CORK INSTITUTE OF TECHNOLOGY
INSTITIÚID TEICNEOLAÍOCHTA CHORCAÍ

Semester 2 Examinations 2009/10

Module Title: Introduction to Structural Design

Module Code: **CIVL6020**

School: Building and Civil

Programme Title: Bachelor of Engineering in Civil Engineering – Year 2

Programme Code: **CCIVL_7_Y2**

External Examiner(s): Ms. M. Kyne, Mr. J. Murphy
Internal Examiner(s): Mr. T. McKenna, Ms. S. Corcoran

Instructions: **Answer ALL questions from each section**
Use separate answer books for each section

Duration: 2 Hours

Sitting: Summer 2010

Requirements for this examination:
Candidates may refer to
1. 'Approved Design Aids' – (CIT Booklet)
3. 'Designed & Detailed' – (BCA Booklet)

Note to Candidates: Please check the Programme Title and the Module Title to ensure that you have received the correct examination paper.
If in doubt please contact an Invigilator.

Section A –Reinforced Concrete

Q.A1 Reinforced Concrete Beam (Total 50 Marks)

Figure Q.A1, details the slab, beam and column layout of a reinforced concrete structure.
Design and prepare a detailed reinforcement drawing for the simply supported rectangular beam along gridline 3. Beam dimensions are as follows: b=300mm; h=450mm.

(i) Determine the maximum design actions on the beam (10 marks)
(ii) Design the simply supported beam along grid line 3 (35 marks)
Note: No verification for Crack Control is required
(iii) Prepare a reinforcement drawing for the beam designed in section A1. (i & ii) (5 marks)
Use the attached General Arrangement drawing to complete the detailed reinforcement drawing and include the completed drawing with your Answer Book.

Design Information for Q.A1:

Actions on the Structure:

Permanent Actions:

Specific weight of reinforced concrete	= 25 kN/m^3
Weight of suspended ceiling & services	= 0.6 kN/m^2
Blockwork wall (2.5m height on all beams)	= 2.5 kN/m^2 of wall area

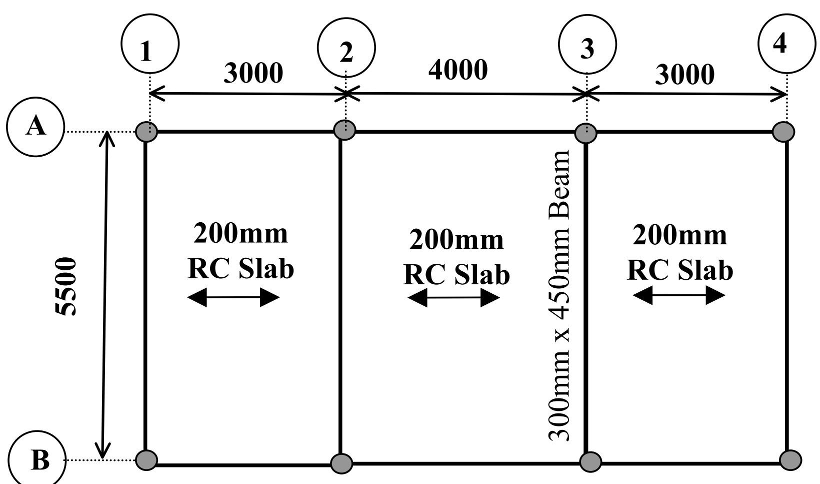
Variable Actions:

Occupancy: Specific Use is 'Office'	= 3.0 kN/m^2
Weight of removable partitions/fittings	= 1.0 kN/m^2

Materials:

Maximum Aggregate size:	d_g	= 20mm
Characteristic yield strength of steel reinforcement:	f_{yk}	= 500 MPa
Characteristic cylinder strength of Concrete:	f_{ck}	= 30 MPa
Characteristic cube strength of Concrete:	$f_{ck,cube}$	*= 37 MPa*
(Cube Strength applies to Repeat Students designing to BS8110)		

Cover: Nominal Cover: c_{nom} = 25mm



All beams to be 300mm wide x 450mm deep
All Columns to be 300mm x 300mm
All Slabs 200mm thick

Figure QA1

Section A: Additional Information

Additional Relevant Extracts from I.S. EN1992-1-1

9.2 Beams

9.2.1 Longitudinal reinforcement

9.2.1.1 Minimum and maximum reinforcement areas
(1) The area of longitudinal tension reinforcement should not be taken as less than $A_{s,min}$

Note 1: See also 7.3 for area of longitudinal tension reinforcement to control cracking.
Note 2: The recommended value of $A_{s,min}$ is given in the following:

$$\mathbf{A_{s\ min} = \frac{0.26\ f_{ctm}\ b_t\ d}{f_{yk}} \geq 0.0013 b_t d} \qquad \textit{(Exp. 9.1N)}$$

Where:
b_t denotes the mean width of the tension zone; f_{ctm} should be determined with respect to the relevant strength class according to Table 3.1.

(3) The cross-sectional area of tension or compression reinforcement should not exceed $A_{s,max}$ outside lap locations.
Note: The recommended value of $A_{s,max}$ for beams is $0,04A_c$

9.2.1.2 Other detailing arrangements
(1) In monolithic construction, even when simple supports have been assumed in design, the section at supports should be designed for a bending moment arising from partial fixity of at least β_1 of the maximum bending moment in the span.

Note 1: From Irish National Annex, $\boldsymbol{\beta_1} \mathbf{=0.25}$
Note 2: The minimum area of longitudinal reinforcement section defined in 9.2.1.1 (1) applies.

