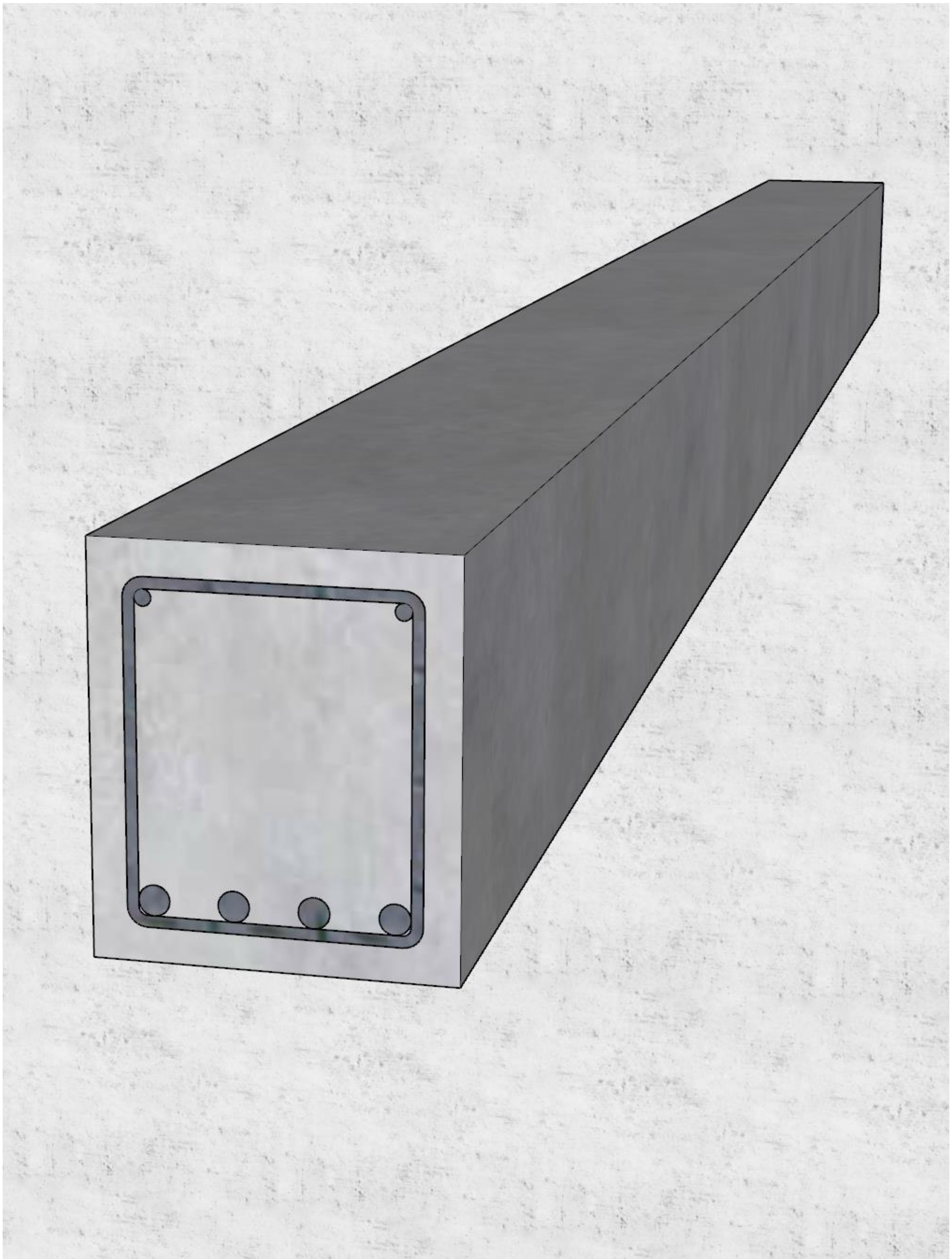
Doubly Reinforced Concrete Beam Design (CSA A23.3-14)



Doubly Reinforced Concrete Beam Design (CSA A32.3-14)

Determine the required reinforcement steel area for a concrete beam carrying service dead and live loads. First, check if singly reinforced beam section is suitable. If not, try doubly reinforced concrete beam section by adding compression reinforcement. It is desired that the section for this beam be tension controlled. Compare the calculated values in the Reference and the hand calculations with values obtained by spBeam engineering software program from StructurePoint.

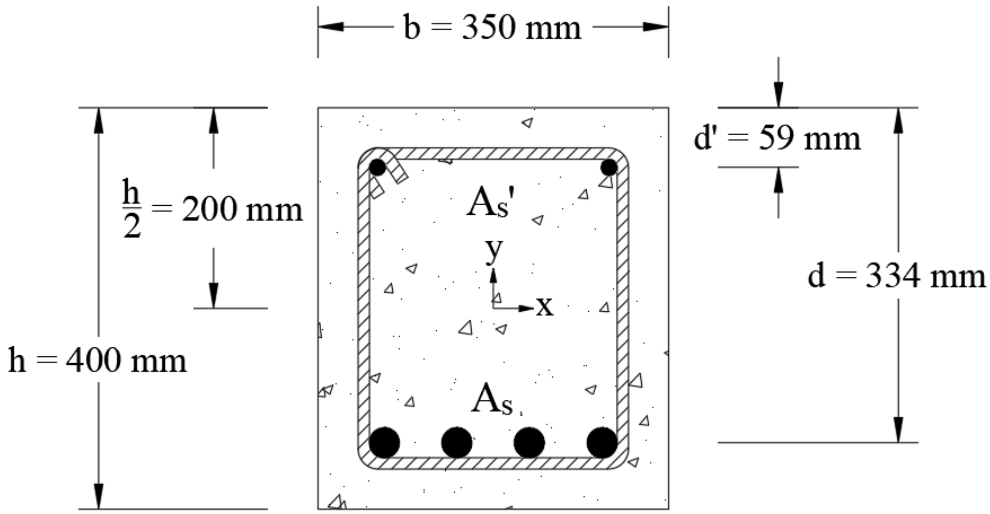


Figure 1 – Doubly Reinforced Concrete Beam Cross-Section

Contents

Code

Design of Concrete Structures (CSA A23.3-14) and Explanatory Notes on CSA Group standard A23.3-14 “Design of Concrete Structures”

Reference

Reinforced Concrete Structures, 2nd Edition, 2018, Omar Chaallal, Presses de l´Université du Québec, Example 4.4

spBeam Engineering Software Program Manual v5.50, StructurePoint, 2018

Design Data

f_c' = 30 MPa

f_y = 400 MPa

Beam span length, L = 6.00 m

Beam cross-section: 350 mm x 400 mm

Dead loads and live loads resulting in factored moment, M_f = 230 kN-m

Use No. 30M bars for longitudinal reinforcement (A_s = 700 mm^2, d_b = 29.9 mm)

Use No. 15M bars for compression rebars (A_s = 200 mm^2, d_b = 16 mm)

Use No. 10M bars for stirrups (A_s = 100 mm^2, d_b = 11.3 mm)

Clear cover = 40 mm ***CSA A23.3-14 (Table 17)***

Solution

The first step in the solution is to determine the ratio of tension reinforcement (ρ) and ratio of tension reinforcement corresponding to balanced section conditions (ρ_b). if $\rho > \rho_b$**,** the addition of compression reinforcement will be considered. Note that the reference recommends to provide compression reinforcement when the tension reinforcement ratio (ρ) reaches 80% to 85% of ρ_b (80% of ρ_b is used for this example).

