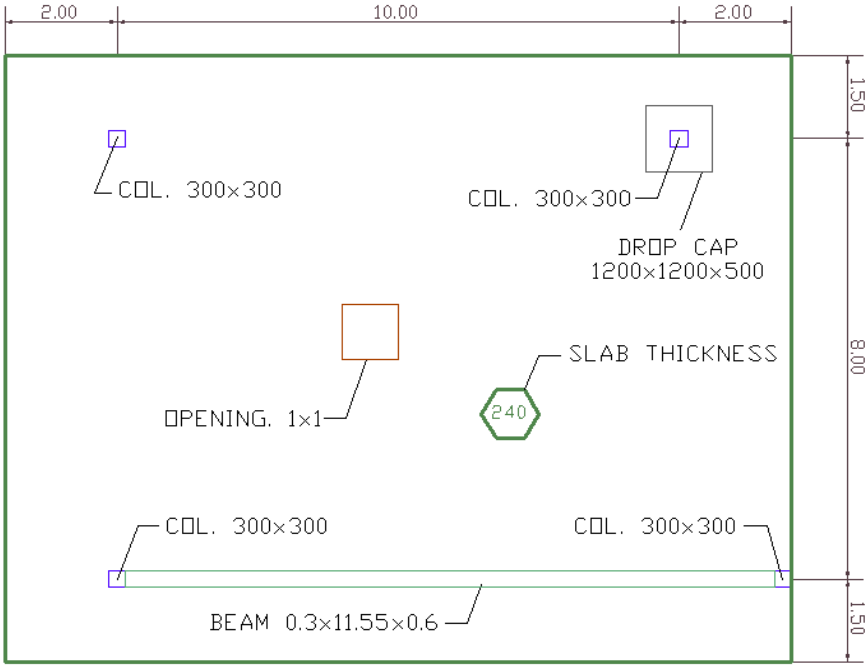
STRESS CHECK AND REBAR VERIFICATION

1.0 OBJECTIVE

This example illustrates how you can verify the stresses and other design values reported by Floor-Pro. It presents the input data and the results obtained from a column supported floor system, followed by steps to take for their verification.

2.1 GEOMETRY AND STRUCTURE DEFINITION

The plan view and other characteristics of the floor system selected are shown in **Figs. 2.1-1** through **2.1-3**. Two design sections are selected for verification. One is through a region of the slab that includes the opening (design section 1205) [1]. The other is through the beam (design section 2202). Results of the following two sections are verified (**Fig. 2.1-4**). In both instances, the sections selected do not meet the requirements of the design code (ACI-318-02). This is indicated by the broken lines (shown in violet in color prints) in **Fig. 2.1-4.**



Note: Units are in m and mm

FIGURE 2.1-1 PLAN VIEW

[1] Note the convention used for definition of design sections. The first digit refers to the support line, the second to the span and the last two to the design section from the beginning of the span. For example, design section 3412 means the third support line, fourth span and the twelfth section.