(3) Any compression longitudinal reinforcement (diameter φ) which is included in the resistance calculation should be held by transverse reinforcement with spacing not greater than 15φ.

9.2.2 Shear reinforcement
(6) The maximum longitudinal spacing between shear assemblies should not exceed $s_{l,max}$.

$$\mathbf{s_{l,max} = 0{,}75d\ (1 + \cot\alpha)} \qquad \textit{(Exp 9.6N)}$$

where α is the inclination of the shear reinforcement to the longitudinal axis of the beam.

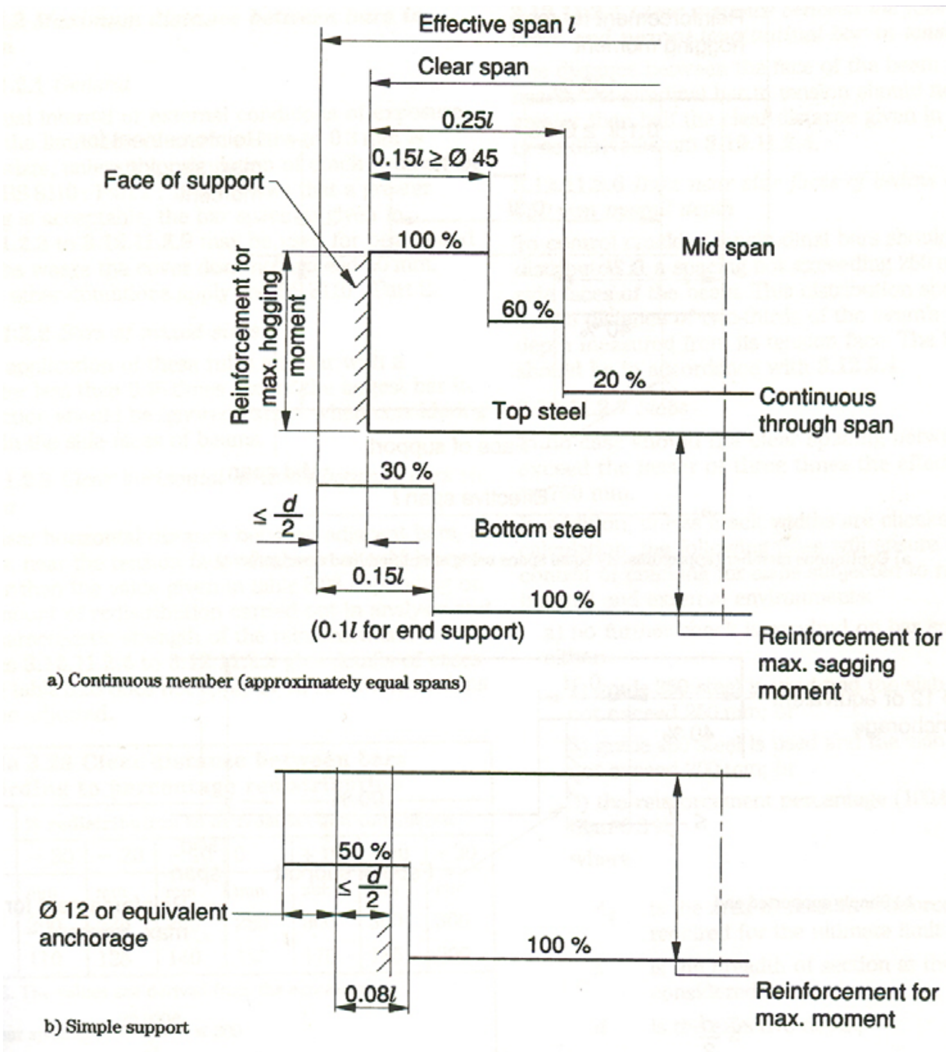
(8) The transverse spacing of the legs in a series of shear links should not exceed $s_{t,max}$:

