UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualification:-

B.Sc.

ES217A: Structural Form and Function A

COURSE CODE	:	**ENVS217A**
UNIT VALUE	:	**0.50**
DATE	:	**07-MAY-03**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

03-C0420-3-40

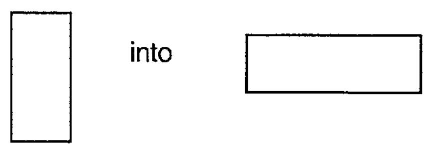
TURN OVER

ENVS 217A Structural Form and Function

Answer FOUR questions. All questions carry the same marks.

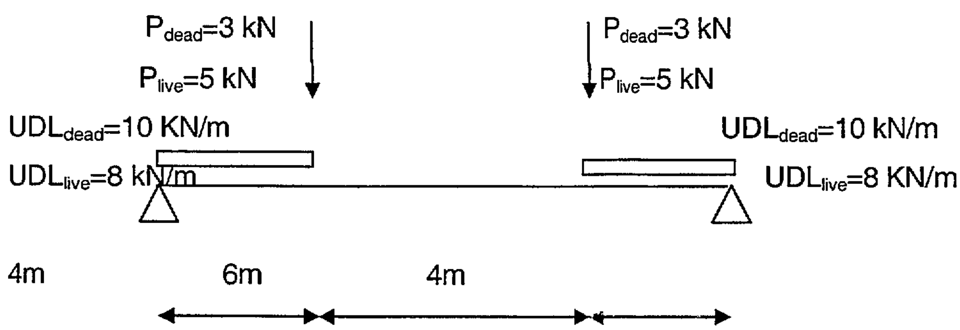
1. (a) Explain how the following concepts are realised in analysing and designing structural elements: (i) stability, (ii) strength (iii) flexibility/rigidity of structures in connection with stresses, (iv) Young's modulus and (v) centre of gravity. (8marks)

(b) Show using an example of a rectangular section 300mm by 75mm that changing its orientation while using it as a beam, will affect its resistance to bending (8.5 marks)



(c) Comment on what assumptions are made in truss design and what are the implications of these assumptions. (8.5 marks)

2. (a) Using graphs provided sketch shear force and bending moment diagrams and calculate and locate maximum values using given formulas, for the beam shown below. Carry out the calculations for **design** (not characteristic) loading. (15 marks)



(b) Comment on stability of frames - describe principles behind braced and unbraced frames and how the moments and forces from horizontal loadings are transferred to the foundations in both types. (10 marks)

3. Compare approach to design of beams for man-made materials (steel) and nature-made materials (timber). Please describe stages of design for a simply supported beam in both materials and point out the differences and similarities. (25marks)

4. (a) Describe stages of design of a simply beam in RC concrete grade C30, using tables provided. Please sketch and describe the types of reinforcement in a typical beam (12.5 marks)

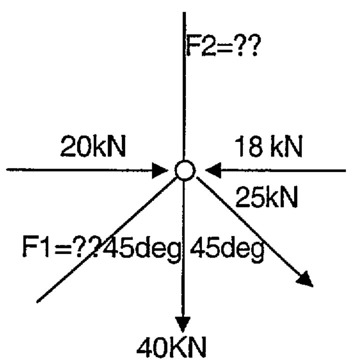
(b) Discuss stability conditions for retaining walls (three instances) supported by sketches and descriptions of the preventative measures. (12.5 marks)

5. (a) Describe displacement and replacement piles (materials and methods of construction) and their behaviour with cohesive and cohesionless soils. (12.5 marks)

(b) Describe types and conditions of use of shallow foundations. (6 marks)

(c) Describe engineering characteristics and behaviour of cohesive and non-cohesive soils. (6.5 marks)

6. (a) Resolve the given below truss joint for the unknown forces in marked members (value of the force and state if tensile or compressive). (12.5 marks)



(b) Describe composite floors, commenting on the following: (i) deck; (ii) slab span and depths; (iii) concrete type and grade; (iv) the construction and composite loading; (v) forms of shear connection. (12.5 marks)

7. (a) Assuming the tensile force = 8500 kN, design a UC element in tension assuming that the maximum design tensile strength of steel is 275 N/mm^2 and calculate the elongation of the element. Young's modulus = 2.05 E5 N/mm^2 and original length = 1.5m. (12.5 marks)

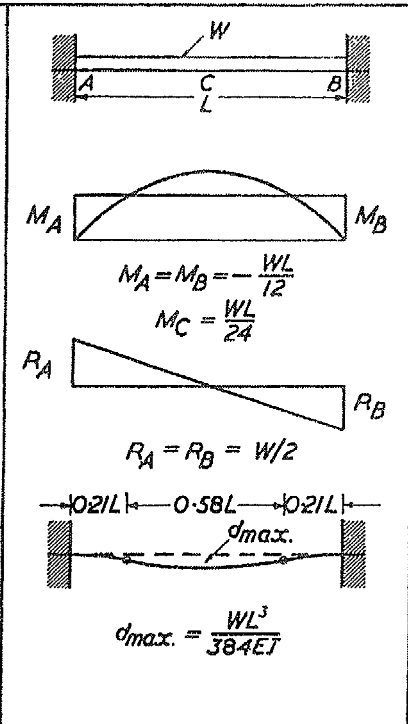
(b) Describe the design procedure for checking the vertical capacity of masonry (6 marks)

(c) Describe the design procedure for checking the lateral capacity of the solid masonry walls. (6.5 marks)

END OF PAPER

03-C420a-3-40

BUILT—IN BEAMS

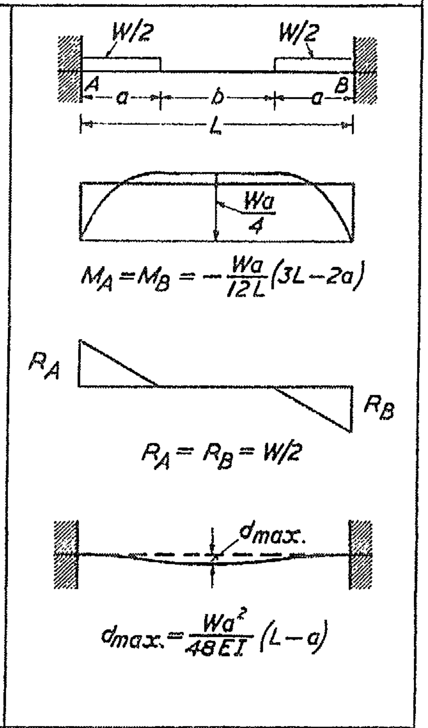


$M_A = M_B = -\frac{WL}{12}$

$M_C = \frac{WL}{24}$

$R_A = R_B = W/2$

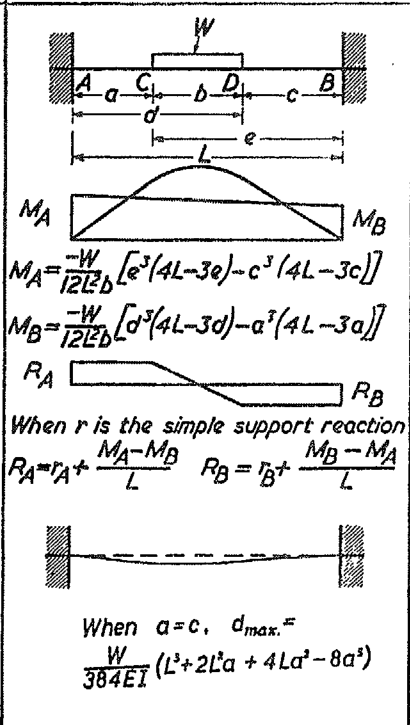
$d_{max.} = \frac{WL^3}{384EI}$



$M_A = M_B = -\frac{Wa}{12L}(3L-2a)$

$R_A = R_B = W/2$

$d_{max.} = \frac{Wa^2}{48EI}(L-a)$



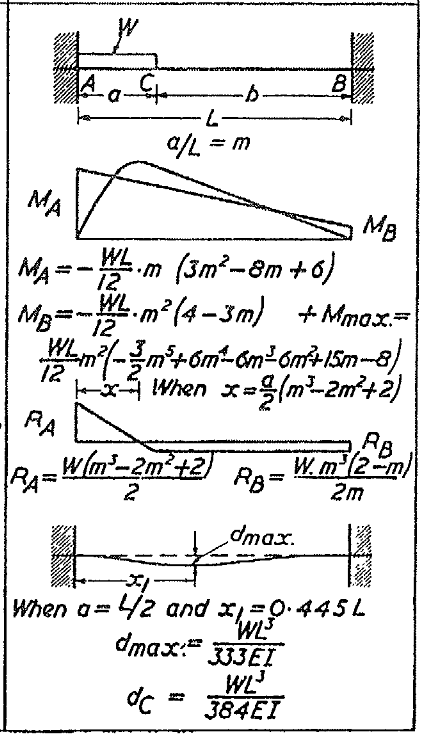
$M_A = \frac{-W}{12L^2b}\left[e^3(4L-3e)-c^3(4L-3c)\right]$

