se.		
📄 Beam, Column, Rib, Beam Slab												< Ratio _{lim} min(M _{Edy} , M _{Edy})
Limit ratio of bending moment for uniaxial method	P _{M,lim}	0.10		0.10	-			Independent	1D (Bea	Solver se.		$\frac{\min(M_{Ed,y} , M_{Ed,z})}{\max(M_{Ed,y} , M_{Ed,z})} = Ratio_{uni}$
Design method (beams)		Auto		Auto				Independent	Beam,B	Solver se.		> Ratio _{lim}
Design method (columns)		Auto		Auto				Independent	Column	Solver se.		
Coefficient increasing statically required reinforcem.	. Coeff _{stat.up}	0.00		0.00	-			Independent	Beam,B	Solver se.	<<	
Coefficient increasing statically required reinforcem.	. Coeff _{stat.lo}	0.00		0.00	-			Independent	Beam,B	Solver se.		
Coefficient increasing statically required reinforcem.	. Coeff _{stat}	0.00		0.00	-			Independent	Column	Solver se.		
Design longitudinal and shear reinforcement due to.	-	V		V				Independent	1D (Bea	. Solver se.		
Interaction diagram												
Shear												
1 Torsion												Limit ratio of bending moments for usir
Stress limitations												uniaxial design method. If ratio of
Cracking forces												bending moments is lesser than limit ratio, uniaxial design method is used ar
Deflections												smaller value of bending moment and
Detailing provisions												shear force is neglected.
🗄 Beam (Rib)											~	

Uniaxial bending calculation



Principle

The reinforcement is designed for N_{Ed} and one bending moment $M_{Ed,y}$ or $M_{Ed,z}$:

- Uniaxial around y: MEdz is ignored, the reinforcement is designed only for NEd and MEd,y
- Uniaxial around z: MEdy is ignored, the reinforcement is designed only for NEd and MEd,z

If Auto selection of design method is selected and $\rho_M \le \rho_{M,lim}$, the rule to choose between uniaxial method around y or z is:

- If $M_{Ed,y} > M_{Ed,z} \rightarrow As = Asy is designed for forces N_{Ed} and M_{Ed,y}$
- If M_{Ed,z} > M_{Ed,y} → As = Asz is designed for forces N_{Ed} and M_{Ed,z}

Example: open the example 'Uniaxial bending.esa'

Geometry Column cross-section: RECT 350x350mm² Height: 4,5 m Concrete grade: C45/55

Concrete Setup

Item Concrete settings > Internal forces ULS: 'eccentricities' are not taken in account (only 1st order moments are considered).

	ex:						Find		View		Ad	vano	ed	L	Default	:
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Solver s	etting															
H General	ral															
Interr	nal forces															
Ab	solute limit ratio for modification of internal forces	Ratioint	,abs	5,00		5,00		kN			Independ	ent	1D (B	ea	Solver	se
Re	lative limit ratio for modification of internal forces	Ratioint	,rel	0,10		0,10		-			Independ	ent	1D (B	ea	Solver	se
Mo	dification of internal forces			No		No					Independ	ent	1D (B	ea	Solver	se
Us	e equivalent first order value			1		1			5.8.8.2(2	2)	EN 1992-	1-1	Colum	n	Solver	se
De	termination of unfavourable direction			Auto		Auto			5.8.9		EN 1992-	1-1	Colum	In	Solver	se
🖃 Int	ternal forces ULS															
	Take into account additional tensile force caused by s					V			9.2.1.3(2	2)	EN 1992-	1-1	Beam	,Ri	Solver	se
	Use minimum value of eccentricity					V			6.1(4)		EN 1992-	1-1	Colum	n	Solver	se
•	Use geometric imperfection					V			5.2(5)		EN 1992-	1-1	Colum	n	Solver	se
	Use second order effect					V			5.8.8		EN 1992-	1-1	Colum	n	Solver	se
	Estimation ratio of longitudinal reinforcement for recalc	μs		2,00		2,00		%	6.2.3		EN 1992-	1-1	Colum	n	Solver	se
	Shear force reduction above supports								6.2.1(8)		EN 1992-	1-1	Beam	,B	Solver	se
	Moment reduction above supports								5.3.2.2 (A)	EN 1992-	1.1	Room	P	Coluce	

Item Detailing provisions are not taken in account, to view the pure results (according to the Eurocode, always a minimum reinforcement percentage must be added).

tional annex:								Fin	d View -	Advand	ced Defaul	ŧ
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Solver setting												
General												
Internal forces												
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Interaction diagram												
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H Torsion												
⊞ Stress limitations												
Cracking forces												
Deflections				_								
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Beam slab												
Column			ſ									
Longitudinal								0.0(0)	EN 1000 1 1	0.1	Solver s	
Check min. bar distance						V		8.2(2)	EN 1992-1-1			
Check max, bar distance								0.2.2(4)	Independent EN 1992-1-1		Solver s	
Check max. bar distance (torsion) Check min. reinforcement area						V V		9.2.3(4) 9.5.2(2)	EN 1992-1-1 EN 1992-1-1		Solver s	
Check max, reinforcement area						V		9.5.2(2)	EN 1992-1-1 EN 1992-1-1		Solver s	
Check min. bar diameter						v V		9.5.2(3)	EN 1992-1-1 EN 1992-1-1		Solver s	
Check min. number of bars						V		9.5.2(1)	EN 1992-1-1		Solver s	
								0.0.2(4)	LI4 1002-1-1	Column	_	~

Loads Column B1: LC1: Permanent load > F = 500 kN; M_y = 100 kNm LC2: Variable load > F = 1000 kN; M_y = 100 kNm

Column B2: LC1: Permanent load > F = 500 kN; M_y = 100 kNm LC2: Variable load > F = 1000 kN; M_y = 100 kNm; M_z = 10 kNm

Combination according to the Eurocode: ULS Combination = $1,35 \times LC1 + 1,50 \times LC2$ Design normal force N_{Ed} = $1,35 \times 500 + 1,50 \times 1000 = 2175$ kN Design moment M_{yd} = $1,35 \times 100 + 1,50 \times 100 = 285$ kNm Additional design moment in column B2 M_{zd} = 22.5 kNm

Results

Go to Reinforcement design > 1D members > Reinforcement design, ask the value for $A_{s,req}$, and click the action buttons [Refresh] and [Preview].