$$\mathbf{s_{t,max} = 0{,}75d \leq 600\ mm} \qquad \textit{(Exp 9.8N)}$$

Simplified Rules of Curtailment

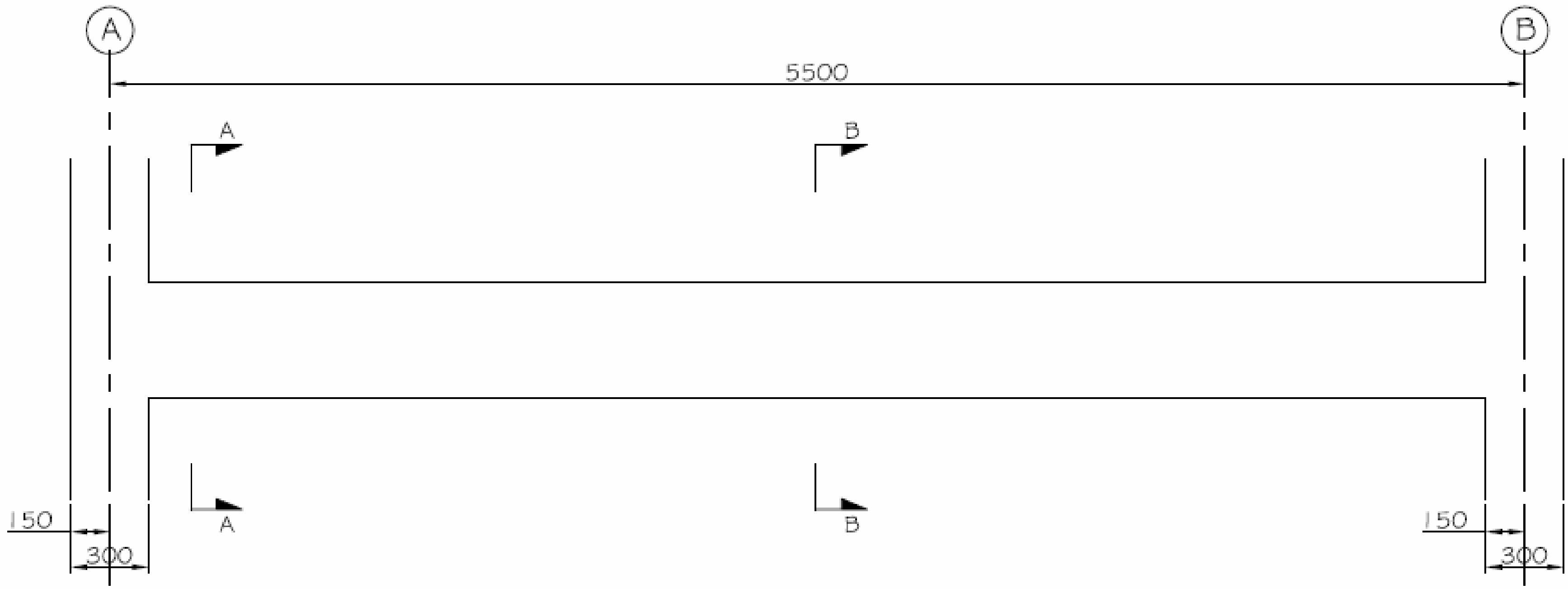
These following simplified rules of curtailment may be applied where:

a) For beams designed predominantly for Uniformly Distributed Loads (u.d.l's)
b) In the case of continuous beams, when the spans are approximately equal (not varying by more than 15%)



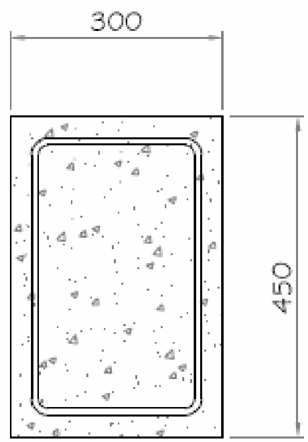
Anchorage & Lap Lengths

Concrete Class C30/37											
		Bond Conditions	Reinforcement in Tension, bar diameter, Ø (mm)								Reinforcement in Compression
			8	10	12	16	20	25	32	40	
Anchorage length, l_{bd}	Straight Bars Only	Good	210	280	360	530	690	900	1150	1560	36Ø
		Poor	290	400	520	750	990	1280	1640	2230	51Ø
	Other Bars	Good	290	360	430	580	720	900	1150	1560	36Ø
		Poor	410	520	620	820	1030	1280	1640	2230	51Ø
Lap Length, l_0	50% Lapped in one location (α_6 = 1.4)	Good	290	390	510	740	970	1260	1610	2180	50Ø
		Poor	410	560	720	1050	1380	1790	2290	3110	72Ø
	100% Lapped in one location (α_6 = 1.5)	Good	310	420	540	790	1040	1350	1720	2340	54Ø
		Poor	430	600	780	1130	1480	1920	2460	3340	77Ø



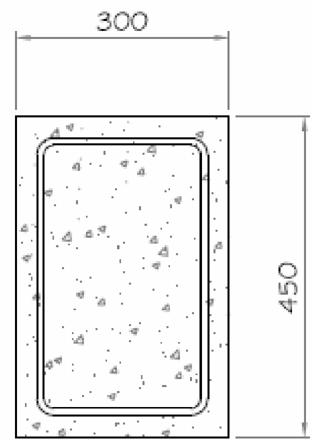
Elevation of RC Beam on GL3

(Scale 1:25)



Section A-A

Scale 1:10



Section B-B

Scale 1:10

Notes:

1. 1. General
- All dimensions are in millimetres unless noted otherwise.

2. Specification
- Concrete to the grade C30/37.
- Reinforcement yield strength to be 500N/mm²
- Nominal Cover to reinforcement shall be 25mm minimum.

Q. A1 (iii): Please return with Answer Book

Student Name: ______________________

Student No.: ______________________

<u>For Students Repeating Exam Only</u>

Section A: Additional <u>British Standard</u> Information

<u>Additional Relevant Extracts from B.S. 8110</u>

Flexure Design

$$K = \frac{M}{f_{cu} b d^2}$$

If K < K`

$$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{0.9}}\right)$$

$$A_s = \frac{M}{0.95 f_y z}$$

If K > K`

$$z = d\left(0.5 + \sqrt{0.25 - \frac{K'}{0.9}}\right)$$

$$A'_s = \frac{\left(K - K'\right) f_{cu} b d^2}{0.95 f_y \left(d - d'\right)}$$

$$A_s = \frac{K' f_{cu} b d^2}{0.95 f_y z} + A'_s$$

Shear Design

$$\upsilon = \frac{V}{b_v d}$$

$$\frac{A_{sv}}{S_v} = \frac{b(\upsilon - \upsilon_c)}{0.95 f_{yv}}$$

Table 3.8 Values of v_c design concrete shear stress

$\frac{100A_s}{b_v d}$	Effective depth mm							
	125	150	175	200	225	250	300	≥ 400
	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
≤ 0.15	0.45	0.43	0.41	0.40	0.39	0.38	0.36	0.34
0.25	0.53	0.51	0.49	0.47	0.46	0.45	0.43	0.40
0.50	0.67	0.64	0.62	0.60	0.58	0.56	0.54	0.50
0.75	0.77	0.73	0.71	0.68	0.66	0.65	0.62	0.57
1.00	0.84	0.81	0.78	0.75	0.73	0.71	0.68	0.63
1.50	0.97	0.92	0.89	0.86	0.83	0.81	0.78	0.72
2.00	1.06	1.02	0.98	0.95	0.92	0.89	0.86	0.80
≥ 3 .00	1.22	1.16	1.12	1.08	1.05	1.02	0.98	0.91