$M_B = \frac{-W}{12L^2b}\left[d^3(4L-3d)-a^3(4L-3a)\right]$

When r is the simple support reaction

$R_A = r_A + \frac{M_A - M_B}{L}$ $R_B = r_B + \frac{M_B - M_A}{L}$

When $a=c$, $d_{max.} = \frac{W}{384EI}(L^3+2L^2a+4La^2-8a^3)$



$a/L = m$

$M_A = -\frac{WL}{12}\cdot m\,(3m^2-8m+6)$

$M_B = -\frac{WL}{12}\cdot m^2(4-3m)$ $+M_{max.} = \frac{WL}{12}m^2\left(-\frac{3}{2}m^5+6m^4-6m^3-6m^2+15m-8\right)$ When $x = \frac{a}{2}(m^3-2m^2+2)$

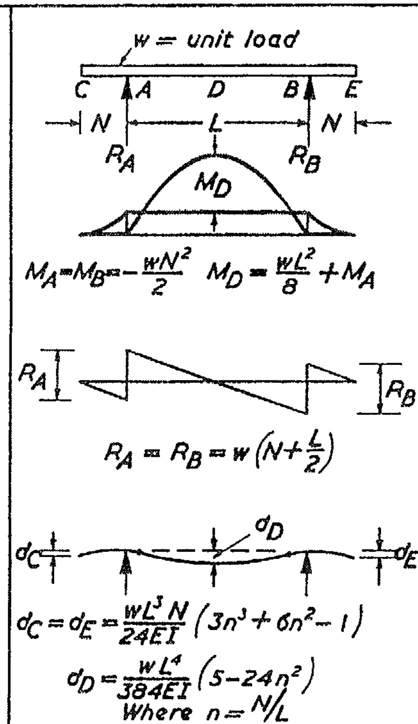
$R_A = \frac{W(m^3-2m^2+2)}{2}$ $R_B = \frac{W.m^3(2-m)}{2m}$

When $a = L/2$ and $x_1 = 0{\cdot}445L$

$d_{max.} = \frac{WL^3}{333EI}$

$d_C = \frac{WL^3}{384EI}$

SIMPLY SUPPORTED BEAMS



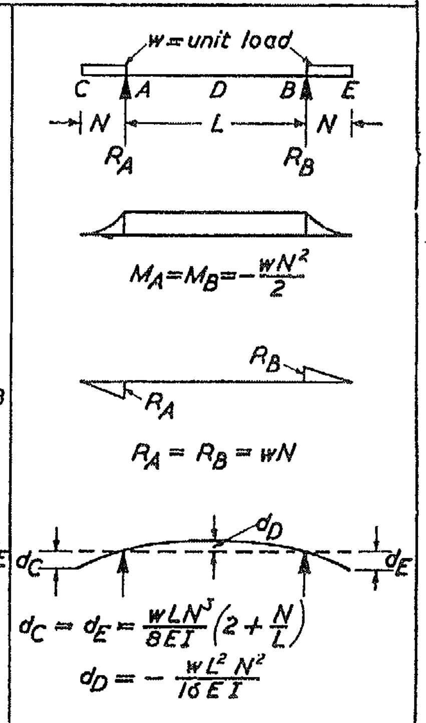
$M_A = M_B = -\frac{wN^2}{2}$ $M_D = \frac{wL^2}{8} + M_A$

$R_A = R_B = w\left(N+\frac{L}{2}\right)$

$d_C = d_E = \frac{wL^3N}{24EI}(3n^3+6n^2-1)$

$d_D = \frac{wL^4}{384EI}(5-24n^2)$

Where $n = N/L$

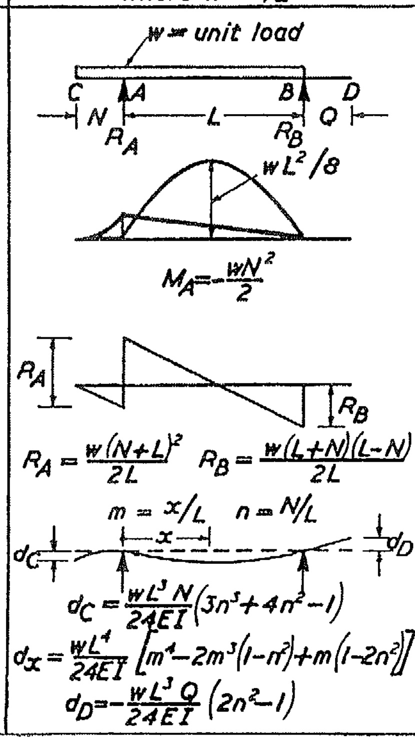


$M_A = M_B = -\frac{wN^2}{2}$

$R_A = R_B = wN$

$d_C = d_E = \frac{wLN^3}{8EI}\left(2+\frac{N}{L}\right)$

$d_D = -\frac{wL^2N^2}{16EI}$



$M_A = -\frac{wN^2}{2}$

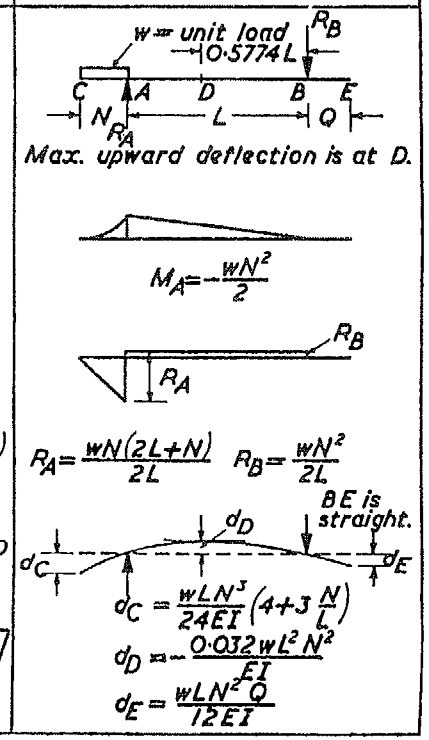
$R_A = \frac{w(N+L)^2}{2L}$ $R_B = \frac{w(L+N)(L-N)}{2L}$

$m = x/L$ $n = N/L$

$d_C = \frac{wL^3N}{24EI}(3n^3+4n^2-1)$

$d_x = \frac{wL^4}{24EI}\left[m^4-2m^3(1-n^2)+m(1-2n^2)\right]$

$d_D = -\frac{wL^3Q}{24EI}(2n^2-1)$



Max. upward deflection is at D.