1. Flexural Design

1.1. Required and Provided Reinforcement

Using the simplified formula shown in the reference with $M_r = M_f$ and d = 0.9h, estimate $A_{s.estimated}$ and deduce the number of layers required.

$$A_{s,estimated} = \frac{M_f}{\phi_s \times f_y \times (0.9 \times 0.9 \times h)} = \frac{230}{0.85 \times 400 \times (0.81 \times 400)} = 2087.87 \text{ mm}^2$$

$$\left.\begin{aligned} A_{s,estimated} &= 2087.87 \text{ mm}^2 \\ b &= 350 \text{ mm} \end{aligned}\right\} \rightarrow 3 \text{ No. 30M bars} = 2100 \text{ mm}^2 \text{ in 1 layer}$$

Reinforced Concrete Structures, Chaallal (Table 4.3)

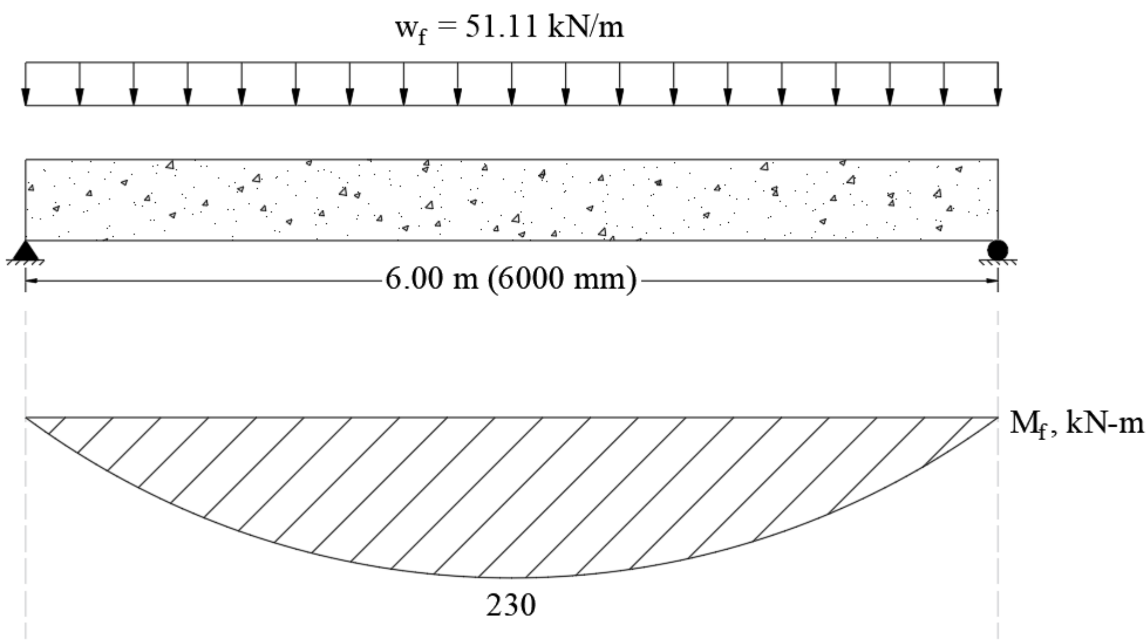


Figure 2 – Bending Moment Diagram

For this beam, the moment at the midspan governs the design.

$$M_f = 230 \text{ kN-m}$$

Use 30M bars with 40 mm concrete cover per ***CSA A23.3-14 (Table 17)***. The distance from extreme compression fiber to the centroid of longitudinal tension reinforcement, *d*, is calculated below:

$$d = h - \left(\text{clear cover} + d_{b,stirrups} + \frac{d_{Longitudinal\ bar}}{2} \right)$$

$$d = 400 - \left(40 + 11.3 + \frac{29.9}{2} \right) = 333.75 \text{ mm}$$

$$d' = \text{clear cover} + d_{b,stirrups} + \frac{d_{Compression\ rebar}}{2}$$

$$d' = 40 + 11.3 + \frac{16}{2} = 59.30 \text{ mm}$$

$$K_r = \frac{M_r}{b \times d^2} = \frac{230}{350 \times 333.75^2} = 5.9 \text{ MPa}$$

Using Table 4.4 from the reference.

$$\left. \begin{array}{l} f_{c'} = 30 \text{ MPa} \\ f_y = 400 \text{ MPa} \\ k_r = 5.9 \text{ MPa} \end{array} \right\} \rightarrow \left\{ \begin{array}{l} \rho = 0.0232 \\ \rho_b = 0.0263 \end{array} \right.$$

Reinforced Concrete Structures, Chaallal (Table 4.4)

Assume that $\rho_1 = 80\% \times \rho_b$ ***Reinforced Concrete Structures, Chaallal (Table 4.4)***

$$\rho_1 = 0.80 \times \rho_b = 0.80 \times 0.0263 = 0.0210$$

$$\rho = 0.0232 > 0.0210 \rightarrow \text{Compression reinforcement recommended}$$

$$A_{s1} = \rho_1 \times b \times d = 0.0210 \times 350 \times 334 = 2457.74 \text{ mm}^2$$

$\therefore \phi_c = 0.65$ ***CSA A23.3-14 (8.4.2)***

$\therefore \phi_s = 0.85$ ***CSA A23.3-14 (8.4.3)***

$$a = \frac{\phi_s \times f_y \times A_{s1}}{\alpha_1 \times \phi_c \times f_c' \times b} = \frac{0.85 \times 400 \times 2457.74}{0.805 \times 0.65 \times 30 \times 350} = 152.10 \text{ mm}$$

Where:

$\alpha_1 = 0.85 - 0.0015 f_c' = 0.85 - 0.0015 \times 30 = 0.805 > 0.67$ ***CSA A23.3-14 (10.1.7)***

$\beta_1 = 0.97 - 0.0025 f_c' = 0.97 - 0.0025 \times 30 = 0.895 > 0.67$ ***CSA A23.3-14 (10.1.7)***

The corresponding nominal moment is:

$$M_{r1} = \phi_s \times f_y \times A_{s1} \times \left(d - \frac{a}{2}\right)$$

$$M_{r1} = 0.85 \times 400 \times 2457.74 \times \left(333.75 - \frac{152.10}{2}\right) = 215.34 \text{ kN-m} < M_f = 230 \text{ kN-m}$$

Therefore, compression reinforcement is needed to increase the amount of tension reinforcement enough to achieve the required strength.

