QUALITY ASSURANCE & VERIFICATION

For structural design calculations in website eurocodeapplied.com

TEST PROCEDURE

Each of the calculations is tested for accuracy against independent results. The following testing procedures are followed:

Description of Test Types	
Unit test	Automatic test of a single component of the calculation by using automated computer testing
Independent verification	Automatic test of the final results and/or selected intermediate results of the calculation by comparison with published results in the literature (e.g. engineering books, scientific papers, design software programs, other websites etc.)
Manual inspection	Manual inspection of the calculation printout by a qualified civil engineer

ACCEPTABILITY CRITERIA

The acceptability criteria vary depending on the calculation context. Engineering judgment is required in order to judge the acceptability of the result. In general for numerical results of calculations an error less of 1% is considered very good. For certain calculation components that are based on approximations or on different calculation methods as compared to the benchmark results the acceptability criteria may be more relaxed and even a difference of 10% may be considered acceptable. Where such conditions apply it is clearly explained in the comments following the verification checks. Generally approximate design procedures are acceptable when they yield more conservative results as compared to more elaborate design procedures.

Eurocode 1 - Wind peak velocity pressure

https://eurocodeapplied.com/design/en1991/wind-peak-velocity-pressure

INDEPENDENT VERIFICATION

Comparison with official worked example in European Commission – Joint Research Centre website (https://eurocodes.jrc.ec.europa.eu)

Worked Example: Determination of loads on a building envelope (https://eurocodes.jrc.ec.europa.eu/doc/WS2008/SX016a-EN-EU.pdf)

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
q_b, z=7.3m	0.4225 kPa	0.423 kPa	<0.12%	Pass ✓
$q_p(z)$, z=7.3m	0.911 kPa	0.911 kPa	<0.1%	Pass ✓

Comments: Small deviations due to rounding of the results in 3 decimal digits.

INDEPENDENT VERIFICATION

Comparison with published results in the website “onlinestructuraldesign.com”

Preview version of calculation “Wind load base pressure” (http://onlinestructuraldesign.com/preview/Wind_load_metric.pdf)

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
$q_p(z)$, z=0.01m	0.720 kPa	0.720 kPa	0%	Pass ✓
$q_p(z)$, z=5m	0.720 kPa	0.720 kPa	0%	Pass ✓
$q_p(z)$, z=5.5m	0.752 kPa	0.752 kPa	0%	Pass ✓
$q_p(z)$, z=10m	0.961 kPa	0.961 kPa	0%	Pass ✓
$q_p(z)$, z=20m	1.227 kPa	1.227 kPa	0%	Pass ✓
$q_p(z)$, z=25m	1.318 kPa	1.318 kPa	0%	Pass ✓
$q_p(z)$, z=30m	1.395 kPa	1.395 kPa	0%	Pass ✓
$q_p(z)$, z=35m	1.460 kPa	1.460 kPa	0%	Pass ✓
$q_p(z)$, z=40m	1.519 kPa	1.519 kPa	0%	Pass ✓
$q_p(z)$, z=45m	1.570 kPa	1.570 kPa	0%	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
$q_p(z)$, z=50m	1.618 kPa	1.618 kPa	0%	Pass ✓

Eurocode 1 - Wind peak velocity pressure – UK National Annex

https://eurocodeapplied.com/design/en1991/wind-peak-velocity-pressure-uk

INDEPENDENT VERIFICATION

Comparison with published results in the pdf publication by steelconstruction.info website: "Publication SCI P394 - Wind Actions to BS EN1991-1-4" by A F Hughes (https://www.steelconstruction.info/images/e/e7/SCI_P394.pdf).

Worked example in Chapter 9.1 "Wind load on a building (Sheffield Bioincubator)", pages 63-74

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
q_p at sector S1	0.682 kPa	0.681 kPa	0.1%	Pass ✓
q_p at sector S2	0.518 kPa	0.519 kPa	0.2%	Pass ✓
q_p at sector S3	0.459 kPa	0.460 kPa	0.2%	Pass ✓
q_p at sector S4	0.455 kPa	0.455 kPa	0%	Pass ✓
q_p at sector S5	0.466 kPa	0.467 kPa	0.2%	Pass ✓
q_p at sector S6	0.479 kPa	0.481 kPa	0.4%	Pass ✓
q_p at sector S7	0.563 kPa	0.563 kPa	0%	Pass ✓
q_p at sector S8	0.733 kPa	0.732 kPa	0.1%	Pass ✓
q_p at sector S9	0.878 kPa	0.876 kPa	0.2%	Pass ✓
q_p at sector S10	1.058 kPa	1.059 kPa	0.1%	Pass ✓
q_p at sector S11	1.040 kPa	1.042 kPa	0.2%	Pass ✓
q_p at sector S12	0.858 kPa	0.854 kPa	0.5%	Pass ✓

Comments: The site altitude was considered A = 110.13 m in the calculations instead of A = 105 m. This modification was applied in order to yield the rounded-up value for the altitude correction factor C_{alt} = 1.1 that was considered in the worked example.

UNIT TEST

Verification of the correct implementation of double logarithmic interpolation for Figures NA.3 to NA.8 of UK National Annex to BS EN 1991-1-4:2005+A1:2010. Comparison with the results of the computer program ENC20.exe "EN1991-1-4 & UK NA, C-factor calculator from RWDI-Anemos, Version 2.0 (2007)" (https://www.rwdimedia.com/encalculator_program.html)

Compared Quantities	Examined cases	Difference	Check
$C_e(z)$, $C_{e,T}$, $C_r(z)$, $C_{r,T}$, $I_v(z)_{flat}$, $K_{I,T}$, wind zone A, B or C	17 random combinations of distance to sea d_{Shore}, distance to town d_{Town}, and effective height $z-h_{dis}$. The examined variables take values within their applicable ranges as well as values on their bounds	<0.7%	Pass ✓

Eurocode 1 - Wind load on building side walls (external and internal pressure coefficients)

https://eurocodeapplied.com/design/en1991/wind-pressure-side-walls

INDEPENDENT VERIFICATION

Comparison with official worked example in European Commission – Joint Research Centre website (https://eurocodes.jrc.ec.europa.eu)

Worked Example: Determination of loads on a building envelope (https://eurocodes.jrc.ec.europa.eu/doc/WS2008/SX016a-EN-EU.pdf)

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
c_{pe} for zone D	0.7	0.7	0%	Pass ✓
c_{pe} for zone E	-0.3	-0.3	0%	Pass ✓
w_e for zone D	4.59 kN/m / 7.20m = 0.6375 kPa	0.638 kPa	0.1%	Pass ✓
w_e for zone E	-3.28 kN/m / 7.20m = 0.4556 kPa	0.455 kPa	0.1%	Pass ✓

Comments: Small deviations due to rounding of the results in 3 decimal digits. The internal pressure coefficient in the worked example is considered as c_{pi} = +0.2 when unfavorable or c_{pi} = 0.0 otherwise.

UNIT TEST

Verification of the correct implementation of interpolation for Table 7.1 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
$c_{pe,10}$, $c_{pe,1}$	All values presented in Table 7.1 and also verification of the linear interpolation for the following values of h/d: 0.1, 0.25, 0.625, 1.0, 3.0, 5.0	<0.01%	Pass ✓

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation “Eurocode 1 - Wind Peak Velocity Pressure”. The verifications for this calculation are also applicable here.

Eurocode 1 - Wind load on flat roofs (external and internal pressure coefficients)

https://eurocodeapplied.com/design/en1991/wind-pressure-flat-roof

UNIT TEST

Verification of the correct implementation of interpolation for Table 7.2 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
$c_{pe,10}$, $c_{pe,1}$	All values presented in Table 7.2 for the cases of sharp eaves and parapets and also verification of the linear interpolation for the following values of h_p/h: 0, 0.0125, 0.025, 0.0375, 0.05, 0.075, 0.10	<0.01%	Pass ✓

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation “Eurocode 1 - Wind Peak Velocity Pressure”. The verifications for this calculation are also applicable here.

Eurocode 1 - Wind load on monopitch canopy roofs (net pressure coefficients and overall force coefficient)

https://eurocodeapplied.com/design/en1991/wind-pressure-monopitch-canopy-roof

INDEPENDENT VERIFICATION

Comparison with sample excel calculation provided by user "Rdk". The excel calculation was prepared independently from EurocodeApplied.com.

Excel calculation: Wind load on monopitch canopy roofs according to the National Annex of Singapore (z_0 = 0.05 m, z_{min} = 2.0 m, v_b = 20 m/s, h = 5.0 m, α = 10°, φ = 0, ρ = 1.194 kg/m^3).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
k_r	0.19	0.19	0%	Pass ✓
$c_r(z_e)$	0.87	0.8750	0.6%	Pass ✓
$V_m(z_e)$	17.50 m/s	17.50 m/s	0%	Pass ✓
$I_V(z_e)$	0.22	0.22	0%	Pass ✓
$q_p(z_e)$	0.461 kPa	0.461 kPa	0%	Pass ✓
c_f	-0.9 or +0.5	-0.9 or +0.5	0%	Pass ✓
$F_w/(bd)$	-0.415 kPa or +0.230 kPa	-0.415 kPa or +0.230 kPa	0%	Pass ✓

Comments: Small deviations of intermediate results due to rounding in 2 decimal digits.