$M_A = -\frac{wN^2}{2}$

$R_A = \frac{wN(2L+N)}{2L}$ $R_B = \frac{wN^2}{2L}$

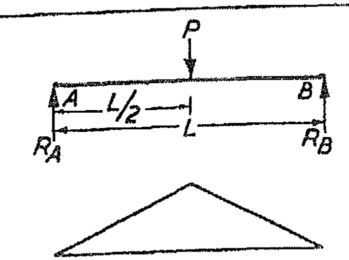
$d_C = \frac{wLN^3}{24EI}\left(4+3\frac{N}{L}\right)$

$d_D = -\frac{0{\cdot}032\,wL^2N^2}{EI}$

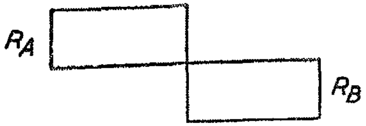
$d_E = \frac{wLN^2Q}{12EI}$

SIMPLY SUPPORTED BEAMS

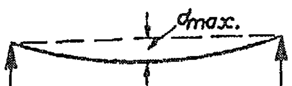
LOADING / MOMENT / SHEAR / DEFLECTION



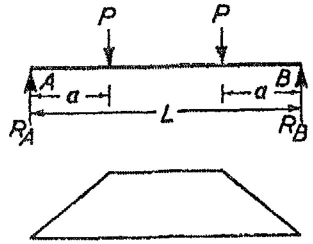
$M_{max.} = \frac{PL}{4}$



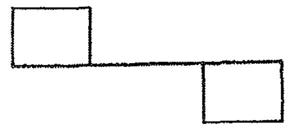
$R_A = R_B = \frac{P}{2}$



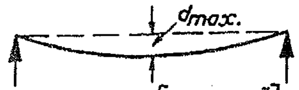
$d_{max.} = \frac{PL^3}{48EI}$



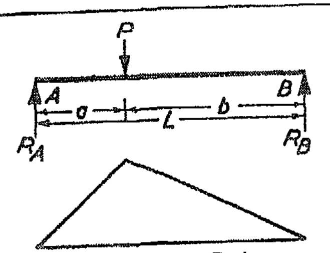
$M_{max.} = Pa$



$R_A = R_B = P$

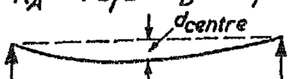


$d_{max.} = \frac{PL^3}{6EI}\left[\frac{3a}{4L} - \left(\frac{a}{L}\right)^3\right]$



$M_{max.} = \frac{Pab}{L}$

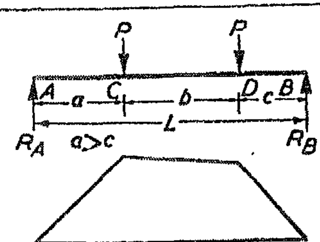
$R_A = Pb/L \quad R_B = Pa/L$



$d_{max.}$ always occurs within $0{\cdot}0774\,L$ of the centre of the beam.
When $b \geqslant a$,

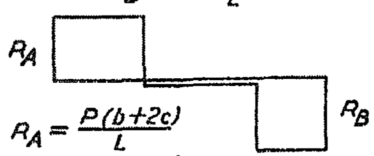
$d_{centre} = \frac{PL^3}{48EI}\left[\frac{3a}{L} - 4\left(\frac{a}{L}\right)^3\right]$

This value is always within $2{\cdot}5\%$ of the maximum value.



$M_C = \frac{Pa(b+2c)}{L}$

$M_D = \frac{Pc(b+2a)}{L}$



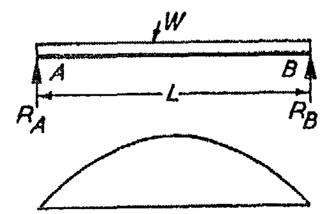
$R_A = \frac{P(b+2c)}{L}$

$R_B = \frac{P(b+2a)}{L}$

For central deflection add the values for each P derived from the formula in the adjacent diagram.

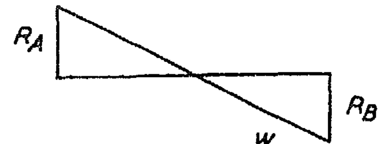
SIMPLY SUPPORTED BEAMS

LOADING / MOMENT / SHEAR / DEFLECTION

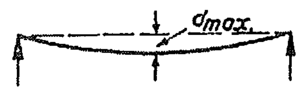


$M_x = \frac{Wx}{2}\left(1 - \frac{x}{L}\right)$

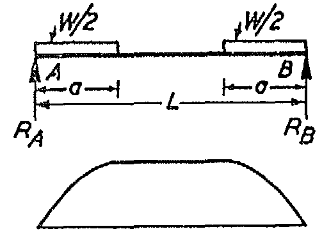
$M_{max.} = \frac{WL}{8}$



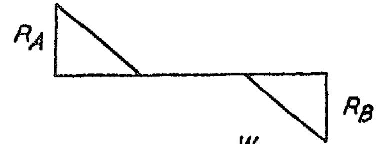
$R_A = R_B = \frac{W}{2}$



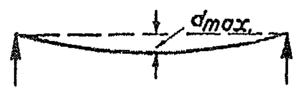
$d_{max.} = \frac{5}{384} \cdot \frac{WL^3}{EI}$



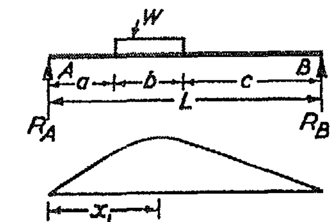
$M_{max.} = \frac{Wa}{4}$



$R_A = R_B = \frac{W}{2}$



$d_{max.} = \frac{Wa\,(3L^2 - 2a^2)}{96EI}$

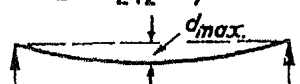


$M_{max.} = \frac{W}{b}\left(\frac{x_1^2 - a^2}{2}\right)$

when $x_1 = a + \frac{R_A b}{W}$

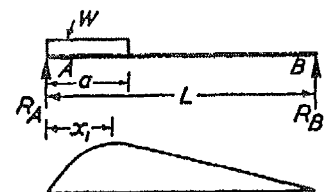
$R_A = \frac{W}{L}\left(\frac{b}{2} + c\right)$

$R_B = \frac{W}{L}\left(\frac{b}{2} + a\right)$



When $a = c$

$d_{max.} = \frac{W}{384EI}\left(8L^3 - 4Lb^2 + b^3\right)$

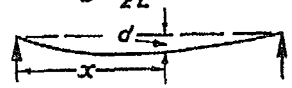


$M_{max.} = \frac{W}{2}a\left(1 - \frac{a}{2L}\right)^2$

when $x_1 = a\left(1 - \frac{a}{2L}\right)$

$R_A = W\left(1 - \frac{a}{2L}\right)$

$R_B = \frac{Wa}{2L}$



When $x \leqslant a$,

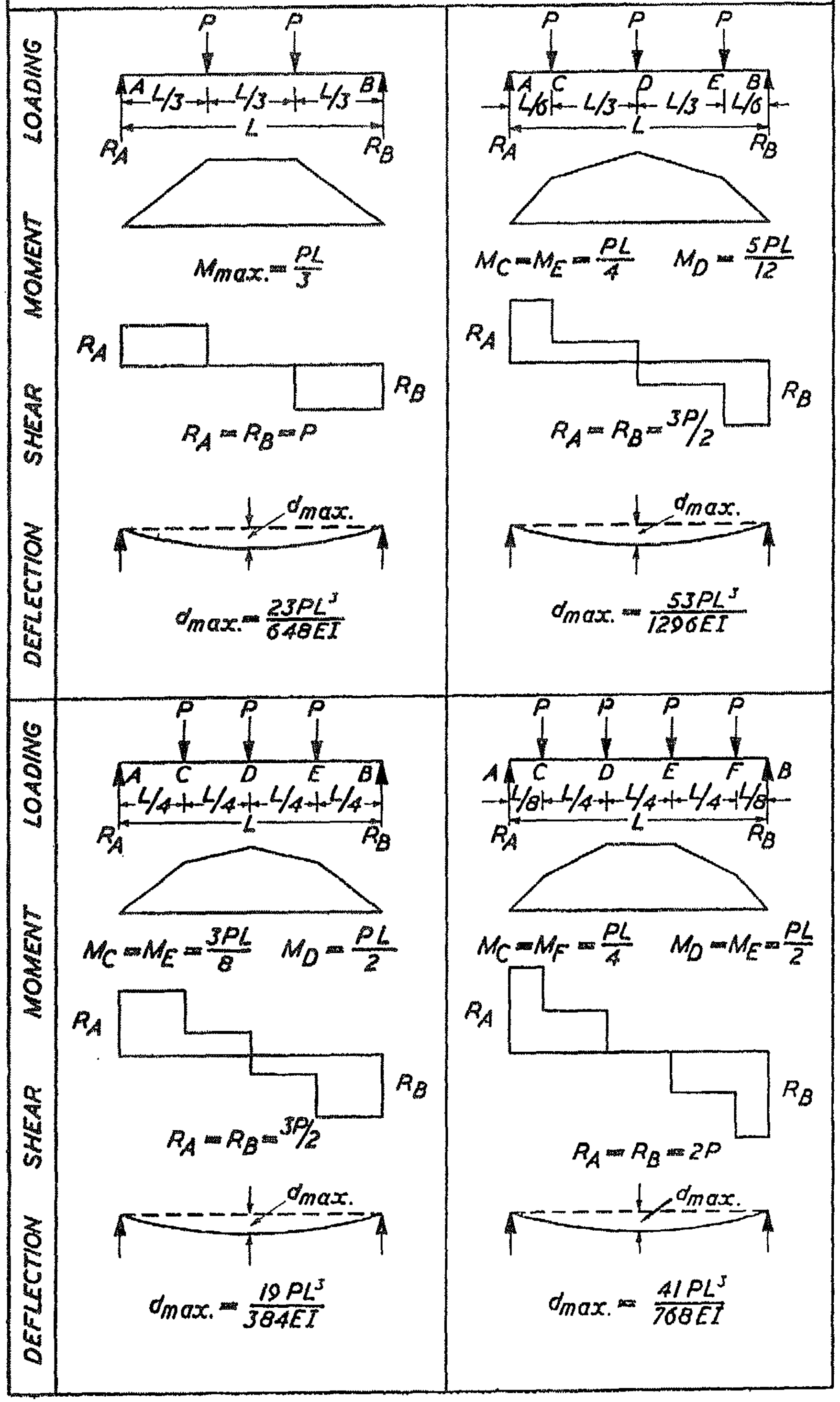
$d = \frac{WL^4}{24aEI}\left[m^4 - 2n(2-n)m^3 + n^2(2-n)^2 m\right]$