1.2. Doubly Reinforced Beam Section

$$M_{r2} = M_f - M_{r1} = 230 - 215.34 = 14.66 \text{ kN-m}$$

$$A'_{s,required} = \frac{M_{r2,required}}{\phi_s \times f_y \times (d - d')} = \frac{14.66}{0.85 \times 400 \times (333.75 - 59.3)} = 157.06 \text{ mm}^2$$

$$A_{s,required} = A_{s1} + A'_{s,required} = 2457.74 + 157.06 = 2614.80 \text{ mm}^2$$

Provide 4 – No. 30M bars ($A_{s,provided}$ = 700 mm^2 per bar) for longitudinal reinforcement

$$A_{s,provided} = 4 \times 700 = 2800 \text{ mm}^2 > A_{s,required} = 2614.80 \text{ mm}^2$$

Provide 2 – No. 15M bars ($A'_{s,provided}$ = 200 mm^2 per bar) for compression rebars.

$$A'_{s,provided} = 2 \times 200 = 400 \text{ mm}^2 > A'_{s,required} = 157.06 \text{ mm}^2$$

The minimum reinforcement shall not be less than

$$A_{s,\min} = \frac{0.2 \times \sqrt{30} \times b \times h}{f_y} = \frac{0.2 \times \sqrt{30} \times 350 \times 400}{400} = 383.41 \text{ mm}^2$$ ***<u>CSA A23.3-14 (10.5.1.2)</u>***

$$A_{s,\min} = 383.41 \text{ mm}^2 < A_{s,provided} = 2800 \text{ mm}^2$$

$$\rho = \frac{A_{s,provided}}{b \times d} = \frac{2800}{350 \times 334} = 0.0239$$

$$\rho' = \frac{A'_{s,provided}}{b \times d} = \frac{400}{350 \times 334} = 0.0034$$

$$\rho_{\max} = \rho_b + \rho' = 0.0263 + 0.0034 = 0.0297 > \rho = 0.0239$$

$$A_{s1,provided} = A_{s,provided} - A'_{s,provided} = 2800 - 400 = 2400 \text{ mm}^2$$

$$a = \frac{\phi_s \times f_y \times A_{s1,provided}}{\alpha_1 \times \phi_c \times f'_c \times b} = \frac{0.85 \times 400 \times 2400}{0.805 \times 0.65 \times 30 \times 350} = 148.52 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{148.52}{0.895} = 165.95 \text{ mm}$$ ***CSA A23.3-14 (10.1.7)***

Where c is the distance from the extreme compressive fibre to the neutral axis.

CSA A23.3-14 (3.2)

$$\varepsilon_{cu} = 0.0035$$ ***CSA A23.3-14 (10.1.3)***

$$\varepsilon_y = \frac{f_y}{E_s} = \frac{400}{200{,}000} = 0.0020$$ ***CSA A23.3-14 (8.5.3.2)***

$$\varepsilon_s^{'} = \frac{c-d'}{c} \times \varepsilon_{cu} = \frac{165.95-59.3}{165.95} \times 0.0035 = 0.0022 > \varepsilon_y = 0.0020$$

Since $\varepsilon_s^{'} > \varepsilon_y \rightarrow A_s^{'}$ is in the plastic stage.

$$M_r = \phi_s \times f_y \times \left[\left(A_s - A_s^{'}\right) \times \left(d - \frac{a}{2}\right) + A_s^{'} \times \left(d - d'\right) \right]$$

$$M_r = 0.85 \times 400 \times \left[\left(2800 - 400\right) \times \left(333.75 - \frac{148.52}{2}\right) + 400 \times \left(333.75 - 59.3\right) \right] = 247.61 \text{ kN-m}$$

$$M_r = 247.61 \text{ kN-m} > M_f = 230 \text{ kN-m}$$ ***o.k.***

1.3. Minimum Requirements and Detailing Provisions

1.3.1. Skin Reinforcement

$h = 400 \text{ mm} < 750 \text{ mm}$ Skin reinforcement is not required ***CSA A23.3-14 (10.6.2)***

1.3.2. Flexural Cracking Control

Check the requirement for distribution of flexural reinforcement to control flexural cracking:

$$z = f_s (d_c A)^{1/3}$$ ***CSA A23.3-14 (10.6.1)***

Use $f_s = 0.6 f_y = 240 \text{ MPa}$ ***CAC Concrete Design Handbook – 4th Edition (2.3.2)***

$$X = d_c = h - d = 400 - 334 = 66.25 \text{mm}$$

$$A = \frac{2 \times X \times b}{n} = \frac{2 \times 66.25 \times 350}{4} = 11{,}593.75 \text{ mm}^2$$

$$z = 240 \times \left(66.25 \times 11{,}593.75\right)^{1/3} = 21{,}979.33 \text{ N/mm} < 25{,}000 \text{ N/mm}$$ ***o.k.***

1.3.3. Deflection

$$L_n = L = 6000 \text{ mm}$$

$$h_{\min} = \frac{L_n}{16}$$ ***CSA A23.3-14 (Table 9.2)***

$$h_{\min} = \frac{6000}{16} = 375 \text{ mm} < h = 400 \text{ mm}$$ ***o.k.***

2. Doubly Reinforced Concrete Beam Design – spBeam Software

spBeam is widely used for analysis, design and investigation of beams, and one-way slab systems (including standard and wide module joist systems) per latest American (ACI 318) and Canadian (CSA A23.3) codes. spBeam can be used for new designs or investigation of existing structural members subjected to flexure, shear, and torsion loads. With capacity to integrate up to 20 spans and two cantilevers of wide variety of floor system types, spBeam is equipped to provide cost-effective, accurate, and fast solutions to engineering challenges.