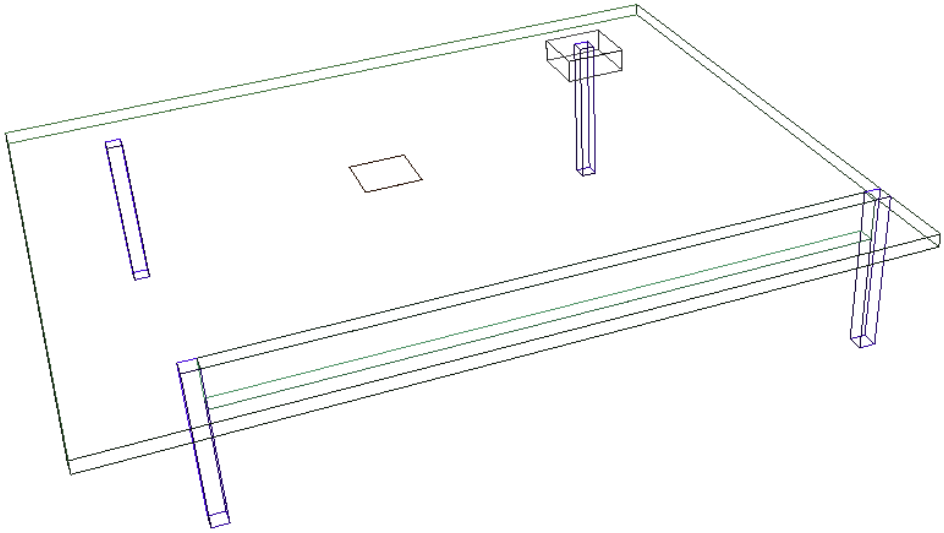


FIGURE 2.1-2 THREE-DIMENSIONAL VIEW OF THE STRUCTURE

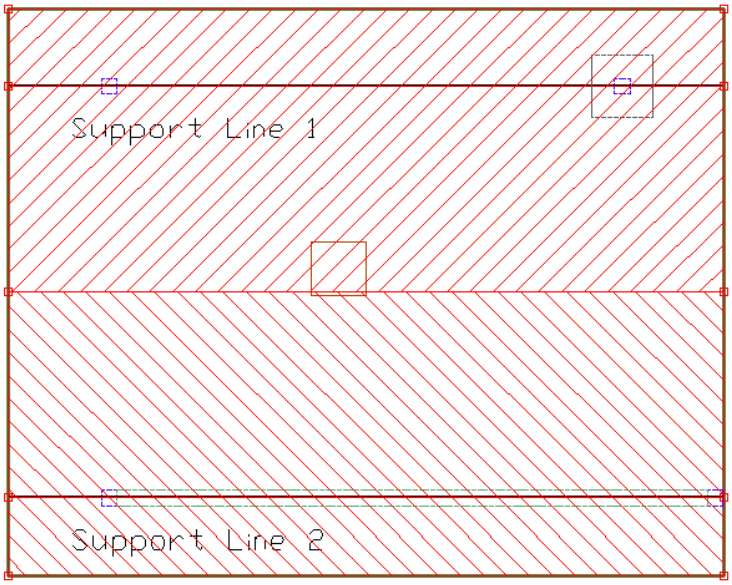


FIGURE 2.1-3 DESIGN STRIPS IN X-DIRECTION

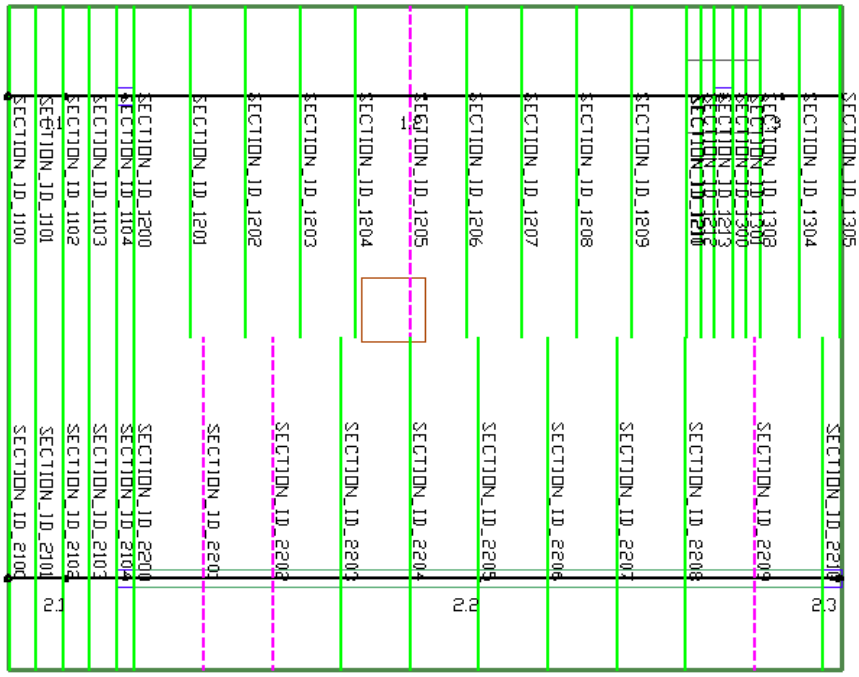


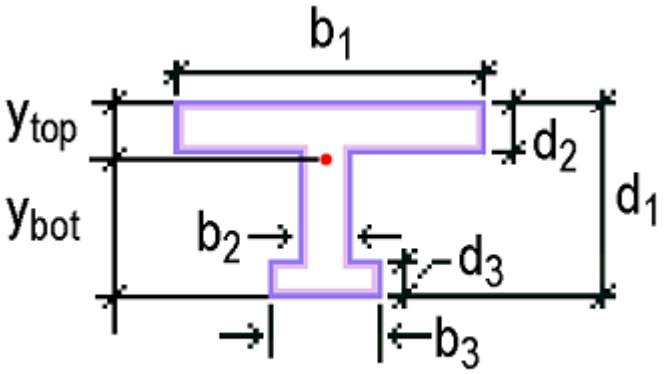
FIGURE 2.1-4 DESIGN SECTION IDENTIFICATION NUMBERS IN X-DIRECTION

2.2 SECTION PROPERTIES

The section properties of the design sections are reported in two input data tables (**Tables 2.2-1 and 2.2-2**). These tables can be viewed, printed or appended to your compiled report. The tables included in this writing are truncated by removing the rows that are not relevant to the current verification. The tables are:

- Data Table 153.2
  Design section geometry as identified by the program, and idealized if need be.
- Data Table 152.2
  This table reports the properties of the section, such as centroid, area, and moment of inertia as calculated and used by the program. The program calculates the centroid of the design section and determines the section properties with respect to the calculated centroid, where applicable.

TABLE 2.2-1 GEOMETRY OF DESIGN SECTIONS



IDEALIZED DESIGN SECTION

153.20 AUTOMATICALLY GENERATED DESIGN SECTIONS
Design Strip: Support Line 1

Design Section	b1	d1	b2	d2	b3	d3
	m	m	m	m	m	m
1204	5.500	0.240	0.000	0.000	0.000	0.000
1205	4.500	0.240	0.000	0.000	0.000	0.000
1206	5.500	0.240	0.000	0.000	0.000	0.000

Design Strip: Support Line 2

Design Section	b1	d1	b2	d2	b3	d3
	m	m	m	m	m	m
2201	5.500	0.600	0.300	0.240	0.000	0.000
2202	5.500	0.600	0.300	0.240	0.000	0.000
2203	5.500	0.600	0.300	0.240	0.000	0.000

TABLE 2.2-2 SECTION PROPERTIES

152.20 AUTOMATICALLY GENERATED DESIGN SECTIONS
