

RKALC General Beam Verification Report

RC and PT beam section calculations with published reference comparisons

RK Software Solutions | 11 October 2026 | Revision 1

Verified by Rabee Kafina

Introduction

This report presents numerical evidence for RKALC General Beam, the reinforced and prestressed concrete section designer using AS 3600:2018 with Amendment 1.

Three published examples test T-beam flexure and shear, prestressed beam moment capacity, and a doubly reinforced beam with elastic compression steel.

Verification findings

Reference and quantity	Published	RKALC	Interpretation
CSI Example 001 Required tension steel	3151 mm ²	3151.03 mm ²	Matches rounding
CSI Example 001 Required shear links	1777 mm ² /m	1776.56 mm ² /m	Matches rounding
Warner Example 7.12 Nominal PT capacity Warner et al. [2]	939 kNm	929.96 kNm	0.96% lower
Warner Example 7.5 Nominal RC capacity Warner et al. [2]	667 kNm	664.18 kNm	0.42% lower

What the evidence establishes

The results support confidence in the implemented section equilibrium, effective depth, compression-block integration, reinforcement stress states and the tested flexural and shear calculations. Independent hand calculations agree with the engine for both textbook cases. Automated regressions also test moment reversal, multiple reinforcement layers, PT stress options and application behaviour.

Published numerical comparisons and application tests provide different evidence. Neither a small difference nor a passing regression establishes complete member compliance. The report records the source inconsistencies, analytical fixture assumptions and unverified design checks so that the numerical agreement can be assessed on its actual scope.

Method and comparison basis

A controlled comparison reproduces the source geometry, force conventions, steel areas and material stresses before considering a selected reinforcement cage. General Beam uses millimetres, MPa, newtons and Nmm internally.

Reported moments are in KN.m and forces in KN. Positive bending places the bottom reinforcement in tension; negative bending places the top reinforcement in tension.

Published design verification and legacy mechanics benchmarks

Reference	Basis and purpose
CSI ETABS Example 001	Direct AS 3600:2018 comparison of required flexural and support-shear reinforcement.
Warner Example 7.5	strain-compatibility benchmark with non-yielding compression steel.
Warner Example 7.12	PT mechanics benchmark, recalculated with the active 2018 stress block.

Warner, Rangan, Hall and Faulkes published Concrete Structures in 1998, predates AS 3600:2001.

Runs therefore use the legacy factors actually printed in the examples; an exact historical code edition is not assigned from the chapter extract. General Beam has no legacy-code mode.

Nominal and factored capacity

$$\text{Design capacity} = \phi \times \text{nominal capacity}$$

Warner et al. [2] examples report nominal M_u . The corresponding engine nominal result is the like-for-like comparison. Factored outputs are stated separately.

General Beam assumes Class N reinforcement for its beam reduction factor; legacy Y-bar notation and yield strength alone do not establish that ductility classification.

Effective depth and reinforcement areas

Overall depth D and tension reinforcement depth d_s are distinct. For multiple layers, the engine uses the area-weighted centroid for effective-depth quantities and solves the stress and force of each actual layer in flexure.

Equivalent continuous areas used by these benchmarks are analytical fixtures, not buildable reinforcement layouts. The page requires physical integer bar counts and must be rerun at the selected cage geometry.

Current concrete stress block

$$\alpha_2 = \max(0.67, 0.85 - 0.0015 f'c) \quad \gamma = \max(0.67, 0.97 - 0.0025 f'c)$$

The RKALC engine integrates the rectangular or T-shaped block to depth $a = \gamma c$ and deducts displaced concrete at bars and ducts. These factors are consistent with the review by Chowdhury and Loo [4]. The concrete deduction is an existing engine modelling choice and is separated from code-factor changes in the RC comparison.

There is no universal percentage acceptance tolerance in these references. Direct comparisons are assessed against source rounding.

Legacy differences are explained by isolated calculations rather than accepted solely because they are small. Every benchmark also checks equilibrium or an independently evaluated equation.

Example 001 RC T beam model

CSI ETABS Software Verification, AS 3600-2018, Example 001 [1], provides the current-code benchmark. Two third-point factored loads of 231 kN on a 6 m span produce $M^* = 462$ kNm in the middle third and $V^* = 231$ kN at the supports. These peak actions occur at different sections.

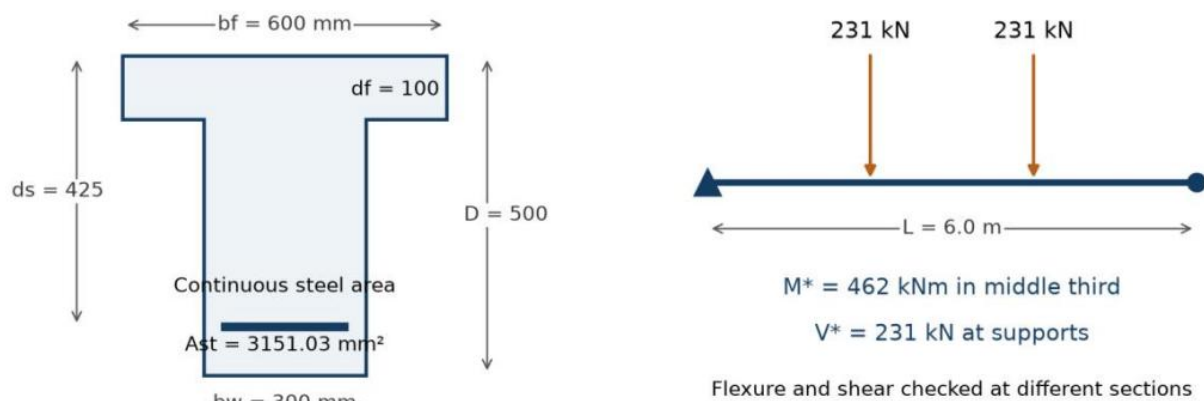


Figure 1- Adopted T-beam geometry and factored loading, redrawn from CSI Example 001. The steel line represents an analytical area at a fixed depth; it is not a selected bar arrangement.

Input	Adopted value
Web / effective flange width	300 / 600 mm
Overall depth / flange thickness	500 / 100 mm
Tension steel depth ds	425 mm
Concrete / reinforcing and link steel strength	30 / 460 MPa
External axial force / torsion / prestress	Zero
Flexural section	$M^* = 462$ kNm; $V^* = 0$; no compression steel
Support-shear section	$M^* = 0$; $V^* = 231$ kN; $A_{st} = 0$

Analytical fixture

The flexural fixture uses continuous tension steel at exactly 425 mm and omits compression and flange-wing reinforcement. The support fixture retains nominal $d = 425$ mm at zero A_{st} and reaches the conservative longitudinal strain bound of 0.003. Two-leg N12 links at 100 mm select the sufficient-minimum-fitment branch; the required link area is a calculated output.

