UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE : CEGE 0021

MODULE NAME : Civil Engineering in Practice

DATE : 21 January 2021

TIME : 10.00

TIME ALLOWED : 3 Hours

CEGE0021: CIVIL ENGINEERING IN PRACTICE

BEng/MEng

Course Examination – 2020/2021

Time allowed: 3 hours

- Answer ALL questions.
- All Questions carry equal marks.
- Tables showing the dimensions and properties of steel Universal Beams and Columns can be found in Appendix A.
- Some design information not included in EN1993 can be found in Appendix B.
- Q1. (a) Computers are commonly used for both design and drawings but based on your experience how useful are they? [5 Marks]
- (b) Determine the suitability in shear, bending and deflection of a $406 \times 178 \times 60$ UB in S275 to support the loading shown in Figure Q1 assuming the beam is fully laterally restrained.

[15 Marks]

(c) Recheck the suitability of the UB section assuming it is laterally and torsionally restrained at supports and at load points only. List any further assumptions.

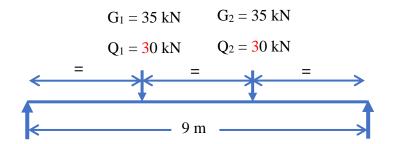
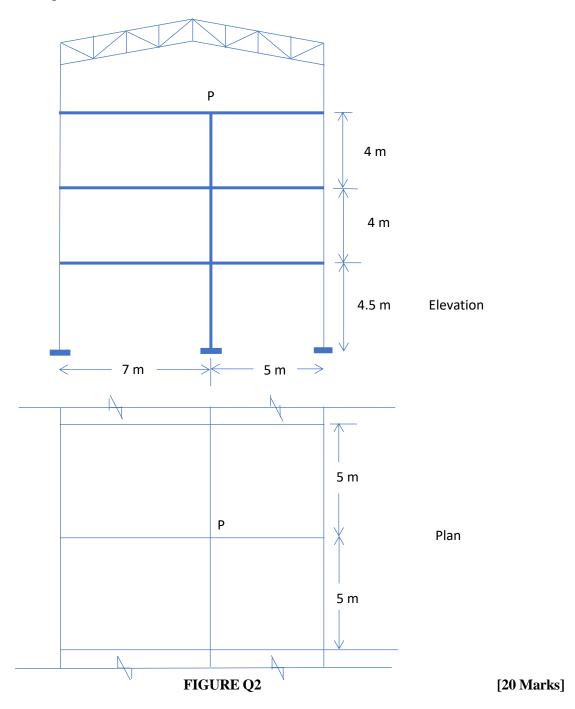


FIGURE Q1

[5 Marks]

TURN OVER

Q2. (a) FIGURE Q2 shows an elevation and part plan of a steel structure of simple construction. Note that the roof is supported by the external columns. Check the suitability of a $203 \times 203 \times 60$ UC in S275 steel for column P by considering the Ground to 1st floor length. Assume all the floors support characteristic permanent (including self weight of slab) and imposed floor loads of 4 kN/m^2 and 3.5 kN/m^2 respectively. List any assumptions.



(b) Describe how the verification procedure for the column would change if the frame was of continuous construction. [5 marks]

[END OF PAPER]

APPENDIX A

- Dimensions and properties of steel UB and UC section

APPENDIX B

DESIGN DATA

- Columns in simple construction
- Classification of sections subject to combined axial load and bending
- Elastic critical moment
- Deflection

A

h

	١
\odot	I
4	I
+	ı
금	١
Č.	١
$\overline{}$	I
<u>ن</u>	I
ω,	۱
7	ı
Φ.	I
4	I
ſΛ	I
~	ı
щ	I
77	۱
~~	I
Ħ	١
-	ı
П	I
4	۱
\vdash	ı
<u>~</u>	ı
Α.	i
	۱
4	I
	١
6	I
\mathbf{g}	ı
_	ı
2	i
	ı
S	1
Ħ	ı
.0	ı
Ή.	ı
ö	ı
92	ı
0,	ı
7	ı
22	ı
ı	ı
+	ı
ä	١
2	ı
Ħ	١
co.	١
$\overline{}$	١
ŝ	ı
H	ı
Ë	ı
earr	
реап	
реап	
al beam	
sal beam	
rsal beam	
rersal beam	
iversal beam	
niversal beam	
universal beam	
l universal beam	
el universal beam	
eel universal beam	
steel universal beam	
steel universal beam	
of steel universal beam	
of steel universal beam	
s of steel universal beam	
ies of steel universal beam	
rties of steel universal beam	
erties of steel universal beam	
perties of steel universal beam	
operties of steel universal beam	
roperties of steel universal beam	
properties of steel universal beam	
l properties of steel universal beam	
nd properties of steel universal beam	
ind properties of steel universal beam	
and properties of steel universal beam	
is and properties of steel universal beam	
ns and properties of steel universal beam	
ions and properties of steel universal beam	
sions and properties of steel universal beam	
nsions and properties of steel universal beam	
ensions and properties of steel universal beam	
nensions and properties of steel universal beam	
imensions and properties of steel universal beam	
Dimensions and properties of steel universal beam	
Dimensions and properties of steel universal beam	
Dimensions and properties of steel universal beam	
Dimensions and properties of steel universal beam	
_	
_	
_	
le B1 Dimensions and properties of steel universal beam	
_	
_	
_	
_	

					1											1						
				Din	тепзіоні											B	Properties					
Designation Sorial Mass	Mass	Depth of	Width of	This 177-seb	Thickness Flange	Root radius	¥	Ratios for local buckling	or ling	Second moments of area	тотепс rea	Radius of Erration	tius	Elastic	pic ace	Plastic modulus	E Com	Buckling Torsional Warping Torsional Area of parameter index constant constant secuon	Torsional index	Warping constant c	Torsional	Area of section
5	per metre (Ag)	section D (mm)	лесцоп В (тт)	t (тт)	T (mm)	г (тт)	mets d (mm)	Flange b/T	Web d/t	Axis x-x (cm ⁴)	Axis y-y (cm³)	Axis x-x (cm)	Axis y-y (cm)	Axis x-x (cm²)	Axis y-y (cm³)	Axis x-x (cm³)	Axis y-y (cm³)	3	×	H (dm^6)	y (cm ⁴)	A (cm^2)
914×419	388	920.5	420.5	21.5	36.6	24.1	799.1	5.74	37.2	719 000;	45 400	38.1	9.58	15 600	2 160	17 700	3 340	0.884	26.7	88.7	1730	494
914×305	289 253	926.6	418.5 307.8 305.5	19.4	32.0 27.9	24.1 19.1 19.1	824.5 824.5 824.5	5.47	42.1	505 000 505 000 437 000	15 600 13 300	37.0 37.0 36.8	6.51 6.42 6.42		1670 1010 872 738	12 500 12 600 10 900 9 520	1 600 1 370	0.867 0.866 0.866	31.9 36.2	31.2	929 627 421	369 323 385
838×292	201 226 194	903.0 850.9 840.7	303.4 293.8 292.4	15.2	20.2	19.1	824.5 761.7 761.7	5.48		340 000 279 000	9 430 11 400 9 070	35.6 33.6	6.06 6.27 6.06		621 773 620	8 360 9 160 7 650	983 1210 974	0.853 0.87 0.862	46.8 35.0 41.6	19.3	293 514 307	256 289 247
762×267	176 197 173 147	769.6 762.0 753.9	291.6 266.7 265.3	15.6 14.3 12.9	18.8 25.4 21.6 17.5	17.8 16.5 16.5	685.8 685.8 685.8 685.8	5.28 6.17 7.58		240 000 240 000 205 000 169 000	6 850 5 470	30.9 30.5 30.5	5.39		513 412	6 200 5 170	959 807 649	0.864 0.864 0.857	33.2 33.2 45.1	11.3 9.38 7.41	405 267 161	251 250 188
#177000	152	687.6	254.5 253.7 253.7	13.2	21.0 19.0	15.2	615.1	6.06	46.6	150 000	5 780 5 180 4 380	27.6	5.46		454 408 346	5 000 4 5 000 4 5 000	710 638 542	0.871	35.5 38.7 43.9	5.72	219	194 179 160
610×305	238	633.0	311.5	14.1	31.4	16.5 16.5 16.5	537.2	4.96 6.50		208 000 15 200 125 000	15 800 11 400 9 300	25.8 25.8 25.6	7.22		1 020 743 610	7 460 5 520 4 570	1 570 1 140 937	0.886	21.1	14.3 10.1 8.09	788 341 200	304 228 190
610×229	140 125 113	611.9	230.1 229.0 228.2	13.1	22.1 19.6 17.3	12.7	547.3	5.21 5.84 6.60		112 000 98 600 87 400	3 930 3 440 2 910	25.0 24.9 24.6	5.03 4.96 4.88		392 344 301	4 150 3 680 3 290 2 880	612 536 470	0.875 0.873 0.87	30.5 34.0 37.9	3.45 2.99 2.99	217 155 112	178 160 144
533×210	122 109 101 92	539.5 539.5 536.7 533.1	211.9 210.7 210.1 209.3	12.8 11.6 10.9	18.8	12.7	476.5 476.5 476.5 476.5	6.04 6.04 6.71	41.1 41.1 46.7	76 200 66 700 61 700 47 500	2 390 2 940 2 690 2 390	22.1 21.9 21.8 21.7 21.7	4.67 4.56 4.51 4.51		320 279 257 229 192	3 200 2 820 2 620 2 370 2 060	501 435 400 356	0.876 0.875 0.874 0.872	27.6 30.9 33.1 36.4	2.32 1.99 1.82 1.60	180 126 102 76.2 51.3	156 139 118 118
457×191	88 82 74	467.4 463.6 460.2 457.2	192.8 192.0 191.3 190.5	11.4 10.6 9.9 9.1	19.6 17.7 16.0 14.5	10.2	407.9 407.9 407.9	5.42 5.98 6.57		45 700 41 000 37 100 33 400	2 340 2 090 1 870 1 670	19.1 19.0 18.8 18.7	4.28 4.23 4.19		243 217 196 175	2 230 2 010 1 830 1 660	378 338 304 272	0.88 0.879 0.877 0.876	25.8 28.3 30.9 33.9	1.17 1.04 0.923 0.819	121 90.5 69.2 52.0	125 114 105 95.0
457×152	82 74 67 60	465.1 461.3 457.2 454.7	153.5 152.7 152.9 152.9	9.9 9.9 9.1 8.0	18.9 17.0 15.0 13.3	10.2	407.0 407.0 407.0 407.7	5.06 5.06 5.75		28 500 28 500 28 500 25 500	1 140 1 010 878 794 645	18.5 18.5 18.3 18.3	3.26 3.26 3.23 3.23	1 560 1 250 1 120 949	149 133 116 104 84.6	1 800 1 620 1 440 1 280	235 209 182 163	0.87 0.87 0.867 0.869	30.0 33.6 37.5 43.9	0.569 0.499 0.429 0.387	89.3 66.6 47.5 33.6 21.3	104 95.0 85.4 75.9
406×178 406×140	4 5 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	412.8 409.4 406.4 402.6 402.6	179.7 178.8 177.8 177.6	9.7 7.8 7.6	16.0 14.3 12.8 10.9	10.2	360.5 360.5 360.5 360.5	5.62 6.25 8.15 6.36	37.2 41.0 47.4 52.1	27 300 24 300 21 500 18 600 15 600	1 540 1 360 1 200 1 020 539	17.0 16.9 16.8 16.5	4.03 4.00 3.97 3.85		172 153 135 114	1 500 1 350 1 190 1 050 888	267 237 208 177 118	0.881 0.88 0.88 0.872 0.872	27.6 30.5 33.9 38.5 38.8	0.608 0.533 0.464 0.39 0.206	63.0 46.0 32.9 22.7	95.0 85.5 76.0 68.4 59.0
356×171	8 2 15 5 4 5 12 4	397.3 364.0 358.6 355.6	141.8 173.2 172.1 171.5	6.9 9.1 8.0 8.0	8.6 15.7 13.0 11.5	10.2	359.7 312.3 312.3 312.3	8.24 5.52 6.62 7.46 8.81		12 500 19 500 16 100 14 200 12 100	411 1360 1110 968 812	15.9 15.1 14.9 14.8	2.89 3.99 3.92 3.87		58.0 157 129 113	721 1 210 1 010 895 774	91.1 243. 199 174	0.859 0.887 0.884 0.882 0.875	47.4 24.4 28.9 32.2	0.155 0.413 0.331 0.286 0.238	10.6 55.5 33.1 23.6	49.4 85.4 72.2 64.6 57.0
356×127 305×165	98 8 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	352.8 348.5 310.9 307.1	126.0 125.4 166.8 165.7	5.9 7.7 7.0	10.7 8.5 13.7 11.8	10.2 10.2 8.9 8.9	311.2 311.2 265.7 265.7	5.89 7.38 7.02 7.02		10 100 8 200 11 700 9 950 8 520	357 280 1 060 897 763	14.3 14.0 13.1 3.0	2,59 3,94 3,96 3,85		56.6 44.7 127 108 92.4	654 540 845 723 624	88.7 70.2 195 166	0.854 0.89 0.89 0.89 0.88	35.3 42.2 23.7 27.2 31.1	0.104 0.081 0.234 0.196 0.164	14.9 6.68 34.5 22.3	49.4 41.8 68.4 58.9
305×127	48	306.6	125.2	8.0	14.0	8.9	264.6	5.14	33.1	9 500 8 140	460 388	12.5	2.75		73.5 62.5	706 610	116 98.2	0.874	23.3	0.101	31.4	60.8 53.2

Table B1 Continued

	10			1																
	Area of section	7	(cm ²)		47.5	41.8	36.3	31.4	55.1	47.5	40.0	36.2	32.2	28.4	38.0	32.3	29.0	24.2	20.5	16.8
	nsional s	*	(cma)			12.1								4.31			28.9			
	Buckling Torsional Warping Torsional Area of grameter index constant constant section	H	(mp)			0.0441 1							_	-					0.00473 3	
	Torsional index co	*			9.6	31.7	7.0	3.8	1.1	4.3	9.4	7.5	1.4	6.5	1.5	5.4	2.6	2.6	19.5	16.2
	Buckling T parameter	2	ij			0,866													_	
	~	Axis	ر س			29.8														
Properties	Plastic modulus		(cm³) (a															•		
						8 480														
	Blastic modulus		(cm³)			37.8														
		Axis				415													57	
	Radius of gyration	Axis	(E)			2.15														
		Axis	(cm)		12.3	12.5	12.2	11.8	10.9	10.8	10.5	10.5	10.3	10.00	8.72	8.54	8.49	7.49	6.40	5.33
	Second тотеп of area	Axis	(cm)		337	193	157	120	677	571	449	178	148	120	384	310	163	138	90.4	56,2
	Secon	Axis	(cm)		7 160	6 490	5 420	4 390	9 560	5 560	4 440	4 010	3410	2870	2 890	2360	2 090	1360	838	477
	for kling	Web d/r			36.7	41.8	45.2	47.6	30.0	34.2	35.9	35.2	36.9	38,8	27.3	29.7	32.6	31.2	26.5	23.0
	Ratios for local buckling	Flange b/T			5.77	4.74	5.72	7.47	5.80	6.72	8.49	5.10	6.07	7.47	6.97	8,55	5.46	6.43	5.77	5.01
	Depth between fillets	ש	(mm)		264.6	275.9	275.9	275,9	218.9	218,9	218.9	225.1	225.1	225.1	172.3	172.3	169.4	146.8	121.8	9.96
	Root radius		(mm)		8,9	9.7	9.7	9.7	9.7	7,6	7.6	9.7	2.6	9.7	9.7	9.6	9.2	9.7	9.7	9.7
sions	28		mm)			10,8														
Dimension	Thickness Web Flan		(mm)		.2	9.	۳.	œ;	6.						6.3		2	۲,	9	6
	Width y	•	(mm) (i		23.5 7	102.4 6	31.9 6	01.6	47.3 7					-			01.6	01.6	8,9 4	5.2
	Depth II	В	(mm)			312.7 10	_			_	_	_		_		_		_	~	
	D D	tre D			30	31	30	30	25		•••	•	•	- '			•••	17	15	12
	Designation Ma	metra	(Ag)		37	33	28	25	43	37	31	28	25	22	30	25	23	19	16	13
	Denig Serial size		(mm)			305×102		*	254×146			254×102			203×133		203×102	178×102	152×89	127×76

 $Z_{\rm z} \ W_{pl,y} \ W_{pl,z}$

Ž

 \mathbf{i}_{z}

 \mathbf{h}_{w}

b t_w

Ч

6

Table B2 Dimensions and properties of steel universal columns (structural sections to BS 4: Part 1 and BS 4848; Part 4)

System Depth Print Thicknet Depth Print Final Print Act					Dim	mensions											Properties	ies					
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		ion Mass	Depth of	Width of	Th Web		Root	Depth between		ss for ckling	Second	moment	Rad of gyra	ins trion	Blass	tic us	Plast		Buckling	Torsional index	Warping constant	Torsional	l Area of section
634 674.7 424.1 47.6 77.0 15.2 290.2 2.75 6.10 275 000 82700 18.0 11.0 11.600 4.630 14.200 7110 0.843 45.4 436. 416.2 5.5 15.2 290.2 3.10 6.91 227 000 82700 18.0 10.9 996.3 996 12.100 6060 0.844 61.0 436.4 41.0 40.0 4.06.4 4.00.4 40.0 4.00.4 40.0 4.00.4 40.0 4.00.4 40.0 4.00.4 40.0 4.00.4 40.0 4.0 4	(mm)	metrs (kg)	D (mm)	B (mm)	(mm)	T (mm)	(mm)	d (mm)	Flange b/T		Axis $x \rightarrow x$ (cm^4)	Axis 3-y (cm ⁴)	Axis x-x (cm)	Axis y.y. (cm)	Axis x-x (cm³)	Axis y-y (cm³)	Axis x-x (cm³)	Axis Cm ³	2	×	. H (dm ⁶)	g (cm ⁴)	A (cm^2)
457 45.5. 418.5 4.2. 4.2. 87.9 12. 200.2 4.14 8.14 1700 57 900 17.5 10.7 89 90 2200 12.100 000 0.839 419.1 417.0 26.5 412.4 55.9 88.0 15.2 200.2 4.14 8.14 1700 57 900 17.5 10.7 89 90 2200 12.0 0.000 0.839 419.1 417.0 26.5 412.4 55.9 88.0 15.2 200.2 4.14 8.14 1700 57 900 17.5 10.7 89 90 220 220 0.839 419.0 410.0 10.8 10.0 4.1 10.5 700 220 0.839 110.0 10.0 10.0 16.8 10.4 69 0.2 220 0.839 110.0 10.0 10.0 16.8 10.4 69 0.2 220 0.839 110.0 10.0 10.0 16.8 10.4 69 0.2 220 0.839 110.0 10.0 10.0 16.8 10.4 69 0.2 220 0.839 110.0 10.0 10.0 16.8 10.0 16.8 10.4 69 0.2 220 0.839 110.0 10.0 10.0 16.8 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10	356×406	634	474.7	424.1	47.6	77.0	15.2	290.2	2.75	6,10	275 000	98 200	18.5	11.0	11 600	4 630	14 200	7 110	0.843	5.46	38.8	13 700	808
393 419.1. 407.0. 30.6. 419.2. 407.0. 30.6. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.2. 407.0. 419.0.	60	467	436.6	418,5	35.0	0,00	15.2	2007	3.56	16.0	183 000	67 000	17.5	10.9	006.6	3 950	10000	0000	0,841	6,05	31.1	9 240	702
340 406.4 403.0 26.5 42.9 15.2 290.2 54.7 **11.0 12.200 48.60 16.8 10.4 6.030 23.90 2.24 9.2.7 **11.0 12.200 48.60 16.6 10.3 5.80 19.90 2.84 0.83 48.60 18.60 18.90 2.84 0.83 48.60 18.60 18.90 2.89 0.83 48.60 18.60 18.90 18.90 18.90 0.83 48.60 18.60		393	419.1	407.0	30.6	49.2	15.2	290.2	4,14	9.48	14 700	55 400	17.1	10.5	7 000	2 720	8 230	4 160	0.837	7.86	19.0	3 550	501
RB 477 287 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488 398 488		340	406.4	403.0	26.5	42.9	15.2	290.2	4.70	11.0	12 200	46 800	16.8	10.4	6 030	2 320		3 540	0.836	8,85	15.5	2 340	433
REB 477 427.0 424.4 48.0 53.2 15.2 290.2 5.99 67.0 7.0 7.0 424.4 48.0 53.2 15.2 290.2 6.99 17.2 0.0 15.0 55.0 15.0 55.0 15.0 55.0 15.0 55.0 15.0 55.0 15.0 55.0 <th< td=""><td></td><td>197</td><td>381.0</td><td>399.0</td><td>18 5</td><td>30.0</td><td>15.2</td><td>200.2</td><td>5.47</td><td>15.8</td><td>70 100</td><td>38 700</td><td>16.2</td><td>10.3</td><td>2 080</td><td>1 940</td><td></td><td>0267</td><td>0.833</td><td>10.2</td><td>12.3</td><td>1 440</td><td>366</td></th<>		197	381.0	399.0	18 5	30.0	15.2	200.2	5.47	15.8	70 100	38 700	16.2	10.3	2 080	1 940		0267	0.833	10.2	12.3	1 440	366
202 374.7 374.4 1 6.8 27.0 15.2 290.2 17.3 63.00 15.0 95.7 35.40 1 26.0 39.7 374.4 1 6.8 27.0 1 7.2 29.0 27.0 37.0 1.5 39.0 1.5 290.2 31.0 1 5.0 1 3.0 1 3.0 1 3.0 1 3.0 1 3.0 1 3.0 1 3.0 1 3.0 1 3.0 1 3.0 2 3.0 2 3.0 2 3.0 2 3.0 2 3.0 3 3.0 2 3.0 3 3.0 3 3.0 3 4.0 1 3.0 3 4.0 1 3.0 3 4.0 1 3.0 3 4.0 1 3.0 3 4.0 1 3.0 3 4.0	COLCORE	477	427.0	424.4	48.0	53.2	15.2	290.2	3.99	6.05	172 000	68 100	16.8	10.6	8 080	3 2 10		4 980	0.815	6.91	23.8	5 700	200
177 368.3 372.1 14.5 23.8 15.2 290.2 73.00 17.0 36.0 15.0 9.52 3.10 11.00 34.0 167.0 0.844 153 356.0 370.2 17.2 18.2 290.2 8.94 23.0 17.0 20.0 18.8 9.46 2.680 944 2.680 19.0 2.680 19.0 2.890 19.0 3.0 17.0 2.800 18.8 9.46 2.800 19.0 2.800 19.0 2.800 19.0 2.800 19.0 2.800 19.0 19.0 2.800 19.0 2.800 19.0 19.0 2.800 19.0 2.800 19.0 19.0 2.800 19.0 19.0 2.800 19.0 19.0 2.800 19.0 19.0 2.800 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0	356×368	202	374.7	374.4	16.8	27.0	15.2	290.2	6,93	17.3	99 300	23 600	16,0	9.57	3 540	1 260	3 980	1 920	0.844	13.3	7.14	260	258
153 352.0 370.2 12.6 20.7 15.2 290.2 8.94 28.0 14.5 26.0 14.30 14.8 0.1 14.5 26.0 14.30 14.8 0.1 27.0 26.0 14.30 0.844 28.0 27.0 15.2 246.6 3.65 3.1 15.0 246.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0 14.0 15.0		177	368.3	372.1	14.5	23.8	15.2	290.2	7.82	20,0	57 200	20 500	15.9	9.52	3 100	1 100	3 460	1 670	0.844	15.0	6.07	383	226
129 355.5 368.3 10,7 17.5 15.2 290.2 10,5 17.6 10.0 15.6 39.9 2.6 7.1 4.2 20.0 14.6 16.0 15.6 4.3 17.5 19.6 17.7 18.0 17.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 14.6 10.0 1		153	362,0	370.2	12.6	20.1	15.2	290.2	8,94	23.0	48 500	17 500	15.8	9.46	2 680	944	2 960	1 430	0.844	17.0	5.09	251	195
283 395.3 321.8 26.9 44.1 15.2 246.6 3.65 17 78 800 24.50 14.8 8.24 3.4 31.9 34.0 37.7 15.2 246.6 5.00 12.0 14.5 36.0 14.5 36.0 15.0 24.0 15.0 36.0 14.5 36.0 15.0 36.0 15.0 24.0 15.0 36.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 24.0 15.0 15.0 24.0 15.0 15.0 24.0 15.0 14.0 15.0		129	355.6	368,3	10.7	17.5	15.2	290.2	10.5	27.1	40 200	14 600	15.6	9.39	2 260	190	2 480	1 200	0.843	6.61	4.16	153	165
240 39.26 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 317.9 23.0 15.2 246.6 6.21 15.7 38.00 12.5 0.0 13.9 13.9 23.0 34.0 15.0 26.0 13.2 246.6 6.21 15.7 38.00 13.7 7.82 2.99 13.0 15.0 28.0 15.0 15.0 24.6 6.21 15.7 38.0 10.0 13.7 7.82 2.99 10.30 34.0 15.0 0.85.4 118 34.6 15.2 246.6 6.21 15.7 28.0 10.7 13.7 7.82 20.0 10.7 10.7 10.8 2.89 10.85 2.86 10.85 10.85 10.85 10.85 10.85 10.85 10.85 10.85 10.85 10.85 10.85 10.85 10.85	305×305	283	365.3	321.8	26.9	44.1	15.2	246.6	3.65	9,17	78 800	24 500	14.8	8.25	4310	1 530	2 100	2 340	0.855	7.65	6.33	2 030	360
198 39.9 914.1 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 192.2 31.4 31.4 31.4 31.4 31.4 31.4 31.4 31.4 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 30.6 <td></td> <td>240</td> <td>352.6</td> <td>317.9</td> <td>23.0</td> <td>37.7</td> <td>15.2</td> <td>246.6</td> <td>4.22</td> <td>10.7</td> <td>64 200</td> <td>20 200</td> <td>14.5</td> <td>8.14</td> <td>3 640</td> <td>1 270</td> <td>4 250</td> <td>1 950</td> <td>0.854</td> <td>8.73</td> <td>5.01</td> <td>1 270</td> <td>306</td>		240	352.6	317.9	23.0	37.7	15.2	246.6	4.22	10.7	64 200	20 200	14.5	8.14	3 640	1 270	4 250	1 950	0.854	8.73	5.01	1 270	306
118 314.5 306.8 11.9 18.7 15.2 246.6 9.00 24.7 2500 12.500 13.9 789 2370 806 206 0.851 11.8 314.5 306.8 11.9 18.7 15.2 246.6 9.00 24.9 20.0 13.9 10.00 13.9 7.89 2370 806 0.851 10.0 10.0 10.0 10.0 10.0 13.9 7.89 2370 806 0.851 10.0 10.0 10.0 10.0 10.0 10.0 13.9 7.89 2370 806 0.851 10.0 10.0 10.0 10.0 10.0 10.0 10.0 13.0 10.0 10		198	339.9	314.1	19.2	31.4	15.2	246.6	5.00	12.8	50 800	16 200	14.2	8.02	2 990	1 030	3 440	1 580	0.854	10.2	3.86	734	252
147 306.8 1 13.6 24.7 13.6 246.6 9.90 24.9 2200 10.00 13.7 7.82 20.0 091. 2500 10.00 0851 10.0 0851 10.0 0851 10.0 0851 10.0 091. 246.5 10.0 10.0 0.0 10.0 0.0 10.0 0.0 10.0 0.0		128	321.26	310.0	7.01	0,0	2,01	240.0	0.21	15.7	38 700	12 500	13.9	68.7	2370	800	2 680	1 230	0.852	12.5	2,86	379	201
97 307.8 304.8 9.9 15.4 15.2 246.6 9.90 24.9 220.0 720 13.4 7.68 1440 477 1590 723 0.852 167 289.1 264.5 19.2 31.7 10.4 29.00 960 11.9 6.79 10.70 74 1500 72.0 10.85 10.85 11.9 6.67 1630 77 11.9 0.85 10.85 10.85 10.85 10.85 11.9 0.86 11.9 6.77 11.0 20.0 10.85 11.0 6.67 1630 77 11.30 0.85 12.0 0.84 10.85 11.1 6.77 11.0 20.0 18.9 11.1 6.77 11.0 20.0 18.9 <t< td=""><td></td><td>118</td><td>314.5</td><td>306.8</td><td>11.0</td><td>18.7</td><td>15.2</td><td>246.6</td><td>8.20</td><td>20.7</td><td>27 600</td><td>9010</td><td>13.6</td><td>7.75</td><td>1 260</td><td>587</td><td>1 950</td><td>1 050</td><td>0.851</td><td>14.1</td><td>2,38</td><td>250</td><td>175</td></t<>		118	314.5	306.8	11.0	18.7	15.2	246.6	8.20	20.7	27 600	9010	13.6	7.75	1 260	587	1 950	1 050	0.851	14.1	2,38	250	175
167 289.1 264.5 19.2 31.7 12.7 200.3 4.17 10.4 29.90 9.80 11.9 6.79 2070 741 24.0 11.9 6.85 132 266.4 25.3 12.7 200.3 4.17 10.4 29.90 9.80 11.6 6.67 16.30 77 14.90 89.9 132 266.4 25.5 10.5 17.3 12.7 200.3 5.16 17.4 19.0 19.0 11.0 6.67 16.30 77 14.90 68.5 256.4 25.4 13.6 14.2 200.3 5.9 14.4 19.0 19.1 14.0 87 14.2 19.0 88.0 88.0 19.0 11.0 6.67 16.0 98.9 48.2 11.0 6.67 16.30 77 14.2 10.8 19.0 18.0 11.0 6.67 16.30 77 14.9 68.0 11.0 6.67 16.30 77 14.9 <td></td> <td>97</td> <td>307.8</td> <td>304.8</td> <td>6.6</td> <td>15.4</td> <td>15.2</td> <td>246.6</td> <td>00.6</td> <td>24.9</td> <td>22 200</td> <td>7 270</td> <td>13.4</td> <td>7.68</td> <td>1 440</td> <td>477</td> <td></td> <td>723</td> <td>0.85</td> <td>103</td> <td>1.55</td> <td>1 10</td> <td>123</td>		97	307.8	304.8	6.6	15.4	15.2	246.6	00.6	24.9	22 200	7 270	13.4	7.68	1 440	477		723	0.85	103	1.55	1 10	123
132 276.4 Z61.0 15.6 25.3 12.7 200.3 5.16 12.8 22.600 75.0 11.6 6.67 1630 576 1870 879 0.85 107 266.7 258.3 13.0 26.0 15.4 17.0 500 11.3 6.57 1310 457 14.90 68.9 89.9 14.90 68.9 89.9 11.0 45.0 11.0 67.0 11.0 45.0 11.0 67.0 11.0 45.0 11.0 67.0 11.0 68.0 89.4 30.5 18.4 30.8 98.0 12.4 94.0 11.1 6.46 894 30.5 18.4 0.845	254×254	167	289.1	264.5	19.2	31.7	12.7	200.3	4.17	10.4	29 900	9 800	11.9	6.79	2 070	741		1 130	0.852	8.49	1.62	625	212
107 266.7 258.3 13.0 20.5 12.7 200.3 6.30 15.4 17.50 59.0 11.3 6.57 1310 457 1490 695 0.848 86 224.0 254.0 16.0 16.0 16.0 17.0 17.0 11.1 6.46 894 305 97 456 0.849 71 224.0 254.0 16.2 16.2 16.0 5.09 12.4 940 3120 5.27 13.0 46.0 3120 5.27 13.0 46.0 36.0 11.1 6.46 894 36.5 18.9 46.0 36.0 11.1 6.46 894 36.9 37.4 18.9 6.2 18.9 46.0 36.0 27.7 53.2 86.1 29.9 49.0 36.0 36.0 36.0 36.0 36.0 36.0 36.0 36.0 36.0 36.0 37.0 46.0 37.0 46.0 37.0 46.0 37.0 46.0		132	276.4	261.0	15.6	25.3	12.7	200.3	5.16	12.8	22 600	7 520	11.6	6.67	1 630	976	1 870	879	0.85	10.3	1.18	322	169
89 2604 255-9 10,5 17.3 12.7 200.3 7.40 19.1 14.00 4850 11.2 6.52 11.00 379 1230 375 0.849 73 22.4.0 25.4.0 14.2 12.7 200.3 8.94 23.3 11.400 3870 11.1 6.46 894 365 989 462 0.849 71 215.9 20.6 14.2 12.7 160.9 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 9.16 5.96 15.6 760 2.94 5.16		[04	266.7	258.3	13,0	20.5	12.7	200,3	6.30	15.4	17 500	2 900	11.3	6.57	1 310	457		695	0.848	12,4	0.894	173	137
73 224,0 254,0 8.6 142 12.7 200.3 8.94 22.3 11400 8870 11.1 6.46 894 305 989 462 0.849 987 224.2 2068 130.2 205.2 10.2 160.9 5.06 15.6 15.6 25.0 9.7 7 6.85 851 299 979 452 0.845 989 206.2 10.3 17.3 10.2 160.9 5.06 15.6 7 650 2540 9.16 5.28 708 246 802 374 0.855 20 200.5 205.2 9.3 14.2 10.2 160.9 7.2 17.3 6.00 2.040 8.96 5.19 5.10 19.9 5.6 15.0 10.2 160.9 7.2 17.3 6.00 2.040 8.96 5.19 5.10 19.9 5.10 19.0 10.2 160.9 9.24 22.0 5.0 15.0 8.90 5.16 5.10 19.9 5.20 70.0 15.0 15.1 14.9 15.1 14.9 15.1 15.2 10.2 16.0 10.2 16.0 10.2 16.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15		68	260.4	255.9	10,5	17.3	12.7	200,3	7.40	19.1	14 300	4 850	11.2	6.52	1 100	379	0	575	0.849	14.4	0.716	104	114
86 222.3 206.8 13.0 20.5 10.2 160.9 5.09 12.4 9.460 3120 9.27 5.32 851 299 979 456 0.85 6.85 71 215.9 206.2 10.3 17.3 10.2 160.9 5.09 12.4 9.460 3120 9.16 5.28 788 246 802 374 0.857 6.85 6.85 200.2 203.2 13.3 17.3 10.2 160.9 5.06 17.6 7.6 0.00 17.0 8.90 5.19 581 199 652 303 10.847 11.5 10.2 160.9 11.5 10.2 160.9 11.5 200 17.0 11.0 11.0 11.0 11.0 11.0 11.0 11		73	254.0	254.0	8.6	14.2	12.7	200.3	8,94	23,3	11 400	3 870	11.1	6,46	894	305		462	0.849	17.3	0.557	57.3	92.9
71 215.9 206.2 10.3 17.3 10.2 160.9 5.96 15.6 7 650 2 540 9.16 5.28 708 246 802 374 0.852 60 2050.5 205.2 9.3 17.3 10.2 160.9 7.23 17.3 6 090 2 040 8.96 5.19 581 199 652 303 0.847 8.2 206.2 203.9 87 12.5 10.2 160.9 8.16 20.1 5.260 1770 8.90 5.16 510 174 568 264 0.848 46 203.2 203.3 7.3 11.0 10.2 160.9 8.26 20.1 5.260 1770 8.90 5.16 510 174 568 264 0.848 97 203.2 13.3 11.5 10.2 160.9 9.24 22.0 769 8.81 5.11 449 151 497 230 0.846 93 17.3 161.8 154.4 8.1 11.5 7.6 123.5 6.71 15.2 220 709 6.84 3.87 274 91.8 310 140 0.848 93 17.3 152.9 6.5 9.4 7.6 123.5 8.13 18.7 1740 558 6.75 3.82 221 73.1 247 111 0.848 91.8 7.5 123.5 8.11 2.0.2 12.0 493 6.51 3.68 166 52.9 184 80.9 0.837	203×203	86	222.3	208.8	13.0	20.5	10.2	160.9	5.09	12.4	9 460	3 120	9,27	5,32	851	299		456	0.85	10,2	0.317	138	110
60 209,6 205,2 9,3 14,2 10,2 160,9 7,23 17,3 6,990 2,040 8,96 5,19 581 199 652 303 0,847 52 206,2 206,2 203,9 870 12,5 10,2 160,9 8,16 20,1 5,26 1770 8,90 5,16 510 174 568 264 0,848 46 200,2 203,2 7,3 11,0 10,2 160,9 9,24 22,0 4.560 1540 8,81 5,11 449 151 449 151 497 200 0,846 37 10,18 154,8 8,1 11,5 7,6 123,5 6,71 15,2 2,220 709 6,84 3,87 274 9,18 310 140 6,848 30 157.5 152,9 6,6 9,4 7,6 123,5 8,13 18,7 1740 558 6,75 3,82 221 73,1 247 111 0,848 2 152.4 152,4 6,1 6,8 7,6 123,5 11,2 20,2 1260 403 6,51 3,68 166 52,9 184 80,9 0,837		71	215.9	206.2	10.3	17.3	10.2	160,9	5.96	15.6	7 650	2 540	9.16	5.28	708	246		374	0.852	11.9	0.25	81.5	91.1
52 206.2 203.9 870 12.5 10.2 160.9 8.16 20.1 5.260 1770 8.90 5.16 510 174 568 264 0.848 46 20.3 203.2 203.2 7.3 11.0 10.2 160.9 9.24 22.0 4.560 1540 8.81 5.11 4.49 151 4.97 230 0.846 37 161.8 154.9 8.1 11.5 7.6 123.5 6.71 15.2 2.220 7.9 6.84 3.87 274 91.8 310 140 0.848 30 157.5 152.9 6.6 9.4 7.6 123.5 8.13 18.7 1740 558 6.75 3.82 221 73.1 247 111 0.848 23 152.4 152.4 6.1 6.8 7.6 123.5 11.2 20.2 1260 403 6.51 3.68 166 52.9 184 80.9 0.837		9	209.6	205.2	6.6	14.2	10.2	160.9	7.23	17.3	060 9	2 040	8,96	5,19	581	199		303	0,847	14.1	0.195	46.6	75.8
46 203.2 203.2 7.3 11.0 10.2 160.9 9.24 22.0 4560 1540 8.81 5.11 449 151 497 230 0.846 37 151.8 154.4 8.1 11.5 7.6 123.5 6.71 15.2 2.22 709 6.84 3.87 274 91.8 310 140 0.848 30 177.5 152.9 6. 9.4 7.6 123.5 6.71 17.0 758 6.75 3.82 221 73.1 247 111 0.848 23 152.4 152.4 6.1 6.8 7.6 123.5 11.2 20.2 1260 403 6.51 3.68 166 52.9 184 80.9 0.837		23	206.2	203.9	æ.	12.5	10.2	160.9	8.16	20.1	5 260	1 770	8,90	5,16	210	174		264	0.848	15,8	0.166	32.0	6.99
37 101.8 154.4 8.1 11.5 7.6 123.5 6.71 15.2 2.220 709 6.84 3.87 274 91.8 310 140 0.848 30 157.5 152.9 6.6 9.4 7.6 123.5 8.13 18.7 1740 558 6.75 3.82 221 73.1 247 111 0.848 23 152.4 152.4 6.1 6.8 7.6 123.5 11.2 20.2 1260 403 6.51 3.68 166 52.9 184 80.9 0.837		46	203.2	203.2	7.3	11.0	10.2	160.9	9.24	22.0	4 560	1 540	8.81	5.11	449	151		230	0.846	17.7	0,142	22.2	58.8
157.5 152.9 6.6 9.4 7.6 123.5 8.13 18.7 1740 558 6.75 3.82 221 73.1 247 111 0.848 152.4 152.4 6.1 6.8 7.6 123.5 11.2 20.2 1260 403 6.51 3.68 166 52.9 184 80.9 0.837	152×152	37	161.8	154.4	8.1	11.5	1.6	123.5	6.71	15.2	2 220	402	6.84	3.87	274	91,8		140	0.848	13.3	0.04	19.5	47.4
152.4 152.4 6.1 6.8 7.6 123.5 11.2 20.2 1260 403 6.51 3.68 166 52.9 184 80.9 0.837		30	157.5	152.9	9.9	9.4	7.6	123.5	8.13	18.7	1 740	558	6.75	3.82	221	73.1	247	111	0.848	16.0	0,0306	10.5	38.2
		23	152.4	152.4	6.1	6.8	7.6	123.5	11.2	20.2	1 260	403	6.51	3.68	991	52,9	184	80.9	0.837	20.4	0.0214	4.87	29.8

A $Z_{\rm z} \ W_{\rm pl,y} \ W_{\rm pl,z}$ Ń \mathbf{i}_{z} \mathbf{h}_{w} þ h

APPENDIX B:

DESIGN DATA

(a) Columns in simple construction

$$\frac{N_{\text{Ed}}}{N_{\text{b,z,Rd}}} + \frac{M_{\text{y,Ed}}}{M_{\text{b,Rd}}} + 1.5 \frac{M_{\text{z,Ed}}}{M_{\text{z,Rd}}} \le 1.0$$

where

 $M_{b,Rd} = \chi_{LT} W_y f_y / \gamma_{M1} \ (from \ clause \ 6.3.2.1, \ EC3 \ Part \ 1.1)$

 $M_{z,Rd} = W_{pl,z} f_y \! / \! \gamma_{M1}$

 $N_{b,z,Rd} = \chi_z A f_y / \gamma_{M1}$

(b) Classification of cross sections subject to combined axial load and bending

$$\alpha = \frac{1}{2} \left(1 + \frac{N_{\rm Ed}}{t_{\rm w} df_{\rm v}} \right) \le 1.0$$

(c) Elastic critical moment

The elastic critical moment for lateral torsional buckling, M_{cr}, for a beam may be taken as:

$$M_{cr} = C_1 \frac{\pi}{L_{cr}} (EI_z GI_t)^{0.5} \left(1 + \frac{\pi^2 EI_w}{L_{cr}^2 GI_t} \right)^{0.5}$$

where C_1 Bending moment shape factor (see Table 1, page 9)

E Young's modulus

G Shear modulus

I_t Torsion constant for the section

I_w Warping constant for the section

L_{cr} Critical buckling length

 I_z Moment of inertia about z-z axis

(d) Deflection

Maximum deflection, δ , of a simply supported beam supporting two point-loads W/2 at the third points is obtained from (Arya, Design of Structural Elements, 3^{rd} Ed, 2009, p22)

$$\delta = \frac{23WL^3}{1296EI}$$

where L is the span length, E the Young's modulus and I the second moment of area

Loading and support conditions	Bending moment diagra	m	Ψ	C ₁
ψM 	(a)	ψ = + 1	+1	1.00
'	(b)	$\psi = 0$	0	1.88
	(c)	$\psi = -1$	-1	2.75
	(d)		1	1.132
	(e)		-	1.285
↓ ^F	(f)		-	1.365
↓ ^F ↓	(g)	4	-	1.565
↓ ^F ↓ ^F ↑ ↑ ↑ ↑ * * * * * * * * * * * * * * *	(h)		-	1.046

Table 1