Design Strip: Support Line 1

Design Section	Start(x,y)	End(x,y)	Centroid (local x,z)	Area	I	Ytop	Ybot
	m	m	m	mm2	mm4	mm	mm
1204	(5.850,10.000)	(5.850,4.500)	(2.750,2.880)	1320000	6336000000.00	120	120
1205	(6.775,10.000)	(6.775,4.500)	(2.250,2.880)	1080000	5184000000.00	120	120
1206	(7.700,10.000)	(7.700,4.500)	(2.750,2.880)	1320000	6336000000.00	120	120

Design Strip: Support Line 2

Design Section	Start(x,y)	End(x,y)	Centroid (local x,z)	Area	I	Ytop	Ybot
	m	m	m	mm2	mm4	mm	mm
2201	(3.305,4.500)	(3.305,-1.000)	(2.750,2.857)	1428000	16487000000.00	143	457
2202	(4.460,4.500)	(4.460,-1.000)	(2.750,2.857)	1428000	16487000000.00	143	457
2203	(5.615,4.500)	(5.615,-1.000)	(2.750,2.857)	1428000	16487000000.00	143	457

The "Start" and "End" columns list the coordinates of the beginning and end of a design section. The "Centroid" column gives the distance of the centroid of the design section along its length from the start of the section. The following is the verification of the properties of the two sections selected:

- Section 1205
  This is a rectangular section with the following dimensions:
  b1 = 4.5 m
  d1 = 0.240 m

  From **Table 2.2-2** the actual length of the design section is given by:

  $b = [(X2 - X1)^2 + (Y2 - Y1)^2]^{0.5} =$

  $[(6.775 - 6.775)^2 + (4.500 - 10.000)^2]^{0.5} = 5.5$ m

  However, since 1[2] m of the design section falls within an opening, the "idealized" section is only 4.5 m. The cross-sectional area and other properties of the section are determined using the solid part of the cross-section.

  Area $= 4.5*0.240*10^6 = 1.08$ E6 mm^2 OK
  Moment of inertia (I) $= (4.5*0.240^3/12)*1000^4 = 5.184$ E9 mm^4 , OK

  (From **Table 2.2-2** I = 5.184 E9 mm^4.)