The support zero-steel idealisation follows the source shear calculation. It is not an adequate physical support detail and does not pass the engine's additional longitudinal-force check.

Example 001 results and interpretation

Quantity	Published	RKALC
Required tension area A_{st}	3151 mm ²	3151.03 mm ²
Flexural ϕ	0.85 in calculations	0.85
Concrete α_2 / γ	0.805 / 0.895	0.805 / 0.895
Compression block depth a	100.066 mm	100.0656 mm
Design moment at required A_{st}	462 kNm	462.000 kNm
Shear effective depth d_v	382.5 mm	382.5 mm
Longitudinal strain ϵ_x	0.003	0.003
Concrete shear factor k_v	0.0727	0.072727
Strut angle θ_v	50°	50°
Nominal concrete shear V_{uc}	45.71 kN	45.7099 kN
Required A_{sv}/s	1777 mm ² /m	1776.56 mm ² /m

Interpretation

The required flexural area and link area reproduce the published design outputs within rounding. The final compression block extends just below the 100 mm flange, so this is a useful check of flange-to-web integration. The engine gives $c = 111.805$ mm and $k_{uo} = 0.263071$. Its nominal moment is 543.529 kNm; applying $\phi = 0.85$ recovers the 462 kNm demand.

For two-leg N12 links, the required area corresponds to spacing no greater than 127.32 mm. N12 at 125 mm satisfies this area criterion before other detailing checks. Keeping the span A_{st} at the support changes the calculated requirement to 509.05 mm²/m because the longitudinal strain calculation has different inputs.

Source inconsistencies and secondary differences

Page 6 states flexural $\phi = 0.80$ in prose, while the working uses 0.85. Page 7 states shear $\phi = 0.70$, while the link-area calculation uses 0.75. General Beam uses 0.85 for this flexural case, 0.75 for sufficient-fitment shear and 0.70 for web crushing.

The displayed web-crushing equation evaluates to 932.305 kN nominal, not the printed 1243 kN. General Beam gives 652.614 kN at $\phi = 0.70$; the source's separate 719.25 kN figure is also inconsistent with that equation. This secondary result is not claimed as a published numerical match, although it exceeds the 231 kN demand.

The engine's minimum links are 285.77 mm²/m; the source repeats 228.26 mm²/m despite its own expression giving about 285.77. Its minimum tension area is 300 mm²; the engine gives 298.79 mm² from $M_{uo} \geq 1.2 M_{cr}$. Neither minimum governs the main reinforcement result.

These qualif

Calculation	Nominal M_u kNm	Factored ϕM_u kNm
Published textbook result	939	Not supplied
Exact legacy hand arithmetic	938.431	Not compared

Calculation	Nominal Mu kNm	Factored ϕ Mu kNm
RKALC retaining book areas and $f_{pu} = 1600$ MPa	929.958	790.465
Geometric bar / current strand areas; $f_{pu} = 1600$ MPa	926.719	787.711
Same current areas; bonded code approximation	940.009	799.008

Effect of stress block factors

Quantity	Legacy hand	RKALC controlled
α_2 / γ	0.85 / 0.822	0.802 / 0.890
Compression block a	186.275 mm	197.423 mm
Neutral axis c	226.611 mm	221.824 mm
Bar force / tendon force	720 / 800 kN	720 / 800 kN

The controlled engine result is 0.963% below the published 939 kNm and 0.903% below exact legacy arithmetic. Lower α_2 requires a deeper concrete block and reduces the lever arm. With the yielded forces fixed, γ changes the neutral axis and strain checks rather than the block's force-centroid lever arm. The source's displayed arithmetic gives about 938.49 kNm; its 939 kNm result contains a small separate numerical difference.

Independent tendon strain check

$$\epsilon_{pu} = f_{pe} / E_p + \epsilon_{ce} + 0.003 (d_p - c) / c$$

Using the source moduli and effective stress gives $\epsilon_{pu} = 0.011375$ with legacy c and 0.011568 with current c. Both exceed the idealised yield strain $1600/190000 = 0.008421$. This supports retaining $f_{pu} = 1600$ MPa for the controlled comparison. Specified- f_{pu} mode does not itself solve a tendon stress-strain curve; this independent calculation supplies the justification.

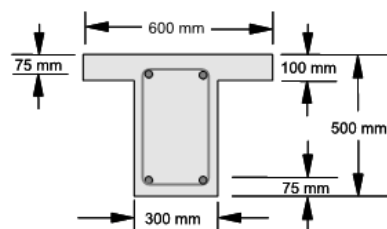
Current area and tendon model variants

Geometric area for four 24 mm bars is 1809.56 mm^2 ; five current 12.7 mm strands give $A_p = 493 \text{ mm}^2$. Using the bonded approximation with $f_{pb} = 1870$ MPa gives $f_{pu} = 1656.55$ MPa and $M_u = 940.01$ kNm. Its closeness to 939 kNm includes compensating area and stress changes and is not the controlled verification result.

All analytical variants omit compression bars. They are not full-page physical cage designs. The 800 mm depth requires side-face reinforcement review. The book gives nominal capacity only; the factored values above assume $\phi = 0.85$ and suitable Class N reinforcement.

Software Verification

PROGRAM NAME: ETABS
REVISION NO.: 0



Beam Section

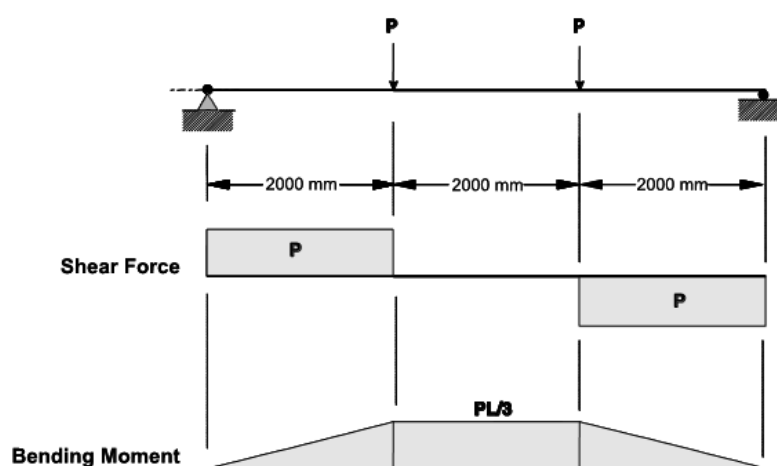


Figure 1 The Model Beam for Flexural and Shear Design

GEOMETRY, PROPERTIES AND LOADING

Clear span,	L	=	6000	mm
Overall depth,	h	=	500	mm
Flange thickness,	D_s	=	100	mm
Width of web,	b_w	=	300	mm
Width of flange,	b_f	=	600	mm
Depth of tensile reinf.,	d_{sc}	=	75	mm