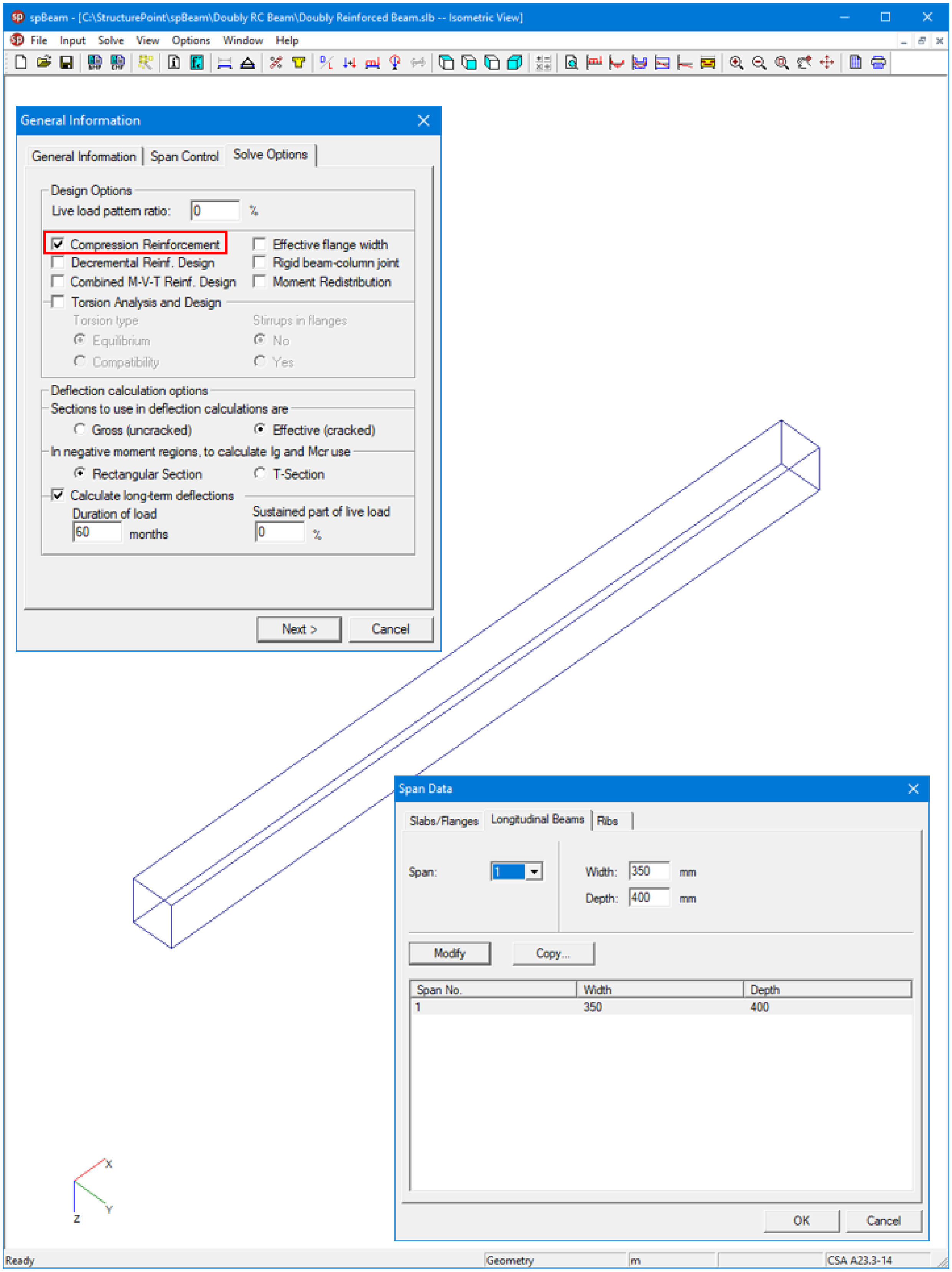
spBeam provides top and bottom bar details including development lengths and material quantities, as well as live load patterning and immediate and long-term deflection results. Using the moment redistribution feature engineers can deliver safe designs with savings in materials and labor. Engaging this feature allows up to 20% reduction of negative moments over supports reducing reinforcement congestions in these areas.

Beam analysis and design requires engineering judgment in most situations to properly simulate the behavior of the targeted beam and take into account important design considerations such as: designing the beam as rectangular or T-shaped sections; using the effective flange width or the center-to-center distance between the beam and the adjacent beams. Regardless which of these options is selected, spBeam provide users with options and flexibility to:

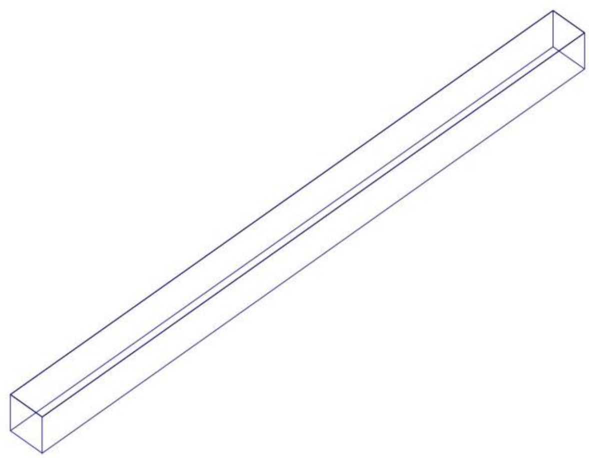
1. Design the beam as a rectangular cross-section or a T-shaped section.
2. Use the effective or full beam flange width.
3. Include the flanges effects in the deflection calculations.
4. Invoke moment redistribution to lower negative moments
5. Using gross (uncracked) or effective (cracked) moment of inertia
6. Design the beam as singly or doubly reinforced section.

The investigation mode is selected in the creation of the spBeam model for comparison purposes (to reflect the assumption made by the reference to enforce the compression reinforcement when ρ reaches 80% of ρ_b).

For illustration and comparison purposes, the following figures provide a sample of the input modules and results obtained from an spBeam model created for the doubly reinforced beam discussed in this example.


spBeam - [C:\StructurePoint\spBeam\Doubly RC Beam\Doubly Reinforced Beam.slb -- Isometric View]
File Input Solve View Options Window Help
General Information
General Information
Span Control
Solve Options
Design Options
Live load pattern ratio: 0 %
Compression Reinforcement
Effective flange width
Decremental Reinf. Design
Rigid beam-column joint
Combined M-V-T Reinf. Design
Moment Redistribution
Torsion Analysis and Design
Torsion type
Equilibrium
Compatibility
Stirrups in flanges
No
Yes
Deflection calculation options
Sections to use in deflection calculations are
Gross (uncracked)
Effective (cracked)
In negative moment regions, to calculate Ig and Mcr use
Rectangular Section
T-Section
Calculate long-term deflections
Duration of load
60 months
Sustained part of live load
0 %
Next >
Cancel
Span Data
Slabs/Flanges
Longitudinal Beams
Ribs
Span: 1
Width: 350 mm
Depth: 400 mm
Modify
Copy...
Span No. Width Depth
1 350 400
OK
Cancel
X
Y
Z
Ready
Geometry
m
CSA A23.3-14

spBeam v5.50
A Computer Program for Analysis, Design, and Investigation of
Reinforced Concrete Beams and One-way Slab Systems