  Distance from the centroid to the top and bottom = (0.240/2)*1000 = 120 mm.
  (From **Table 2.2-2**, distance = 120 mm OK)

- Section 2202
  Using the section display tool of the program and an exaggerated vertical scale the geometry of the design section is shown in **Fig. 2.2-1**. The dimensions of the section are:

  Section width b1 = 5.5 m
  Section depth d1 = 0.6 m
  Flange thickness d2 = 0.240 m
  Web thicknessb2 = 0.300 m

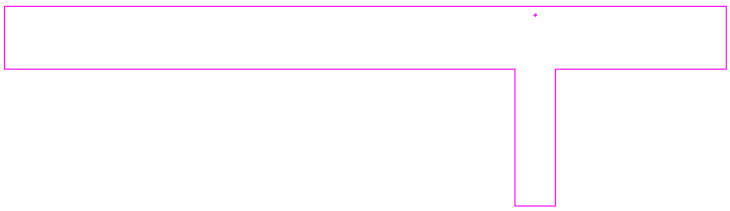


FIGURE 2.2-1 GEOMETRY OF DESIGN SECTION 2202

From the above dimensions, the following values are obtained. The minor discrepancy is due to the report and the hand calculation using two decimal points only.

[2] The distance 1m was measured on the plan using the "measure" tool of the program and the appropriate snap tools

Area = [(5.5 *0.240) + 0.300 *(0.6 – 0.240)]*1000^2 = 1.428 E6 mm^2
(From **Table 2.2-2** 1.428 E6 mm^2 OK)
Moment of inertia I = 1.6487 E10 mm^4
(From **Table 2.2-2** I = 1.6487 E10 mm^4 OK)

Distance of centroid to bottom = 457 mm
(From **Table 2.2-2** Ybot = 457 mm OK)

Distance of centroid to top = 143 mm
(From **Table 2.2-2** Ytop = 143 mm OK)

2.3 DESIGN ACTIONS

The integral of the calculated actions (moments, shears, axial) are listed in report **Table 2.3-1** for load combinations selected by you. In this case, the following load combinations were selected: Sustained Load, and Strength. For each design section the program calculates three forces and three moments referenced to the centroid of the design section. However, the table lists only the four primary actions used in design of the section. The six actions are reported elsewhere.

TABLE 2.3-1 DESIGN VALUES

154.20 DESIGN ACTIONS FOR AUTOMATICALLY GENERATED SECTIONS
Load Combination:Service(Sustained Load)

Design Strip: Support Line 1

Design section	Moment	Shear	Axial	Torsion	Top Stress	Bottom Stress	Centroid Stress
	kN-m	kN	kN	kN-m	N/mm2	N/mm2	N/mm2
1204	267.875	0.864	-1123.928	34.766	-5.925	4.222	-0.851
1205	263.497	1.030	-1078.970	1.541	-7.099	5.100	-0.999
1206	279.485	-7.250	-1152.391	-58.572	-6.166	4.420	-0.873

Design Strip: Support Line 2

Design section	Moment	Shear	Axial	Torsion	Top Stress	Bottom Stress	Centroid Stress
	kN-m	kN	kN	kN-m	N/mm2	N/mm2	N/mm2
2201	360.775	194.309	-1190.245	-176.690	-3.956	9.173	-0.834
2202	412.345	36.830	-1187.624	-19.954	-4.400	10.610	-0.832
2203	442.078	21.220	-1207.465	6.227	-4.672	11.420	-0.846

Load Combination:Strength(Dead and Live)

Design Strip: Support Line 1

Design section	Moment	Shear	Axial	Torsion
	kN-m	kN	KN	kN-m
1204	667.413	62.724	97.389	94.959
1205	683.405	17.154	122.787	-12.062
1206	726.534	-26.666	95.391	-183.167

Design Strip: Support Line 2

Design section	Moment	Shear	Axial	Torsion
	kN-m	kN	KN	kN-m
2201	453.049	458.178	-39.429	-449.908
2202	912.286	339.877	-62.178	-326.650
2203	1249.893	243.460	-84.360	-210.940

2.4 STRESS CHECK

Consider section 2202 through the beam for verification of stresses reported.