Software Verification

PROGRAM NAME: ETABS
REVISION NO.: 0

Effective depth,	d	=	425	mm
Depth of comp. reinf.,	d'	=	75	mm
Concrete strength,	f'_c	=	30	MPa
Yield strength of steel,	f_y	=	460	MPa
Concrete unit weight,	w_c	=	0	kN/m ³
Modulus of elasticity,	E_c	=	25×10^5	MPa
Modulus of elasticity,	E_s	=	2×10^8	MPa
Poisson's ratio,	ν	=	0.2	
Dead load,	P_d	=	30	kN
Live load,	P_l	=	130	kN

TECHNICAL FEATURES TESTED

- Calculation of flexural and shear reinforcement
- Application of minimum flexural and shear reinforcement

RESULTS COMPARISON

Table 1 shows the comparison of the total factored moments in the design strip. They match exactly for this problem. Table 1 also shows the design reinforcement comparison.

Table 1 Comparison of Moments and Flexural Reinforcements

Method	Moment (kN-m)	Reinforcement Area (sq-mm)
		A_s^+
ETABS	462	3151
Calculated	462	3151

$$A_{s,min}^+ = 300 \text{ sq-mm}$$



Software Verification

PROGRAM NAME: ETABS
REVISION NO.: 0

Table 2 Comparison of Shear Reinforcements

Shear Force (kN)	Reinforcement Area, $\frac{A_v}{s}$ (sq-mm/m)	
	ETABS	Calculated
231	1777	1777

COMPUTER FILE: AS 3600-2018 Ex001

CONCLUSION

The computed results show an exact match for the flexural and the shear reinforcing.

Doubly reinforced RC beam benchmark model (Example 7.5)

Warner et al. [2], Example 7.5, Figure 7.9, printed pages 163–164, checks a doubly reinforced rectangular section. Its initial assumption that both layers yield is rejected. The final source iteration keeps the compression steel elastic and reports $M_u = 667$ kNm.

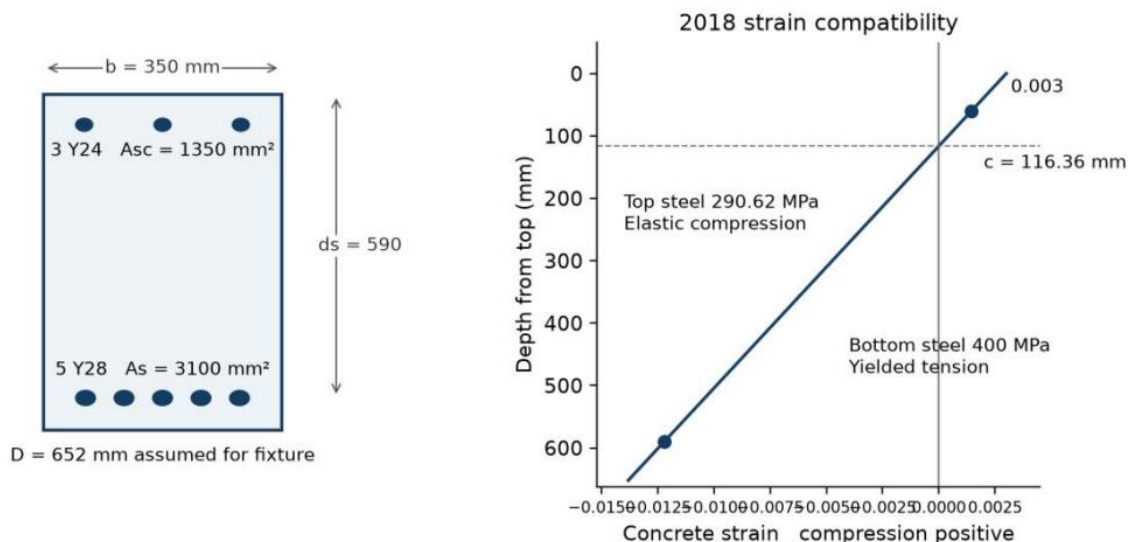


Figure 2- Adopted RC section and current strain diagram, redrawn from Example 7.5. Bar-centre depths are source dimensions; overall $D = 652$ mm is an analytical fixture assumption, not a dimension supplied by the book.

Input	Published value
Width	350 mm
Tension steel	5 Y28; $A_s = 3100 \text{ mm}^2$; $d_s = 590$ mm
Compression steel	3 Y24; $A_{sc} = 1350 \text{ mm}^2$; $d_c = 60$ mm
Concrete strength	30 MPa
Steel yield strength / modulus	400 / 200000 MPa
Legacy α_2 / γ	0.85 / 0.836
Prestress / external axial force	Zero

The dimension 590 mm is the bottom reinforcement depth measured from the top; it is not the overall beam depth. $D = 652$ mm, clear cover 36 mm and a 12 mm stirrup reproduce both source bar-centre depths with 24 and 28 mm bars. At zero axial force, the comparison depends on the specified bar depths rather than that assumed overall depth.

The controlled run preserves the rounded source areas using equivalent continuous steel. A separate run uses integer bar counts and geometric circular areas at the same depths.

RC beam benchmark results and interpretation

Calculation	c mm	Top stress MPa	Mu kNm
Published trial-and-error solution	115	287	667
Exact legacy equilibrium	114.512	285.623	667.567
2018 factors; gross concrete retained	113.462	282.713	665.119
RKALC; source areas; net concrete	116.361	290.618	664.179
RKALC; geometric 3Y24 and 5Y28 areas	115.432	288.128	659.984

Compression steel remains elastic

In the controlled engine run the top steel strain is 0.001453, below the yield strain of 0.002. Its compression stress is 290.62 MPa. Bottom strain is approximately 0.01221 and its stress reaches 400 MPa. The regression tests these different stress states explicitly; an assumption that both faces yield would not reproduce this example.

$$T = A_s f_y \quad C_s = A_{sc} E_s \times 0.003 (c - d_c) / c$$

$$C_c = \alpha_2 f'_c (b \gamma c - A_{sc}) \quad C_c + C_s = T$$

An independent quadratic solution gives $c = 116.361$ mm. The forces are $T = 1240.000$ kN, $C_s = 392.334$ kN and $C_c = 847.666$ kN. Their sum closes to floating-point precision. The 104.143 mm block contains the whole top bar, whose bottom is at 72 mm, so full displaced area and its first moment are deducted.

Interpreting the capacity difference

General Beam's 664.18 kNm is 0.423% below the published 667 kNm. The source stops at $c = 115$ mm with approximately 5 kN residual compression; exact legacy equilibrium gives 667.567 kNm. Updating only the stress-block factors lowers this to 665.119 kNm. Deducting displaced concrete lowers it by another 0.940 kNm to 664.179 kNm. These are distinct numerical and modelling effects.