Contents

1. Input Echo

1.1. General Information

File Name	C:\StructurePoint\s...\Doubly Reinforced Beam.slb
Project	Doubly Reinforced Beam
Frame	
Engineer	SP
Code	CSA A23.3-14
Reinforcement Database	CSA G30.18
Mode	Investigation
Number of supports =	2
Floor System	One-Way/Beam

1.2. Solve Options

Live load pattern ratio = 0%
Deflections are based on cracked section properties.
In negative moment regions, Ig and Mcr DO NOT include flange/slab contribution (if available)
Long-term deflections are calculated for load duration of 60 months.
0% of live load is sustained.
Compression reinforcement calculations selected.
Default incremental rebar design selected.
Combined M-V-T reinforcement design NOT selected.
Moment redistribution NOT selected.
Effective flange width calculations NOT selected.
Rigid beam-column joint NOT selected.
Torsion analysis and design NOT selected.

1.3. Material Properties

1.3.1. Concrete: Slabs / Beams

w_c	2400	kg/m^3
f'_c	30	MPa
E_c	26621	MPa
f_r	1.6432	MPa
Precast concrete	No	

1.3.2. Concrete: Columns

w_c	2400	kg/m^3
f'_c	30	MPa
E_c	26621	MPa
f_r	3.2863	MPa
Precast concrete	No	

1.3.3. Reinforcing Steel

f_y	400	MPa
f_{yt}	400	MPa
E_s	200000	MPa
Epoxy coated bars	No	

1.4. Reinforcement Database

Size	Db	Ab	Wb	Size	Db	Ab	Wb
	mm	mm^2	kg/m		mm	mm^2	kg/m
#10	11	100	1	#15	16	200	2
#20	20	300	2	#25	25	500	4
#30	30	700	5	#35	36	1000	8
#45	44	1500	12	#55	56	2500	20

1.5. Span Data

1.5.1. Slabs

Span	Loc	L1	t	wL	wR	H_{min}
		m	mm	m	m	mm
1	Int	6.000	0	0.175	0.175	0

1.5.2. Ribs and Longitudinal Beams

Span	Ribs			Beams		Span
	b	h	Sp	b	h	H_{min}
	mm	mm	mm	mm	mm	mm
1	0	0	0	350	400	375

1.6. Support Data

1.6.1. Columns

Support	c1a	c2a	Ha	c1b	c2b	Hb	Red %
	mm	mm	m	mm	mm	m	
1	0	0	0.000	0	0	0.000	0
2	0	0	0.000	0	0	0.000	0

1.6.2. Boundary Conditions

Support	Spring		Far End	
	K_z	K_{ry}	Above	Below
	kN/mm	kN-mm/rad		
1	0	0	Fixed	Fixed
2	0	0	Fixed	Fixed

1.7. Load Data

1.7.1. Load Cases and Combinations

Case	Load
Type	LIVE
U1	1.000

1.7.2. Line Loads

Case/Patt	Span	Wa	La	Wb	Lb
		kN/m	m	kN/m	m
Load	1	51.11	0.000	51.11	6.000

STRUCTUREPOINT - spBeam v5.50
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1.8. Reinforcement Criteria

1.8.1. Slabs and Ribs

	Units	Top Bars		Bottom Bars	
		Min.	Max.	Min.	Max.
Bar Size		#20	#35	#20	#35
Bar spacing	mm	30	450	30	450
Reinf ratio	%	0.20	5.00	0.20	5.00
Clear Cover	mm	40		40	

There is NOT more than 300 mm of concrete below top bars.

1.8.2. Beams

	Units	Top Bars		Bottom Bars		Stirrups	
		Min.	Max.	Min.	Max.	Min.	Max.
Bar Size		#15	#15	#30	#30	#10	#10
Bar spacing	mm	30	450	30	450	150	450
Reinf ratio	%	0.20	5.00	0.20	5.00		
Clear Cover	mm	51		51			
Layer dist.	mm	30		30			
No. of legs						2	6
Side cover	mm					40	
1st Stirrup	mm					75	

There is NOT more than 300 mm of concrete below top bars.

1.9. Reinforcing Bars

1.9.1. Top Bars

Span	Left			Continuous		Right		
	Bars	Length	Cover	Bars	Cover	Bars	Length	Cover
		m	mm		mm		m	mm
1				2-#15	51			

1.9.2. Bottom Bars

Span	Continuous		Discontinuous			
	Bars	Cover	Bars	Length	Start	Cover
		mm		m	m	mm
1	4-#30	51				

1.9.3. Transverse Reinforcement

Span	Stirrups (2 legs each unless otherwise noted)
1	10-#10 @ 186 + <-- 2325 --> + 10-#10 @ 186

2. Design Results

2.1. Flexural Capacity

Span	Top						Bottom				
	x	$A_{s,top}$	ΦM_n-	M_u-	Comb Pat	Status	$A_{s,bot}$	ΦM_n+	M_u+	Comb Pat	Status
	m	mm²	kNm	kNm			mm²	kNm	kNm		
1	0.000	400	-48.97	0.00	U1 All	OK	2800	248.33	0.00	U1 All	OK
	2.100	400	-48.97	0.00	U1 All	OK	2800	248.33	209.30	U1 All	OK
	3.000	400	-48.97	0.00	U1 All	OK	2800	248.33	230.00	U1 All	OK
	3.900	400	-48.97	0.00	U1 All	OK	2800	248.33	209.30	U1 All	OK
	6.000	400	-48.97	0.00	U1 All	OK	2800	248.33	0.00	U1 All	OK

2.2. Longitudinal Beam Transverse Reinforcement Capacity

2.2.1. Section Properties

Span	d_v	$(A_v/s)_{min}$	ΦV_c	$V_{r,max}$
	mm	mm²/mm	kN	kN
1	300.4	0.288	67.37	512.51

2.2.2. Beam Transverse Reinforcement Capacity

			Required					Provided			
Span	Start	End	X_u	V_u	Comb/Patt	A_v/s	Reqd/Min	A_v	Sp	A_v/s	ΦV_n
	m	m	m	kN		mm²/mm		mm²	mm	mm²/mm	kN
1	0.000	0.075	0.300	137.98	U1/All	-----	-----	-----	-----	-----	-----
	0.075	1.838	0.300	137.98	U1/All	0.484	1.68	200.0	186	1.078	224.58
	1.838	4.162	4.162	59.41	U1/All	0.000	0.00	-----	-----	-----	66.20
	4.162	5.925	5.700	137.98	U1/All	0.484	1.68	200.0	186	1.078	224.58
	5.925	6.000	5.700	137.98	U1/All	-----	-----	-----	-----	-----	-----