- Geometry (from **Table 2.2-2**)
  - Area = 1.428 E6 mm^2
  - Moment of inertia = 1.6487 E10 mm^4
  - Distance to bottom fiber = 457 mm
- Actions (from **Table 2.3-1**)
  - Moment = 412.345 kN-m (tension at bottom)
  - Axial = -1187.624 kN (compression)

Stress at bottom is given by:

$f_b = P/A + M*Y_b/I$ = (-1187624 /1.428 E6 + (412.345 *10^6)* 457/ 1.6487 E10)
= -0.831 + 11.430 = 10.599 N/mm^2 (tension)
(ADAPT -> 10.610 N/mm^2 from **Table 2.3-1** OK)

Stress at centroid (precompression)

$f_{centroid}$ = P/A = -1187624/1.428 E6 = -0.831 N/mm^2 (compression)
(ADAPT -> -0.832 N/mm^2 from **Table 2.3-1** OK)

2.5 REINFORCEMENT VALUES

Reinforcement is provided for service condition and strength. The results are reported in **Table 2.5-1**. Herein, the reinforcement required for strength condition of design section 1205 is verified.

TABLE 2.5-1 SUMMARY OF REQUIRED AND PROVIDED REINFORCEMENT

156.20 DESIGN SECTION REBAR FOR AUTOMATICALLY GENERATED SECTIONS

Load Combination: Service(Sustained Load)

Design Strip: Support Line 1 Design Criteria: SERVICE_SUSTAINED_LOAD

<Bending rebar>

Design section	As top	As bot	Top bar	Bottom bar
	mm2	mm2		
1204	0	5797	0-15mm	12-25mm
1205	0	5758	0-15mm	12-25mm
1206	0	6091	0-15mm	12-25mm

Design Strip: Support Line 2 Design Criteria: SERVICE_SUSTAINED_LOAD

<Bending rebar>

Design section	As top	As bot	Top bar	Bottom bar
	mm2	mm2		
2201	1424	0	8-15mm	0-25mm
2202	0	0	0-15mm	0-25mm
2203	0	0	0-15mm	0-25mm

Load Combination: Strength(Dead and Live)

Design Strip: Support Line 1 Design Criteria: STRENGTH

<Bending rebar>

Design section	As top	As bot	Top bar	Bottom bar
1204	0	6170	0-15mm	13-25mm
1205	0	6340	0-15mm	13-25mm
1206	0	6849	0-15mm	14-25mm

Design Strip: Support Line 2 Design Criteria: STRENGTH

<Bending rebar> <Shear rebar>

Design section	As top	As bot	Top bar	Bottom bar	Av	U-Strip spacing
	mm2	mm2			mm2/m	mm
2201	0	1843	0-15mm	4-25mm	0.00	0
2202	0	2647	0-15mm	6-25mm	0.00	0
2203	0	3328	0-15mm	7-25mm	0.00	0

Reinforcement reported by ADAPT is 6340 mm^2 at bottom for design section 1205

- Geometry of section
  b1 = 4.5 m *1000 = 4500 mm
  d1 = 0.240 m * 1000 = 240 mm

- Material
  Concrete f'c = 26.36 N/mm^2
  PT fpu = 1860 N/mm^2
  fse = 118*1000/98 = 1204 N/mm^2
  CGS = 30 mm [3]

[3] The location of the strands are measured from the cross-sectional geometry of the design section using the "Create a Cut at Specified Location" and "Measure" tools of the program. The dimension is given in m from the top. CGS = 1000(0.24 – 0.21) = 30 mm.

Rebar strength 400 N/mm^2
Rebar cover 16 mm
Rebar size #25 (25 mm diameter)

- Reinforcement
  PT = 10 strands * 98 = 980 mm^2 (from input data)
  Rebar = 6340 mm^2 (from report of **Table 2.5-1**)

- Design moment
  M_u = 683.405 kN-m

- Verification
  - Determine ultimate stress in prestressing (fps)
    Span 10 m
    Depth 240 mm (0.240 m)
    Span/depth ration = 10/0.240 = 42 > 35, hence use
    $f_{ps} = f_{se} + 70 + f'_c/(300\ \rho_p) \quad < f_{se} + 200$ (Eqn 18-5 of ACI-318)

$$\rho_p = A_{ps}/b*d_p$$

$$d_p = 240 - 30 = 210 \text{ mm}$$

$$\rho_p = A_{ps}/b*d_p = 980 / (4500 * 210) = 1.04x10^{-3}$$

$$f_{ps} = 1204 + 70 + 26.36/(300 * 1.04x10^{-3}) = 1358 \text{ N/mm}^2$$
$$< 1204 + 200 = 1404 \text{ N/mm}^2 \text{ OK}$$