The geometric areas for integer bars are $A_{sc} = 1357.168 \text{ mm}^2$ and $A_s = 3078.761 \text{ mm}^2$. With the same depths, this separate input change gives 659.984 kNm. Factored capacities at the engine's $\phi = 0.85$ are 564.55 kNm for the source-area case and 560.99 kNm for integer bars. The book provides no factored comparison target.

What this case verifies

The example checks strain compatibility and equilibrium when compression reinforcement has not yielded. The independent solution agrees with the engine's nominal moment, concrete resultant, steel forces and neutral axis. Cover, bar spacing, anchorage, shear and service behaviour are outside this published moment-capacity example.

EXAMPLE 7.5 MOMENT CAPACITY OF DOUBLY REINFORCED SECTION (COMPRESSIVE STEEL NOT AT YIELD)

Determine the moment capacity M_u of the doubly reinforced section shown in the diagram below.

Concrete strength $f'_c = 30 \text{ MPa}$; $\gamma = 0.836$

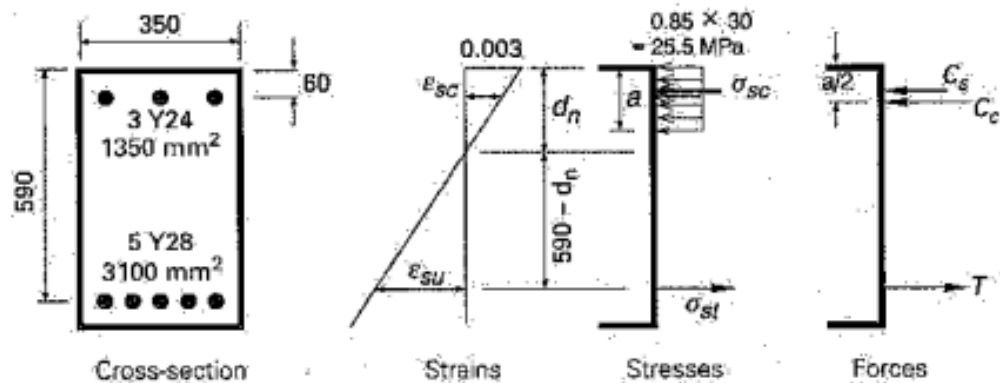


Figure 7.9 Section for Example 7.5

We assume initially that all steel yields before M_u is reached. Then:

Tensile steel force: $T = 3100 \times 400 = 1240 \times 10^3 \text{ N}$

Compressive steel force: $C_s = 1350 \times 400 = 540 \times 10^3 \text{ N}$

Concrete compressive force: $C_c = 25.5 \times 350 \times a = 8.925a \times 10^3 \text{ N}$

$\Sigma H = 0$: $8.925a + 540 = 1240$; $a = 78 \text{ mm}$

Check yield assumption: $d_n = \frac{78}{0.836} = 93 \text{ mm}$

The tensile steel has clearly yielded.

Compressive steel: $\epsilon_{sc} = \frac{0.003(93 - 60)}{93} = 0.0011 < \epsilon_{sy}$

Our assumption that the compressive steel had yielded is shown to be invalid and we must start again, knowing now that this steel is in the elastic range.

We could proceed by expressing the compressive steel strain and stress, and the concrete compressive force, in terms of the unknown d_n . The condition for horizontal equilibrium, $C_c + C_s - T = 0$, would then yield a quadratic equation which could be solved for d_n . This is similar to the approach used in Example 7.3.

Instead, in this example we will use a trial and error approach, iterating on assumed values of d_n until we find the correct value, which satisfies the equilibrium condition $C_c + C_s - T = 0$.

(1) Try $d_n = 100$ mm

Compressive steel strain: $\epsilon_{sc} = 0.003 \left(\frac{100 - 60}{100} \right) = 0.0012$

Compressive steel force: $C_s = 0.0012 \times 200,000 \times 1350 = 324 \times 10^3$ N

Concrete compressive force: $C_c = 8.925a = 7.461d_n = 746$ kN

As before: $T = 1240$ kN

Check equilibrium: $\Sigma H = 746 + 324 - 1240 = -170$ kN (tension)

Since $\Sigma H \neq 0$, the guessed value of d_n is incorrect; we need a larger value.

(2) Try $d_n = 120$ mm

This gives $C_s = 405$ kN, $C_c = 895$ kN, $\Sigma H = 60$ kN (compression), showing that the value of d_n is too large. A new value is obtained by linearly interpolating from the results of the first two trials.

(3) Try $d_n = 120 - \frac{120 - 100}{60 - (-170)} \times 60 = 115$ mm

This gives $\sigma_{sc} = 287$ MPa, $C_s = 387$ kN, $C_c = 858$ kN

Check equilibrium: $\Sigma H = 858 + 387 - 1240 = +5 = 0$ OK

Calculate M_{tu} taking moments about the top fibre:

$$M_{tu} = 1240 \times 590 - 858 \times \frac{0.836 \times 115}{2} - 387 \times 60 \text{ kNmm}$$

$$= 667 \text{ kNm}$$

PT beam benchmark model

Warner et al., Concrete Structures [2], Example 7.12, Figure 7.14, printed pages 179–180, evaluates a rectangular beam with both reinforcing bars and prestressing steel. Its source result is $M_u = 939$ kNm, assuming the bars and tendons reach their stated idealised yield strengths.