UNIT TEST

Verification of the correct implementation of interpolation for Table 7.6 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
Overall force coefficient c_f, Net pressure coefficients $c_{p,net}$ for zones A, B, B	All values presented in Table 7.6 for the cases of blockage factor φ = 0, φ = 1.0 and also intermediate values for φ = 0.5.	<0.01%	Pass ✓

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation "Eurocode 1 - Wind Peak Velocity Pressure". The verifications for this calculation are also applicable here.

Eurocode 1 - Wind load on free-standing walls and parapets (net pressure coefficients)

https://eurocodeapplied.com/design/en1991/wind-pressure-freestanding-wall

UNIT TEST

Verification of the correct implementation of interpolation for Table 7.9 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
$c_{p,net}$	All values presented in Table 7.9 and also verification of the linear interpolation for the following values of the variables l/h: 1, 3, 4, 5, 7.5, 10, 20, l_{corner}/h = 0, 0.5, 1.0, φ = 0.8, 0.9, 1.0	<0.01%	Pass ✓

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation “Eurocode 1 - Wind Peak Velocity Pressure”. The verifications for this calculation are also applicable here.

Eurocode 1 - Wind load on prism elements with rectangular cross-section (force coefficient)

https://eurocodeapplied.com/design/en1991/wind-force-rectangular

UNIT TEST

Verification of the correct implementation of interpolation for Figure 7.23 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
$c_{f,0}$	The following values of the ratio d/b: 0.1, 0.15, 0.2, 0.6, 0.7, 1.0, 2.0, 5.0, 10, 20, 30	<0.1%	Pass ✓

UNIT TEST

Verification of the correct implementation of interpolation for Figure 7.24 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
ψ_r	The following values of the ratio r/b: 0, 0.1, 0.2, 0.3, 0.4, 0.5	<0.1%	Pass ✓

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation “Eurocode 1 - Wind Peak Velocity Pressure”. The verifications for this calculation are also applicable here.

Eurocode 1 - Wind load on circular cylinders (force coefficient)

https://eurocodeapplied.com/design/en1991/wind-force-cylinder

UNIT TEST

Verification of the correct implementation of interpolation for Figure 7.28 of EN 1991-1-4:2005+A1:2010.

Compared Quantities	Examined cases	Difference	Check
$c_{f,0}$	17 combinations of values for k/b and Re in order to test the two distinct branches of the figure and the upper and lower bounds 1.2 and 0.4 respectively.	<1%	Pass ✓

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation "Eurocode 1 - Wind Peak Velocity Pressure". The verifications for this calculation are also applicable here.

Eurocode 1 - Wind load on signboards (force coefficient)

https://eurocodeapplied.com/design/en1991/wind-signboard

UNIT TEST

The calculation of the peak velocity pressure $q_p(z_e)$ and the associated intermediate results is performed by using the components of the calculation “Eurocode 1 - Wind Peak Velocity Pressure”. The verifications for this calculation are also applicable here.

Eurocode 2 - Concrete creep coefficient & shrinkage strain

https://eurocodeapplied.com/design/en1992/creep-shrinkage

INDEPENDENT VERIFICATION

Comparison with published results in the book "Designers' Guide to EN 1992-2 - Eurocode 2: Design of Concrete Structures - Part 2: Concrete Bridges" by C.R. Hendy and D.A. Smith - Thomas Telford.

Worked Example 3.1-1: Calculation of $\varphi(\infty, t_0)$ for bridge pier.

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
a_1	0.80	0.80	0%	Pass ✓
a_2	0.94	0.94	0%	Pass ✓
φ_{RH}	1.13	1.13	0%	Pass ✓
$\beta(f_{cm})$	2.42	2.42	0%	Pass ✓
$\beta(t_0)$	0.48	0.48	0%	Pass ✓
$\varphi(\infty, t_0)$	1.31	1.32	0.8%	Pass ✓

Comments: Small deviations occur because the calculation in eurocodeapplied.com maintains greater accuracy for the intermediate results.

INDEPENDENT VERIFICATION

Comparison with published results in the Verification Manual of computer program SOFiSTiK 2020 (Verification - Design Code Benchmarks - SOFiSTiK Service Pack 2020-1 Build 40)

Benchmark DCE-EN18 - Creep and Shrinkage Calculation of a Rectangular Prestressed Concrete CS: The creep coefficient and the shrinkage strain are calculated for the case of a rectangular concrete cross-section.

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
h_0	500 mm	500 mm	0%	Pass ✓
k_h	0.7	0.7	0%	Pass ✓
β_{RH}	0.7564	0.7564	0%	Pass ✓
$\varepsilon_{cd,0}$	25.33×10^{-5}	25.329×10^{-5}	<0.004%	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
$\varepsilon_{cd}(\infty)$	$25.33\times10^{-5}\times k_h = 17.73\times10^{-5}$	17.73×10^{-5}	0%	Pass ✓
$\varepsilon_{ca}(\infty)$	6.25×10^{-5}	6.25×10^{-5}	0%	Pass ✓
$\varepsilon_{cs}(\infty)$	$25.33\times10^{-5}\times k_h + 6.25\times10^{-5} = 23.98\times10^{-5}$	23.98×10^{-5}	0%	Pass ✓
$\beta(f_{cm})$	2.562	2.562	0%	Pass ✓
α_1	0.8658	0.8658	0%	Pass ✓
α_2	0.9597	0.9597	0%	Pass ✓
α_3	0.9022	0.9022	0%	Pass ✓
φ_{RH}	1.1691	1.169035	0.006%	Pass ✓
$\beta(t_0)$	0.48844	0.488624	0.04%	Pass ✓
φ_0	1.463	1.463	0%	Pass ✓
$\varphi(\infty, t_0)$	1.463	1.463	0%	Pass ✓

Comments: The value of the coefficient k_h is applied correctly in SOFiSTiK in order to calculate the value of the evolution of the drying shrinkage part $\varepsilon_{ds}(t,t_s) = k_h \times \varepsilon_{cd,0} \times \beta_{ds}(t,t_s)$ of the total shrinkage strain $\varepsilon_{cs}(t,t_s) = \varepsilon_{ds}(t,t_s) + \varepsilon_{cd}(t,t_s)$. However the maximum value of the drying shrinkage part at infinite time $t = \infty$ is wrongly reported by SOFiSTiK as $\varepsilon_{ds}(\infty,t_s) = \varepsilon_{cd,0}$. The correct value is $\varepsilon_{ds}(\infty,t_s) = k_h \times \varepsilon_{cd,0}$ and it is obtained by setting t = ∞ in the equation of $\beta_{ds}(t,t_s)$ leading to the expected value of the time-evolution coefficient $\beta_{ds}(\infty,t_s) = 1$. This discrepancy is taken into account in the verifications above by appropriately adjusting the reported value in of the drying shrinkage part in the SOFiSTiK benchmark results using the value of $k_h = 0.7$.

Eurocode 2 - Table of concrete design properties

https://eurocodeapplied.com/design/en1992/concrete-design-properties

MANUAL INSPECTION

Comparison with design standard EN 1992-1-1:2004+AC:2010 Table 3.1

Compared Quantities	Examined cases	Difference	Check
f_{ck}, f_{cm}, f_{ctm}, E_{cm}	All concrete classes from C12/15 to C90/105	None	Pass ✓

Comments: Small deviations occur because the calculation in eurocodeapplied.com maintains greater accuracy for the intermediate results.

Eurocode 2 - Concrete nominal cover for reinforcement and prestressing steel

https://eurocodeapplied.com/design/en1992/concrete-cover

INDEPENDENT VERIFICATION

Comparison with published results in the book "Designers' Guide to EN 1992-2 – Eurocode 2: Design of Concrete Structures – Part 2: Concrete Bridges" by C.R. Hendy and D.A. Smith – Thomas Telford.

Worked Example 4.4-1: Cover for deck slab.

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Structural Class	S4	S4	None	Pass ✓
$c_{min,dur}$	25 mm	25 mm	0%	Pass ✓
$c_{min,b}$	20 mm	20 mm	0%	Pass ✓
c_{min}	25 mm	25 mm	0%	Pass ✓
c_{nom}	35 mm	35 mm	0%	Pass ✓

Eurocode 2 - SLS design for crack-control of rectangular reinforced concrete cross-section

https://eurocodeapplied.com/design/en1992/sls-crack-control-rectangular-section

INDEPENDENT VERIFICATION

Comparison with results from computer program SOFiSTiK 2023 (Service Pack 2024-0.1 Build 3)

Design for crack-control is performed for the case of a rectangular cross-section (h = 1.0m, b = 0.5m, ∅25 bottom bars to be determined so that the calculated crack width is $w_k \leq$ 0.3mm, 4∅20 top bars, no side bars, f_{yk} = 500 MPa, C30/37 concrete, distance from edge to reinforcement centroid = 75 mm, cover to reinforcement surface c = 62.5 mm). Applied axial force N and bending moment M are N = -1000 kN, M = 500 kNm. Two stress-strain laws are examined for concrete in compression: case 1 = parabolic stress-strain law according to EN 1992-1-1 §3.1.7(1) without material safety factors (i.e. maximum value of concrete stress f_{ck}), case 2: linear stress-strain law (no tension) with a reduced value for the effective modulus of elasticity to account for creep equal to 10000 MPa.