Looking at the Detailed output for column B1:

Determination type of calculation

Calculation maximum bending moments around y and z axis $M_{y,max} = -285 \text{ kNm } M_{z,max} = 0 \text{ kNm}$ Calculation maximum ratio of bending moments $p_M = 0$ Determination type of calculation $p_M = 0 < p_{M,lim} = 0.1 \text{ and } |M_{y,max}| = 285 \text{ kNm} > |M_{z,max}| = 0 \text{ kNm} =>$ $= > \text{ Uniaxial method around y axis. Moment M z will not take into account (Mz = 0 \text{ kNm}).$

The numerical results of the calculation are as follows (standard output):

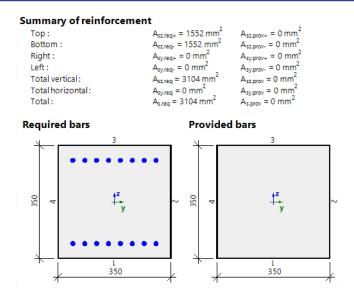
Column B1		RECT (350; 350)					
EC EN 1992-1-1:2004/AC	2008	Section 0 [dx = 0	m]				
Member length	Ld = 4.5 m	Materials					
Buckling length y	Ly = 9.01 m	Concrete	C45/55				
Buckling length z	Lz = 9.01 m	Reinforcement	B 500A				
Longitudinal reinfor	cement	:	Shear reinforcement				
φ = 16 mm, c = 30 mm,			n _{s.req} = 2, φ _{s.req} = 8 mm, α _{s.req} = 90 °				

Design of longitudinal reinforcement

A_{5,2+}: 1.35°LC1+1.50°LC2 : N_{Ed} = -2175 kN, M_{Edy} = -285 kNm, M_{Edz} = 0 kNm A_{5,2}: 1.35°LC1+1.50°LC2 : N_{Ed} = -2175 kN, M_{Edy} = -285 kNm, M_{Edz} = 0 kNm

Required

E	Edge	Layer	y [m]	z [m]	A _{s.stat} [mm ²]	A _{s.det.min} [mm ²]	A _{s.det.max} [mm ²]	ΔA _{s.tor} [mm ²]	A _{s.req} [mm ²]	A _{s.req.bar} [mm ²]	Reinf
1	1	1	0	-0.129	1552	0	0	0	1552	1608	8 ф 16
З	3	1	0	0.129	1552	0	0	0	1552	1608	8φ16



Looking at the Detailed output for column B2:

Determination type of calculation

Calculation maximum bending moments around y and z axis

 $M_{y,max} = -285 \ kNm \ M_{z,max} = -22.5 \ kNm \ Calculation maximum ratio of bending moments$

рм = 0.0789

Determination type of calculation

 $\rho_M = 0.0789 < \rho_{M,lim} = 0.1$ and $|M_{y,max}| = 285$ kNm > $|M_{z,max}| = 22.5$ kNm =>

= > Uniaxial method around y axis. Moment M_z will not take into account (M_z = 0 kNm).

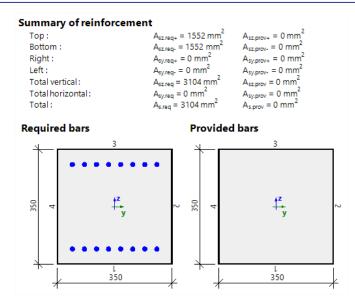
And the Standard output:

n 0 [dx = 0 m] erials
erials
ete C45/55
rcement B 500A
Shear reinforcement
$n_{s,req} = 2$, $\varphi_{s,req} = 8$ mm, $\alpha_{s,req} = 90$

A_{s.z}: 1.35*LC1+1.50*LC2 : N_{Ed} = -2175 kN, M_{Edy} = -285 kNm, M_{Edz} = 0 kNm

Required

Edge	Layer	y [m]	z [m]	A _{s.stat} [mm ²]	A _{s.det.min} [mm ²]	A _{s.det.max} [mm ²]	ΔA _{s.tor} [mm ²]	A _{s.req} [mm ²]	A _{s.req.bar} [mm ²]	Reinf
1	1	0	-0.129	1552	0	0	0	1552	1608	8 ф 16
3	1	0	0.129	1552	0	0	0	1552	1608	8 ф 16



Even if an additional bending moment in the z direction is present in column B2, according to the limit ratio the uniaxial method was used, and the same amount of reinforcement is required for columns B1 and B2.

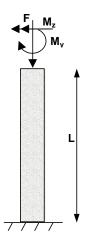
The user has the possibility to force the biaxial method design on column B2 using 1D member data in Settings per member > 1D member data:

Concrete 4 ×	CMD	X
Concrete settings (structure)	Name CMD1 Member B2 Member type Column Advanced mode Image: Column Solver setting Image: Column Image: General Image: Column	•
	 Design As Beam, Column, Rib, Beam Slab Design method (columns) Coefficient increasing statically required reinforcem 0.00 Design longitudinal and shear reinforcement due to 	· · · · · · · · · · · · · · · · · · ·

Amount of required reinforcement will be slightly higher in this case since M_{Edz} is also considered.

Colu	umn l	B2				REC	T (350;	350)		
EC EN 1	1992-1-1:2	004/AC:20	008			Secti	on 0 [dx =	0 m]		
Mem	ber length		Ld =	4.5 m		Mat	erials			
Buckl	ing length	у	Ly =	9.01 m		Conc	rete	C45,	/55	
Buckl	ing length	z	Lz =	9.01 m		Reinf	orcement	B 50	0A	
Longit	udinal r	einforc	ement					Shear	reinfo	rcement
φ = 1	6 mm, c =	30 mm,						n _{s.rec}	q = 2, φ _{s.rec}	_q = 8 mm, α _{s.req} = 90 °
		0*LC2 : N	_{Ed} = -2175	kN, M _{Edy}	= -285 kN					
A _{sz} : 1.3: equired			u	en la company	- 205 KINI	n, w _{Edz} =	-25 KINM			
A _{sz} : 1.3 equired Edge		y [m]	z [m]	A _{s.stat}		A _{s.det.max}	ΔA _{s.tor} [mm ²]	A _{s.req} [mm ²]	A _{s.req.bar} [mm ²]	Reinf
equired	I	У	z	A _{s.stat}	As.det.min	A _{s.det.max}	ΔA _{s.tor}			Reinf 11¢16

Biaxial bending calculation



This method allows to design reinforcement for a normal force (N_{Ed}) and biaxial bending moments. This method is based on an interaction formula, equation 5.39 in EN 1992-1-1.

$$\left(\frac{M_{Edz}}{M_{Rdz}}\right)^a + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^a \le 1,0$$
(5.39)

where:

 $M_{Edz/y}$ design moment, including a 2nd order moment (if required)

*M*_{Rdz/y} moment resistance

a exponent:

- 1	or circular and elliptical cross sections: $a = 2$
-----	--

- for rectangular cross sections:

$N_{\rm Ed}/N_{\rm Rd}$	0,1	0,7	1,0
a =	1,0	1,5	2,0

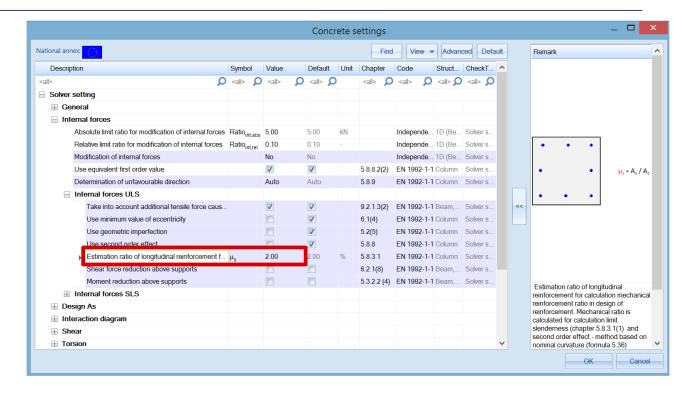
with linear interpolation for intermediate values

*N*_{Ed} design value of axial force

 N_{Rd}

- = $A_c \cdot (f_{cd} + \mu_s \cdot f_{yd})$, design axial resistance of the section, where: A_c gross area of the concrete section
- Ac gross area of the concrete section
 f_{cd} design value of concrete compressive strength
- f_{yd} design yield strength of reinforcement
- μ_s estimation ratio of longitudinal reinforcement from the Concrete settings or 1D member data

The ratio μ_s can be set in Concrete settings > Solver Settings > Internal forces > Internal forces ULS:



Circular columns

For circular and oval columns, the design method is always the biaxial calculation, regardless of the design method set in the Concrete settings.