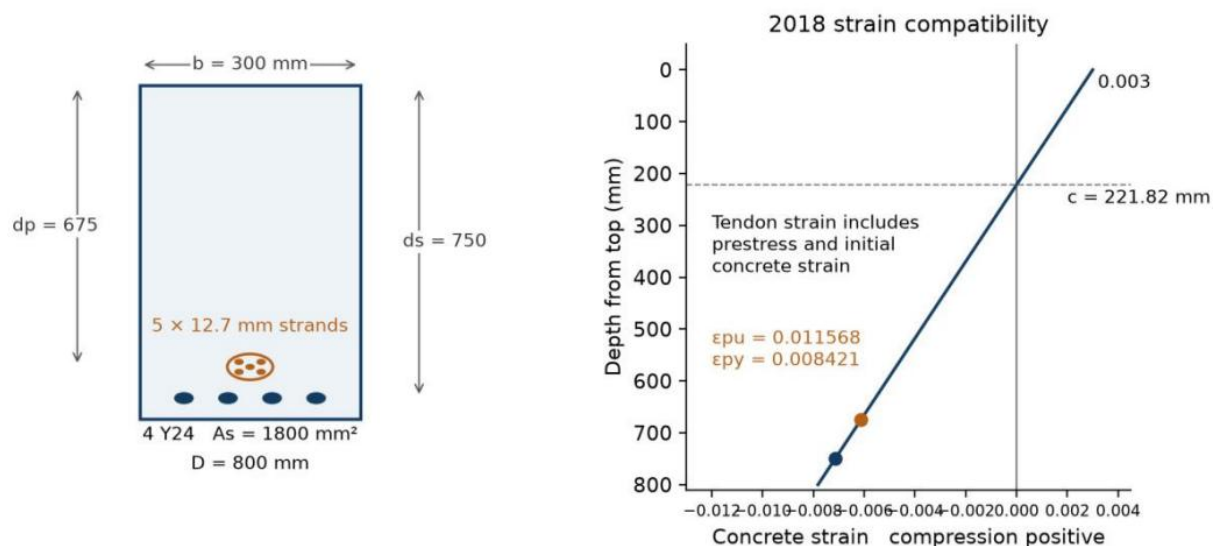


Figure 3 - Adopted PT section and concrete strain diagram, redrawn from Example 7.12. Five strands are shown as one schematic tendon bundle; duct dimensions and detailed strand placement are not supplied by the source.

Input	Published value
Section width / overall depth	300 / 800 mm
Rebar area / depth / yield strength	1800 mm ² / 750 mm / 400 MPa
Tendon area / depth	500 mm ² / 675 mm
Prestressing steel	Five 12.7 mm strands; no compression bars
Concrete strength / legacy α_2 / γ	32 MPa / 0.85 / 0.822
Ultimate tendon stress / effective stress	1600 / 1000 MPa
Tendon / concrete modulus	190000 / 28570 MPa

The tendon is 125 mm from the bottom and the bars are 50 mm from the bottom. Effective prestress is 500 kN and $P/Ag = 2.0833$ MPa. The controlled engine run retains the source areas and specifies ultimate tendon stress of 1600 MPa. The strain treatment is interpreted as bonded behaviour.

Cover, stirrup diameter, duct diameter and the split of stressing losses are fixture assumptions used to reproduce the stated depths and effective stress. They are not source construction details or verification of transfer or service behaviour.

PT beam benchmark results and interpretation

Calculation	Nominal Mu kNm	Factored ϕ Mu kNm
Published textbook result	939	Not supplied
Exact legacy hand arithmetic	938.431	Not compared
RKALC retaining book areas and fpu = 1600 MPa	929.958	790.465
Geometric bar / current strand areas; fpu = 1600 MPa	926.719	787.711
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Effect of stress block factors

Quantity	Legacy hand	RKALC controlled
α_2 / γ	0.85 / 0.822	0.802 / 0.890
Compression block a	186.275 mm	197.423 mm
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Bar force / tendon force	720 / 800 kN	720 / 800 kN

The controlled engine result is 0.963% below the published 939 kNm and 0.903% below exact legacy arithmetic. Lower α_2 requires a deeper concrete block and reduces the lever arm. With the yielded forces fixed, γ changes the neutral axis and strain checks rather than the block's force-centroid lever arm. The source's displayed arithmetic gives about 938.49 kNm; its 939 kNm result contains a small separate numerical difference.

Independent tendon strain check

$$\epsilon_{pu} = f_{pe} / E_p + \epsilon_{ce} + 0.003 (d_p - c) / c$$

Using the source moduli and effective stress gives $\epsilon_{pu} = 0.011375$ with legacy c and 0.011568 with current c. Both exceed the idealised yield strain $1600/190000 = 0.008421$. This supports retaining fpu = 1600 MPa for the controlled comparison. Specified-fpu mode does not itself solve a tendon stress-strain curve; this independent calculation supplies the justification.

Current area and tendon model variants

Geometric area for four 24 mm bars is 1809.56 mm²; five current 12.7 mm strands give $A_p = 493$ mm². Using the bonded approximation with fpb = 1870 MPa gives fpu = 1656.55 MPa and Mu = 940.01 kNm. Its closeness to 939 kNm includes compensating area and stress changes and is not the controlled verification result.

All analytical variants omit compression bars. They are not full-page physical cage designs. The 800 mm depth requires side-face reinforcement review. The book gives nominal capacity only; the factored values above assume $\phi = 0.85$ and suitable Class N reinforcement.

Regression evidence and verification coverage

All three published-example scripts and the engine regression suite completed successfully for this report. The engine suite contains 19 test groups with 64 numerical assertions plus condition and mode-matrix checks. Browser regressions also completed through the live ASP.NET General Beam page with no recorded JavaScript page errors.

Evidence	Checks exercised
Section properties and geometry	Rectangle and T properties; circular void integrals; flange compression in both moment directions.
Flexural equilibrium	RC/PT internal forces and moment; reinforcement stress limits; moment reversal; factored axial equilibrium; required steel.
Multiple main reinforcement layers	Unequal areas and diameters; centroid depths; per-layer stresses including an inner layer below yield; vertical gaps.
Prestress and transverse actions	Bonded/unbonded formulas; specified ultimate stress; duct effects; shear/torsion sign invariance.
Service and review conditions	Cracked-section reversal; creep/shrinkage response; missing flange distribution; side-face and other review flags.
Browser and user inputs	RC/PT and both shapes; decimal and reversed actions; validation; stale results cleared; layer add/remove/reset and preview; responsive and print layouts.

Evidence strength

The CSI benchmark directly tests published 2018 reinforcement calculations. The two textbook benchmarks test physical section mechanics against independent arithmetic while explaining current-factor differences. Engine regressions test broader implementation behaviour. Browser checks establish that inputs and outputs are connected correctly; they do not independently certify every engineering formula.

Scope of confidence

Together, these checks support confidence in the tested General Beam section calculations and provide reproducible evidence for review. They do not establish blanket compliance for every section, material, load history or amendment of AS 3600. An overall page pass relates to the checks implemented and the inputs provided.

Further independent published checks should cover negative bending of T sections, torsion with shear, unbonded PT, service cracking and stresses, transfer stages and multiple reinforcement layers. Project design must also address effective flange width, anchorage and development, cover and exposure, side-face reinforcement, flange–web interface shear, fire, deflection and complete member action envelopes.