NOTE 1. Allowance has been made in these figures for a γ_m of 1.25.
NOTE 2. The values in the table are derived from the expression:
$0.79\left\{100A_s/(b_v d)\right\}^{1/3}(400/d)^{1/4}/\gamma_m$
where
$\frac{100A_s}{b_v d}$ should not be taken as greater than 3;
$\frac{400}{d}$ should not be taken as less than 1.
For characteristic concrete strengths greater than 25 N/mm^2, the values in this table may be multiplied by $(f_{cu}/25)^{1/3}$. The value of f_{cu} should not be taken as greater than 40.

Table 3.9 Basic span/effective depth ratio for rectangular or flanged beams

Support conditions	Rectangular sections	Flanged beams with $\frac{b_w}{b} \leq 0.3$
Cantilever	7	5.6
Simply supported	20	16.0
Continuous	26	20.8

Table 3.10 Modification factor for tension reinforcement

Service stress	M/bd^2								
	0.50	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**
100	2.00	2.00	2.00	1.86	1.63	1.36	1.19	1.08	1.01
150	2.00	2.00	1.98	1.69	1.49	1.25	1.11	1.01	0.94
(f_y = 250) 167	2.00	2.00	1.91	1.63	1.44	1.21	1.08	0.99	0.92
200	2.00	1.95	1.76	1.51	1.35	1.14	1.02	0.94	0.88
250	1.90	1.70	1.55	1.34	1.20	1.04	0.94	0.87	0.82
300	1.60	1.44	1.33	1.16	1.06	0.93	0.85	0.80	0.76
(f_y = 460) 307	1.56	1.41	1.30	1.14	1.04	0.91	0.84	0.79	0.76

NOTE 1. The values in the table derive from the equation:

$$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0 \qquad \text{equation 7}$$

where

M is the design ultimate moment at the centre of the span or, for a cantilever, at the support.

NOTE 2. The design service stress in the tension reinforcement in a member may be estimated from the equation:

$$f_s = \frac{2f_y A_{s\ req}}{3A_{s\ prov}} \times \frac{1}{\beta_b} \qquad \text{equation 8}$$

NOTE 3. For a continuous beam, if the percentage of redistribution is not known but the design ultimate moment at mid-span is obviously the same as or greater than the elastic ultimate moment, the stress f_s in this table may be taken as $2/3 f_y$

Table 3.11 Modification factor for compression reinforcement

$100\frac{A'_{s\ prov}}{bd}$	Factor
0.00	1.00
0.15	1.05
0.25	1.08
0.35	1.10
0.50	1.14
0.75	1.20
1.0	1.25
1.5	1.33
2.0	1.40
2.5	1.45
$\geq$ 3.0	1.50

NOTE 1. The values in this table are derived from the following equation:

Modification factor for compression reinforcement =

$$1 + \frac{100A'_{s\ prov}}{bd} \Big/ \left(3 + \frac{100A'_{s\ prov}}{bd}\right) \leq 1.5 \qquad \text{equation 9}$$

NOTE 2. The area of compression reinforcement A used in this table may include all bars in the compression zone, even those not effectively tied with links.

SECTION B

A column is being subjected to the unfactored axial loading as shown in Fig QB1.

LOADING

F_1 : $G_k = 75kN$

$Q_k = 175kN$

F_2 : $G_k = 20kN$

$Q_k = 75kN$

Note: Allow 1kN/m for the column self wt.

TO DO:

B1. Determine the load the column is being subjected to **(6 marks)**

B2. Determine whether a 203 UC71 is adequate to take the loads. **(44 marks)**

Note: the floor beams provide directional restraint at the top of the column, the foundation is a pin