When $x \geqslant a$,

$d = \frac{WL^4}{24aEI} \cdot n^2\left[2m^3 - 6m^2 + m(4+n^2) - n^2\right]$

where $m = x/L$ and $n = a/L$

SIMPLY SUPPORTED BEAMS



BUILT – IN BEAMS

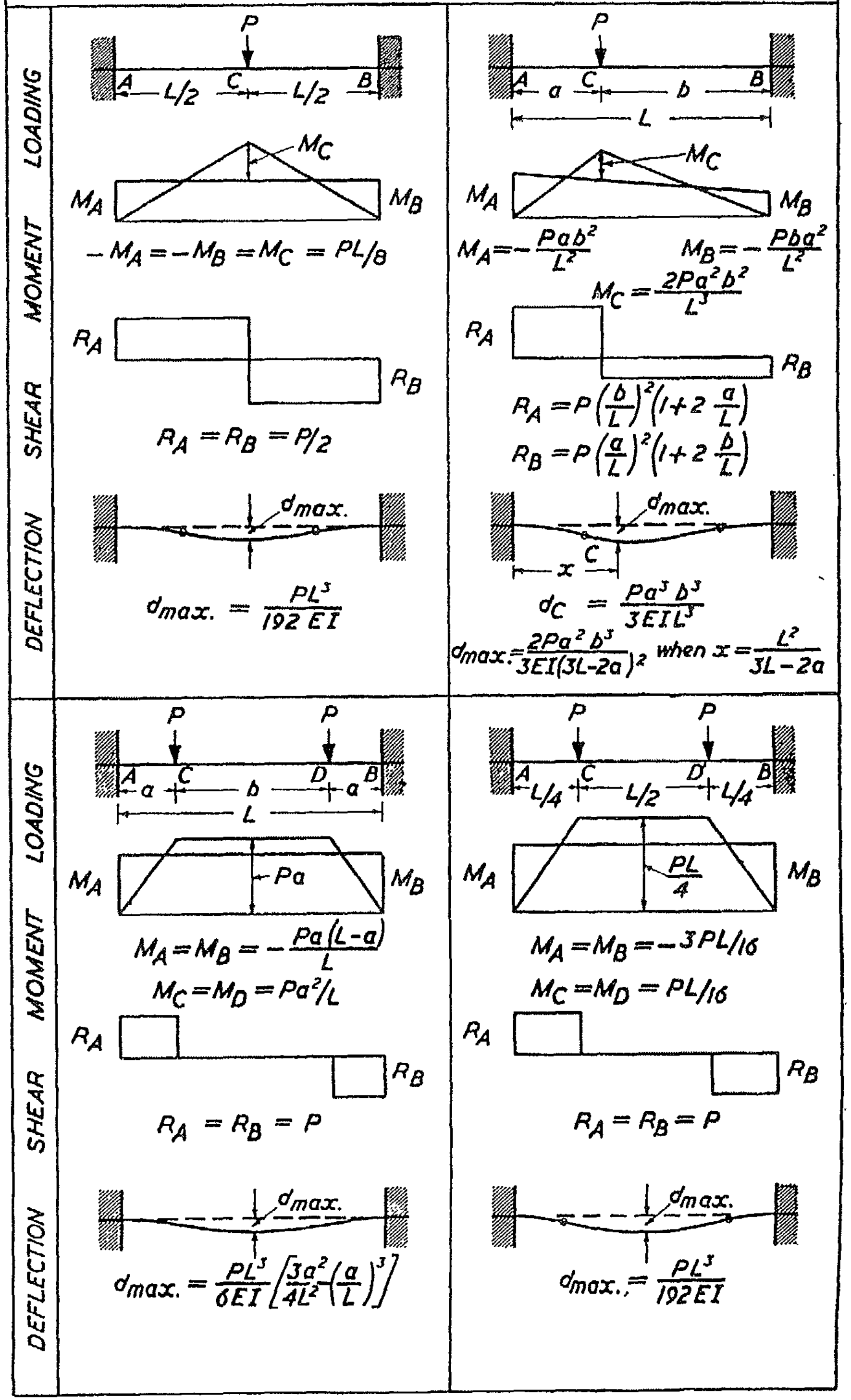


Table 27 Ultimate shear stresses v_c (N/mm²) for beams

$\frac{100 A_s}{b_v d}$	Effective depth, mm 150	175	200	225	250	300	≥400
≤0.15	0.46	0.44	0.43	0.41	0.40	0.38	0.36
0.25	0.54	0.52	0.50	0.49	0.48	0.46	0.42
0.50	0.68	0.66	0.64	0.62	0.59	0.57	0.53
0.75	0.76	0.75	0.72	0.70	0.69	0.64	0.61
1.00	0.86	0.83	0.80	0.78	0.75	0.72	0.67
1.50	0.98	0.95	0.91	0.88	0.86	0.83	0.76
2.00	1.08	1.04	1.01	0.97	0.95	0.91	0.85
≥3.00	1.23	1.19	1.15	1.11	1.08	1.04	0.97

Note to Table 27
The tabulated values apply tor f_{cu} = 30N/mm²
For f_{cu} = 25N/mm² the tabulated values should be divided by 1.062.
For f_{cu} = 35N/mm² the tabulated values should be multiplied by 1.053.
For f_{cu} = 40N/mm² the tabulated values should be multiplied by 1.10.

The term A_s relates to that area of longitudinal tension reinforcement that continues for a distance d beyond the section being considered. At supports the full area of tension reinforcement at the section may be considered, provided that the normal rules for curtailment and anchorage are met.

Shear reinforcement in the form of vertical links should be provided in accordance with the minimum areas shown in Table 28.

The spacing of links in the direction of the span should not exceed 0.75d. At right angles to the span the horizontal spacing should be such that no longitudinal tension bar is more than 150mm from a tension leg of a link; this spacing should in any case not exceed d.

Table 28 Minimum provision of links in beams

value of v N/mm²	Area of shear reinforcement
$v < (v_c + 0.4)$	Minimum links for whole length of beam $A_{sv} > \frac{0.4\, b_w S_v}{0.87 f_{yv}}$
$(v_c + 0.4) < v$	Links only provided $A_{sv} > b_w \frac{S_v (v - v_c)}{0.87 f_{yv}}$

where b_w is the width in mm of (the web of) the beam
S_v is the spacing of the links in mm (200)
A_{sv} is the total cross-section of the link(s) in mm² (2 legs for a single closed link, 4 legs for double closed links) and
f_{yv} is the characteristic strength of the links in N/mm² (250)

4.4.2.2 Durability

The requirements for durability in any given environment are:

(*a*) an upper limit to the water/cement ratio
(*b*) a lower limit to the cement content
(*c*) a lower limit to the thickness of the cover to the reinforcement
(*d*) good compaction, and
(*e*) adequate curing.

Values for (*a*), (*b*) and (*c*) which, in combination, will be adequate to ensure durability are given in Table 18 for various environments.