Total tension = 980 * 1358+ 6340* 400
= (1330840+ 2536000)/1000 = 3867 kN

Depth of compression zone: a = 3867 * 1000/(0.85*26.36*4500) = 38mm

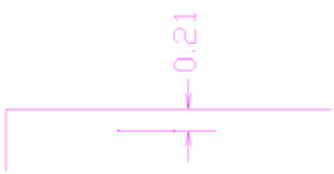
Depth of neutral axis: c = 38 mm / 0.80 = 47 mm

Distance to farthest reinforcement: d_t = 240 – 16 – 0.5*25 = 212 mm

c/d_t = 47/212 = 0.22 < 0.375 , hence ϕ = 0.90

Design capacity (ϕM_n) is given by:

ϕM_n = 0.90[1330840 (210 – 38/2) + 2536000 (212– 38/2)]/10^6 = 669.274 kN-m

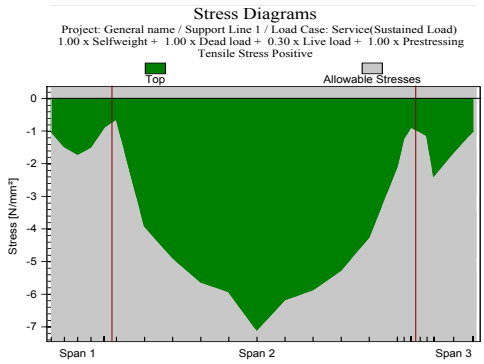


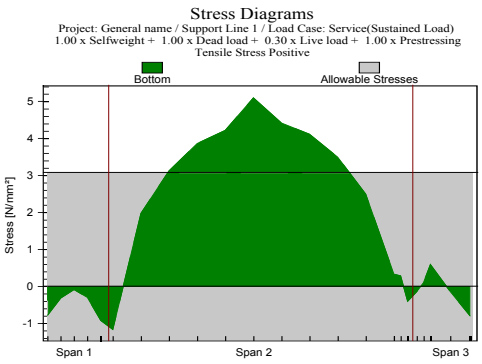
The design moment (Mu) is 683.405 kN-m. The difference between the hand calculation (669.274 kN-m) and the required value from the program (683.405) is 2.0%. The apparent discrepancy is due to the fact that the program's computation is based on "strain compatibility," whereas the above verification was carried out using the simple code formulas. Using strain compatibility, the stresses calculated for the prestressing strands are generally higher. This leads to a smaller value for the required rebar, as reported in **Table 2.5-1.**

2.6 SUMMARY REPORT

The summary report generated for each of the design strips and shown as an example for design strip 1 lists the critical stresses, along with the envelope of the reinforcement required and provided.

SUPPORT LINE 1

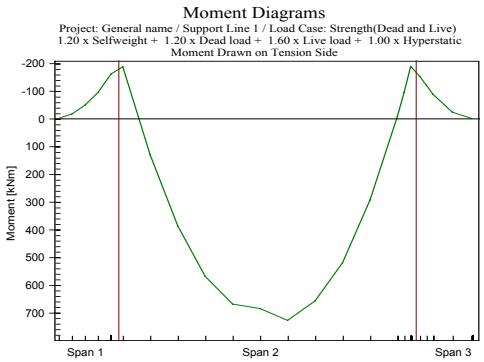




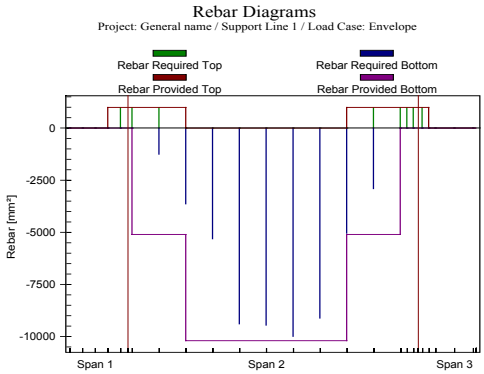
(a) Max tension 0.0 N/mm2, Allowable 3.1 N/mm2
Max compression -9.8 N/mm2, Allowable -11.9 N/mm2

(b) Max tension 7.9 N/mm2, Allowable 3.1 N/mm2
Max compression -1.8 N/mm2, Allowable -11.9 N/mm2

DESIGN STRIP SERVICE COMBINATION STRESSES
(Tension stress positive)



DESIGN STRIP "DESIGN MOMENT (Mu)"
(Moment is drawn on the tension side)



DESIGN STRIP REINFORCEMENT REQUIRED AND PROVIDED