Case 1: Parabolic stress-strain law

Compared Quantity	SOFiSTiK Result	Result from eurocodeapplied.com	Difference	Check
x	354.1 mm	356 mm	0.5%	Pass ✓
ε_{top}	-0.693 ‰	-0.69 ‰	0.4%	Pass ✓
ε_{bottom}	1.265 ‰	1.25 ‰	1.2%	Pass ✓
$\sigma_{c,min}$	-17.20 MPa	-17.15 MPa	0.3%	Pass ✓
$\sigma_{s,min}$	-109.3 MPa	-109.0 MPa	0.3%	Pass ✓
$\sigma_{s,max}$	223.57 MPa	221.3 MPa	1.0%	Pass ✓
$h_{c,eff}$	188.0 mm	188 mm	0%	Pass ✓
$\rho_{p,eff}$	3.68 %	3.70 %	0.5%	Pass ✓
k_2	0.5	0.5	0%	Pass ✓
$s_{r,max}$	328.11 mm	327.4 mm	0.2%	Pass ✓
$\varepsilon_{sm} - \varepsilon_{cm}$	0.92 ‰	0.914 ‰	0.7 %	Pass ✓
$A_{s,req}$	34.56 cm^2	34.68 cm^2	0.3%	Pass ✓
w_k	0.3 mm	0.3 mm	0%	Pass ✓

Case 2: Linear stress-strain law with $E_{c,eff}$ = 10000 MPa

Compared Quantity	SOFiSTiK Result	Result from eurocodeapplied.com	Difference	Check
x	480.8 mm	481 mm	0.04%	Pass ✓
ε_{top}	-1.296 ‰	-1.30 ‰	0.3%	Pass ✓
ε_{bottom}	1.399 ‰	1.40 ‰	0.1%	Pass ✓
$\sigma_{c,min}$	-12.96 MPa	-12.97 MPa	0.1%	Pass ✓
$\sigma_{s,min}$	-218.7 MPa	-218.9 MPa	0.1%	Pass ✓
$\sigma_{s,max}$	239.44 MPa	239.9 MPa	0.2%	Pass ✓
$h_{c,eff}$	187.8 mm	173 mm	8%	See comment 1
$\rho_{p,eff}$	3.72 %	4.01 %	8%	See comment 1
k_2	0.5	0.5	0%	Pass ✓
$s_{r,max}$	326.61 mm	318.5 mm	2.4%	See comment 1
$\varepsilon_{sm} - \varepsilon_{cm}$	0.93 ‰	0.939 ‰	1.0 %	Pass ✓
$A_{s,req}$	34.97 cm²	34.70 cm²	0.8%	Pass ✓
w_k	0.3 mm	0.3 mm	0%	Pass ✓

Comments:

1. According to EN 1992-1-1 §7.3.2(3) the height of the effective zone in tension cannot be larger than (h – x) / 3 = (1000 mm – 481 mm) / 3 = 173 mm. SOFiSTiK does not seem implement this rule for the examined case. Some derived quantities are also affected by this discrepancy.

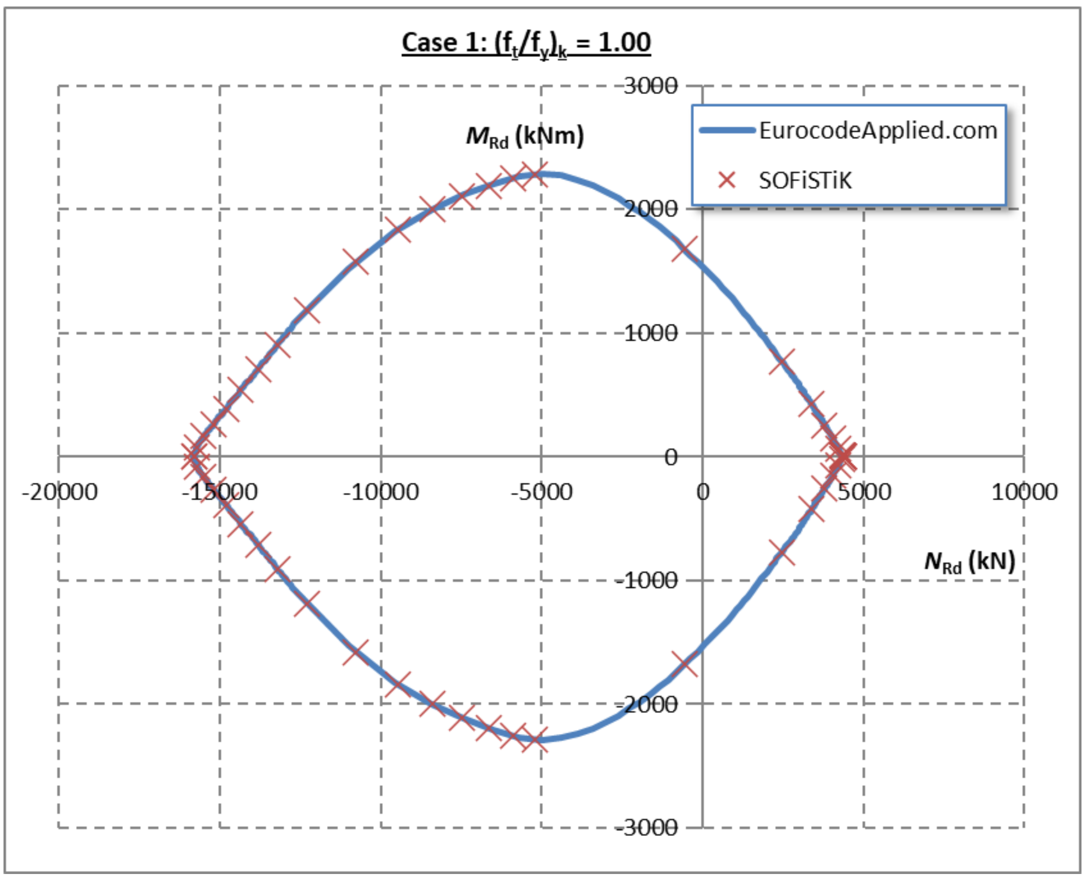
Eurocode 2 - ULS design of circular (or tubular) reinforced concrete cross-section for bending and axial force

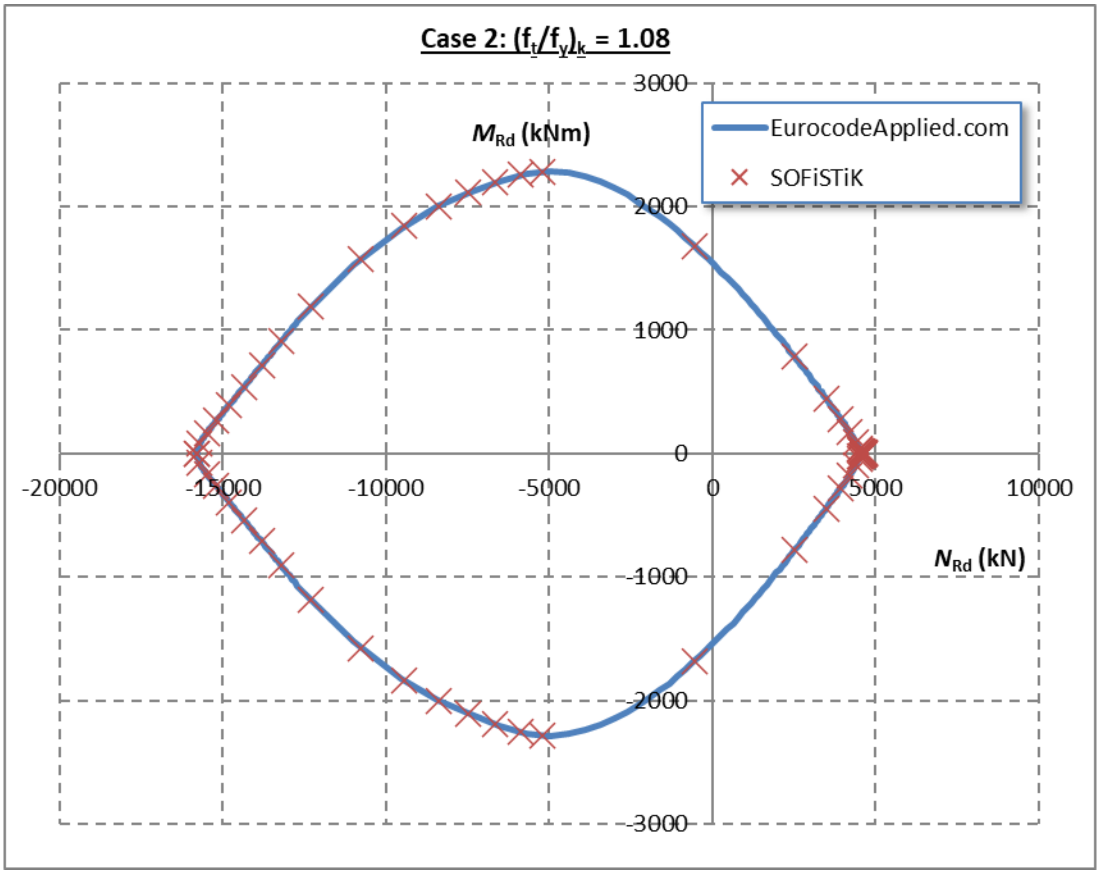
https://eurocodeapplied.com/design/en1992/uls-design-circular-section