As (*a*) and (*b*) at present cannot be checked by methods that are practical for use during construction, Table 18 gives, in addition, the characteristic strengths that have to be specified in the UK to ensure that requirements (*a*) and (*b*) are satisfied.

Table 18 Durability requirements for beams

Conditions of exposure (For definitions see Appendix C)	Cover to *all* reinforcement mm	mm	mm
Mild	25	20	20
Moderate	—	35	30
Severe	—	—	40
Very severe	—	—	50
Maximum free water/cement ratio	0.65	0.60	0.55
Minimum cement content, kg/m³	275	300	325
Characteristic concrete strength in the UK, N/mm²	30	35	40

Notes to Table 18
1. The cover to *all* reinforcement should not be less than the nominal maximum size of the aggregate.
2. The cover in mm to the *main* reinforcement should not be less the the bar size.

The strengths quoted in Table 18 will often require cement contents that are higher than those given in Table. The potential problems of increased shrinkage arising from high cement and water contents should be considered in the design.

4.4.2.1 Fire resistance

The member sizes and reinforcement covers required to provide fire resistance are shown in Table 17.

Table 17 Fire resistance and cover for beams

Fire resistance h	Minimum width, mm simply supported	continuous	Cover to main steel, mm simply supported	continuous
1	120	120	30	20
1½	150	120	40	35
2	200	150	50	50
3	240	200	70	60
4	280	240	80	70

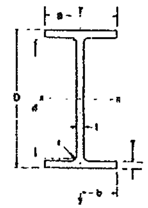
4.4.4 Span/effective depth ratios

The span/effective depth should not exceed the appropriate value in Table 20. Compliance with these ratios will normally ensure that the total deflection does not exceed span/250.

Table 20 Span/effective depth ratios for beams

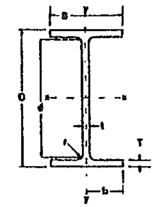
	$b_w/b = 1$	$b_w/b \leq 0.3$
cantilever	7	5.6
simply supported	20	16.0

UNIVERSAL BEAMS – DIMENSIONS AND PROPERTIES
To BS 4: Part 1: 1980



Designation		Depth of Section D	Width of Section B	Thickness		Root Radius r	Web	Ratios For Local Buckling		Second Moment of Area		Radius of gyration	
Serial size	Mass per metre			Web t	Flange T		Depth between fillets d	Flange b/T	Web d/t	Axis x-x	Axis y-y	Axis x-x	Axis y-y
mm	kg	mm	mm	mm	mm	mm	mm			cm⁴	cm⁴	cm	cm
457 x 152	82	465·1	153·5	10·7	18·9	10·2	406·9	4·08	38·0	36215	1143	18·6	3·31
	74	461·3	152·7	9·9	17·0	10·2	406·9	4·49	41·1	32435	1012	18·5	3·26
	67	457·2	151·9	9·1	15·0	10·2	406·9	5·06	44·7	28577	878	18·3	3·21
	60	454·7	152·9	8·0	13·3	10·2	407·7	5·75	51·0	25464	794	18·3	3·23
	52	449·8	152·4	7·6	10·9	10·2	407·7	6·99	53·6	21345	645	17·9	3·11
406 x 178	74	412·8	179·7	9·7	16·0	10·2	360·5	5·62	37·2	27329	1545	17·0	4·03
	67	409·4	178·8	8·8	14·3	10·2	360·5	6·25	41·0	24329	1365	16·9	4·00
	60	406·4	177·8	7·8	12·8	10·2	360·5	6·95	46·2	21508	1199	16·8	3·97
	54	402·6	177·6	7·6	10·9	10·2	360·5	8·15	47·4	18626	1017	16·5	3·85
406 x 140	46	402·3	142·4	6·9	11·2	10·2	359·6	6·36	52·1	15647	539	16·3	3·02
	39	397·3	141·8	6·3	8·6	10·2	359·6	8·24	57·1	12452	411	15·9	2·89
356 x 171	67	364·0	173·2	9·1	15·7	10·2	312·2	5·52	34·3	19522	1362	15·1	3·99
	57	358·6	172·1	8·0	13·0	10·2	312·2	6·62	39·0	16077	1109	14·9	3·92
	51	355·6	171·5	7·3	11·5	10·2	312·2	7·46	42·8	14156	968	14·8	3·87
	45	352·0	171·0	6·9	9·7	10·2	312·2	8·81	45·3	12091	812	14·6	3·78
356 x 127	39	352·8	126·0	6·5	10·7	10·2	311·1	5·89	47·9	10087	357	14·3	2·69
	33	348·5	125·4	5·9	8·5	10·2	311·1	7·38	52·7	8200	280	14·0	2·59
305 x 165	54	310·9	166·8	7·7	13·7	8·9	265·6	6·09	34·5	11710	1061	13·1	3·94
	46	307·1	165·7	6·7	11·8	8·9	265·6	7·02	39·7	9948	897	13·0	3·90
	40	303·8	165·1	6·1	10·2	8·9	265·6	8·09	43·6	8523	763	12·9	3·85
305 x 127	48	310·4	125·2	8·9	14·0	8·9	264·6	4·47	29·7	9504	460	12·5	2·75
	42	306·6	124·3	8·0	12·1	8·9	264·6	5·14	33·1	8143	388	12·4	2·70
	37	303·8	123·5	7·2	10·7	8·9	264·6	5·77	36·7	7162	337	12·3	2·67
305 x 102	33	312·7	102·4	6·6	10·8	7·6	275·8	4·74	41·8	6487	193	12·5	2·15
	28	308·9	101·9	6·1	8·9	7·6	275·8	5·72	45·2	5421	157	12·2	2·08
	25	304·8	101·6	5·8	6·8	7·6	275·8	7·47	47·6	4387	120	11·8	1·96
254 x 146	43	259·6	147·3	7·3	12·7	7·6	218·9	5·80	30·0	6558	677	10·8	3·51
	37	256·0	146·4	6·4	10·9	7·6	218·9	6·72	34·2	5556	571	10·8	3·47
	31	251·5	146·1	6·1	8·6	7·6	218·9	8·49	35·9	4439	449	10·5	3·35
254 x 102	28	260·4	102·1	6·4	10·0	7·6	225·0	5·10	35·2	4008	178	10·5	2·22
	25	257·0	101·9	6·1	8·4	7·6	225·0	6·07	36·9	3408	148	10·3	2·14
	22	254·0	101·6	5·8	6·8	7·6	225·0	7·47	38·8	2867	120	10·0	2·05
203 x 133	30	206·8	133·8	6·3	9·6	7·6	172·3	6·97	27·3	2887	384	8·72	3·18
	25	203·2	133·4	5·8	7·8	7·6	172·3	8·55	29·7	2356	310	8·54	3·10
203 x 102	23	203·2	101·6	5·2	9·3	7·6	169·4	5·46	32·6	2090	163	8·49	2·37
178 x 102	19	177·8	101·6	4·7	7·9	7·6	146·8	6·43	31·2	1360	138	7·49	2·39
152 x 89	16	152·4	88·9	4·6	7·7	7·6	121·8	5·77	26·5	838	90·4	6·40	2·10
127 x 76	13	127·0	76·2	4·2	7·6	7·6	96·6	5·01	23·0	477	56·2	5·33	1·83

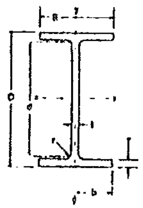
UNIVERSAL BEAMS – DIMENSIONS AND PROPERTIES
To BS 4: Part 1: 1980