For circular and oval columns, the required number of reinforcement bars is spread equally along the face of the column.

Example: 'Circular column.esa'

Geometry

Column cross-section: CIRC diameter 400mm Height: 4,5 m Concrete grade: C45/55

Loads

Load configuration:	N _{Ed} = 2175,00 kN
	M _{yd} = 142,50 kNm
	$M_{zd} = 0 \text{ kNm}$

Concrete Setup

Geometrical imperfection and 2nd order moments are deactivated: Concrete settings > Internal forces ULS:

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Solver	setting									
🗄 Gen	neral									
🗉 Inte	ernal forces									
A	Absolute limit ratio for modification of internal forces	Ratio _{int,a}	bs 5,	00	5,00	kN		Independent	1D (Bea	Solver s
F	Relative limit ratio for modification of internal forces	Ratio _{int,re}	el 0,	10	0,10	-		Independent	1D (Bea	Solver s
N	Modification of internal forces		N)	No			Independent	1D (Bea	Solver s
U	Jse equivalent first order value		1		V		5.8.8.2(2)	EN 1992-1-1	Column	Solver s
0	Determination of unfavourable direction		AL	<i>i</i> to	Auto		5.8.9	EN 1992-1-1	Column	Solver s
=	Internal forces ULS									
	Take into account additional tensile force caused by s				V		9.2.1.3(2)	EN 1992-1-1	Beam,Ri	Solver s
	Use minimum value of eccentricity]	1		6.1(4)	EN 1992-1-1	Column	Solver s
1	 Use geometric imperfection]	V		5.2(5)	EN 1992-1-1	Column	Solver s
	Use second order effect]	V		5.8.8	EN 1992-1-1	Column	Solver s
	Estimation ratio of longitudinal reinforcement for recalc	μs	Ζ,	00	2,00	%	6.2.3	EN 1992-1-1	Column	Solver s
	Shear force reduction above supports						6.2.1(8)	EN 1992-1-1	Beam,B	Solver s
	Moment reduction above supports						5.3.2.2 (4)	EN 1992-1-1	Beam, B	Solver s

All detailing provisions are considered.

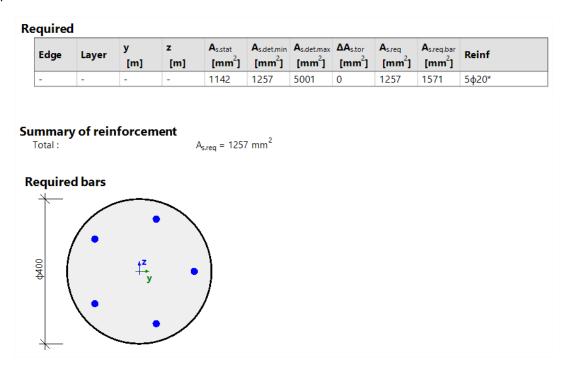
Design defaults

The bar diameter is set to ϕ 20mm in Reinforcement design > Design defaults > Tab Columns, or from 1D Member data if applied.

in the second															
ional annex:										ind	View		Advance	Det	ault
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Design defaults															
Beam (Rib)															
Beam slab Beam slab Solution Solutio															
Column															
Longitudinal															
Use a template of provided reinforcement						V					Indepen	dent	Column	Desig	n d
A Main															
Type of cover				User		Auto			4.4.1		EN 1992	2-1-1	Column	Desig	n d
Concrete cover (c)		с		35.0		30.0		mm	4.4.1		EN 1992	2-1-1	Column	Desig	n d
Diameter		d _{s.m}		20.0		16.0		mm			EN 1992	2-1-1	Column	Desig	n d
E Stirrups															

Results

Go to Reinforcement design > 1D members > Reinforcement design. Choose Standard output in the Properties window and open the Preview at the bottom of the Properties window:



In this example $A_{s,req}$ is determined by the minimum amount of reinforcement according to the detailing provision, $A_{s,det,min}$.

Since $A_{s,req} = 1257 \text{ mm}^2$, the software will propose 5 bars of $\phi 20 \text{mm} (5*314 \text{mm}^2 = 1571 \text{mm}^2 = A_{s,req,bar})$ which is the closest amount of bar with $A_{s,req,bar} > A_{s,req}$.

Note that SCIA Engineer uses the real area of the bars to calculate the required reinforcement area. So, the final required reinforcement displayed on the screen is $A_{s,req,bar}$.

Remark 1: If you choose a template without bars predefined in Design Default, for example "Column_Circ-Empty", the software will display only the A_{s,req} and not A_{s,req,bar} as mentioned above.

ional annex:							Find View - Advanced Default	Remark
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Design defaults					Column_Circ	_Empty		
Beam (Rib)					Column_Circ	-		
🗄 Beam slab					Column_Circ			
Column					Column_Circ	_Basic_Ad		
Longitudinal								
Use a template of provided reinforcement			\checkmark	1		_		_
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Circular			Column_(🔻		Description	Empty re		
Oval			Column_Ov		Member t	Column		
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Type of cover			Auto	Auto	Mode	Standard		
Stirrups								
Diameter of stirrups	d _{ss}		8.0	8.0				
Number of cuts	n _s		2.0	2.0				
								· · · · · · · · · · · · · · · · · · ·
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Remark 2:

According to *EN1992-1-1 art 9.5.2(4)*, there is a minimum number of bars in a circular column. This parameter is set by default to "4" in Concrete Setup > Detailing provisions > Column > Longitudinal.

ion	al annex: 🔤 🎧						Find	View	- Adv	vanced	Default	
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+	Internal forces											
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+	Interaction diagram											
+	Shear											
+	Torsion											
+	Stress limitations											
+	Cracking forces											
+	Deflections											
-	Detailing provisions											
	🗄 Beam (Rib)											
	🗄 Beam slab											
	Column											
	Longitudinal											
	Check min. bar distance			V	\checkmark			8.2(2)	EN 1992-1-1	Column	Solver se	
	Minimal bar distance	Slc,min		20	20		mm	8.2(2)	EN 1992-1-1	Column	Solver se	
	Check max. bar distance								Independent	Column	Solver se	
	Check max. bar distance (torsion)			1	1			9.2.3(4)	EN 1992-1-1	Column	Solver se	
		Slct,max		350	350		mm	9.2.3(4)	EN 1992-1-1	Column	Solver se	
	Check min. reinforcement area			V	\checkmark			9.5.2(2)	EN 1992-1-1		Solver se	
	Check max. reinforcement area			V	1			9.5.2(3)	EN 1992-1-1	Column	Solver se	
	Check min. bar diameter			V	\checkmark			9.5.2(1)	EN 1992-1-1	Column	Solver se	
	Charaly minimum has af here		-	172				9.5.2(4)	EN 1992-1-1	Column	Solver se	
	 Minimal number of bars in circular column 	NIc,min		4,0	4)			9.5.2(4)	EN 1992-1-1	Column	Solver se	
	- Iransverse											
	Check max. percentage of stirrups			V	1			6.2.3(3)	EN 1992-1-1	Column	Solver se	×

If we increase the loads: Fz = -1250 kN M = 50 kNmthe results are as follows:

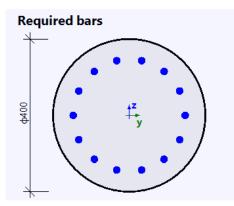
Exemple: "Circular column_increase.esa"

Overall Design (ULS)

Linear calculation Combination: CO1 Coordinate system: Principal Extreme 1D: Global Selection: All Longitudinal required reinforcement

Name	dx [m]	Case	Member	A _{sz req+} [mm ²] A _{sz req bar+} [mm ²]	A _{sz req} - [mm ²] A _{sz req bar-} [mm ²]	A _{sy req+} [mm ²] A _{sy req bar+} [mm ²]	A _{sv req} - [mm ²] A _{sv req bar-} [mm ²]	A _{sz req} [mm ²] A _{sz req bar} [mm ²]	A _{sv req} [mm ²] A _{sv req bar} [mm ²]	A _{s req} [mm ²] A _{s req bar} [mm ²]	ReinfReq
B1	0,000	CO1	Column	1041	1041	1041	1041	2082	2082	4164	14φ20
				1100	1100	1100	1100	2199	2199	4398	

The corresponding bar configuration is:



Calculation of internal forces

Determining if member is in compression

2nd order effects, geometrical imperfection and minimal eccentricity are considered only if:

- Member type = Column
- Compression in the column is relatively high

In SCIA Engineer, there is a parameter which allows to decide whether a member is in compression or if the compression is too small to be considered.

In Concrete settings > Solver setting > General:

	Con	crete se	tting	s						_ □ ×
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Solver setting										
General										
Limit value of unity check	Lim.check	1.0	1.0			Indepe	All (B	Solve		
Value of unity check for not calculated unity check	Ncal.che	3.0	3.0			Indepe	All (B	Solve		
The coefficient for calculation effective depth of cross-section	Coeff _d	0.9	0.9			Indepe	All (B	Solve		
The coefficient for calculation inner lever arm	Coeff,	0.9	0.9			Indepe	All (B	Solve		
The coefficient for calculation force, where member as under compression	Coeff _{com}	0.1	.1			Indepe	All (B	Solve		$N_{Ed} \leq Coeff_{com} \cdot A_c \cdot f_{cd}$
E Creep										
⊞ SLS										
Default sway type									<<	
⊞ Minimal concrete cover										
Internal forces										
Design As										
Interaction diagram										
Shear										
Torsion										The coefficient for calculation force,
Stress limitations										where member is considered as under
Cracking forces										compression. If NEd <= Ncom => member under compression
Deflections										·
Detailing provisions										
										~
						۵	5			OK Cancel

Condition is:

- If $N_{Ed} \leq$ Coeff_{com} $\cdot f_{cd} \cdot A_c$ Member is in compression
- If N_{Ed} > Coeff_{com} ·f_{cd} · A_c Compression is not sufficient (zero or relatively small)

This result can be viewed in Reinforcement design > 1D member > Internal forces.

The Detailed output gives:

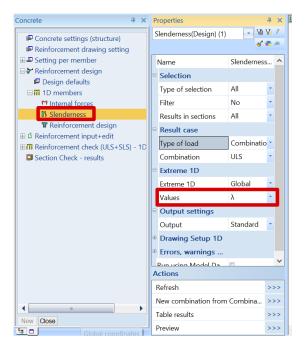
ompr	ession member
Limita	xial force to consider member as compression:
	$N_{com} = -Coeff_{com} \cdot (f_{cd} \cdot A_c) = -0.1 \cdot (30 \cdot 10^6 \cdot 0.123) = -368 \text{ kN}$
Check	condition:
	$N_{Ed} < N_{com} = -1100 \text{ kN} < -368 \text{ kN} \dots$ compression member
	First and second order eccentricity shall be taken into account, because the member is considered as a ression member (significant normal force is presented).

Choice between 1st and 2nd order calculation

Slenderness – Check of the criteria $\lambda < \lambda$ lim

- If $\lambda < \lambda_{\text{lim}}$, 1st order effects have to be taken into account with geometric imperfection (art 5.2)
- If $\lambda > \lambda_{\text{lim}}$, 2nd order effects have to be taken into account with geometric imperfection (art 5.2)

The values for λ and λ_{lim} , and the corresponding check, can be found in the Concrete menu > Reinforcement design > 1D member > Slenderness



The Standard output shows the check of $\lambda > \lambda_{lim}$ and indicates whether a 1st or 2nd order calculation should be done.

Slenderness(Design)

Linear calculation Load case: LC1 Coordinate system: Principal Extreme 1D: Global Selection: All

Column B1	RECT (350; 350)
EC EN 1992-1-1:2004/AC:2008	Section 0 [dx = 0 m]

Slenderness

Axis	Braced	L _{z/y} [m]	β _{zz/yy} [-]	l _{0z/y} [m]	λ _{z/y} [-]	λ limz/y [-]	$\lambda_{z/y} > \lambda_{limz/y}$
у-у⊥	No	4.5	2	9.01	89.2	46.5	2 nd order
z-z⊥	No	4.5	2	9.01	89.2	46.5	2 nd order

1st order effects

1st order effects (eccentricity) are always considered.

There are 2 ways to calculate the 1st order moments and eccentricity in SCIA Engineer depending on check box **Use equivalent first order value** in Concrete Setup > Internal forces.

tional annex:					Fin	d View •	Advan	ced Defa	ult	Remark
Description	Symbol	Value	Default	Unit	Chapter	Code	Structure	CheckT	^	
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Solver setting										
General										
Internal forces										
Absolute limit ratio for modification of internal forces	Ratio _{int,abs}	5.00	5.00	kN		Independent	1D (Bea	. Solver s		
Relative limit ratio for modification of internal forces	Ratio _{int,rel}	0.10	0.10	-		Independent	1D (Bea	. Solver s		
Modification of internal forces		No	No			Independent	1D (Bea	. Solver s		
Use equivalent first order value		V	V		5.8.8.2(2)	EN 1992-1-1	Column	Solver s		$M_{0e} = 0.6 \cdot M_{02} + 0.4 \cdot M_{01} \ge 0.4$
Determination of unfavourable direction		Auto	Auto		5.8.9	EN 1992-1-1	Column	Solver s		
Internal forces ULS										
Take into account additional tensile force caused			V		9.2.1.3(2)	EN 1992-1-1	Beam,R	. Solver s		
Use minimum value of eccentricity		V	V		6.1(4)	EN 1992-1-1	Column	Solver s	<	<<
Use geometric imperfection		\checkmark	V		5.2(5)	EN 1992-1-1	Column	Solver s		
Use second order effect			1		5.8.8	EN 1992-1-1	Column	Solver s		
Estimation ratio of longitudinal reinforcement for r	μ _s	2.00	2.00	%	5.8.3.1	EN 1992-1-1	Column	Solver s		
Shear force reduction above supports					6.2.1(8)	EN 1992-1-1	Beam,B	Solver s		
Moment reduction above supports					5.3.2.2 (4)	EN 1992-1-1	Beam,B	Solver s		The first order moment is taken into
Internal forces SLS										account as equivalent first order
Design As										moment, if this parameter is ON.
H Shear										
1 Torsion										
E Cracking forces									~	

The 2 options are:

• Use equivalent first order value = YES, bending moments at the ends of the column will be taken to calculate an equivalent 1st order bending moment. This leads to the same 1st order bending moment along the whole length of the member.