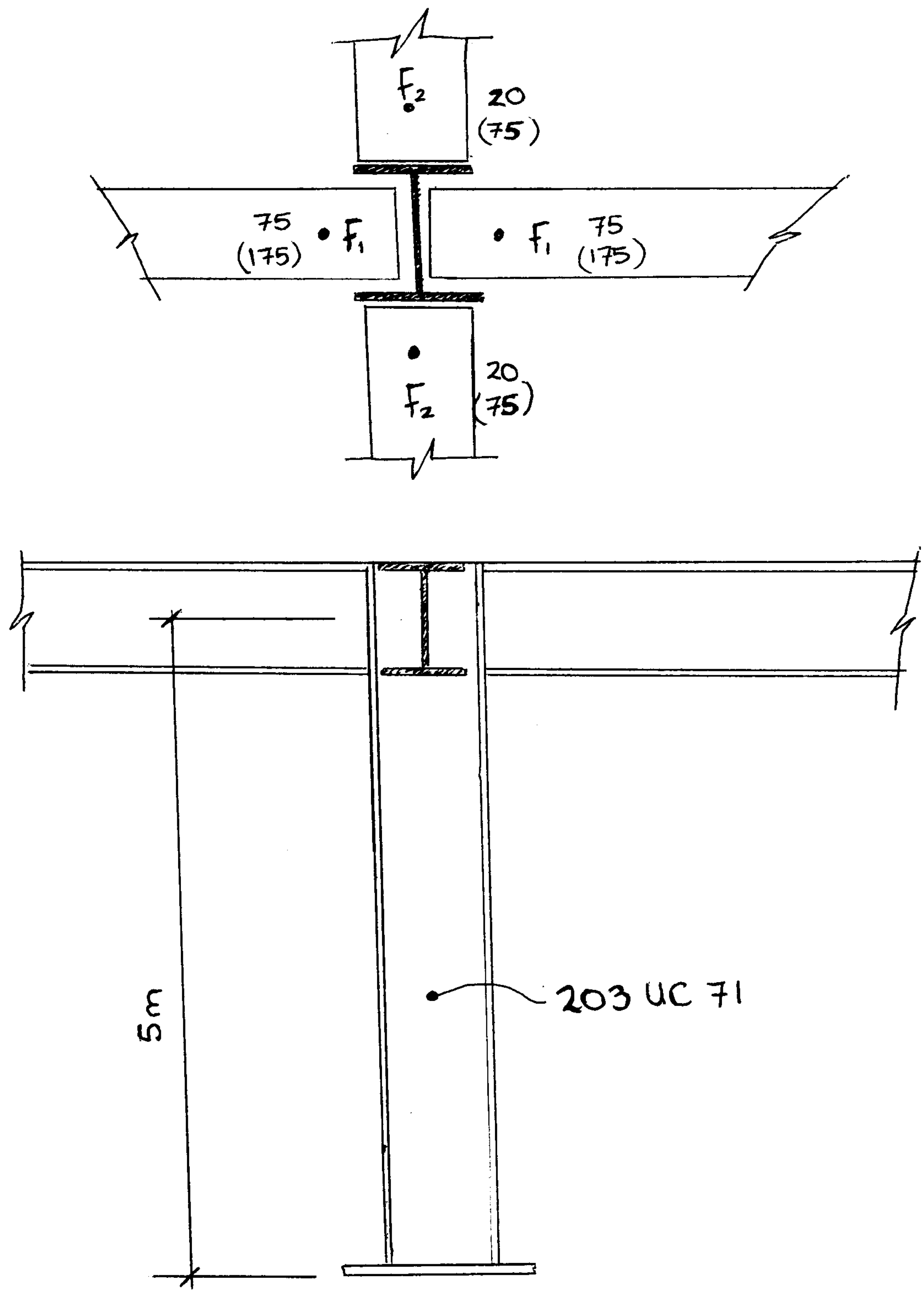


Figure QB1

TABLES from BS5950

Section 3. Properties of materials and section properties

3.1 Structural steel

3.1.1 Design strength

This standard covers the design of structures fabricated from structural steels conforming to the grades and product standards specified in BS 5950-2. If other steels are used, due allowance should be made for variations in properties, including ductility and weldability.

The design strength p_y should be taken as $1.0Y_s$ but not greater than $U_s/1.2$ where Y_s and U_s are respectively the minimum yield strength R_{eH} and the minimum tensile strength R_m specified in the relevant product standard. For the more commonly used grades and thicknesses of steel from the product standards specified in BS 5950-2 the value of p_y may be obtained from Table 9. Alternatively, the values of R_{eH} and R_m may be obtained from the relevant product standard.

NOTE Additional requirements apply where plastic analysis is used, see 5.2.3.

Table 9 — Design strength p_y

Steel grade	Thickness[a] less than or equal to mm	Design strength p_y N/mm²
S 275	16	275
	40	265
	63	255
	80	245
	100	235
	150	225
S 355	16	355
	40	345
	63	335
	80	325
	100	315
	150	295
S 460	16	460
	40	440
	63	430
	80	410
	100	400

[a] For rolled sections, use the specified thickness of the thickest element of the cross-section.

3.1.2 Notch toughness

The notch toughness of the steel, as quantified by the Charpy impact properties, should conform to that for the appropriate quality of steel for avoiding brittle fracture, see 2.4.4.

Table 11 — Limiting width-to-thickness ratios for sections other than CHS and RHS

Compression element			Ratio[a]	Limiting value[b]		
				Class 1 plastic	Class 2 compact	Class 3 semi-compact
Outstand element of compression flange	Rolled section		b/T	9ε	10ε	15ε
	Welded section		b/T	8ε	9ε	13ε
Internal element of compression flange	Compression due to bending		b/T	28ε	32ε	40ε
	Axial compression		b/T	Not applicable		
Web of an I-, H- or box section[c]	Neutral axis at mid-depth		d/t	80ε	100ε	120ε
	Generally[d]	If r_1 is negative:	d/t	$\frac{80\varepsilon}{1+r_1}$ but $\geq 40\varepsilon$	$\frac{100\varepsilon}{1+r_1}$	$\frac{120\varepsilon}{1+2r_2}$ but $> 40\varepsilon$
		If r_1 is positive:	d/t		$\frac{100\varepsilon}{1+1.5r_1}$ but $\geq 40\varepsilon$	
	Axial compression[d]		d/t	Not applicable		
Web of a channel			d/t	40ε	40ε	40ε
Angle, compression due to bending (Both criteria should be satisfied)			b/t	9ε	10ε	15ε
			d/t	9ε	10ε	15ε
Single angle, or double angles with the components separated, axial compression (All three criteria should be satisfied)			b/t	Not applicable		15ε
			d/t			15ε
			$(b + d)/t$			24ε
Outstand leg of an angle in contact back-to-back in a double angle member			b/t	9ε	10ε	15ε
Outstand leg of an angle with its back in continuous contact with another component						
Stem of a T-section, rolled or cut from a rolled I- or H-section			D/t	8ε	9ε	18ε

[a] Dimensions b, D, d, T and t are defined in Figure 5. For a box section b and T are flange dimensions and d and t are web dimensions, where the distinction between webs and flanges depends upon whether the box section is bent about its major axis or its minor axis, see **3.5.1**.
[b] The parameter $\varepsilon = (275/p_y)^{0.5}$.
[c] For the web of a hybrid section ε should be based on the design strength p_{yf} of the flanges.
[d] The stress ratios r_1 and r_2 are defined in **3.5.5**.