Elastic modulus		Plastic modulus		Buckling Parameter u	Torsional Index x	Warping Constant H	Torsional Constant J	Area of Section	Designation	
Axis x-x	Axis y-y	Axis x-x	Axis y-y						Mass per metre	Serial size
cm³	cm³	cm³	cm³			dm⁶	cm⁴	cm²	kg	mm
1557	149·0	1800	235·4	0·872	27·3	0·569	89·3	104·5	82	457 x 152
1406	132·5	1622	209·1	0·870	30·0	0·499	66·6	95·0	74	
1250	115·5	1441	182·2	0·867	33·6	0·429	47·5	85·4	67	
1120	103·9	1284	162·9	0·869	37·5	0·387	33·6	75·9	60	
949	84·6	1094	133·2	0·859	43·9	0·311	21·3	66·5	52	
1324	172·0	1504	266·9	0·881	27·6	0·608	63·0	95·0	74	406 x 178
1188	152·7	1346	236·5	0·880	30·5	0·533	46·0	85·5	67	
1058	134·8	1194	208·3	0·880	33·9	0·464	32·9	76·0	60	
925·3	114·5	1048	177·5	0·872	38·5	0·390	22·7	68·4	54	
777·8	75·7	888·4	118·3	0·870	38·8	0·206	19·2	59·0	46	406 x 140
626·9	58·0	720·8	91·08	0·859	47·4	0·155	10·6	49·4	39	
1073	157·3	1212	243·0	0·887	24·4	0·413	55·5	85·4	67	356 x 171
896·5	128·9	1009	198·8	0·884	28·9	0·331	33·1	72·2	57	
796·2	112·9	894·9	174·1	0·882	32·2	0·286	23·8	64·6	51	
686·9	95·0	773·7	146·7	0·875	36·9	0·238	15·7	57·0	45	
571·8	56·6	653·6	88·68	0·872	35·3	0·104	14·9	49·4	39	356 x 127
470·6	44·7	534·8	70·24	0·864	42·2	0·081	8·68	41·8	33	
753·3	127·3	844·8	195·3	0·890	23·7	0·234	34·5	68·4	54	305 x 165
647·9	108·3	722·7	165·8	0·890	27·2	0·196	22·3	58·9	46	
561·2	92·4	624·5	141·5	0·888	31·1	0·164	14·7	51·5	40	
612·4	73·5	706·1	115·7	0·874	23·3	0·101	31·4	60·8	48	305 x 127
531·2	62·5	610·5	98·24	0·872	26·5	0·0842	21·0	53·2	42	
471·5	54·6	540·5	85·66	0·871	29·6	0·0724	14·9	47·5	37	
415·0	37·8	479·9	59·85	0·866	31·7	0·0441	12·1	41·8	33	305 x 102
351·0	30·8	407·2	48·92	0·858	37·0	0·0353	7·63	36·3	28	
287·9	23·6	337·8	37·98	0·844	43·8	0·0266	4·65	31·4	25	
505·3	92·0	568·2	141·2	0·889	21·1	0·103	24·1	55·1	43	254 x 146
434·0	78·1	485·3	119·6	0·889	24·3	0·0858	15·5	47·5	37	
353·1	61·5	395·6	94·52	0·879	29·4	0·0662	8·73	40·0	31	
307·9	34·9	353·4	54·84	0·873	27·5	0·0279	9·64	36·2	28	254 x 102
265·2	29·0	305·6	45·82	0·864	31·4	0·0228	6·45	32·2	25	
225·7	23·6	261·9	37·55	0·854	35·9	0·0183	4·31	28·4	22	
279·3	57·4	313·3	88·05	0·882	21·5	0·0373	10·2	38·0	30	203 x 133
231·9	46·4	259·6	71·39	0·876	25·4	0·0295	6·12	32·3	25	
206·0	32·1	232·0	49·50	0·890	22·6	0·0153	6·87	29·0	23	203 x 102
153·0	27·2	171·0	41·90	0·889	22·6	0·00998	4·37	24·2	19	178 x 102
110·0	20·3	124·0	31·40	0·889	19·5	0·00473	3·61	20·5	16	152 x 89
76·1	14·7	85·0	22·70	0·893	16·2	0·002	2·92	16·8	13	127 x 76

UNIVERSAL BEAMS – DIMENSIONS AND PROPERTIES

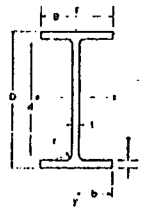
To BS 4: Part 1: 1980



Designation: Serial size	Designation: Mass per metre	Depth of Section D	Width of Section B	Thickness: Web t	Thickness: Flange T	Root Radius r	Web: Depth between fillets d	Ratios For Local Buckling: Flange b/T	Ratios For Local Buckling: Web d/t	Second Moment of Area: Axis x-x	Second Moment of Area: Axis y-y	Radius of gyration: Axis x-x	Radius of gyration: Axis y-y
mm	kg	mm	mm	mm	mm	mm	mm			cm⁴	cm⁴	cm	cm
914x419	388	920.5	420.5	21.5	36.6	24.1	799.0	5.74	37.2	718742	45407	38.1	9.58
	343	911.4	418.5	19.4	32.0	24.1	799.0	6.54	41.2	625282	39150	37.8	9.46
914x305	289	926.6	307.8	19.6	32.0	19.1	824.4	4.81	42.1	504594	15610	37.0	6.51
	253	918.5	305.5	17.3	27.9	19.1	824.4	5.47	47.7	436610	13318	36.8	6.42
	224	910.3	304.1	15.9	23.9	19.1	824.4	6.36	51.9	375924	11223	36.3	6.27
	201	903.0	303.4	15.2	20.2	19.1	824.4	7.51	54.2	325529	9427	35.6	6.06
838x292	226	850.9	293.8	16.1	26.8	17.8	761.7	5.48	47.3	339747	11353	34.3	6.27
	194	840.7	292.4	14.7	21.7	17.8	761.7	6.74	51.8	279450	9069	33.6	6.06
	176	834.9	291.6	14.0	18.8	17.8	761.7	7.76	54.4	246029	7792	33.1	5.90
762x267	197	769.6	268.0	15.6	25.4	16.5	685.8	5.28	44.0	239894	8174	30.9	5.71
	173	762.0	266.7	14.3	21.6	16.5	685.8	6.17	48.0	205177	6846	30.5	5.57
	147	753.9	265.3	12.9	17.5	16.5	685.8	7.58	53.2	168966	5468	30.0	5.39
686x254	170	692.9	255.8	14.5	23.7	15.2	615.0	5.40	42.4	170147	6621	28.0	5.53
	152	687.6	254.5	13.2	21.0	15.2	615.0	6.06	46.6	150319	5782	27.8	5.46
	140	683.5	253.7	12.4	19.0	15.2	615.0	6.68	49.6	136276	5179	27.6	5.38
	125	677.9	253.0	11.7	16.2	15.2	615.0	7.81	52.6	118003	4379	27.2	5.24
610x305	238	633.0	311.5	18.6	31.4	16.5	537.2	4.96	28.9	207571	15838	26.1	7.22
	179	617.5	307.0	14.1	23.6	16.5	537.2	6.50	38.1	151631	11412	25.8	7.08
	149	609.6	304.8	11.9	19.7	16.5	537.2	7.74	45.1	124660	9300	25.6	6.99
610x229	140	617.0	230.1	13.1	22.1	12.7	547.2	5.21	41.8	111844	4512	25.0	5.03
	125	611.9	229.0	11.9	19.6	12.7	547.2	5.84	46.0	98579	3933	24.9	4.96
	113	607.3	228.2	11.2	17.3	12.7	547.2	6.60	48.9	87431	3439	24.6	4.88
	101	602.2	227.6	10.6	14.8	12.7	547.2	7.69	51.6	75720	2912	24.2	4.75
533x210	122	544.6	211.9	12.8	21.3	12.7	476.5	4.97	37.2	76207	3393	22.1	4.67
	109	539.5	210.7	11.6	18.8	12.7	476.5	5.60	41.1	66739	2937	21.9	4.60
	101	536.7	210.1	10.9	17.4	12.7	476.5	6.04	43.7	61659	2694	21.8	4.56
	92	533.1	209.3	10.2	15.6	12.7	476.5	6.71	46.7	55353	2392	21.7	4.51
	82	528.3	208.7	9.6	13.2	12.7	476.5	7.91	49.6	47491	2005	21.3	4.38
457x191	98	467.4	192.8	11.4	19.6	10.2	407.9	4.92	35.8	45717	2343	19.1	4.33
	89	463.6	192.0	10.6	17.7	10.2	407.9	5.42	38.5	41021	2086	19.0	4.28
	82	460.2	191.3	9.9	16.0	10.2	407.9	5.98	41.2	37103	1871	18.8	4.23
	74	457.2	190.5	9.1	14.5	10.2	407.9	6.57	44.8	33388	1671	18.7	4.19
	67	453.6	189.9	8.5	12.7	10.2	407.9	7.48	48.0	29401	1452	18.5	4.12