INDEPENDENT VERIFICATION

Comparison with results from computer program SOFiSTiK 2020 (Service Pack 2020-8 Build 1505)

The M-N interaction diagram is calculated for the case of a tubular cross-section (D_{ext} = 1.0m, D_{int} = 0.5m, 2×16∅20 bars f_{yk} = 500 MPa, C30/37 concrete, distance from edge to reinforcement centroid = 75 mm). Two hardening laws are examined for reinforcement steel: case 1 = horizontal branch $(f_t/f_y)_k$ = 1.00, and case 2 = inclined horizontal branch $(f_t/f_y)_k$ = 1.08, ε_{uk} = 5.0%, ε_{ud} = 0.9×5.0% = 4.5%). The comparison of the interaction diagrams is shown below where identical results are observed. The maximum bending moment difference is 0.02% of the peak bending moment.




Case 2: $(f_t/f_y)_k$ = 1.08
M_{Rd} (kNm)
N_{Rd} (kN)
EurocodeApplied.com
SOFiSTiK
3000
2000
1000
0
-1000
-2000
-3000
-20000
-15000
-10000
-5000
0
5000
10000

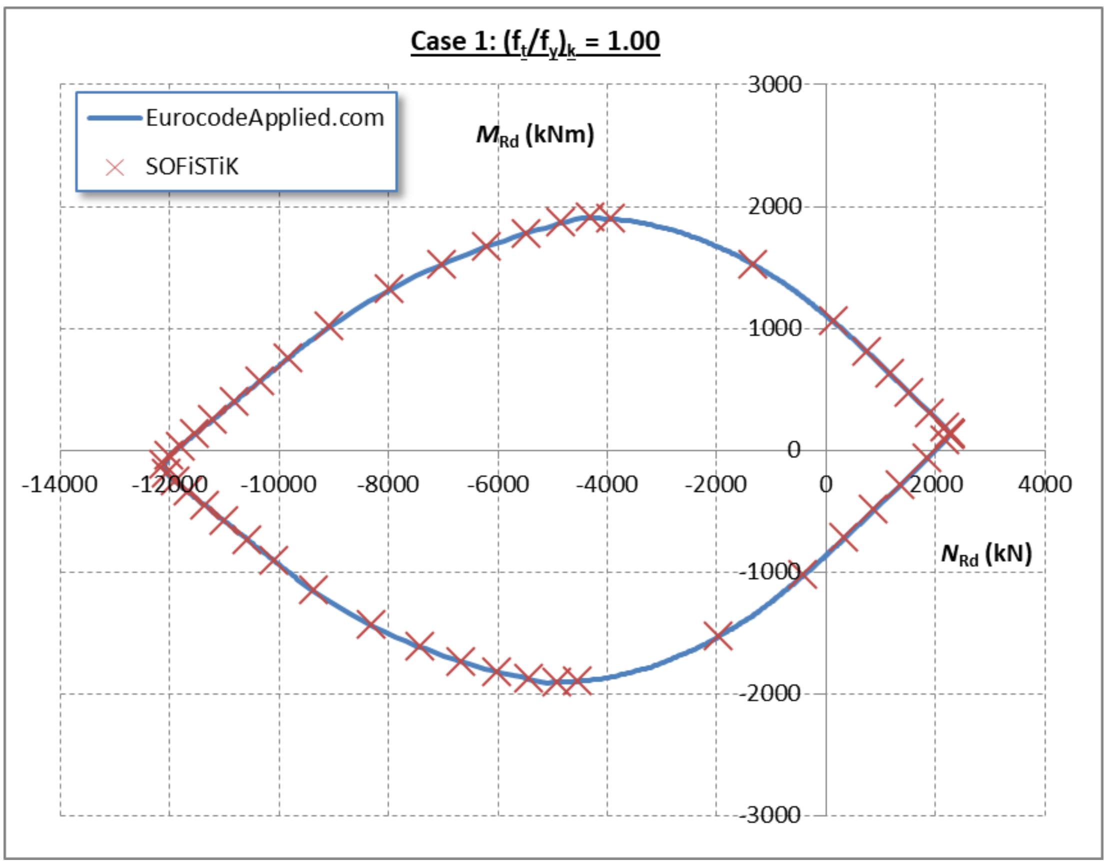
Eurocode 2 - ULS design of rectangular reinforced concrete cross-section for bending and axial force

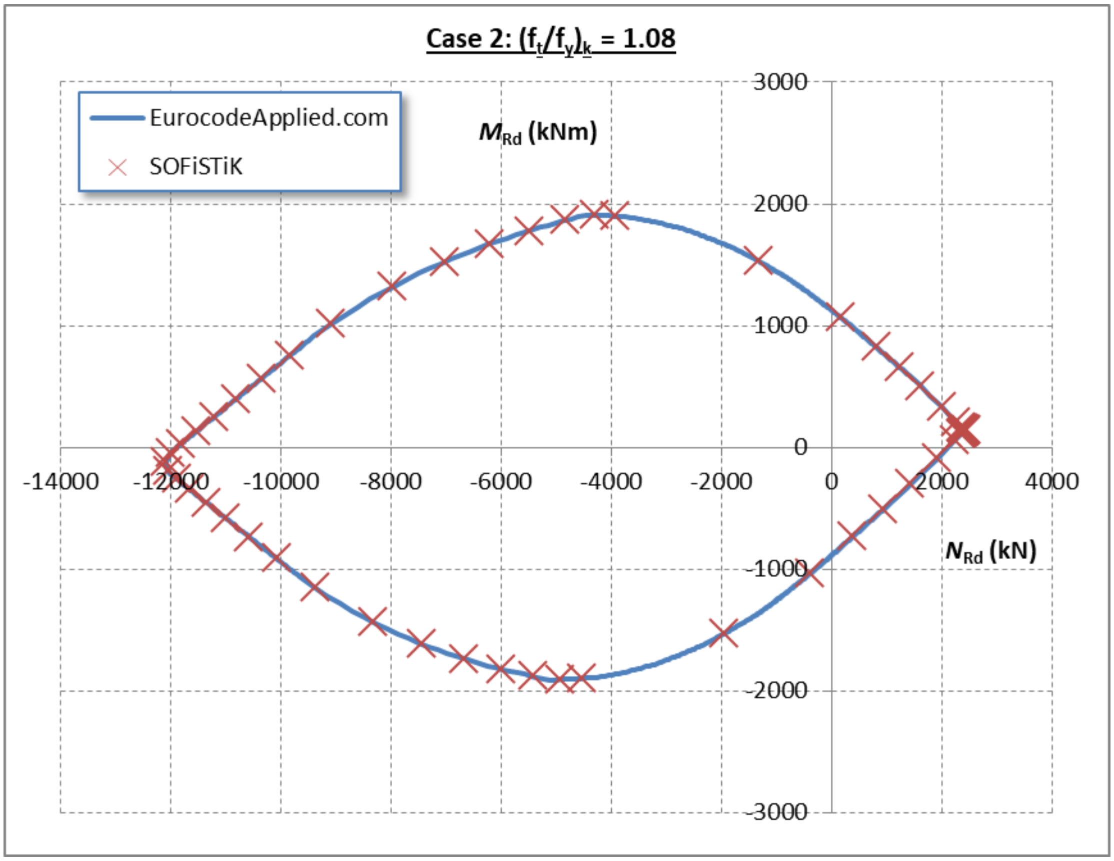
https://eurocodeapplied.com/design/en1992/uls-design-rectangular-section

INDEPENDENT VERIFICATION

Comparison with results from computer program SOFiSTiK 2020 (Service Pack 2020-8 Build 1505)

The M-N interaction diagram is calculated for the case of a rectangular cross-section (h = 1.5m, b = 0.5m, 4∅25 bottom bars, 4∅20 top bars, 2×5∅16 side bars, f_{yk} = 500 MPa, C30/37 concrete, distance from edge to reinforcement centroid = 75 mm). Two hardening laws are examined for reinforcement steel: case 1 = horizontal branch $(f_t/f_y)_k$ = 1.00, and case 2 = inclined horizontal branch $(f_t/f_y)_k$ = 1.08, ε_{uk} = 5.0%, ε_{ud} = 0.9×5.0% = 4.5%). The comparison of the interaction diagrams is shown below where identical results are observed. The maximum bending moment difference is 0.1% of the peak bending moment.