EXAMPLE 7.12

MOMENT CAPACITY OF SECTION WITH PRESTRESSING STEEL

The ultimate moment M_u is to be calculated for the section shown in Fig 7.14, which has a prestressing cable consisting of five 12.7 mm strands with a total area of 500 mm^2 , and four Y24 reinforcing bars ($A_s = 1800 \text{ mm}^2$). The properties of the concrete and prestressing steel are:

Concrete: $f'_c = 32 \text{ MPa}$ $\gamma = 0.822$ $E_c = 28,570 \text{ MPa}$

Prestressing steel: $f_{py} = 1600 \text{ MPa}$ $E_p = 190,000 \text{ MPa}$ $\sigma_{pe} = 1000 \text{ MPa}$

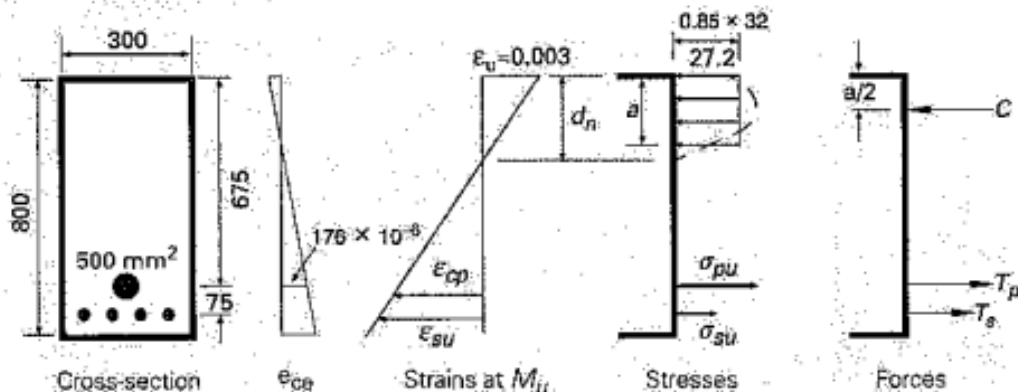


Figure 7.14 Section for Example 7.12

Assume that all steel yields: $\sigma_{pu} = f_{py} = 1600 \text{ MPa}$; $\sigma_{su} = f_{sy} = 400 \text{ MPa}$

Then $T_s = 400 \times 1800 = 720 \times 10^3 \text{ N}$; $T_p = 1600 \times 500 = 800 \times 10^3 \text{ N}$

Compressive force: $C = 27.2 \times 300a = 8160a \text{ N}$

For equilibrium $C = T_s + T_p$: $8.16a = 720 + 800 = 1520$

Stress block depth: $a = 186.2 \text{ mm}$

Now check the steel yield assumptions:

Neutral axis depth: $d_n = 186.2/0.822 = 227 \text{ mm}$

From the strain diagram: $\epsilon_{su} = 0.003(750 - 227)/227 = 0.0069 > \epsilon_{sy}$ OK

$\epsilon_{cp} = 0.003(675 - 227)/227 = 0.0059$

Now $\epsilon_{ce} = 0.000176$ and: $\epsilon_{pe} = 1000/190,000 = 0.0053$

Total steel strain at M_u : $\epsilon_{pu} = 0.0059 + 0.000176 + 0.0053 = 0.0114$

This exceeds the yield strain: $\epsilon_{py} = 1600/190,000 = 0.0084$, so the assumption that the prestressing steel yields before M_u is also valid.

Concrete compressive force $C = 1520 \text{ kN}$. We calculate M_u by taking moments about the top fibre:

$$M_u = 720 \times 0.75 + 800 \times 0.675 - 1520 \times 0.1862/2 = 939 \text{ kNm}$$

Sources and reproducibility

Published references

- [1] Computers and Structures, Inc. ETABS Software Verification, AS 3600-2018, Example 001, revision 0. Supplied PDF: AS 3600-2018 Example 001, pages 2–8. Principal targets: $A_{st} = 3151 \text{ mm}^2$ and $A_{sv/s} = 1777 \text{ mm}^2/\text{m}$.
- [2] Warner, R. F., Rangan, B. V., Hall, A. S. and Faulkes, K. A. (1998). Concrete Structures. Addison Wesley Longman. Example 7.5 and Figure 7.9, pp. 163–164; Example 7.12 and Figure 7.14, pp. 179–180. Supplied chapter extract: ReferenceBook.pdf, PDF pages 15–16 and 31–32 respectively.
- [3] University of Adelaide publication record for Concrete Structures confirms the four authors, publisher and 1998 publication date. <https://digital.library.adelaide.edu.au/items/1405fa61-c91b-4137-91be-25ba1b23d95e/full>
- [4] Chowdhury, S. and Loo, Y.-C. (2019). The New Australian Concrete Structures Standard AS 3600:2018 – Aspects of Its Complexity and Effectiveness. Athens Journal of Technology and Engineering, 6(3), 163–178. <https://www.athensjournals.gr/technology/2019-6-3-2-Chowdhury.pdf>

Manual inputs for users to test

Open General Beam and click Reset example before each case. Enter the values below using whole bars and strands. These manual runs supplement the exact-area benchmarks in this report; the published rounded areas are not forced into the page.

Section materials and reinforcement

Page input	CSI Example 001	Example 7.5	Example 7.12
Design type	RC	RC	PT
Section shape	T-section	Rectangular	Rectangular
Width / web width (mm)	300	350	300
Overall depth (mm)	500	652	800
Flange width / thickness (mm)	600 / 100	Not applicable	Not applicable
Clear cover to stirrup (mm)	26.6	36	26
Concrete strength f'_c (MPa)	30	30	32
Rebar / fitment strength (MPa)	460 / 460	400 / 400	400 / 400
Aggregate size (mm)	20	20	20
Ultimate moment M^* (kNm)	462	500 ¹	700 ¹
Ultimate shear / torsion / external axial force	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Service moment / external axial force	0 / 0	0 / 0	0 / 0
Transfer moment / external axial force	Not applicable	Not applicable	0 / 0
Top main layer 1	2 N12	3 N24	2 N12
Bottom main layer 1	3 N28	5 N28	4 N24
Bottom main layer 2	2 N28	None	None
Clear gap to bottom layer 2 (mm)	22	Not applicable	Not applicable
Additional top flange bars	0	Not applicable	Not applicable
Stirrups	2-leg N12 @ 100	2-leg N12 @ 150	2-leg N12 @ 150
Crack limit (mm)	0.3	0.3	0.3
Effective creep / shrinkage ($\mu\epsilon$)	0 / 0	0 / 0	0 / 0

¹ The textbooks calculate moment capacity without an applied design moment. The 700 and 500 kNm demands are illustrative inputs; they do not change the zero-axial-force capacity. Zero service and transverse actions restrict these screenshots to the flexural comparison.

CSI: click + Bottom layer to add the second row. Delete any extra rows left from a previous run. The adopted cover and layer spacing preserve the published bottom steel centroid at 425 mm. Example 7.5 uses an assumed overall depth of 652 mm to preserve the book's bar-centre depths.