UNIVERSAL BEAMS – DIMENSIONS AND PROPERTIES

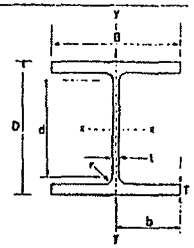
To BS 4: Part 1: 1980



Elastic modulus: Axis x-x	Elastic modulus: Axis y-y	Plastic modulus: Axis x-x	Plastic modulus: Axis y-y	Buckling Parameter u	Torsional Index x	Warping Constant H	Torsional Constant J	Area of Section	Designation: Mass per metre	Designation: Serial size
cm³	cm³	cm³	cm³			dm⁶	cm⁴	cm²	kg	mm
15616	2160	17657	3339	0.884	26.7	88.7	1730	494.5	388	914x419
13722	1871	15474	2890	0.883	30.1	75.7	1190	437.5	343	
10891	1014	12583	1603	0.867	31.9	31.2	929	368.8	289	914x305
9507	871.9	10947	1372	0.866	36.2	26.4	627	322.8	253	
8259	738.1	9522	1162	0.861	41.3	22.0	421	285.3	224	
7210	621.4	8362	982.5	0.853	46.8	18.4	293	256.4	201	
7986	772.9	9157	1211	0.870	35.0	19.3	514	288.7	226	838x292
6648	620.4	7648	974.4	0.862	41.6	15.2	307	247.2	194	
5894	534.4	6809	841.5	0.856	46.5	13.0	222	224.1	176	
6234	610.0	7167	958.7	0.869	33.2	11.3	405	250.8	197	762x267
5385	513.4	6197	807.3	0.864	38.1	9.38	267	220.5	173	
4483	412.3	5174	649.0	0.857	45.1	7.41	161	188.1	147	
4911	517.7	5624	810.3	0.872	31.8	7.41	307	216.6	170	686x254
4372	454.5	4997	710.0	0.871	35.5	6.42	219	193.8	152	
3988	408.2	4560	637.8	0.868	38.7	5.72	169	178.6	140	
3481	346.1	3996	542.0	0.862	43.9	4.79	116	159.6	125	
6559	1017	7456	1574	0.886	21.1	14.3	788	303.8	238	610x305
4911	743.3	5521	1144	0.886	27.5	10.1	341	227.9	179	
4090	610.3	4572	936.8	0.886	32.5	8.09	200	190.1	149	
3626	392.1	4146	612.5	0.875	30.5	3.99	217	178.4	140	610x229
3222	343.5	3677	535.7	0.873	34.0	3.45	165	159.6	125	
2879	301.4	3288	470.2	0.870	37.9	2.99	112	144.5	113	
2515	255.9	2882	400.0	0.863	43.0	2.51	77.2	129.2	101	
2799	320.2	3203	500.6	0.876	27.6	2.32	180	155.8	122	533x210
2474	278.8	2824	435.1	0.875	30.9	1.99	126	138.6	109	
2298	256.6	2620	400.0	0.874	33.1	1.82	102	129.3	101	
2076	228.6	2366	356.2	0.872	36.4	1.60	76.2	117.8	92	
1798	192.2	2056	300.1	0.865	41.6	1.33	51.3	104.4	82	
1956	243.0	2232	378.3	0.880	25.8	1.17	121	125.3	98	457x191
1770	217.4	2014	337.9	0.879	28.3	1.04	90.5	113.9	89	
1612	195.6	1833	304.0	0.877	30.9	0.923	69.2	104.5	82	
1461	175.5	1657	272.2	0.876	33.9	0.819	52.0	95.0	74	
1296	152.9	1471	237.3	0.873	37.9	0.706	37.1	85.4	67	

UNIVERSAL COLUMNS – DIMENSIONS AND PROPERTIES

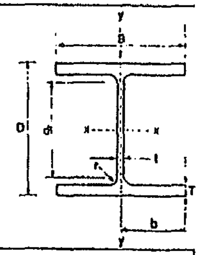
To BS 4: Part 1: 1980



Designation		Depth of Section	Width of Section	Thickness		Root Radius	Web	Ratios For Local Buckling		Second Moment of Area		Radius of gyration	
Serial size	Mass per metre	D	B	Web t	Flange T	r	Depth between fillets d	Flange b/T	Web d/t	Axis x-x	Axis y-y	Axis x-x	Axis y-y
mm	kg	mm	mm	mm	mm	mm	mm			cm⁴	cm⁴	cm	cm
356 x 406	634	474·7	424·1	47·6	77·0	15·2	290·1	2·75	6·10	275140	98211	18·5	11·0
	551	455·7	418·5	42·0	67·5	15·2	290·1	3·10	6·91	227023	82665	18·0	10·9
	467	436·6	412·4	35·9	58·0	15·2	290·1	3·56	8·08	183118	67905	17·5	10·7
	393	419·1	407·0	30·6	49·2	15·2	290·1	4·14	9·48	146765	55410	17·1	10·5
	340	406·4	403·0	26·5	42·9	15·2	290·1	4·70	11·0	122474	46816	16·8	10·4
	287	393·7	399·0	22·6	36·5	15·2	290·1	5·47	12·8	99994	38714	16·5	10·3
	235	381·0	395·0	18·5	30·2	15·2	290·1	6·54	15·7	79110	31008	16·2	10·2
356 x 368	202	374·7	374·4	16·8	27·0	15·2	290·1	6·93	17·3	66307	23632	16·0	9·57
	177	368·3	372·1	14·5	23·8	15·2	290·1	7·82	20·0	57153	20470	15·9	9·52
	153	362·0	370·2	12·6	20·7	15·2	290·1	8·94	23·0	48525	17469	15·8	9·46
	129	355·6	368·3	10·7	17·5	15·2	290·1	10·5	27·1	40246	14555	15·6	9·39
305 x 305	283	365·3	321·8	26·9	44·1	15·2	246·6	3·65	9·17	78777	24545	14·8	8·25
	240	352·6	317·9	23·0	37·7	15·2	246·6	4·22	10·7	64177	20239	14·5	8·14
	198	339·9	314·1	19·2	31·4	15·2	246·6	5·00	12·8	50832	16230	14·2	8·02
	158	327·2	310·6	15·7	25·0	15·2	246·6	6·21	15·7	38740	12524	13·9	7·89
	137	320·5	308·7	13·8	21·7	15·2	246·6	7·11	17·9	32838	10672	13·7	7·82
	118	314·5	306·8	11·9	18·7	15·2	246·6	8·20	20·7	27601	9006	13·6	7·75
	97	307·8	304·8	9·9	15·4	15·2	246·6	9·90	24·9	22202	7268	13·4	7·68
254 x 254	167	289·1	264·5	19·2	31·7	12·7	200·2	4·17	10·4	29914	9796	11·9	6·79
	132	276·4	261·0	15·6	25·3	12·7	200·2	5·16	12·8	22575	7519	11·6	6·68
	107	266·7	258·3	13·0	20·5	12·7	200·2	6·30	15·4	17510	5901	11·3	6·57
	89	260·4	255·9	10·5	17·3	12·7	200·2	7·40	19·1	14307	4849	11·2	6·52
	73	254·0	254·0	8·6	14·2	12·7	200·2	8·94	23·3	11360	3873	11·1	6·46
203 x 203	86	222·3	208·8	13·0	20·5	10·2	160·8	5·09	12·4	9462	3119	9·27	5·32
	71	215·9	206·2	10·3	17·3	10·2	160·8	5·96	15·6	7647	2536	9·16	5·28
	60	209·6	205·2	9·3	14·2	10·2	160·8	7·23	17·3	6088	2041	8·96	5·19
	52	206·2	203·9	8·0	12·5	10·2	160·8	8·16	20·1	5263	1770	8·90	5·16
	46	203·2	203·2	7·3	11·0	10·2	160·8	9·24	22·0	4564	1539	8·81	5·11
152 x 152	37	161·8	154·4	8·1	11·5	7·6	123·4	6·71	15·2	2218	709	6·84	3·87
	30	157·5	152·9	6·6	9·4	7·6	123·4	8·13	18·7	1742	558	6·75	3·82
	23	152·4	152·4	6·1	6·8	7·6	123·4	11·2	20·2	1263	403	6·51	3·69

UNIVERSAL COLUMNS – DIMENSIONS AND PROPERTIES

To BS4: Part I: 1980



Elastic modulus		Plastic modulus		Buckling Parameter	Torsional Index	Warping Constant	Torsional Constant	Area of Section	Designation	
Axis x-x	Axis y-y	Axis x-x	Axis y-y	u	x	H	J		Mass per metre	Serial size
cm³	cm³	cm³	cm³			dm⁶	cm⁴	cm²	kg	mm
11592	4632	14247	7114	0·843	5·46	38·8	13700	808·1	634	356x406
9964	3951	12078	6058	0·841	6·05	31·1	9240	701·8	551	
8388	3293	10009	5038	0·839	6·86	24·3	5820	595·5	467	
7004	2723	8229	4157	0·837	7·86	19·0	3550	500·9	393	
6027	2324	6994	3541	0·836	8·85	15·5	2340	432·7	340	
5080	1940	5818	2952	0·835	10·2	12·3	1440	366·0	287	
4153	1570	4689	2384	0·834	12·1	9·54	812	299·8	235	
3540	1262	3977	1917	0·844	13·3	7·14	560	257·9	202	356x368
3104	1100	3457	1668	0·844	15·0	6·07	383	225·7	177	
2681	943·8	2984	1430	0·844	17·0	5·09	251	195·2	153	
2264	790·4	2482	1198	0·843	19·9	4·16	153	164·9	129	
4314	1525	5101	2337	0·855	7·65	6·33	2030	360·4	283	305x305
3641	1273	4245	1947	0·854	8·73	5·01	1270	305·6	240	
2991	1034	3436	1576	0·854	10·2	3·88	734	252·3	198	
2368	806·3	2680	1228	0·852	12·5	2·88	379	201·2	158	
2049	691·4	2298	1052	0·851	14·1	2·38	250	174·6	137	
1755	507·0	1953	891·7	0·851	16·2	1·97	160	149·8	118	
1442	476·9	1589	723·5	0·850	19·3	1·55	91·1	123·3	97	
2070	740·6	2417	1132	0·852	8·49	1·62	625	212·4	167	254x254
1634	576·2	1875	878·6	0·850	10·3	1·18	322	168·9	132	
1313	456·9	1485	695·5	0·848	12·4	0·894	173	136·6	107	
1099	378·9	1228	575·4	0·849	14·4	0·716	104	114·0	89	
894·5	305·0	988·6	462·4	0·849	17·3	0·557	57·3	92·9	73	
851·5	298·7	978·8	455·9	0·850	10·2	0·317	138	110·1	86	203x203
708·4	246·0	802·4	374·2	0·852	11·9	0·250	81·5	91·1	71	
581·1	199·0	652·0	302·8	0·847	14·1	0·195	46·6	[illegible]	60	
510·4	173·6	568·1	263·7	0·848	15·8	0·166	32·0	66·4	52	
449·2	151·5	497·4	230·0	0·846	17·7	0·142	22·2	58·8	46	
274·2	91·78	310·1	140·1	0·848	13·3	0·040	19·5	47·4	37	152x152
221·2	73·06	247·1	111·2	0·848	16·0	0·0306	10·5	38·2	30	
165·7	52·95	184·3	80·87	0·837	20·4	0·0214	4·87	29·8	23	

CONSERVATIVE APPROACH

$\lambda = \left(\frac{L_e}{r_y}\right) w \rightarrow 0.94$

[redacted]ndix B Bending strength, p_b, tables

Table B1 Bending strength, p_b, (In N/mm²) for rolled sections with equal flanges for p_y = 265 N/mm²

λ \ x	5	10	15	20	25	30	35	40	45	50
30	265	265	265	265	265	265	265	265	265	265
35	265	265	265	265	265	265	265	265	265	265
40	265	265	265	265	265	264	264	264	263	263
45	265	265	261	258	256	255	254	254	254	254
50	265	261	253	249	247	246	245	244	244	244
55	265	255	246	241	238	236	235	235	234	234
60	265	250	239	233	229	227	226	225	224	224
65	265	245	232	225	221	218	216	215	214	214
70	265	240	225	217	212	209	207	205	204	204
75	263	235	219	210	204	200	198	196	195	194
80	260	230	213	202	196	191	189	187	185	184
85	257	226	207	195	188	183	180	178	176	175
90	254	222	201	188	180	175	171	169	167	166
95	252	217	196	182	173	167	163	160	158	157
100	249	213	190	176	166	160	156	153	150	149
105	247	209	185	170	160	153	148	145	143	141
110	244	206	180	164	154	147	142	138	136	134
115	242	202	176	159	148	140	135	132	129	127
120	240	198	171	154	142	135	129	125	123	121
125	237	195	167	149	137	129	124	120	117	115
130	235	191	163	144	132	124	119	114	111	109
135	233	188	159	140	128	119	114	109	106	104
140	231	185	155	136	124	115	109	105	102	99
145	229	182	152	132	120	111	105	101	97	95
150	227	179	148	129	116	107	101	97	93	91
155	225	175	145	125	112	103	97	93	89	87
160	223	173	142	122	109	100	94	89	86	83
165	221	170	139	119	106	97	91	86	83	80
170	219	167	136	116	103	94	88	83	80	77
175	217	165	133	113	100	91	85	80	77	74
180	215	162	130	110	97	88	82	77	74	71
185	213	160	128	108	95	86	79	75	71	69
190	211	157	125	105	92	83	77	73	69	66
195	209	155	123	103	90	81	75	70	67	64
200	207	153	120	101	88	79	73	68	65	62
210	204	148	116	96	84	75	69	64	61	58
220	200	144	112	93	80	71	65	61	58	55
230	197	140	108	89	77	68	62	58	54	52
240	194	136	104	86	74	65	59	55	52	49
250	190	132	101	83	71	63	57	52	49	47
λ_L	70·7	46·7	42·3	40·7	40·0	39·7	39·4	39·3	39·2	39·1

Table B2 Bending strength, p_b, (In N/mm²) for rolled sections with equal flanges for p_y = 275 N/mm²

λ \ x	5	10	15	20	25	30	35	40	45	50
30	275	275	275	275	275	275	275	275	275	275
35	275	275	275	275	275	275	275	275	275	275
40	275	275	275	275	274	273	272	272	272	272
45	275	275	269	266	264	263	263	263	263	263
50	275	269	261	257	255	253	253	252	252	251
55	275	262	254	248	246	244	243	242	241	241
60	275	258	246	240	236	234	233	232	231	230
65	275	252	239	232	227	224	223	221	221	220
70	274	247	232	223	218	215	213	211	210	209
75	271	242	225	215	209	206	203	201	200	199
80	269	237	219	208	201	196	193	191	190	189
85	265	233	213	200	193	188	184	182	180	179
90	262	228	207	193	185	179	175	173	171	169
95	260	224	201	186	177	171	167	164	162	160
100	257	219	195	180	170	164	159	156	153	152
105	254	215	190	174	163	156	151	148	146	144
110	252	211	185	168	157	150	144	141	138	136
115	250	207	180	162	151	143	138	134	131	129
120	247	204	175	157	145	137	132	128	125	123
125	245	200	171	152	140	132	126	122	119	116
130	242	196	167	147	135	126	120	116	113	111
135	240	193	162	143	130	121	115	111	108	106
140	238	190	159	139	126	117	111	106	103	101
145	236	186	155	135	122	113	106	102	99	96
150	233	183	151	131	118	109	102	98	95	92
155	231	180	148	127	114	105	99	94	91	88
160	229	177	144	124	111	101	95	90	87	84
165	227	174	141	121	107	98	92	87	84	81
170	225	171	138	118	104	95	89	84	81	78
175	223	169	135	115	101	92	86	81	78	75
180	221	166	133	112	99	89	83	78	75	72
185	219	163	130	109	96	87	80	76	72	70
190	217	161	127	107	93	84	78	73	70	67
195	215	158	125	104	91	82	76	71	68	65
200	213	156	122	102	89	80	74	69	65	63
210	209	151	118	98	85	76	70	65	62	59
220	206	147	114	94	81	72	66	62	58	55
230	202	143	110	90	78	69	63	58	55	52
240	199	139	106	87	74	66	60	56	52	50
250	195	135	103	84	72	63	57	53	50	47
λ_L	68·4	45·5	41·3	39·9	39·2	38·9	38·7	38·6	38·5	38·4