Case 2: $(f_t/f_y)_k$ = 1.08
EurocodeApplied.com
SOFiSTiK
M_{Rd} (kNm)
N_{Rd} (kN)
3000
2000
1000
0
-1000
-2000
-3000
-14000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
4000

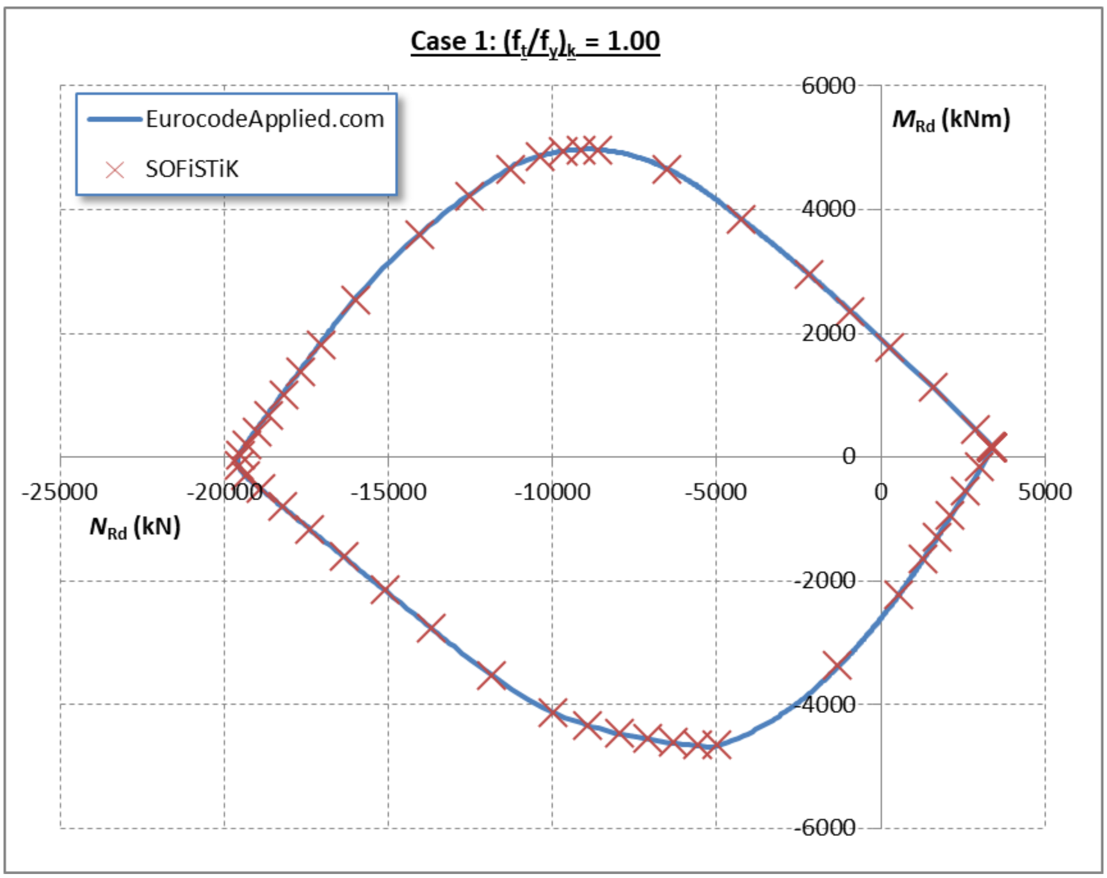
Eurocode 2 - ULS design of I-shaped and T-shaped reinforced concrete cross-section for bending and axial force

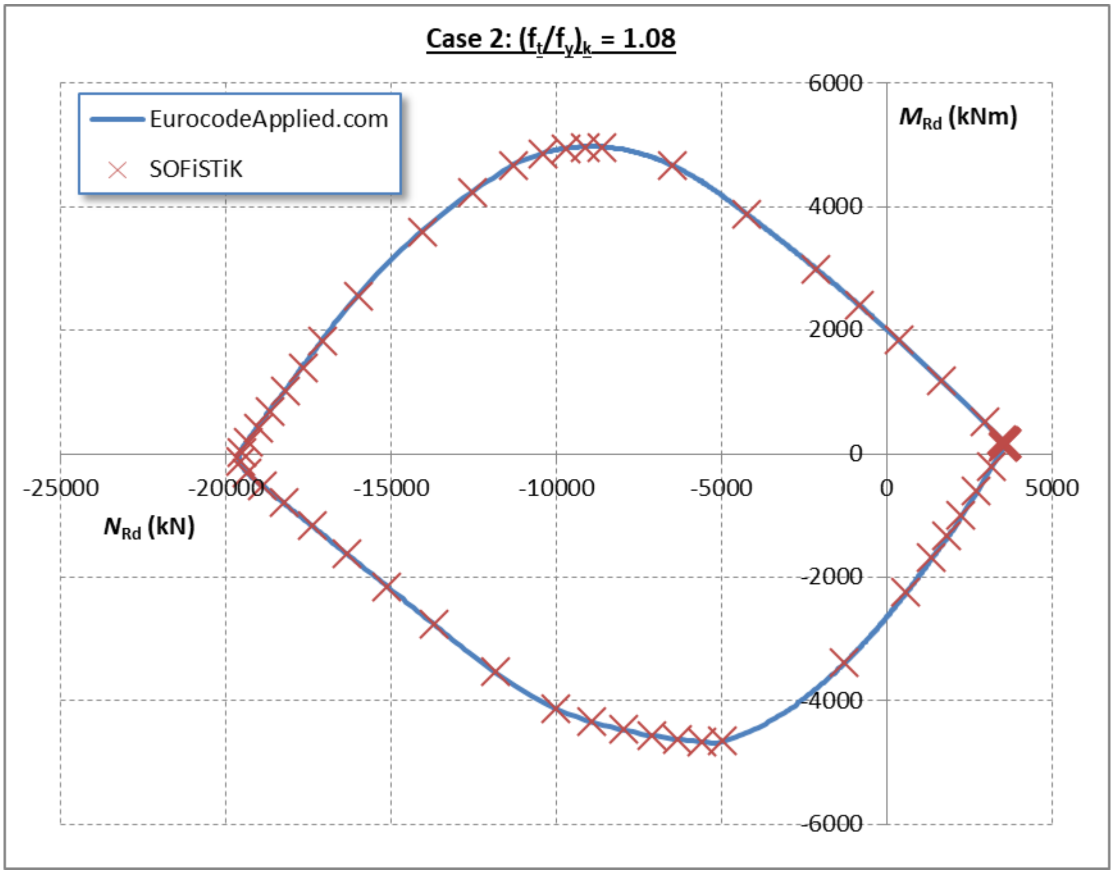
https://eurocodeapplied.com/design/en1992/uls-design-i-shaped-section

INDEPENDENT VERIFICATION

Comparison with results from computer program SOFiSTiK 2020 (Service Pack 2020-8 Build 1505)

The M-N interaction diagram is calculated for the case of an T-shaped cross-section (h = 1.5m, b_w = 0.4m, $b_{f,top}$ = 1.5m, $t_{f,top}$ = 0.2m, 3∅25 bottom bars at 75 mm distance from bottom concrete edge, 10∅20 top bars at 100 mm distance from top concrete edge, 2×8∅16 side bars, f_{yk} = 500 MPa, C30/37 concrete, distance from edge to reinforcement centroid = 75 mm). Two hardening laws are examined for reinforcement steel: case 1 = horizontal branch $(f_t/f_y)_k$ = 1.00, and case 2 = inclined horizontal branch $(f_t/f_y)_k$ = 1.08, ε_{uk} = 5.0%, ε_{ud} = 0.9×5.0% = 4.5%). The comparison of the interaction diagrams is shown below where identical results are observed. The maximum bending moment difference is 0.1% of the peak bending moment.




Case 2: $(f_t/f_y)_k$ = 1.08
EurocodeApplied.com
SOFiSTiK
M_{Rd} (kNm)
N_{Rd} (kN)
6000
4000
2000
0
-2000
-4000
-6000
-25000
-20000
-15000
-10000
-5000
0
5000

Eurocode 2 - Design of shear connection at the interface between concrete cast at different times

https://eurocodeapplied.com/design/en1992/shear-connection-design

INDEPENDENT VERIFICATION

Comparison with published results in the Verification Manual of computer program SOFiSTiK 2020 (Verification – Design Code Benchmarks – SOFiSTiK Service Pack 2020-1 Build 40)

Benchmark DCE-EN11 - Shear at the interface between concrete cast at different times: Calculation of shear connection reinforcement at the interface between web and flange of T-beam cross-section.