 $e_{0y} = M_{0ez} / N_{Ed}, e_{0z} = M_{0ey} / N_{Ed}$

With $M_{0e} = 0.6 \cdot M_{02} + 0.4 \cdot M_{01} \ge 0.4 \cdot M_{02}$

 Use equivalent first order value = NO, 1st order eccentricity is calculated from bending moments in current section. As a result, bending moments in each section can be different.

$$e_{0y} = M_z / N_{Ed}, e_{0z} = M_y / N_{Ed}$$

Values of the 1st order eccentricities and moments can be viewed in Reinforcement design > 1D member > Internal Forces.

Standard output gives:

Internal forces (Design)

Linear calculation Combination: ULS Coordinate system: Principal Extreme 1D: Global Selection: All

Column B1	RECT (350; 350)
EC EN 1992-1-1:2004/AC:2008	Section 0 [dx = 0 m]

Internal forces (FEM-based)

Extreme: ULS/1 (ULS) Type: Combination (linear) Design situation: EN-ULS (STR/GEO) Set B

Type of load	N	My	Mz	Vy	Vz	M _x
Type of load	[kN]	[kNm]	[kNm]	[kN]	[kN]	[kNm]
Internal forces (FEM-based)	-300.0	-30.0	0.0	0.0	0.0	0.0
Content: LC1						

Slenderness

Axis	Braced	L _{z/y} [m]	β _{zz/yy} [-]	l _{0z/y} [m]	λ _{z/y} [-]	λ _{limz/y} [-]	$\lambda_{z/y} > \lambda_{limz/y}$
у-у⊥	No	4.5	2	9.01	89.2	46.5	2 nd order
z-z⊥	No	4.5	2	9.01	89.2	46.5	2 nd order

Unfavourable direction

Second order effect and imperfections

Axis	N _{Ed} [kN]	M _{0Edy/z} [kNm]	M _{2y/z} [kNm]	M _{Edy/z} [kNm]	e _{0z/y} [mm]	e _{iz/y} [mm]	e _{0min,z/y} [mm]	e _{0Edz/y} [mm]	e _{2z/y} [mm]	e _{Edz/y} [mm]
у-у⊥	-300	-30	0	-30	100	0	0	100	0	100
z-z-	-300	0	0	0	0	0	0	0	0	0

Design forces (recalculated)

Type of load	N _{Ed}	M _{Ed,y}	M _{Ed,z}	V _{Ed,y}	V _{Ed,z}	M _{Ed,x}
	[kN]	[kNm]	[kNm]	[kN]	[kN]	[kNm]
Design forces (recalculated)	-300.0	-30.0	0.0	0.0	0.0	0.0

Geometrical imperfection (art.5.2)

The effect of geometric imperfections always have to be taken into account: both in a 1st and 2nd order calculation.

Geometrical imperfection is by default activated in Concrete settings > Internal forces

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Description	Symbol	Value	1	Default	Unit	Chapter	Code	Structure	CheckTy	•	
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Solver setting											
General											
Internal forces											
Absolute limit ratio for modification of internal forces	Ratio _{int,abs}	5.00	5	5.00	kN		Independent	1D (Bea	Solver set		
Relative limit ratio for modification of internal forces	Ratio _{int,rel}	0.10	0	0.10	-		Independent	1D (Bea	Solver set		
Modification of internal forces		No		No			Independent		Solver set		$\theta_1 = 0$
Use equivalent first order value		\checkmark	[1		5.8.8.2(2)	EN 1992-1-1	Column	Solver set		
Determination of unfavourable direction		Auto	F	Auto		5.8.9	EN 1992-1-1	Column	Solver set		$\Theta_1 = \Theta_0 \cdot \alpha_h \cdot \alpha_m$
Internal forces ULS											
Take into account additional tensile force caused by she		\checkmark		1		9.2.1.3(2)	EN 1992-1-1	Beam,Ri	Solver set		
Use minimum value of eccentricity			[1		6.1(4)	EN 1992-1-1	Column	Solver set	<<	
Use geometric imperfection		V		1		5.2(5)	EN 1992-1-1	Column	Solver set		
Use second order effect				1		5.8.8	EN 1992-1-1	Column	Solver set		
Estimation ratio of longitudinal reinforcement for recalcul	μ _s	2.00	2	2.00	%	5.8.3.1	EN 1992-1-1	Column	Solver set		
Shear force reduction above supports						6.2.1(8)	EN 1992-1-1	Beam,Be	Solver set		
Moment reduction above supports						5.3.2.2 (4)	EN 1992-1-1	Beam,Be	Solver set		The geometric imperfection is taken int
⊞ Internal forces SLS											account for calculation first order
🗄 Design As											eccentricity, if this parameter is ON.
Interaction diagram											
Torsion											
H Stress limitations											
E Cracking forces									~		

In SCIA Engineer, the geometrical imperfection is represented by an inclination according to clause 5.2(5) in EN 1992-1-1.

For both axis (y and z of LCS), the inclination is calculated as followed:

$$\theta_{i,y(z)} = \theta_0 \cdot \alpha_h \cdot \alpha_{m,y(z)}$$
(5.1)

 θ_0 basic value of inclination

reduction factor for length of column or height of structure: $\alpha_h = 2/\sqrt{I}$; $2/3 \le \alpha_h \le 1$ α_h $\alpha_{m,v(z)} = \sqrt{(0.5 \cdot (1 + 1 / m_{v(z)}))}$ reduction factor for numbers of members: $\alpha_{m,y(z)}$ L length of column or height of structure depending on:

- isolated member I = L, where L is the length of the member
- not isolated member I = H, where H is the total height of building (buckling system).
- number of vertical members contributing to the total effect of the imperfection perpendicular m_{y(z)} to y(z).

Values of I and $m_{y(z)}$ will be defined in the buckling data.

The effect of imperfection for isolated column and for structure is always taken into account as an eccentricity according to clause 5.2(7a) in EN 1992-1-1:

$$e_{i,y} = \theta_{i,z} \cdot I_{0,z} / 2, e_{i,z} = \theta_{i,y} \cdot I_{0,y} / 2$$

The imperfection shall be taken into account in ultimate limit states and does not need to be considered for serviceability limit states, see clause 5.2(2P) and 5.2(3) in EN 1992-1-1.

The user can set independently if the imperfection will be taken into account for ULS or SLS in the Concrete settings.

A minimum 1st order eccentricity is also calculated according to clause 6.1(4) in EN 1992-1-1. This can be viewed in Concrete settings > Internal forces > Use minimum value of eccentricity

ional annex:							Find Vie	w 🔻 Adva	nced Defau	lt	Remark
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Solver setting											
H General											
Internal forces											
Absolute limit ratio for modification of internal forces	Ratio _{int,ab}		5.00	5.00	kN		Independent	1D (Bea	Solver set		
Relative limit ratio for modification of internal forces	Ratio _{int,rel}		0.10	0.10	-		Independent	1D (Bea	Solver set		
Modification of internal forces			No	No			Independent	1D (Bea	Solver set		$e_0 = e_1 + e_i$
Use equivalent first order value			V	\checkmark		5.8.8.2(2)	EN 1992-1-1		Solver set		
Determination of unfavourable direction			Auto	Auto		5.8.9	EN 1992-1-1	Column	Solver set		
Internal forces ULS											
Take into account additional tensile force caused by she		_	V	V		9.2.1.3(2)	EN 1992-1-1	Beam,Ri	Solver set		$e_0 = \max \left(e_1 + e_i \right); \frac{h}{30}; 20 \text{mm}$
Use minimum value of eccentricity				V		6.1(4)	EN 1992-1-1	Column	Solver set	<<	
Use geometric imperfection			V	\checkmark		5.2(5)	EN 1992-1-1		Solver set		
Use second order effect				\checkmark		5.8.8	EN 1992-1-1	Column	Solver set		
Estimation ratio of longitudinal reinforcement for recalcul	μ_{s}		2.00	2.00	%	5.8.3.1	EN 1992-1-1	Column	Solver set		
Shear force reduction above supports						6.2.1(8)	EN 1992-1-1				
Moment reduction above supports						5.3.2.2 (4)	EN 1992-1-1	Beam,Be	Solver set		The minimum value of eccentricity is
Internal forces SLS											taken into account for calculation first
Use geometric imperfection						5.2(5)	EN 1992-1-1	Column	Solver set		order eccentricity, if this parameter is ON.
Design As											
Interaction diagram											
H Shear											
H Torsion											
Stress limitations										~	