2.3. Slab Shear Capacity

Span	b	d_v	β	V_{ratio}	ΦV_c	V_u	X_u
	mm	mm			kN	kN	m
1	--- Not checked ---						

2.4. Material TakeOff

2.4.1. Reinforcement in the Direction of Analysis

Top Bars	18.8 kg	<=>	3.14 kg/m	<=>	8.971 kg/m²
Bottom Bars	131.9 kg	<=>	21.98 kg/m	<=>	62.800 kg/m²
Stirrups	18.5 kg	<=>	3.09 kg/m	<=>	8.822 kg/m²
Total Steel	169.2 kg	<=>	28.21 kg/m	<=>	80.593 kg/m²
Concrete	0.8 m³	<=>	0.14 m³/m	<=>	0.400 m³/m²

3. Deflection Results: Summary

3.1. Section Properties

3.1.1. Frame Section Properties

Notes:
M+ve values are for positive moments (tension at bottom face).
M-ve values are for negative moments (tension at top face).

		M_{+ve}			M_{-ve}		
Span	Zone	I_g	I_{cr}	M_{cr}	I_g	I_{cr}	M_{cr}
		mm⁴	mm⁴	kNm	mm⁴	mm⁴	kNm
1	Left	1.8667e+009	1.1242e+009	15.34	1.8667e+009	2.6021e+008	-15.34
	Midspan	1.8667e+009	1.1242e+009	15.34	1.8667e+009	2.6021e+008	-15.34
	Right	1.8667e+009	1.1242e+009	15.34	1.8667e+009	2.6021e+008	-15.34

3.1.2. Frame Effective Section Properties

			Load Level					
			Dead		Sustained		Dead+Live	
Span	Zone	Weight	M_{max}	I_e	M_{max}	I_e	M_{max}	I_e
			kNm	mm⁴	kNm	mm⁴	kNm	mm⁴
1	Middle	1.000	0.00	1.8667e+009	0.00	1.8667e+009	230.00	1.1244e+009
	Span Avg	----	----	1.8667e+009	----	1.8667e+009	----	1.1244e+009

3.2. Instantaneous Deflections

3.2.1. Extreme Instantaneous Frame Deflections and Corresponding Locations

					Live			Total	
Span	Direction	Value	Units	Dead	Sustained	Unsustained	Total	Sustained	Dead+Live
1	Down	Def	mm	---	---	28.81	28.81	---	28.81
		Loc	m	---	---	3.000	3.000	---	3.000
	Up	Def	mm	---	---	---	---	---	---
		Loc	m	---	---	---	---	---	---

3.3. Long-term Deflections

3.3.1. Long-term Deflection Factors

Notes:
Deflection multiplier, Lambda, depends on moment sign at sustained load level and Rho' in given zone.

Time dependant factor for sustained loads = 2.000

		M_{+ve}					M_{-ve}			
Span	Zone	$A_{s,top}$	b	d	Rho'	Lambda	$A_{s,bot}$	b	d	Rho'	Lambda
		mm²	mm	mm	%		mm²	mm	mm	%	
1	Midspan	400	350	341	0.335	1.713	2800	350	334	2.397	0.910

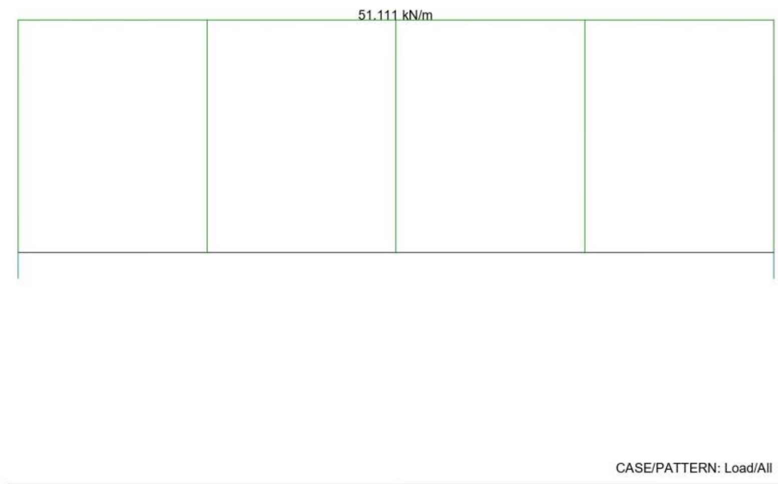
3.3.2. Extreme Long-term Frame Deflections and Corresponding Locations

Notes:
Incremental deflections due to creep and shrinkage (cs) based on sustained load level values.
Incremental deflections after partitions are installed can be estimated by deflections due to:
- creep and shrinkage plus unsustained live load (cs+lu), if live load applied before partitions,
- creep and shrinkage plus live load (cs+l), if live load applied after partitions.
Total deflections consist of dead, live, and creep and shrinkage deflections.

Span	Direction	Value	Units	cs	cs+lu	cs+l	Total
1	Down	Def	mm	---	28.81	28.81	28.81
		Loc	m	---	3.000	3.000	3.000
	Up	Def	mm	---	---	---	---
		Loc	m	---	---	---	---

4. Diagrams

4.1. Loads



spBeam v5.50. Licensed to: STRUCTUREPOINT. License ID: 00000-0000000-4-20C84-20C84

File: C:\StructurePoint\spBeam\Doubly RC Beam\Doubly Reinforced Beam.slb

Project: Doubly Reinforced Beam

Frame:

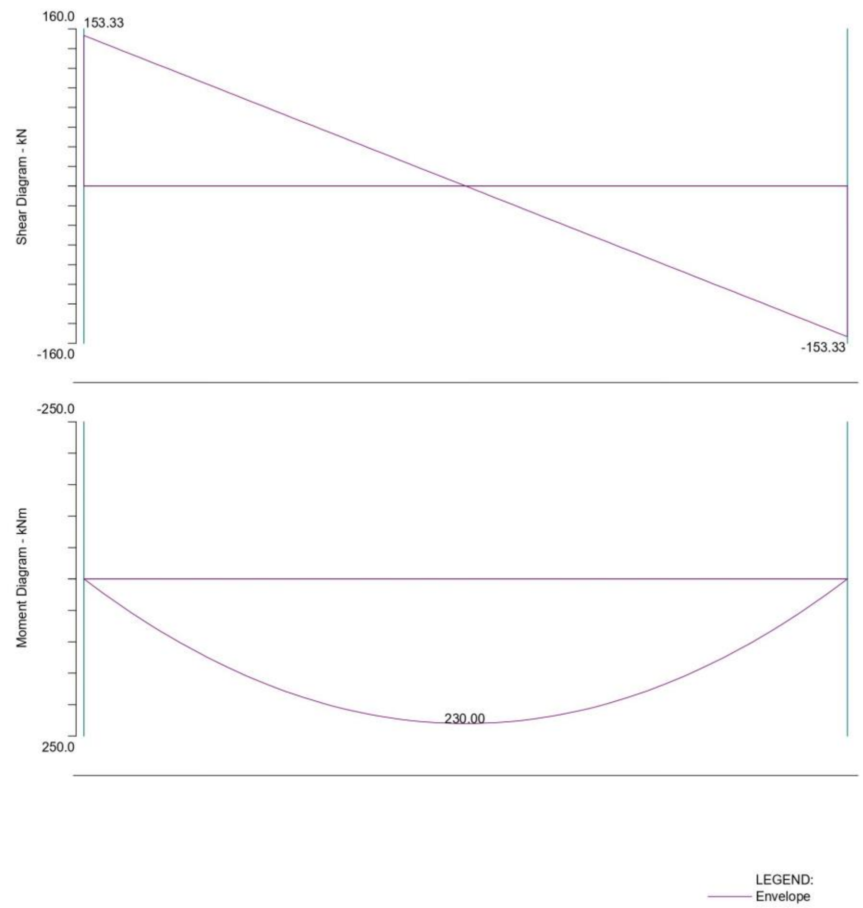
Engineer: SP

Code: CSA A23.3-14

Date: 11/12/21

Time: 09:02:00

4.2. Internal Forces



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Project: Doubly Reinforced Beam

Frame:

Engineer: SP

Code: CSA A23.3-14

Date: 11/12/21

Time: 09:02:00

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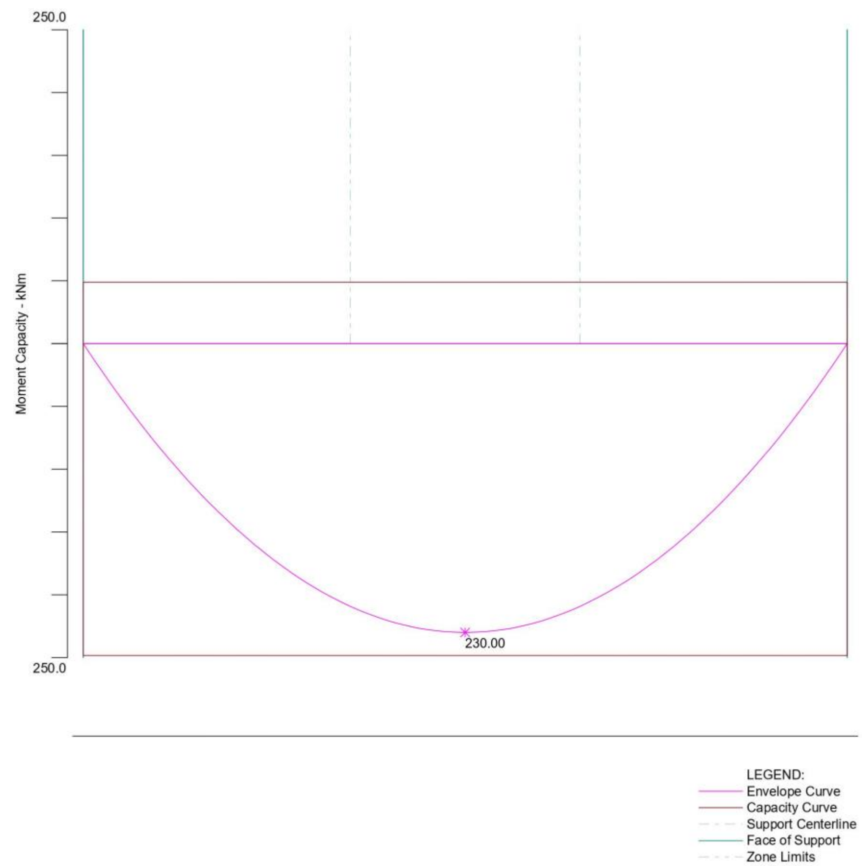
4.3. Moment Capacity



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Project: Doubly Reinforced Beam

Frame:

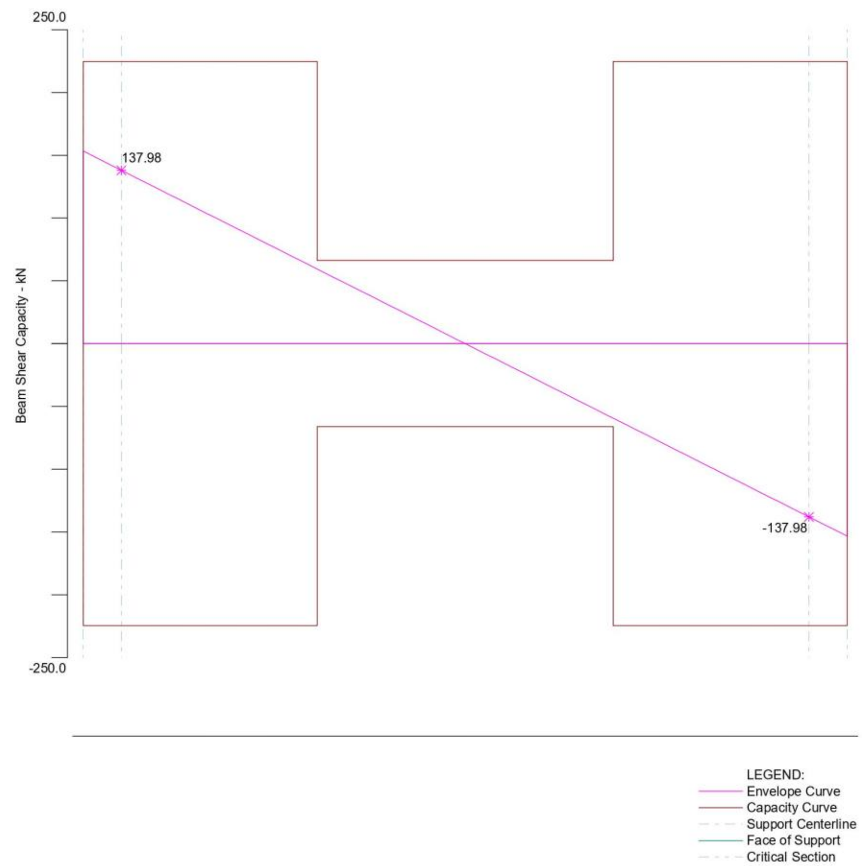
Engineer: SP

Code: CSA A23.3-14

Date: 11/12/21

Time: 09:02:00

4.4. Shear Capacity



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Project: Doubly Reinforced Beam