PT inputs and expected screenshot results

Additional inputs for Example 7.12

PT page input	Enter
Concrete at stressing f'_{ci} (MPa)	32
Strand size and grade	12.7 mm · 1870 MPa
Tendon system / duct material	Bonded / Grouted steel
Number of tendons / strands per tendon	1 / 5
Tendon centre from bottom (mm)	125
Duct outside diameter (mm)	50
Jacking stress / f_{pb} (%)	75
Loss to transfer (%)	5
Total loss at service (%)	28.69875
Vertical prestress P_v (kN)	0
Ultimate tendon stress method	User specified
Justified ultimate tendon stress (MPa)	1600

Expected results with the selected whole bars

Result	CSI Example 001	Example 7.12	Example 7.5
Bottom steel area (mm ²)	3,079	1,810	3,079
Bottom effective depth (mm)	425	750	590
Prestressing area (mm ²)	Not applicable	493	Not applicable
Effective P/Ag (MPa)	Not applicable	2.05	Not applicable
Nominal moment capacity (kNm)	536.33	939.16	659.98
Design moment capacity (kNm)	455.88	798.29	560.99

Taking and interpreting screenshots

Enter the project/member reference, then open Calculations in the navbar. Capture the section preview and the Flexural strength table, including the Nominal / design moment capacity row. The dashboard rounds capacities more than the detailed report.

CSI Example 001: five N28 bars provide less than the required area, so the selected arrangement fails the 462 kNm demand. Required tension steel is approximately 3,126 mm² with the added top bars. This manual screenshot does not reproduce the separate published support-shear case with zero longitudinal steel.

Example 7.5: 3 N24 and 5 N28 give 659.98 kNm versus 667 kNm published. Actual bar areas and current stress-block/net-concrete conventions explain the difference. Label these screenshots as manual whole-bar comparisons; the earlier exact-area benchmark tables remain the controlled comparisons.

Example 7.12: the page uses 493 mm² of strands and requires two top N12 bars, whereas the analytical book model has 500 mm² and no top steel. The 939.16 kNm result is close to the published 939 kNm because input and code effects offset; it is not an exact match of assumptions.

Serviceability: section analysis

This section records the General Beam serviceability implementation as at 11 October 2026. Crack control is assessed by an explicit calculated width under AS 3600:2018 incorporating Amendment 1, Clause 8.6.2.3 [5].

Elastic properties and cracked steel stress

The OneSteel booklet [6], Figures 5.7 and 5.8 supply the conventional transformed cracked-rectangle reference for the neutral axis, inertia and tensile steel stress.

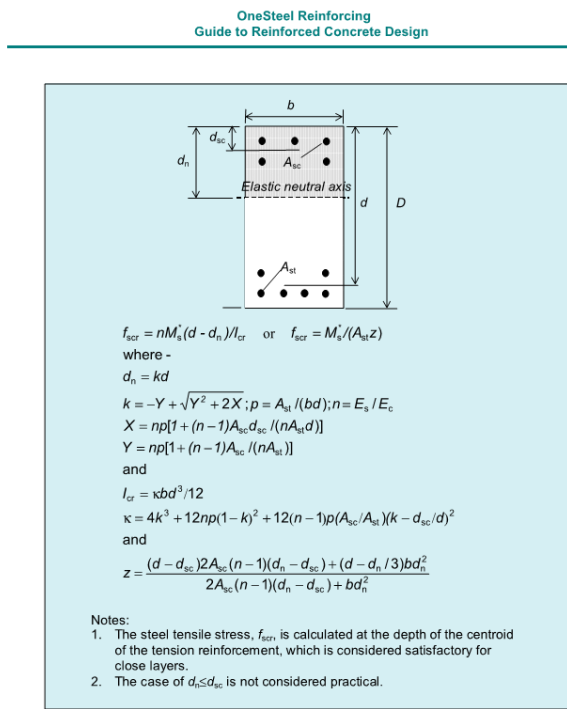


Figure 5.7 Calculation of f_{scr} for a Rectangular Beam – Positive or Negative Bending

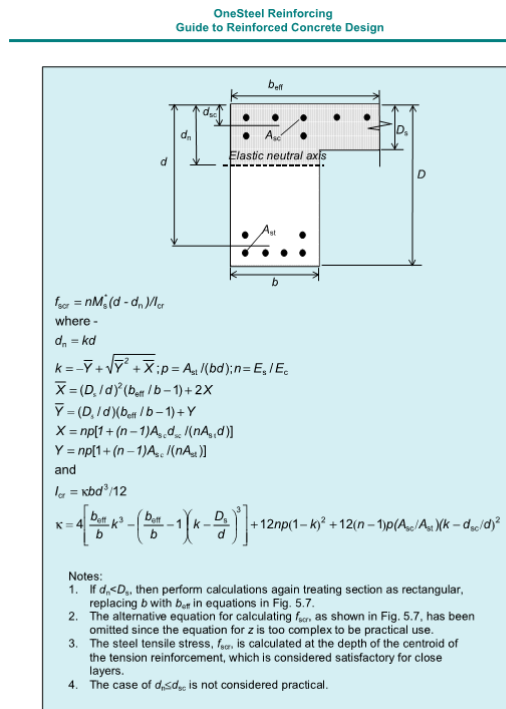


Figure 5.8 Calculation of f_{scr} for an L-Beam or T-Beam – Positive Bending

General Beam solves the same elastic force and moment equilibrium using the actual rectangle or T-section, each reinforcement row and no concrete tension. Circular concrete areas occupied by bars and tendon ducts are deducted from the compression region. Small differences from the booklet's lumped transformed-area treatment are expected.

$$n = E_s / E_c; \quad \sigma_{scr} = n M_s (d - x) / I_{cr}$$

Here x is the cracked neutral-axis depth from the compression face, d is the tensile-steel depth, and I_{cr} is inertia transformed to concrete. The displayed equation is the rectangular, zero-axial-force benchmark.

The general solver uses strain compatibility and equilibrium for nonzero axial force, multiple layers, prestress and T-sections. Compression is positive; σ_{scr} used in the width equation is the positive magnitude of tensile steel stress.

The width calculation uses the short-term cracked solution, $E_s = 200000$ MPa and E_c calculated at a density of 2400 kg/m^3 .

For $f'_c \leq 37$ MPa, $E_c = 2400^{1.5} \times 0.043\sqrt{f'_c + 3}$. Above 37 MPa, $E_c = 2400^{1.5} \times [0.024\sqrt{f'_c + 3} + 0.12]$. Ultimate and service moments are independent; a negative service moment reverses the tension face.

Prestress and other stress checks

PT is represented by the effective prestressing force and its eccentricity. Bonded tendon stiffness and tendon area are not credited in the crack-width calculation; ordinary deformed reinforcement provides the

effective crack-control area. The explicit-width route is used for PT through Clause 8.6.3(c), subject to the stated model limits.

$$\sigma_{\text{top,bottom}} = (N_s + P_{\text{eff}})/A + M_{\text{eff}} y/I$$

The signed y distance gives the top/bottom stress signs. The uncracked concrete section excludes ducts. Actions are referenced to the gross concrete centroid; the effective moment includes the axial centroid shift and prestress eccentricity.