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
f_{cd}	14.17 MPa	14.17 MPa	0%	Pass ✓
f_{yd}	434.78 MPa	434.78 MPa	0%	Pass ✓
f_{ctd}	1.02 MPa	1.02 MPa	0%	Pass ✓
v_{Edi}	1.68 MPa	1.68 MPa	0%	Pass ✓
$v_{Rdi,max}$	4.9585 MPa	3.825 MPa × 0.7 / [0.6×(1 - 25MPa / 250MPa)] = 4.9583 MPa *	<0.1%	Pass ✓
A_s/s (per web edge)	4.99 cm^2/m	29.95 cm^2/m × 0.2m / 1.2 = 4.99 cm^2/m **	0%	Pass ✓

Comments:

1. The SOFiSTiK verification example is calculated according to the German National Annex. For the German NA the value of the maximum shear strength of the concrete interface $v_{Rdi,max}$ is calculated for the case of indented interface using ν = 0.7 instead of the default value ν = 0.6 ×(1 - f_{ck} / 250MPa), where f_{ck} = 25MPa. The relevant correction factor 0.7 / [0.6×(1 - 25MPa / 250MPa)] is applied on the calculated value indicated by (*) for comparison purposes.

2. The SOFiSTiK verification example is calculated according to the German National Annex. For the German NA the value of the resistance of the shear interface v_{Rdi} is calculated by considering the contribution of shear connection reinforcement multiplied by the factor 1.2. Moreover for the SOFiSTiK verification example the required shear connection reinforcement corresponds to half of the web width 0.40m / 2 = 0.20m. The relevant correction factor 0.2m / 1.2 is applied on the calculated value indicated by (**) for comparison purposes.

Eurocode 2 - Table of reinforcement anchorage length and lap length

https://eurocodeapplied.com/design/en1992/anchorage-and-lap-length-table

MANUAL INSPECTION

Comparison with existing anchorage and lap length tables created by the authors

Compared Quantities	Examined cases	Difference	Check
l_{bd}, l_0	Concrete classes C20/25, C25/30, C30/37, C35/45	None	Pass ✓

Eurocode 2 - Table of reinforcement area and weight for distributed reinforcement bars and individual reinforcement bars

https://eurocodeapplied.com/design/en1992/reinforcement-quantity-table

MANUAL INSPECTION

Comparison with existing reinforcement area tables created by the authors

Compared Quantities	Examined cases	Difference	Check
A_s, A_s/s	Spacing s from 0.05m to 0.30m, bar diameter ∅8 to ∅32, number of individual bars from 1 to 10	None	Pass ✓

Eurocode 3 - Table of design properties for structural steel

https://eurocodeapplied.com/design/en1993/steel-design-properties

MANUAL INSPECTION

Comparison with design standard EN 1993-1-1:2004+AC:2010 Table 3.1

Compared Quantities	Examined cases	Difference	Check
f_y, f_u	All steel classes from S235 to S460	None	Pass ✓

Eurocode 3 - Table of design properties for flanged steel profiles (IPE, HEA, HEB, HEM)

https://eurocodeapplied.com/design/en1993/ipe-hea-heb-hem-design-properties

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 5.1: Cross-section classification under combined bending and compression (406 x 178 x 54 UB, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
A	6900 mm^2	6895 mm^2	0.1 %	Pass ✓
Flange class in compression	1	1	None	Pass ✓
Web class in pure compression	4	4	None	Pass ✓
Web class in combined bending and compression	2	2	None	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.2: Cross-section resistance in compression (254 x 254 x 73 UC, grade S355).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Flange class in compression	2	2	None	Pass ✓
Web class in pure compression	1	1	None	Pass ✓
A	9310 mm^2	9310 mm^2	0 %	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
N_{Rk}	3305 kN	3305 kN	0 %	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.3: Cross-section resistance in bending (welded cross-section, steel grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Flange class in compression	1	1	None	Pass ✓
Web class in pure bending	3	3	None	Pass ✓
$W_{el,y}$	2536249 mm^3	2536249 mm^3	0 %	Pass ✓
$M_{Rd,el,y}$	697.5 kNm	697.5 kNm	0 %	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 - Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.5: Cross-section resistance under combined bending and shear (406 x 178 x 74 UB, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Flange class in compression	1	1	None	Pass ✓
Web class in pure bending	1	1	None	Pass ✓
A	9450 mm^2	9451 mm^2	0.01%	Pass ✓
$W_{pl,y}$	1501000 mm^3	1500806 mm^3	0.01%	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
$M_{c,y,Rd}$	412 kNm	412.7 kNm	0.2%	Pass ✓
A_{vz}	4341 mm^2	4341 mm^2	0%	Pass ✓
$V_{pl,Rd}$	689.2 kN	689.2 kN	0%	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book "Designers' Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.6: Cross-section resistance under combined bending and compression (457 x 19J x 98 UB, grade S235).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Flange class in compression	1	1	None	Pass ✓
Web class in pure compression	2	2	None	Pass ✓
A	12500 mm^2	12526 mm^2	0.2%	Pass ✓
$W_{pl,y}$	2232000 mm^3	2232410 mm^3	0.02%	Pass ✓
$N_{pl,Rd}$	2937.5 kNm	2943.7 kNm	0.2%	Pass ✓
$M_{pl,y,Rd}$	524.5 kNm	524.6kNm	0.02%	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book "Designers' Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.8: Lateral torsional buckling resistance (762 x 267 x 173 UB, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Flange class in compression	1	1	None	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Web class in pure bending	1	1	None	Pass ✓
A	22000 mm^2	22037 mm^2	0.2%	Pass ✓
$W_{pl,y}$	6198000 mm^3	6197679 mm^3	0.01%	Pass ✓
I_z	68.500×10^6 mm^4	68.497×10^6 mm^4	0.004%	Pass ✓
I_T	2670000 mm^4	2513704 mm^4	6%	Pass ✓ (see note)
I_W	9390×10^9 mm^6	9364×10^9 mm^6	0.3%	Pass ✓
$M_{c,y,Rd}$	1704 kNm	1704 kNm	0%	Pass ✓
A_{vz}	12338 mm^2	12338 mm^2	0%	Pass ✓
$V_{pl,Rd}$	1959 kN	1959 kN	0%	Pass ✓

Comments: The torsional constant I_T and warping constant I_w for the case of general custom-built profiles are calculated in eurocodeapplied.com according to the procedure described in EN1993-1-3 Annex C. This procedure estimates the torsional and warping properties for open thin-walled cross-sections. The approximation becomes exact when the cross-section can be ideally approximated as thin walled. For the examined case the deviation in the estimation of the torsional constant I_T and the warping constant I_w is attributed to the deviation of the actual cross-section from the ideal thin-walled cross-section analogy.

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.10: Member resistance under combined bi-axial bending and axial compression (305 x 305 x 240 H section, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Flange class in compression	1	1	None	Pass ✓
Web class in pure compression	1	1	None	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
A	30600 mm^2	30579 mm^2	0.07%	Pass ✓
A_{vz}	8033 mm^2	8585 mm^2	(see note)	N/A
A_{vy}	24227 mm^2	24007 mm^2	0.9%	Pass ✓
I_y	642.0×10^6 mm^4	642.0×10^6 mm^4	0%	Pass ✓
$W_{el,y}$	3643000 mm^3	3642697 mm^3	0.008%	Pass ✓
$W_{pl,y}$	4247000 mm^3	4247074 mm^3	0.002%	Pass ✓
I_z	203.1×10^6 mm^4	203.1×10^6 mm^4	0%	Pass ✓
$W_{el,z}$	1276000 mm^3	1276042 mm^3	0.003%	Pass ✓
$W_{pl,z}$	1951000 mm^3	1950586 mm^3	0.02%	Pass ✓
I_T	12710000 mm^4	12650531 mm^4	0.5%	Pass ✓
I_W	5.03×10^{12} mm^6	5.0248×10^{12} mm^6	0.1%	Pass ✓
$N_{c,Rd}$	8415 kN	8409 kN	0.07%	Pass ✓
$M_{c,y,Rd}$	1168 kNm	1168 kNm	0%	Pass ✓
$M_{c,z,Rd}$	536.5 kNm	536.4 kNm	0.02%	Pass ✓
$V_{pl,z,Rd}$	1275 kN	1363 kN	(see note)	N/A
$V_{pl,y,Rd}$	3847 kN	3811.7 kN	0.9%	Pass ✓

Comments: The shear area calculation is wrong in the Designer's Guide worked example 6.10. According to EN 1993-1-1 Section 6.2.6(3) for rolled I and H sections, load parallel to web, the corresponding shear area is $A_v = A - 2 \cdot bt_f + (t_w + 2 \cdot r) \cdot t_f \geq \eta \cdot h_w \cdot t_w$. In the Designer's Guide worked example 6.10 the shear area is wrongly estimated as: $A_v = A - 2 \cdot bt_f + (t_w + \mathbf{1} \cdot r) \cdot t_f \geq \eta \cdot h_w \cdot t_w$.