Frame:

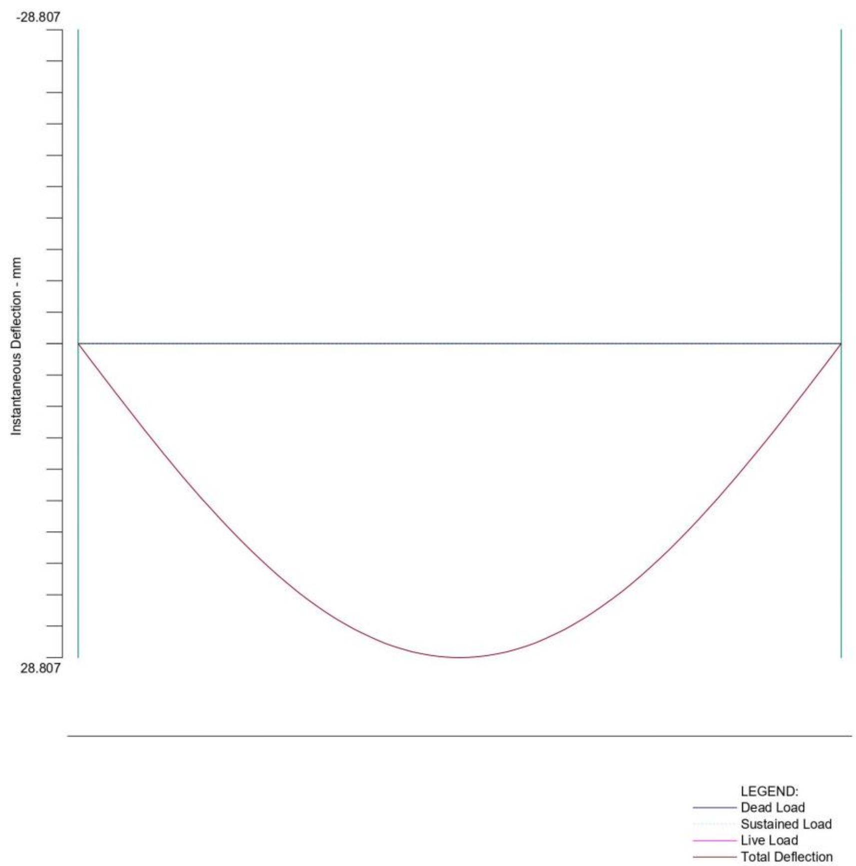
Engineer: SP

Code: CSA A23.3-14

Date: 11/12/21

Time: 09:02:00

4.5. Deflection



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Project: Doubly Reinforced Beam
Frame:
Engineer: SP
Code: CSA A23.3-14
Date: 11/12/21
Time: 09:02:00

STRUCTUREPOINT - spBeam v5.50
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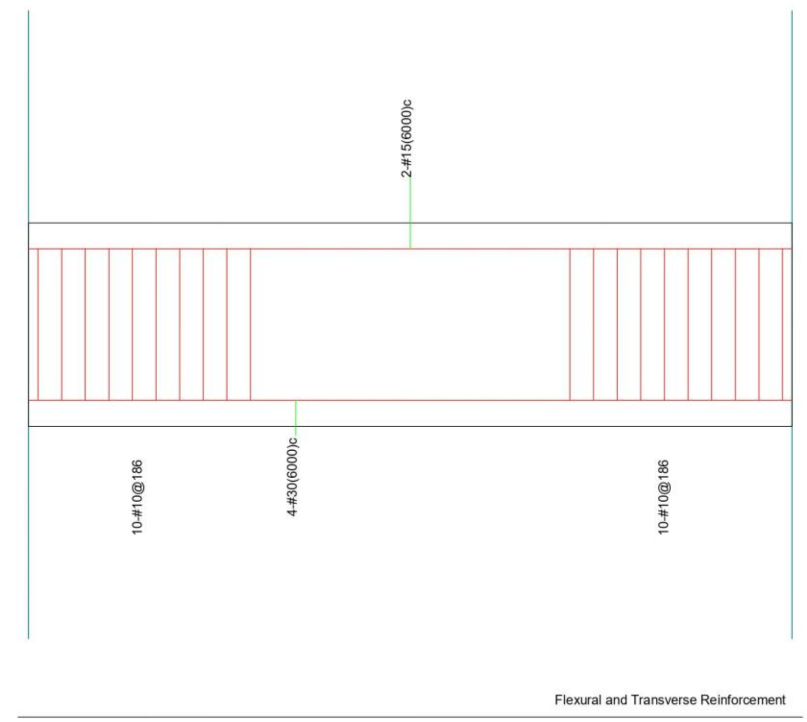
4.6. Reinforcement



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Project: Doubly Reinforced Beam
Frame:
Engineer: SP
Code: CSA A23.3-14
Date: 11/12/21
Time: 09:02:00

3. Comparison of Design Results

Table 1 - Comparison of Results				
Method	**M_f, kN-m**	**$A_{s',top}$, mm²**	**$A_{s,bot}$, mm²**	**M_r, kN-m**
Reference	230	400	2800	250.00*
Hand	230	400	2800	247.61
spBeam	230	400	2800	248.33
* Reference value for Mr is slightly different due to rounding.				

In all of the hand calculations and the reference used illustrated above, the results are in very good agreement with the automated exact results obtained from the spBeam program.

4. Conclusions & Observations

As shown in this example, using compression reinforcement helps in changing the beam failure mode from compression (brittle failure mode) to tension (ductile failure mode). The following shows other applications where the use of doubly reinforced beam sections can be helpful:

The use of compression reinforcement in beams reduces the long-term deflections of a beam subjected to sustained loads. Creep of the concrete in the compression zone transfers load from the concrete to the compression steel, reducing the stress in the concrete. Because of the lower compression stress in the concrete, it creeps less, leading to a reduction in sustained-load deflections.

In seismic regions or if moment redistribution is desired, doubly reinforced beam sections can be helpful since the beam ductility increases when compression reinforcement is used. The strain in the tension reinforcement at failure increases since the depth of the compression stress block decreases, resulting in more ductile behavior.

Compression reinforcement maybe be used for fabrication purposes. It is customary to provide small bars in the corners of the stirrups to hold the stirrups in place in the form and also to help anchor the stirrups. Such reinforcement may have a small effect on strength but can be considered in spBeam for investigation purposes.