Table 23 — Allocation of strut curve

Type of section	Maximum thickness (see note 1)	Axis of buckling x-x	Axis of buckling y-y
Hot-finished structural hollow section		a)	a)
Cold-formed structural hollow section		c)	c)
Rolled I-section	≤40 mm	a)	b)
	>40 mm	b)	c)
Rolled H-section	≤40 mm	b)	c)
	>40 mm	c)	d)
Welded I or H-section (see note 2 and **4.7.5**)	≤40 mm	b)	c)
	>40 mm	b)	d)
Rolled I-section with welded flange cover plates with 0.25 < *U*/*B* < 0.8 as shown in Figure 14a)	≤40 mm	a)	b)
	>40 mm	b)	c)
Rolled H-section with welded flange cover plates with 0.25 < *U*/*B* < 0.8 as shown in Figure 14a)	≤40 mm	b)	c)
	>40 mm	c)	d)
Rolled I or H-section with welded flange cover plates with *U*/*B* ≥ 0.8 as shown in Figure 14b)	≤40 mm	b)	a)
	>40 mm	c)	b)
Rolled I or H-section with welded flange cover plates with *U*/*B* ≤ 0.25 as shown in Figure 14c)	≤40 mm	b)	c)
	>40 mm	b)	d)
Welded box section (see note 3 and **4.7.5**)	≤40 mm	b)	b)
	>40 mm	c)	c)
Round, square or flat bar	≤40 mm	b)	b)
	>40 mm	c)	c)
Rolled angle, channel or T-section Two rolled sections laced, battened or back-to-back Compound rolled sections		Any axis: c)	

NOTE 1 For thicknesses between 40 mm and 50 mm the value of p_c may be taken as the average of the values for thicknesses up to 40 mm and over 40 mm for the relevant value of p_y.

NOTE 2 For welded I or H-sections with their flanges thermally cut by machine without subsequent edge grinding or machining, for buckling about the y-y axis, strut curve b) may be used for flanges up to 40 mm thick and strut curve c) for flanges over 40 mm thick.

NOTE 3 The category "welded box section" includes any box section fabricated from plates or rolled sections, provided that all of the longitudinal welds are near the corners of the cross-section. Box sections with longitudinal stiffeners are NOT included in this category.

Table 24 — Compressive strength p_c (N/mm²) (*continued*)

3) Values of p_c (N/mm²) with $\lambda < 110$ for strut curve b															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	235	245	255	265	275	315	325	335	345	355	400	410	430	440	460
15	235	245	255	265	275	315	325	335	345	355	399	409	428	438	457
20	234	243	253	263	272	310	320	330	339	349	391	401	420	429	448
25	229	239	248	258	267	304	314	323	332	342	384	393	411	421	439
30	225	234	243	253	262	298	307	316	325	335	375	384	402	411	429
35	220	229	238	247	256	291	300	309	318	327	366	374	392	400	417
40	216	224	233	241	250	284	293	301	310	318	355	364	380	388	404
42	213	222	231	239	248	281	289	298	306	314	351	359	375	383	399
44	211	220	228	237	245	278	286	294	302	310	346	354	369	377	392
46	209	218	226	234	242	275	283	291	298	306	341	349	364	371	386
48	207	215	223	231	239	271	279	287	294	302	336	343	358	365	379
50	205	213	221	229	237	267	275	283	290	298	330	337	351	358	372
52	203	210	218	226	234	264	271	278	286	293	324	331	344	351	364
54	200	208	215	223	230	260	267	274	281	288	318	325	337	344	356
56	198	205	213	220	227	256	263	269	276	283	312	318	330	336	347
58	195	202	210	217	224	252	258	265	271	278	305	311	322	328	339
60	193	200	207	214	221	247	254	260	266	272	298	304	314	320	330
62	190	197	204	210	217	243	249	255	261	266	291	296	306	311	320
64	187	194	200	207	213	238	244	249	255	261	284	289	298	302	311
66	184	191	197	203	210	233	239	244	249	255	276	281	289	294	301
68	181	188	194	200	206	228	233	239	244	249	269	273	281	285	292
70	178	185	190	196	202	223	228	233	238	242	261	265	272	276	282
72	175	181	187	193	198	218	223	227	232	236	254	257	264	267	273
74	172	178	183	189	194	213	217	222	226	230	246	249	255	258	264
76	169	175	180	185	190	208	212	216	220	223	238	241	247	250	255
78	166	171	176	181	186	203	206	210	214	217	231	234	239	241	246
80	163	168	172	177	181	197	201	204	208	211	224	226	231	233	237
82	160	164	169	173	177	192	196	199	202	205	217	219	223	225	229
84	156	161	165	169	173	187	190	193	196	199	210	212	216	218	221
86	153	157	161	165	169	182	185	188	190	193	203	205	208	210	213
88	150	154	158	161	165	177	180	182	185	187	196	198	201	203	206
90	146	150	154	157	161	172	175	177	179	181	190	192	195	196	199
92	143	147	150	153	156	167	170	172	174	176	184	185	188	189	192
94	140	143	147	150	152	162	165	167	169	171	178	179	182	183	185
96	137	140	143	146	148	158	160	162	164	165	172	173	176	177	179
98	134	137	139	142	145	153	155	157	159	160	167	168	170	171	173
100	130	133	136	138	141	149	151	152	154	155	161	162	164	165	167
102	127	130	132	135	137	145	146	148	149	151	156	157	159	160	162
104	124	127	129	131	133	141	142	144	145	146	151	152	154	155	156
106	121	124	126	128	130	137	138	139	141	142	147	148	149	150	151
108	118	121	123	125	126	133	134	135	137	138	142	143	144	145	147