INDEPENDENT VERIFICATION

Comparison with published results in the Verification Manual of computer program SOFiSTiK 2020 (Verification – Design Code Benchmarks – SOFiSTiK Service Pack 2020-1 Build 40)

Benchmark DCE-EN14 - Classification of Steel Cross-sections: Cross-section classification under compession and bending (457 x 152 x 74 UB, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check

Compared Quantity	**Published Result**	**Result from eurocodeapplied.com**	**Difference**	**Check**
Flange class in compression due to bending	1	1	None	Pass ✓
Flange class in compression due to bending – Ratio c/t	3.66	3.66	0%	Pass ✓
Flange class in compression due to bending – c/t limit for class 1	8.32	8.32	0%	Pass ✓
Web class in pure bending	1	1	None	Pass ✓
Web class in pure bending – Ratio c/t	42.46	42.46	0%	Pass ✓
Web class in pure bending - c/t limit for class 1	66.53	66.558	<0.1%	Pass ✓
Web class in pure compression	4	4	None	Pass ✓
Web class in pure compression - Ratio c/t	42.46	42.46	0%	Pass ✓
Web class in pure compression- c/t limit for class 3	38.8	38.8	0%	Pass ✓

Eurocode 3 - Table of design properties for steel tubes - Circular Hollow Sections (CHS)

https://eurocodeapplied.com/design/en1993/chs-design-properties

INDEPENDENT VERIFICATION

Comparison with published results in the book "Designers' Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.7: Buckling resistance of a compression member (CHS 244.5 x 10, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
Section class	1	1	None	Pass ✓
A	7370 mm^2	7367 mm^2	0.04%	Pass ✓
I	50730000 mm^4	50731473 mm^4	0.003%	Pass ✓
W_{el}	415000 mm^3	414981 mm^3	0.005%	Pass ✓
W_{pl}	550000 mm^3	550236 mm^3	0.04%	Pass ✓
$N_{c,Rd}$	2026.8 kN	2025.9 kN	0.04%	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the design manual "Konstruktionstabellen – Tables de construction (Construction tables)" by "Stahlbau Zentrum Schweiz – Centre Suisse de la construction metallique (Swiss center of steel construction)"

Table: Hot-rolled tubes (ROR) – Examination of random section (CHS 26.9 x 2.3)

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
m	1.40 kg/m	1.40 kg/m	0%	Pass ✓
A	178 mm^2	178 mm^2	0%	Pass ✓
I	13600 mm^4	13560 mm^4	0.3%	Pass ✓
W_{el}	1010 mm^3	1008 mm^3	0.2%	Pass ✓
W_{pl}	1400 mm^3	1396 mm^3	0.3%	Pass ✓

Compared Quantity	**Published Result**	**Result from eurocodeapplied.com**	**Difference**	**Check**
i	8.7 mm	8.7 mm	0%	Pass ✓
P	0.085 m	0.085 m	0%	Pass ✓

Comments: The results from eurocodeapplied.com are reported after rounding for presentation in the section tables.

Eurocode 3 - Table of design properties for square steel profiles - Square Hollow Sections (SHS)

https://eurocodeapplied.com/design/en1993/shs-design-properties

Content to be added soon.

Eurocode 3 - Table of design properties for rectangular steel profiles - Rectangular Hollow Sections (RHS)

https://eurocodeapplied.com/design/en1993/rhs-design-properties

Content to be added soon.

Eurocode 3 - Table of design properties for metric hexagonal bolts M5 to M39 (stress area, shear strength, tensile strength, bearing strength)

https://eurocodeapplied.com/design/en1993/bolt-design-properties

INDEPENDENT VERIFICATION

Comparison with published results in the design manual "Konstruktionstabellen – Tables de construction (Construction tables)" by "Stahlbau Zentrum Schweiz – Centre Suisse de la construction metallique (Swiss center of steel construction)"

Table: Resistance of bolts – Design values (for γ_{M2} = 1.25)

Compared Quantities	Examined cases	Difference	Check
d,d_0, A, A_s, $F_{v,Rd}$, $F_{t,Rd}$, $F_{b,Rd}$	Bolt sizes from M5 to M30, bolts classes 4.6 and 10.9, connected plate steel class S235, S355	<0.8%	Pass ✓

Comments: Shear resistance of bolts $F_{v,Rd}$ is calculated in the SZS manual based on the gross cross-sectional area A which is valid for the unthreaded part.

Eurocode 3 - ULS design of steel member (beam/column) with doubly-symmetric flanged cross-section (IPE, HEA HEB, HEM, or custom)

https://eurocodeapplied.com/design/en1993/flanged-steel-beam-column-uls-design

UNIT TEST

The calculation of the cross-sectional properties A, I_y, $W_{el,y}$, $W_{pl,y}$, i_y, I_z, $W_{el,z}$, $W_{pl,z}$, i_z, and the corresponding cross-sectional resistances N_{Rd}, $M_{el,Rd}$, $M_{pl,Rd}$, $V_{pl,Rd}$ is performed by using the components of the calculation “Eurocode 3 - Table of Design Properties for Flanged Steel Profiles (IPE, HEA, HEB, HEM)”. The verifications for this calculation are also applicable here. The following verifications consist of additional checks that have not been already performed in the calculation “Eurocode 3 - Table of Design Properties for Flanged Steel Profiles (IPE, HEA, HEB, HEM)”.

UNIT TEST

The calculation of the elastic critical moment for lateral-torsional buckling M_{cr} is performed by using the components of the calculation “Eurocode 3 - Calculation of Elastic Critical Moment for Lateral-Torsional Buckling of Doubly-Symmetric Flanged Cross-Section (IPE, HEA HEB, HEM or custom)”. The verifications for this calculation are also applicable here.

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.5: Cross-section resistance under combined bending and shear (406 x 178 x 74 UB, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
For additional checks see also the calculation “Eurocode 3 - Table of Design Properties for Flanged Steel Profiles (IPE, HEA, HEB, HEM)”				Pass ✓
ρ	0.27	0.27 mm^2	0%	Pass ✓
$M_{y,V,Rd}$	386.8 kNm	386.8 kNm	0%	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.6: Cross-section resistance under combined bending and compression (457 x 19J x 98 UB, grade S235).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
For additional checks see also the calculation "Eurocode 3 - Table of Design Properties for Flanged Steel Profiles (IPE, HEA, HEB, HEM)"				Pass ✓
n	0.48	0.48	0%	Pass ✓
a	0.40	0.40	0%	Pass ✓
$M_{N,y,Rd}$	342.2 kNm	343.2 kNm	0%	Pass ✓

INDEPENDENT VERIFICATION

Comparison with published results in the book "Designers' Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.8: Lateral torsional buckling resistance (762 x 267 x 173 UB, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
For additional checks see also the calculation "Eurocode 3 - Table of Design Properties for Flanged Steel Profiles (IPE, HEA, HEB, HEM)"				Pass ✓
For additional checks see also the calculation "Eurocode 3 - Calculation of Elastic Critical Moment for Lateral-Torsional Buckling of Doubly-Symmetric Flanged Cross-Section (IPE, HEA HEB, HEM or custom)"				Pass ✓
Part 1 of worked example (segment BC)				
C_1	1.052	1.069	1.6%	Pass ✓
M_{cr}	5699 kNm	5766 kNm	1.2%	Pass ✓
$\bar{\lambda}_{LT}$	0.55	0.5437	1.1%	Pass ✓
a_{LT}	0.34	0.34	0%	Pass ✓
Φ_{LT}	0.71	0.71	0%	Pass ✓
x_{LT}	0.86	0.86	0%	Pass ✓
$M_{b,Rd}$	1469 kNm	1473.2 kN	0.3%	Pass ✓
Part 2 of worked example (segment CD)				

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
C_1	1.879	1.77	6%	Pass ✓ (see note)
M_{cr}	4311 kNm	4028.9 kNm	6.5%	Pass ✓ (see note)
$\bar{\lambda}_{LT}$	0.63	0.6504	3.2%	Pass ✓
α_{LT}	0.34	0.34	0%	Pass ✓
Φ_{LT}	0.77	0.7881	2.3%	Pass ✓
χ_{LT}	0.82	0.8110	1.1%	Pass ✓
$M_{b,Rd}$	1402 kNm	1382.2 kN	1.4%	Pass ✓

Comments: The differences between the worked example and eurocodeapplied.com occur because the factor C_1 and the elastic critical moment M_{cr} for lateral-torsional buckling are calculated using different methods. Eurocodeapplied.com uses the information contained in the Non-confliction Complementary Information publication SN003a-EN-EU - "NCCI: Elastic critical moment for lateral torsional buckling", January 23, 2008, which is generally reasonably conservative.

INDEPENDENT VERIFICATION

Comparison with published results in the book “Designers’ Guide to EN 1993-1-1 – Eurocode 3: Design of Steel Structures – General rules and rules for buildings by L. Gardner and D.A. Nethercot – Thomas Telford.

Worked Example 6.10: Member resistance under combined bi-axial bending and axial compression (305 x 305 x 240 H section, grade S275).