Buckling data for I and my(z)

Settings for I and my(z) for the calculation of the geometrical imperfection can be set in the properties of the columns.

Properties		ч×
Member (1)		庙 🌾 🖉
8	4	\$ 🅐 🧯
Name	B1	^
Туре	column (100)	•
Analysis model	Standard	-
Cross-section	CS1 - RECT (350;	·
Alpha [deg]	0.00	
Member system-line	Centre	•
ey [mm]	0	
ez [mm]	0	
LCS	standard	•
LCS Rotation [deg]	0.00	
FEM type	standard	-
Buckling and relative	Default	•
ayer	Layer1	×
Geometry		
Length [m]	4.500	
Shape	Line	\checkmark

Properties > Buckling and relative length > Edit > tab Buckling data:

				ł	Buckling and rel	ative lengths.		· · · · · · · · · · · · · · · · · ·	×
ſ	Base	settings Buckling data							
		уу	Sway yy	ZZ	Sway zz	Tot. heigth	Tot. heigth [m]	my	mz
	1	🗷 Fixed	Settings	🛛 🗹 Fixed	Settings T	Calculate 🔹	20.00	1.00	1.00
	2	🗖 Free		🖾 Free					
		4							

- Tot. height: set type of calculation of total height of building or length of the isolated columns.
 - *Calculate*: H tot will be calculated automatically as sum of lengths of all the members in the buckling system
 - o User: manual input value for Htot in edit box Tot. height
- **my/z**: number of vertical members contributing to the total effect of the imperfection perpendicular to y/z axis of LCS.

Eccentricities due to geometrical imperfections can be viewed in Reinforcement design > 1D member > Internal Forces:

Second order effect and imperfections

Axis	N _{Ed} [kN]	M _{0Edy/z} [kNm]	M _{2y/z} [kNm]	M _{Edy/z} [kNm]	e _{0z/y} [mm]	e _{iz/y} [mm]	e _{0min,z/y} [mm]	e _{0Edz/y} [mm]	e _{2z/y} [mm]	e _{Edz/y} [mm]
у-у⊥_	-405	-49.1	0	-49.1	100	21.2	20	121	0	121
z-z⊥	-405	8.1	0	8.1	0	0	-20	-20	0	-20

After calculation of 1^{st} order eccentricity including effect of imperfection, the 1st order moment, including the effect of imperfections around y (z) axis of LCS is calculated:

$$M_{0Ed,y(z)} = N_{Ed} \cdot e_{oEd,z(y)}$$

 $e_{oEd,y(z)} = e_{0,y(z)} + e_{i,y(z)} > e_{0,\min,y(z)}$

e_{0,y(z)} 1st order eccentricity

eccentricity caused by geometrical imperfection

e_{0,min} minimum first order eccentricity

2nd order effects

The EN 1992-1-1 defines several methods for 2nd order effects with axial loads(general method, simplified method based on nominal stiffness, simplified method based on nominal curvature...).

In SCIA Engineer the following methods are available:

- General method according to clause 5.8.2(2) based on a nonlinear calculation
- Simplified method based on nominal curvature according to clause 5.8.8

The simplified method is taken into account:

- For ultimate limit state
- For Member type = Column with compression according to "Determination if member is in compression"
- If option "Use second order effect" in switched ON, see Concrete settings > Internal forces. This option is activated by default.
- If slenderness λ > λ_{lim}, see chapter "Slenderness criteria"

The nominal 2nd order moment is calculated according to clause 5.8.8.2(3) in EN 1992-1-1:

 $M_{2,y(z)} = N_{Ed} \cdot e_{2,z(y)}$

N_{Ed} design axial force e_{2,z(y)} 2nd order eccentricity

When all mentioned criteria above are met for the simplified method, the 2nd order eccentricity is calculated according to formula:

 $e_{2y(z)} = (1/r)_{z(y)} \cdot I_{0z(y)}^2 / c_{z(y)}$

Otherwise $e_{2y(z)} = 0$

Cz(y)

 $(1/r)_{z(y)}$ curvature around z(y), calculated according to clause 5.8.8.3 $I_{0,z(y)}$ effective length of the column around z(y) – buckling length

factor depending on the curvature distribution around z(y) axis according to clause 5.8.8.2(4)

- = 8, for constant 1st order bending moment (non zero) along the column and in case that equivalent bending moment is taken into account ("Use equivalent first order value" ON).
 - = 10 otherwise.

λ_{z(y)} slenderness

λ_{z(y),lim} limit slenderness

Effective length

The effective length, or buckling length, is by default calculated by SCIA Engineer. Be aware that formulas for automatic calculation are only valid for simple structures! Otherwise it is also possible to input the value of the effective length manually.

Automatic calculation of effective length

Calculation of effective length depends on the type of structure, sway or non-sway.

Two approximate formulas are used: one formula for a non-sway structure (resulting in a buckling factor $\beta \le 1$) and one formula for a sway structure (resulting in a buckling factor $\beta \ge 1$):

• For a non-sway structure:

$$\beta = \frac{(\rho_1\rho_2 + 5\rho_1 + 5\rho_2 + 24)(\rho_1\rho_2 + 4\rho_1 + 4\rho_2 + 12)2}{(2\rho_1\rho_2 + 11\rho_1 + 5\rho_2 + 24)(2\rho_1\rho_2 + 5\rho_1 + 11\rho_2 + 24)}$$

• For a sway structure:

$$\beta = x \sqrt{\frac{\pi^2}{\rho_1 x} + 4}$$

with	β	the buckling factor
	Ĺ	the system length
	E	the modulus of Young
	I	the moment of inertia
	Ci	the stiffness in node i
	Mi	the moment in node i
	фі	the rotation in node i

$$x = \frac{4\rho_1\rho_2 + \pi^2\rho_1}{\pi^2(\rho_1 + \rho_2) + 8\rho_1\rho_2}$$
$$\rho_i = \frac{C_i L}{EI}$$
$$C_i = \frac{M_i}{\phi_i}$$

The values for M_i and ϕ_i are approximately determined by the internal forces and the deformations, calculated by load cases which generate deformation forms, having an affinity with the buckling form.