Table 24 — Compressive strength p_c (N/mm²) (*continued*)

4) Values of p_c (N/mm²) with $\lambda \geq 110$ for strut curve b															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	235	245	255	265	275	315	325	335	345	355	400	410	430	440	460
110	115	118	120	121	123	129	130	131	133	134	138	139	140	141	142
112	113	115	117	118	120	125	127	128	129	130	134	134	136	136	138
114	110	112	114	115	117	122	123	124	125	126	130	130	132	132	133
116	107	109	111	112	114	119	120	121	122	122	126	126	128	128	129
118	105	106	108	109	111	115	116	117	118	119	122	123	124	124	125
120	102	104	105	107	108	112	113	114	115	116	119	119	120	121	122
122	100	101	103	104	105	109	110	111	112	112	115	116	117	117	118
124	97	99	100	101	102	106	107	108	109	109	112	112	113	114	115
126	95	96	98	99	100	103	104	105	106	106	109	109	110	111	111
128	93	94	95	96	97	101	101	102	103	103	106	106	107	107	108
130	90	92	93	94	95	98	99	99	100	101	103	103	104	105	105
135	85	86	87	88	89	92	93	93	94	94	96	97	97	98	98
140	80	81	82	83	84	86	87	87	88	88	90	90	91	91	92
145	76	77	78	78	79	81	82	82	83	83	84	85	85	86	86
150	72	72	73	74	74	76	77	77	78	78	79	80	80	80	81
155	68	69	69	70	70	72	72	73	73	73	75	75	75	76	76
160	64	65	65	66	66	68	68	69	69	69	70	71	71	71	72
165	61	62	62	62	63	64	65	65	65	65	66	67	67	67	68
170	58	58	59	59	60	61	61	61	62	62	63	63	63	64	64
175	55	55	56	56	57	58	58	58	59	59	60	60	60	60	60
180	52	53	53	53	54	55	55	55	56	56	56	57	57	57	57
185	50	50	51	51	51	52	52	53	53	53	54	54	54	54	54
190	48	48	48	48	49	50	50	50	50	50	51	51	51	51	52
195	45	46	46	46	46	47	47	48	48	48	49	49	49	49	49
200	43	44	44	44	44	45	45	45	46	46	46	46	47	47	47
210	40	40	40	40	41	41	41	41	42	42	42	42	42	43	43
220	36	37	37	37	37	38	38	38	38	38	39	39	39	39	39
230	34	34	34	34	34	35	35	35	35	35	35	36	36	36	36
240	31	31	31	31	32	32	32	32	32	32	33	33	33	33	33
250	29	29	29	29	29	30	30	30	30	30	30	30	30	30	30
260	27	27	27	27	27	27	28	28	28	28	28	28	28	28	28
270	25	25	25	25	25	26	26	26	26	26	26	26	26	26	26
280	23	23	23	23	24	24	24	24	24	24	24	24	24	24	24
290	22	22	22	22	22	22	22	22	22	22	23	23	23	23	23
300	20	20	21	21	21	21	21	21	21	21	21	21	21	21	21
310	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20
320	18	18	18	18	18	18	18	19	19	19	19	19	19	19	19
330	17	17	17	17	17	17	17	17	17	18	18	18	18	18	18
340	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17
350	15	15	15	15	15	16	16	16	16	16	16	16	16	16	16

Table 24 — Compressive strength p_c (N/mm²) (*continued*)