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
For additional checks see also the calculation “Eurocode 3 - Table of Design Properties for Flanged Steel Profiles (IPE, HEA, HEB, HEM)”				Pass ✓
For additional checks see also the calculation “Eurocode 3 - Calculation of Elastic Critical Moment for Lateral-Torsional Buckling of Doubly-Symmetric Flanged Cross-Section (IPE, HEA HEB, HEM or custom)”				Pass ✓
n	0.41	0.41	0%	Pass ✓
a	0.22	0.2149	2.3%	Pass ✓
$M_{N,y,Rd}$	773.8 kNm	773.26 kNm	0.07%	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
$M_{N,z,Rd}$	503.9 kNm	503.60 kNm	0.06%	Pass ✓
Utilization for biaxial bending and axial force	0.33	0.3395	2.9%	Pass ✓
$N_{cr,y}$	153943 kN	153949 kN	0.004%	Pass ✓
$\bar{\lambda}_y$	0.23	0.2337	1.6%	Pass ✓
Φ_y	0.53	0.5330	0.6%	Pass ✓
x_y	0.99	0.9880	0.2%	Pass ✓
$N_{b,y,Rd}$	8314 kN	8308.5 kN	0.07%	Pass ✓
$N_{cr,z}$	23863 kN	23867 kN	0.02%	Pass ✓
$\bar{\lambda}_z$	0.59	0.5936	0.6%	Pass ✓
Φ_z	0.77	0.77	0%	Pass ✓
x_z	0.79	0.79	0%	Pass ✓
$N_{b,y,Rd}$	6640 kN	6636.5 kN	0.05%	Pass ✓
C_1	2.752	2.55	7.3%	Pass ✓ (see note)
M_{cr}	17114 kNm	15818 kNm	7.6%	Pass ✓ (see note)
$\bar{\lambda}_{LT}$	0.26	0.2717	4.5%	Pass ✓
a_{LT}	0.21	0.21	0%	Pass ✓
Φ_{LT}	0.54	0.54	0%	Pass ✓
x_{LT}	0.99	0.9840	0.6%	Pass ✓
$M_{b,Rd}$	1152 kNm	1149.3 kN	0.2%	Pass ✓
c_{my}	0.4	0.4	0%	Pass ✓
c_{mz}	0.6	0.6	0%	Pass ✓
c_{mLT}	0.4	0.4	0%	Pass ✓
k_{yy}	0.41	0.41	0%	Pass ✓
k_{zz}	0.78	0.78	0%	Pass ✓
k_{yz}	0.47	0.47	0%	Pass ✓

Compared Quantity	Published Result	Result from eurocodeapplied.com	Difference	Check
k_{zy}	0.79	0.79	0%	Pass ✓
Utilization equation (6.61)	0.66	0.66	0%	Pass ✓
Utilization equation (6.62)	0.97	0.97	0%	Pass ✓

Comments: The differences between the worked example and eurocodeapplied.com occur because the factor C_1 and the elastic critical moment M_{cr} for lateral-torsional buckling are calculated using different methods. Eurocodeapplied.com uses the information contained in the Non-confliction Complementary Information publication SN003a-EN-EU - "NCCI: Elastic critical moment for lateral torsional buckling", January 23, 2008, which is generally reasonably conservative.

INDEPENDENT VERIFICATION

Comparison with the computer program SOFiSTiK – Version 2018 (www.sofistik.de). The utilization of the resistance of an HEB 600, S275 column with 6.0 m height is examined. All applicable verifications for biaxial bending with axial force according to EN 1993-1-1 Section 6 are compared.

Compared Quantities	Examined cases	Difference	Check
Flexural buckling resistance n_y,n_z, lateral-torsional buckling resistance m_y, bending moment resistance m_z, resistance for biaxial bending and axial force according to Method 1 (nm_{yz1}) and Method 2 (nm_{yz2}) of EN1993-1-1	Design for class 1 or class 3. Application of both method 1 and method 2 of EN1993-1-1. Various bending moment diagrams: uniform, linear ψ=0.5, linear ψ=0.0, linear ψ=-0.5, linear ψ=-1.0. Various support conditions at ends: pinned-pined, fixed-pinned, fixed-fixed. Various load arrangements: uniform load, concentrated force at midpoint	n_y < 2.5% n_z < 1.0% m_y < 4.3% m_z < 1.0% nm_{yz1} < 2.7% nm_{yz2} < 2.0%	Pass ✓

Comments:

1. The differences in lateral torsional resistance between the computer program SOFiSTiK and eurocodeapplied.com occur because the elastic critical moment M_{cr} for lateral-torsional buckling are calculated using different methods. Eurocodeapplied.com uses the information contained in the Non-confliction Complementary Information publication SN003a-EN-EU - "NCCI: Elastic critical moment for lateral torsional buckling", January 23, 2008, which is approximate and generally reasonably conservative. The computer program SOFiSTiK uses

more elaborate eigenvalue analysis using finite element discretization of the steel member. In general the results from eurocodeapplied.com are more conservative.

2. The implementation of Method 2 in computer program SOFiSTiK is wrong for linear bending moment diagram and $\psi < -0.5$ in the currently examined version of the program (2018). The reason is that the limits for the equivalent uniform moment factors $c_{my} \geq 0.4$, $c_{mz} \geq 0.4$, $c_{mLT} \geq 0.4$ as specified in EN 1993-1-1 Table B.3 are not properly applied by SOFiSTiK for the cases mentioned above. The comparison with eurocodeapplied.com is not performed for these cases.

Eurocode 3 - Calculation of elastic critical moment for lateral-torsional buckling of doubly-symmetric flanged cross-section (IPE, HEA HEB, HEM or custom)

https://eurocodeapplied.com/design/en1993/elastic-critical-moment

INDEPENDENT VERIFICATION

Comparison with the computer program LTBeam (https://www.cticm.com/logiciel/ltbeam). The elastic critical moment for an IPE 300 beam with 10.0 m length is examined for various bending moment diagrams.

Compared Quantities	Examined cases	Difference	Check
M_{cr}	Various bending moment diagrams: uniform, linear ψ=1.0, 0.9, …, -0.9, -1.0, parabolic bending moment with pinned-pined, fixed-pinned, fixed-fixed support conditions, triangular bending moment with pinned-pined, fixed-pinned, fixed-fixed support conditions	Uniform: < 1% Linear ψ=1.0 to 0.0: < 3% Linear ψ=0.0 to -1.0: < 7% Triangular, pinned-pinned: < 2% Parabolic, pinned-pinned: < 1% Triangular, fixed-fixed: < 3% Parabolic, fixed-fixed: < 2% Triangular, fixed-pinned: < 4% Parabolic, fixed-pinned: < 3%	Pass ✓ (see note)

Comments:

1. The differences in lateral torsional resistance between the computer program SOFiSTiK and eurocodeapplied.com occur because the elastic critical moment M_{cr} for lateral-torsional buckling are calculated using different methods. Eurocodeapplied.com uses the information contained in the Non-confliction Complementary Information publication SN003a-EN-EU - "NCCI: Elastic critical moment for lateral torsional buckling", January 23, 2008, which is approximate and generally reasonably conservative. The computer program LTBeam uses more elaborate eigenvalue analysis using finite element discretization of the steel member. In general the results from eurocodeapplied.com are more conservative.

2. The implementation of Method 2 in computer program SOFiSTiK is wrong for linear bending moment diagram and $\psi < -0.5$ in the currently examined version of the program (2018). The reason is that the limits for the equivalent uniform moment factors $c_{my} \geq 0.4$, $c_{mz} \geq 0.4$, $c_{mLT} \geq 0.4$ as specified in EN 1993-1-1 Table B.3 are not properly applied by SOFiSTiK for the cases mentioned above. The comparison with eurocodeapplied.com is not performed for these cases.

Eurocode 8 - Design acceleration response spectrum (for design of ductile structures in the inelastic range with the behavior factor q)

https://eurocodeapplied.com/design/en1998/design-response-spectrum

Content to be added soon.

Eurocode 8 - Elastic acceleration and displacement response spectra (for design of structures in the elastic range and calculation of displacements)

https://eurocodeapplied.com/design/en1998/elastic-response-spectrum

Content to be added soon.

Eurocode 8 - Preliminary SDOF Analysis of Seismic Isolation

https://eurocodeapplied.com/design/en1998/seismic-isolation-preliminary-sdof

Content to be added soon.

Eurocode 8 - Design Earthquake Action During Construction Phase

https://eurocodeapplied.com/design/en1998/earthquake-action-during-construction

Content to be added soon.

Eurocode 8 - Dynamic earth pressure coefficient for earthquake analysis (Mononobe-Okabe)

https://eurocodeapplied.com/design/en1998/mononobe-okabe

UNIT TEST

The earth pressure coefficients from mononobe-okabe theory should be identical to the corresponding earth pressure coefficients from coulomb theory when no earthquake accelerations are applied

Compared Quantity	Expected Result	Difference	Check
K_{AE} with k_h=k_v=0, δ=0, β=0, ψ=90°	$\tan^2(45°-\varphi/2)$	<0.01%	Pass ✓
K_{PE} with k_h=k_v=0, δ=0, β=0, ψ=90°	$\tan^2(45°+\varphi/2)$	<0.01%	Pass ✓