The calculation of the β ratios is automatically done when calculating the structure linearly. For this, two additional load cases are calculated in the background:

- Load case 1:
 - on the beams, the local distributed loads qy=1 N/m and qz=-100 N/m are used
 - on the columns the global distributed loads Qx =10000 N/m and Qy =10000 N/m are used.
 - Load case 2:
 - on the beams, the local distributed loads qy=-1 N/m and qz=-100 N/m are used
 - $\circ~$ on the columns the global distributed loads Qx =-10000 N/m and Qy=-10000 N/m are used.

Since these load cases, and thus the buckling ratios, are calculated during the linear calculation, it is necessary to always perform a linear calculation of the structure.

Note: The used approach gives good results for frame structures with perpendicular rigid or semi-rigid beam connections. For other cases, the user must evaluate the presented bucking ratios.

By default, the structure is considered as sway in y and z direction. It can be modified for the whole project in Concrete settings > General > Default sway type.

onal ann	nex:					Find	View 🔻	Advanc	ed Defau	ılt
Descrip	tion	Symbol	Value	Default	Unit	Chapter	Code	Struct	CheckT	^
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Solver	setting									
🗏 Ge	neral									
	Limit value of unity check	Lim.check	1.0	1.0			Independe	All (Bea	Solver s	
	Value of unity check for not calculated unity check	Ncal.check	3.0	3.0			Independe	All (Bea	Solver s	
	The coefficient for calculation effective depth of cr	Coeff _d	0.9	0.9			Independe	All (Bea	Solver s	
	The coefficient for calculation inner lever arm	Coeffz	0.9	0.9			Independe	All (Bea	Solver s	
	The coefficient for calculation force, where membe	Coeff _{com}	0.1	0.1			Independe	All (Bea	Solver s	
\pm	Стеер									
H	SLS									
	Default sway type									
	Sway around y axis	Sway yy	V	1			Independe	All (Bea	Solver s	
	Sway around z axis	Sway zz	V	V			Independe	All (Bea	Solver s	
	Minimal concrete cover									
	ernal forces									
	sign As									
	eraction diagram									
🗄 She										
	sion									
	ess limitations									
	acking forces									
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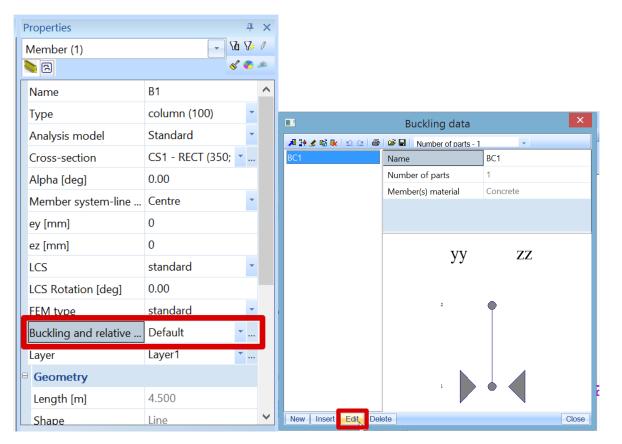
The user can change this default setting for specific columns in the project using either:

• Setting per member > 1D buckling data.

Then select the columns on which you want to apply this modification.

Concrete 7 ×		Buckling data	×
Concrete 4 ×	Ly Lz	Buckling data Name Edit buckling Member(s) material Buckling ky, kz coefficients or buckling lengths All other and LTB coefficients Buckling systems relation zz Secondary member coefficient Beta yy Beta zz Sway yy Sway zz	BB1 Concrete user input • default from LIB manager • zz • Calculate Calculate No • Yes •
		ļ.	OK Cancel

• Properties of columns > Buckling and relative length > Edit > tab Base settings:



	Buckling and relative lengths.			×
Base settings Buckling data				
y y	Name BC1 Buckling systems relation	Number of parts	1	
	ZZ = ZZ 🗸 🗸	Beta yy	Calculate	\checkmark
Ly		Beta zz	Calculate	~
		Sway yy	Yes	~
		Sway zz	No	~
*				_

This new setting has the name, here BC1, which you can attribute to others similar columns in their properties window:

Properties	4	×
Member (1)	- Va V/	Ø
8	S 🐔	*
Name	B1	^
Туре	column (100)	
Analysis model	Standard 🔹	
Cross-section	CS1 - RECT (350; 🝸	
Alpha [deg]	0.00	
Member system-line	Centre 🔹	
ey [mm]	0	
ez [mm]	0	
LCS	standard 🔹	
LCS Rotation [deg]	0.00	
FEM type	standard 🗸	
Buckling and relative	Default	1
Layer	Default 😽	I
Geometry	BC1	
Length [m]	4.500	
Shape	Line	v

The calculated effective length can be viewed in Concrete menu > Reinforcement Design > 1D members > Slenderness:

Concrete 7 ×	Properties	4	×	Report preview										
Concrete settings (structure)	Slenderness(Design) (1			京都会に Default	- 881	III 🕙								
Reinforcement drawing setting		s e	*											
🖃 🕮 Setting per member	Name	Slenderness(Design)	^	Slendern	ess(Des	sian)								
= 1D member data	Selection				•	'g'')								
ID buckling data ID buckling data	Type of selection	All		Linear calculati Combination:										
Design defaults	Filter	No		Coordinate sys		4								
□ m 1D members	Results in sections	All		Extreme 1D: G										
11 Internal forces	Result case			Selection: All										
Slenderness Reinforcement design	Type of load	Combinations												
Reinforcement input+edit	Combination	ULS		Column B1 RECT (350; 350)							(O)			
	Extreme 1D			EC EN 1992-1-1:2		Section 0 [dx = 0 m]								
Section Check - results	Extreme 1D	Global		Slenderness										
	Values	1					0 11	1 6-1						
	Output settings			Axis	Braced	L _{z/y} [m] 4.5	β _{22/yy} [-]	l _{oz/y} [m] 9.01	λ _{z/y} [-] 89.2	λ _{limz/y} [-] 46.5	$\lambda_{z/y} > \lambda_{timz/y}$			
	Output	Standard		y-y z-z	Yes	4.5	2	3.15	31.2	46.5	2 nd order 1 st order			
		Standard		2-2	res	4.5	0.7	5.15	51.2	40.5	1" order			
	Drawing Setup 1D													
	Errors, warnings													
	Run using Model Da	in .												

This value is also displayed in the Standard output for Internal forces, together with the 2nd order eccentricity and the corresponding bending moment:

Type of load	d									
			N	M	,	Mz	Vy	Vz		N ×
		- D	[kN]	•	Nm]	[kNm]		[kN		kNm]
Internal forc Content: 1.35		sed)	-405	.0 -4	0.5	0.0	0.0	0.0	0	0.0
endernes	-		1 7 1		. 📻	freed		· · · ·	•	
Axis		ced	L _{z/y} [m]	β _{zz/yy} [/y [m]	λ _{z/y} [-]	λ _{limz/y} [-]		λ _{limz/y}
у-у		lo	4.5	2		9.01	89.2	40.1	-	order
z-z⊥	Y	es	4.5	0.7	3	3.15	31.2	40.1	1 st (order
econd ord			nperfe	ctions						
Axis	N _{Ed} [kN]	M _{0Edy/z} [kNm]	M _{2y/z} [kNm]	M _{Edy/z} [kNm]	e _{0z/y} [mm]	e _{iz/y} [mm]	e _{0min,z/y}] [mm]	e _{0Edz/y} [mm]	e _{2z/y} [mm]	
Axis										e _{Edz/y} [mm 283

Manual input of effective length

The same 2 options as seen for the automatic calculation, allow to manually input the effective length.