Transfer uses the initial prestress and f'_{ci} , with the general $0.5f'_{ci}$ compression screen.

The $0.6f'_{ci}$ service compression screen is an application elastic-stress review, not an independent compliance proof.

Serviceability: explicit crack-width equations

AS 3600:2018 Clause 8.6.2.3 expresses maximum crack width as maximum crack spacing multiplied by the mean reinforcement–concrete strain difference. The implementation uses the following equations [5]. Units are N, mm and MPa internally; the reported width is in mm.

$$w = s_{r,max} \Delta \epsilon \leq w_{max}$$

$$\Delta \epsilon = \max[\sigma_{scr}/E_s - 0.6 f_{ct}(1 + n_e \rho_{eff})/(E_s \rho_{eff}) + \epsilon_{cs}, \\ 0.6 \sigma_{scr}/E_s]$$

$$n_e = (1 + \phi_{cc}) E_s/E_c; \quad \rho_{eff} = A_{st,eff} / A_{c,eff}$$

ϕ_{cc} is the user's creep coefficient. ϵ_{cs} is the absolute user shrinkage strain: 450 $\mu\epsilon$ is converted to 0.000450. Creep enters n_e and shrinkage is added once. Neither is also added to σ_{scr} . The separate long-term stress diagnostic uses $E_c/(1 + \phi_{cc})$ and free concrete shortening; it does not feed the width equation.

$$h_{c,eff} = \min[2.5(D - d), (D - x)/3, D/2]$$

For a face in flexure, x is measured from the opposite compression face. When the entire section is tensile, the compression-neutral-axis restriction is omitted and the effective face depth is limited to $D/2$. $A_{c,eff}$ integrates the actual flange/web widths through this depth. $A_{st,eff}$ includes only tensile ordinary reinforcement with its centre inside that band. For mixed rows, the largest effective bar diameter and greatest tensile stress are used conservatively.

$$s_{r,max} = 3.4c + 0.3 k_1 k_2 d_b / \rho_{eff}$$

c is clear cover to the longitudinal bar, including the intervening stirrup; d_b is the effective tensile bar diameter. $k_1 = 0.8$ for deformed bars. $k_2 = 0.5$ for flexure; for a wholly tensile cracked section it is $(\epsilon_1 + \epsilon_2)/(2\epsilon_1)$, where $\epsilon_1 \geq \epsilon_2$ are positive tensile-strain magnitudes. Pure tension therefore gives $k_2 = 1.0$.

The default mean axial tensile strength is $f_{ct} = 1.4 \times 0.36\sqrt{f'_c}$, based on Clause 3.1.1.3 for 28-day standard curing. No early-age tensile-strength or measured-strength input is currently provided. This assumption must be reviewed when cracking occurs at a materially different age or strength.

Serviceability: worked RC verification

The reference section is a 1000 × 600 mm rectangle with $f'_c = 40$ MPa, $f_{sy} = 500$ MPa, 2N12 top, 6N20 bottom, 20 mm cover to N12 stirrups, service moment +250 kNm and zero axial force/prestress. Use creep 2.5, shrinkage 450 $\mu\epsilon$ and a width limit of 0.300 mm. The tensile bar axis is 42 mm from the bottom face, so $d = 558$ mm and clear longitudinal-bar cover $c = 32$ mm.

Quantity	Calculated value
Concrete modulus E_c / modular ratio n	32612.921 MPa / 6.13254
Cracked neutral axis x , from top	101.955 mm
Top / bottom steel stress, compression positive	+35.499 / -253.129 MPa
Effective depth $h_{c,eff}$ / concrete area $A_{c,eff}$	105.000 mm / 105000.000 mm ²
Effective tensile reinforcement $A_{st,eff}$	1884.956 mm ²
Effective reinforcement ratio ρ_{eff}	0.01795196
Effective modular ratio n_e / mean f_{ct}	21.46389 / 3.18758 MPa
$c / d_b / k_1 / k_2$	32 mm / 20 mm / 0.8 / 0.5
Maximum crack spacing $s_{r,max}$	242.490 mm
Mean strain difference $\Delta\epsilon$	0.000977709 (977.709 $\mu\epsilon$)
Calculated width w / selected limit	0.237085 mm / 0.300 mm
Width utilisation / result	79.03% / PASS
Bottom bar spacing / equation applicability	183.2 mm $\leq 5(32 + 20/2) = 210$ mm
Tension-face detailing	183.2 mm ≤ 300 mm; edge distance 42 mm ≤ 100 mm

The top concrete face is compressive under this service action. Its two widely spaced top bars therefore do not control flexural crack width.

Width utilisation is w/w_{max} ; it does not combine spacing or edge-distance ratios. Those detailing checks are reported separately.

Serviceability: limits, evidence and references

Applicability and interpretation

Equation 8.6.2.3(3) is evaluated only when tension-face bar spacing $\leq 5(c + d_b/2)$. Wider spacing, missing effective tensile reinforcement, nonconvergence or elastic tensile-steel stress above yield produces “Review required”, without a numeric width or a pass. No extrapolated crack-spacing formula or stress-table fallback is used. The 300 mm tension-face spacing and 100 mm edge-distance checks remain separate under Clause 8.6.1(b).

The concrete tensile face is selected from the short-term cracked strain distribution. A small steel tensile stress caused solely by the separate shrinkage diagnostic does not reclassify a compressed concrete face. At a service state with no tensile concrete face, the current action-only model returns zero width. Previous cracking, restraint forces not supplied as actions, early-age thermal/shrinkage restraint and load-history effects require a separate assessment.

The model handles a section, not total beam deflection, vibration, support settlement or construction-stage envelopes. The mean tensile-strength assumption, multirow simplification and omission of bonded tendon stiffness should be considered when interpreting PT or unusual cages. A serviceability pass concerns only the implemented width, detailing and stress screens.

References and calculation identity

[5] Standards Australia. AS 3600:2018, Concrete structures, incorporating Amendment 1. Clauses 3.1.1.3 and 3.1.2: tensile strength and modulus; 8.1.6.2: transfer screen; 8.6.1(b): detailing; 8.6.2.3, equations (1)–(3): calculated crack width; 8.6.3(c): prestressed width route. Supplied reference: 3600-2018(+A1).pdf. This report does not claim verification against later amendments.

[6] OneSteel Reinforcing (August 2000). Guide to Reinforced Concrete Design, Reinforced Concrete Buildings, RCB-1.1(1), Crack Control of Beams (Part 1: AS 3600 Design). Figure 5.7, printed page 41 (PDF page 47): cracked rectangular section properties and steel stress; Section 3.5: historical crack-width background. Supplied file: crack_control_of_beams_design_booklet.pdf. Its historical Eurocode width formula is not substituted for [5].