5) Values of p_c (N/mm²) with λ < 110 for strut curve c															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	235	245	255	265	275	315	325	335	345	355	400	410	430	440	460
15	235	245	255	265	275	315	325	335	345	355	398	408	427	436	455
20	233	242	252	261	271	308	317	326	336	345	387	396	414	424	442
25	226	235	245	254	263	299	308	317	326	335	375	384	402	410	428
30	220	228	237	246	255	289	298	307	315	324	363	371	388	396	413
35	213	221	230	238	247	280	288	296	305	313	349	357	374	382	397
40	206	214	222	230	238	270	278	285	293	301	335	343	358	365	380
42	203	211	219	227	235	266	273	281	288	296	329	337	351	358	373
44	200	208	216	224	231	261	269	276	284	291	323	330	344	351	365
46	197	205	213	220	228	257	264	271	279	286	317	324	337	344	357
48	195	202	209	217	224	253	260	267	274	280	311	317	330	337	349
50	192	199	206	213	220	248	255	262	268	275	304	310	323	329	341
52	189	196	203	210	217	244	250	257	263	270	297	303	315	321	333
54	186	193	199	206	213	239	245	252	258	264	291	296	308	313	324
56	183	189	196	202	209	234	240	246	252	258	284	289	300	305	315
58	179	186	192	199	205	229	235	241	247	252	277	282	292	297	306
60	176	183	189	195	201	225	230	236	241	247	270	274	284	289	298
62	173	179	185	191	197	220	225	230	236	241	262	267	276	280	289
64	170	176	182	188	193	215	220	225	230	235	255	260	268	272	280
66	167	173	178	184	189	210	215	220	224	229	248	252	260	264	271
68	164	169	175	180	185	205	210	214	219	223	241	245	252	256	262
70	161	166	171	176	181	200	204	209	213	217	234	238	244	248	254
72	157	163	168	172	177	195	199	203	207	211	227	231	237	240	246
74	154	159	164	169	173	190	194	198	202	205	220	223	229	232	238
76	151	156	160	165	169	185	189	193	196	200	214	217	222	225	230
78	148	152	157	161	165	180	184	187	191	194	207	210	215	217	222
80	145	149	153	157	161	176	179	182	185	188	201	203	208	210	215
82	142	146	150	154	157	171	174	177	180	183	195	197	201	203	207
84	139	142	146	150	154	167	169	172	175	178	189	191	195	197	201
86	135	139	143	146	150	162	165	168	170	173	183	185	189	190	194
88	132	136	139	143	146	158	160	163	165	168	177	179	183	184	187
90	129	133	136	139	142	153	156	158	161	163	172	173	177	178	181
92	126	130	133	136	139	149	152	154	156	158	166	168	171	173	175
94	124	127	130	133	135	145	147	149	151	153	161	163	166	167	170
96	121	124	127	129	132	141	143	145	147	149	156	158	160	162	164
98	118	121	123	126	129	137	139	141	143	145	151	153	155	157	159
100	115	118	120	123	125	134	135	137	139	140	147	148	151	152	154
102	113	115	118	120	122	130	132	133	135	136	143	144	146	147	149
104	110	112	115	117	119	126	128	130	131	133	138	139	142	142	144
106	107	110	112	114	116	123	125	126	127	129	134	135	137	138	140
108	105	107	109	111	113	120	121	123	124	125	130	131	133	134	136

Table 24 — Compressive strength p_c (N/mm²) (*continued*)

6) Values of p_c (N/mm²) with $\lambda \geq 110$ for strut curve c															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	235	245	255	265	275	315	325	335	345	355	400	410	430	440	460
110	102	104	106	108	110	116	118	119	120	122	126	127	129	130	132
112	100	102	104	106	107	113	115	116	117	118	123	124	125	126	128
114	98	100	101	103	105	110	112	113	114	115	119	120	122	123	124
116	95	97	99	101	102	108	109	110	111	112	116	117	118	119	120
118	93	95	97	98	100	105	106	107	108	109	113	114	115	116	117
120	91	93	94	96	97	102	103	104	105	106	110	110	112	112	113
122	89	90	92	93	95	99	100	101	102	103	107	107	109	109	110
124	87	88	90	91	92	97	98	99	100	100	104	104	106	106	107
126	85	86	88	89	90	94	95	96	97	98	101	102	103	103	104
128	83	84	86	87	88	92	93	94	95	95	98	99	100	100	101
130	81	82	84	85	86	90	91	91	92	93	96	96	97	98	99
135	77	78	79	80	81	84	85	86	87	87	90	90	91	92	92
140	72	74	75	76	76	79	80	81	81	82	84	85	85	86	87
145	69	70	71	71	72	75	76	76	77	77	79	80	80	81	81
150	65	66	67	68	68	71	71	72	72	73	75	75	76	76	76
155	62	63	63	64	65	67	67	68	68	69	70	71	71	72	72
160	59	59	60	61	61	63	64	64	65	65	66	67	67	67	68
165	56	56	57	58	58	60	60	61	61	61	63	63	64	64	64
170	53	54	54	55	55	57	57	58	58	58	60	60	60	60	61
175	51	51	52	52	53	54	54	55	55	55	56	57	57	57	58
180	48	49	49	50	50	51	52	52	52	53	54	54	54	54	55
185	46	46	47	47	48	49	49	50	50	50	51	51	52	52	52
190	44	44	45	45	45	47	47	47	47	48	49	49	49	49	49
195	42	42	43	43	43	45	45	45	45	45	46	46	47	47	47
200	40	41	41	41	42	43	43	43	43	43	44	44	45	45	45
210	37	37	38	38	38	39	39	39	40	40	40	40	41	41	41
220	34	34	35	35	35	36	36	36	36	36	37	37	37	37	38
230	31	32	32	32	32	33	33	33	33	34	34	34	34	34	35
240	29	29	30	30	30	30	31	31	31	31	31	31	32	32	32
250	27	27	27	28	28	28	28	28	29	29	29	29	29	29	29
260	25	25	26	26	26	26	26	26	27	27	27	27	27	27	27
270	23	24	24	24	24	24	25	25	25	25	25	25	25	25	25
280	22	22	22	22	22	23	23	23	23	23	23	24	24	24	24
290	21	21	21	21	21	21	21	22	22	22	22	22	22	22	22
300	19	19	20	20	20	20	20	20	20	20	21	21	21	21	21
310	18	18	18	19	19	19	19	19	19	19	19	19	19	19	20
320	17	17	17	17	18	18	18	18	18	18	18	18	18	18	18
330	16	16	16	16	17	17	17	17	17	17	17	17	17	17	17
340	15	15	15	16	16	16	16	16	16	16	16	16	16	16	16
350	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15