• Setting per member > 1D buckling data.

Concrete 4 ×		Buckling data	×
Concrete 4 × Concrete settings (structure) Reinforcement drawing setting Setting per member 1 D member data Reinforcement design C Reinforcement check (ULS+SLS) - 1D member Section Check - results	Ly Lz	Name Edit buckling Member(s) material Buckling ky, kz coefficients or buckling lengths All other and LTB coefficients Buckling systems relation zz Secondary member coefficient Beta yy Beta zz Sway yy Sway zz	BB1 Concrete user input • default from LIB manager • zz • Length • Length • Settings • Settings •
			OK Cancel

Click on "Edit buckling" to input the values:

						В	uckling co	efficients					×
	ky	Ly [m]	ly [m]	Sway yy		kz	Lz [m]	lz [m]	Sway zz	Tot. heigth	ot. heigth [n	my	mz
1	1.000	1.000	1.000	Settings	-	1.000	1.000	1.000	Settings 🔽	Calculate	20.000	1.000	1.000

• Properties of columns > Buckling and relative length > Edit:

1st tab: Base settings

	Buckling and relative lengths.		* 187- a & Stall N (SHA ++) + k -	×
Base settings Buckling data				
Y Y	Name BC1 Buckling systems relation	Number of parts	1	
	ZZ = ZZ V	Beta yy	Length	~
Ly Lz		Beta zz	Length	~
		Sway yy	Settings	~
		Sway zz	Settings	~

2nd tab: Buckling data

						Buckling an	d relative l	engths.				×
Ba	ise s	settings Bucklir	ng data									
		уу	ly [m]	Sway yy	ZZ	lz [m]	Sway zz	Tot. heigth	⁻ ot. heigth [m	my	mz	
	1	🗷 Fixed	1.00	Settings	🗹 Fixed	1.00	Settings	Calculate	20.00	1.00	1.00	
	2	Free			Free							

Recalculated internal forces

In Concrete Menu > Reinforcement Design > 1D member > Internal forces.

The design moment, M_{Ed} , is equal to $M_{Ed} = M_{0Ed} + M_2$.

 $\begin{array}{ll} M_2 & 2^{nd} \text{ order bending moment} \\ M_{0Ed} & \text{bending moment taking into account } 1^{st} \text{ order and geometrical imperfections} \end{array}$

Example: '2nd order.esa'

Geometry

Column cross-section: RECT 350x350mm² Height: 4,5 m Concrete grade: C45/55

Concrete Setup

All of the default values are kept. This means that geometrical imperfection and 2nd order effects are taken into account.

Loads

Load configuration:	N _d = 405,00 kN
-	$M_{yd} = 40,50 \text{ kNm}$
	$M_{zd} = 0 \text{ kNm}$

Buckling data

Sway type is set by default. Calculation of the effective length is done automatically by the software.

Slenderness criterion

Check if 2nd order calculation is required following art 5.8.3.1:

Since $\lambda > \lambda_{\text{lim}}$, a 2nd order calculation will be required.

Note: the program automatically takes into account a second order moment if required. So, this check is just extra information for the user.

Internal forces

Ask for M_{Ed} in Reinforcement design > 1D member > Internal forces. The Standard output is chosen:

Internal forces (FEM-based)

Extreme: ULS/1 (ULS) Type: Combination (linear) Design situation: EN-ULS (STR/GEC)) Set B				
Type of load	N [kN]	M _y [kNm]	M _z [kNm]	ν _γ [kN]	V _z [kN]
Internal General (FEAA Incord)	405.0	10.5	0.0	0.0	0.0

	Free 17	[]	f	[]	Fee	f
Internal forces (FEM-based)	-405.0	-40.5	0.0	0.0	0.0	0.0
Content: 1.35*LC1						

M_x [kNm]

Slenderness

Axis	Braced	L _{z/y} [m]	β _{zz/yy} [-]	l _{0z/y} [m]	λ _{z/y} [-]	λ limz/y [-]	$\lambda_{z/y} > \lambda_{limz/y}$
у-у-	No	4.5	2	9.01	89.2	40.1	2 nd order
z-z-	No	4.5	2	9.01	89.2	40.1	2 nd order

Second order effect and imperfections

Axis	N _{Ed} [kN]	M _{0Edy/z} [kNm]	M _{2y/z} [kNm]	M _{Edy/z} [kNm]	e _{0z/y} [mm]	e _{iz/y} [mm]	e _{0min,z/y} [mm]	e _{0Edz/y} [mm]	e _{2z/y} [mm]	e _{Edz/y} [mm]
у-у-	-405	-49.1	-65.3	-114	100	21.2	20	121	161	283
z-z	-405	8.6	65.3	73.9	0	-21.2	-20	-21.2	-161	-183

Design forces (recalculated)

Type of load	N _{Ed}	M _{Ed,y}	M _{Ed,z}	V _{Ed.y}	V _{Ed,z}	M _{Ed,x}
	[kN]	[kNm]	[kNm]	[kN]	[kN]	[kNm]
Design forces (recalculated)	-405.0	-114.4	73.9	0.0	0.0	0.0

Results

The results for the reinforcement design are shown below:

Design of longitudinal reinforcement

 $\begin{aligned} &A_{s,z+}: 1.35^{*}LC1: N_{Ed} = -405 \; kN, \; M_{Edy} = -114 \; kNm, \; M_{Edz} = 74 \; kNm \\ &A_{s,z-}: \; 1.35^{*}LC1: N_{Ed} = -405 \; kN, \; M_{Edy} = -114 \; kNm, \; M_{Edz} = 74 \; kNm \\ &A_{s,y+}: \; 1.35^{*}LC1: N_{Ed} = -405 \; kN, \; M_{Edy} = -114 \; kNm, \; M_{Edz} = 74 \; kNm \\ &A_{s,y-}: \; 1.35^{*}LC1: N_{Ed} = -405 \; kN, \; M_{Edy} = -114 \; kNm, \; M_{Edz} = 74 \; kNm \end{aligned}$

Required

Edge Layer	Lawer	у	z	A _{s.stat}	A _{s.det.min}	A _{s.det.max}	$\Delta A_{s.tor}$	A _{s.req}	A _{s.req.bar}	Reinf
	Layer	[m]	[m]	[mm ²]	[mm ²]	[mm ²]	[mm ²]	[mm ²]	[mm ²]	Keini
1	1	0	-0.129	827	201	1180	0	827	1005	6ф16
2	1	0.129	0	458	201	1180	0	458	603	4ф16
3	1	0	0.129	827	201	1180	0	827	1005	6ф16
4	1	-0.129	0	458	201	1180	0	458	603	4ф16

Determination type of calculation

```
 \begin{array}{l} \mbox{Calculation maximum bending moments around y and z axis} \\ M_{y,max} = -114 \ kNm \ M_{zmax} = 73.9 \ kNm \\ \mbox{Calculation maximum ratio of bending moments} \\ \rho_M = 0.646 \\ \mbox{Determination type of calculation} \\ \rho_M = 0.646 > \rho_{M,lim} = 0.1 \ or \ |M_{y,max}| = 0 \ kNm \ and \ |M_{zmax}| = 0 \ kNm = > \ Biaxial \ method \ \end{tabular}
```

Note that biaxial bending method was used for reinforcement calculation.

Theoretical background

An extended manual that also contains some theoretical background can be found through the help menu of SCIA Engineer: