Structural Scheme Design Guide

Version 3.0
August 1998

Ove Arup & Partners
Arup Research & Development

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THE ARUP STRUCTURAL SCHEME DESIGN GUIDE

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VER 3.0 / Aug 1998

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1. BUILDING GEOMETRY AND ANATOMY

1.1 TYPICAL GRID DIMENSIONS[1]

Preferred dimensions:	Offices & retail	6.0, 7.2, 9.0, 10.5, 12, 15m grids
	Some retail outlets	5.5m or 11m grids (to suit shop units)
	Car parks	(7.5 or 7.2) x (15 - 16m) grids (to span full bay)

Modular sizes for horizontal coordinating dimensions of spaces

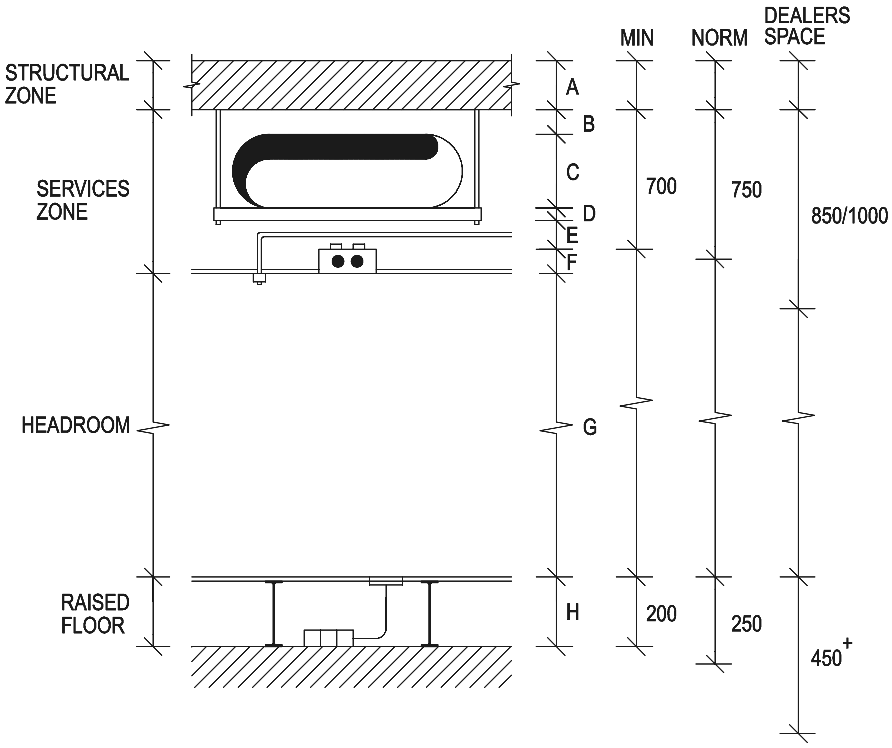
Dimension/space	Range of space (mm)	Multiples of size (mm)
A. Zones for columns and loadbearing walls	200 to 1800	300 or 100
B. Centres of columns and wall zones	from 1200	300 or 100
C. Spaces between column and wall zones	from 1200	300 or 100
D. Openings in walls (e.g. for windows and doorsteps)	from 600	300 or 100
Note: The first preference for the multiple of size in each case is 300		

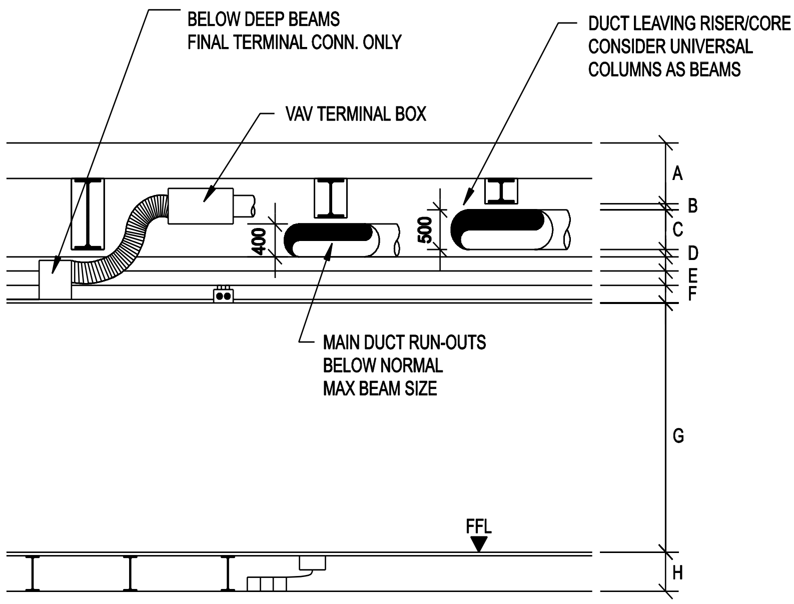
1.2 TYPICAL SECTIONS[1]

Modular sizes for vertical coordinating dimensions of spaces

Dimension/space	Range of space (mm)	Multiples of size (mm)
A. Floor to ceiling, floor to floor (and roof)	up to 3600	100
	from 3600 to 4800	300
	above 4800	600
B. Zones for floors and roofs	100 to 600	100
	above 600	300
C. Changes of floor and roof levels	300 to 2400	300
	above 2400	600
D. Openings in walls (e.g. for windows)	300 to 3000	300 or 100

1.3 TYPICAL SERVICE ZONE REQUIREMENTS[2]





A	Specified by structural engineer
B	50mm deflection and tolerance
C	Approx. 500mm HVAC duct or terminal device
D	50mm support and tolerance
E	50 - 150mm sprinkler zone
F	150mm lighting and ceiling zone
G	Specified by Client / Architect
H	Raised floor - data, telecoms., small power. (Specified by M&E : allow for tolerence & precamber)

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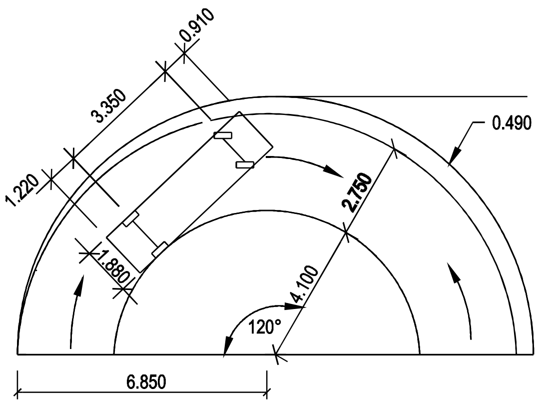
1.4 CAR PARKS

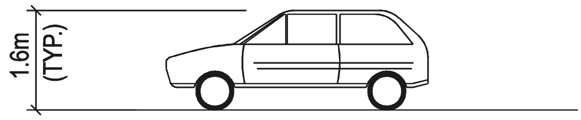
Bay sizes (UK)[3]

Car type	Bay length	Bay width			Turning circle diameter (m)	
		Long stay	General	Short stay	Between kerbs	Between walls
Standard car	4.75	2.30	2.40	2.50	13.0	14.0
Large car	5.65	2.60	2.75	2.90	15.0	-
Disabled persons	4.75	-	3.20 min.	-	-	-
Coaches	12.00	-	4.00	-	Approx. 13.5m	-

Car geometry - area swept for standard large car[3]

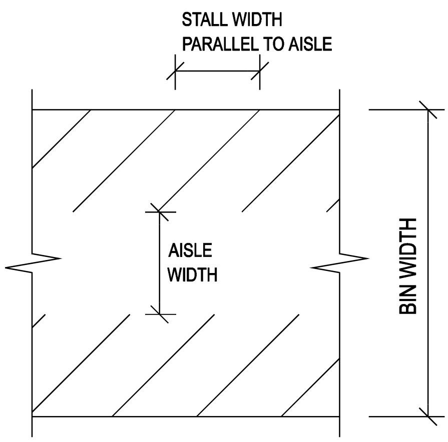
A





ngled parking[3]

Parking angle	Stall width parallel to aisle (m)	Aisle width (one way)		Bin width	
		Minimum (m)	Preferred (m)	Minimum (m)	Preferred (m)
90°	2.40	6.00	6.00	15.50	15.50
80°	2.45	5.25	5.25	15.4	15.4
70°	2.60	4.50	4.70	15.1	15.3
60°	2.80	3.75	4.20	14.4	14.8
50°	3.2	3.50	3.80	13.9	14.2
45°	3.4	3.50	3.60	13.6	13.7



Ramp gradients: recommended maxima[3]

Straight ramps:	rise ≤ 1.500m	1 in 7
	rise > 1.500m	1 in 10
Helical ramps:	rise ≤ 3.000m	1 in 10
	rise > 3.000m	1 in 12

If at the top of a ramp steeper than 1 in 10 the floor or roof is laid to a fall of 1 in 60 or steeper away from the ramp, a transition length should be provided. The transition length length should be at least 3m and its gradient half that of the ramp.

Headroom[3]

Recommended minimum height: 2.050m through the building.
If motorcaravans are to be used, allow approx. 2.300m.
Check if there are any specific access requirements e.g. emergency vehicles.

1.5 REFERENCES

1. BS 6750 : 1986 Modular coordination in building
2. OVE ARUP & PARTNERS, Building Services Concept Design Guide
3. INSTITUTION OF STRUCTURAL ENGINEERS & INSTITUTION OF HIGHWAYS AND TRANSPORTATION, Design Recommendations for Multi-Storey and Underground Car Parks (1984)

3. LOADS

Rev A. 22 Feb 1999, units for load at the end of 3.4 corrected.

3.1 DENSITY OF MATERIALS[1,2]

Material		Density (kN/m^3)	Material		Density (kN/m^3)
Aluminium		27.2	Marble		25.5 - 27.8
Asphalt, paving		22.6	Mastic		11.0
Blockwork	Lightweight	12.6	Mortar, cement		18.9 - 20.4
	Standard	21.2	Mud		16.5 - 18.8
Brickwork	Concrete	22.8	Oils	In bulk	8.8
	Facing	19.7		In barrels	5.7
Cement		14.1		In drums	7.1
Chalk, in lumps		11.0 - 12.6	Plaster		13.3
Clay (in lumps)		11.0	Plasterboard		8.6
Clay (dry)		18.8 - 22.0	Sand	Dry	15.7 - 18.8
Clay (moist)		20.4 - 25.1		Moist	18.1 - 19.6
Clay (wet)		20.4 - 25.1		Wet	18.1 - 20.4
Concrete	Normal	24.0	Sandstones		12.6 - 18.8
	Lightweight	18 - 20	Shale		14.1 - 18.8
Crushed brick		12.6 - 15.7	Slate, Welsh		28.2
Crushed stone		17.3 - 20.4	Snow	Wet compact	3.1
Foamed blocks		13.0		Fresh	0.9
Glass		27.4	Steel		78.5
Gravel, clean		14.1 - 17.3	Timber	C18	- 3.8
Iron	Cast	70.7	(Softwoods)	C24	- 4.2
	Wrought	75.4		C30	- 4.6
Lead, cast or rolled		111.1	Water		9.8
Limestone		25.1			

3.2 DEAD LOADING

3.2.1 General[1,3]

C In the absence of specific details, use the following:

Floor finish (screed) 75mm	1.2 kN/m^2 on plan
Ceiling boards	0.4 kN/m^2 on plan
False ceiling	0.25kN/m^2
Services: nominal	0.25kN/m^2
HVAC	0.4kN/m^2
Demountable lightweight partitions	1.0 kN/m^2 on plan
Blockwork partitions	2.5 kN/m^2 on plan

External walling:

curtain walling and glazing	0.5 kN/m^2 on elevation
cavity walls (lightweight block/brick)	3.5 kN/m^2 on elevation

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3.2.2 Specific dead loading

C Composite construction[4]

Layer		Typical Thickness (mm)	Typical Dead Load on plan kN/m²
Screed	Normal Lightweight	50	1.2 0.9
Slab	Normal Lightweight	130	2.8 - 3.3 * 2.3 - 2.6 *

The lower value is for a trapezoidal deck (Ribdeck AL), the higher value is for a re-entrant profile (Holorib).

C Cladding[1]

Cladding Arrangement		Load on Elevation (kN/m²)
Cladding sheeting and fixings		0.5
Steel wall framing only		0.25 - 0.4
Framing + brick panels and windows		2.4
Framing + steel sheeting		0.75
Windows, industrial type		0.25
Patent glazing:	single	0.3
	double	0.55
Doors - industrial wood		0.4
Lath + plaster + studding		0.5
Plate glass / 25mm thick		0.65
Lead plywood		

C Walls

Wall type	Composition	Dead load on elevation (kN/m²)
Concrete walls	225 wall 12mm plaster each face	5.4 0.2
Masonry wall (280 cavity)	102.5 brick 100 lightweight block and plaster	2.25 1.15
Party wall	Cavity wall two 102.5 brick leaves plastered both sides	5.0
Internal wall	100mm lightweight block plastered both sides 102.5mm brick plastered both sides 225mm thick plastered both sides	1.4 2.75 4.4
Curtain wall	Glazing + spandrel	1.0
Acoustic wall	265 brick and block	2.5
Partition	Demountable	1 on plan
	Stud with lath & plaster	0.76

Roofs[1,5]

Description	Dead load on plan (kN/m^2) (Assuming flat)
Bituman roofing felts (3 layers including chipping)	0.29
Ceiling tray/panels	0.25
Asphalt (19mm, 25mm)	0.41, 0.58
Tiles (clay laid to 100mm gauge)	0.62 - 0.70
Concrete tiles interlocking	0.48 - 0.55

3.3 TYPICAL IMPOSED LOADING[2]

C Be generous at scheme design stage
C Allow for change of use and flexibility of building.
C Make no allowance for imposed load reductions during the scheme design except when assessing the load on foundations.

Use of structure	Intensity of distributed loading (kN/m^2)	Concentrated load
Assembly areas	5.0	3.6
Banking hall	3.0	2.7
Bedrooms (hotels, hospitals)	2.0	1.8
Book stores	2.4 for each metre of storage height (min 6.5)	7.0
Churches	3.0	2.7
Classrooms	3.0	2.7
Communal kitchens	3.0	4.5
Corridors	4.0	4.5
Domestic, floor	1.5	1.4
Factories (general industrial)	5.0	4.5
File rooms in offices	5.0	4.5
- compactus †	7.5	
Garages (cars and light vans)	2.5	9.0
Grandstands (fixed seats)	5.0	3.6
Gymnasia	5.0	3.6
Libraries		
- reading rooms	4.0	4.5
- mobile racking	4.8 for each metre of storage height (min 9.6)	7.0
Plant / motor rooms etc.	7.5	4.5
Museum floors	4.0	4.5
Rooms with mainframe computers	3.5	4.5
Offices, general	2.5 *	2.7
Shops (not stock rooms)	4.0	3.6

* This may increase up to 5.0 kN/m^2 depending on the clients requirements, add 1.0 kN/m^2 for lightweight demountable partitions.

† Compact filing system (usually over a small proportion of the floor area e.g. adjacent to cores).

3.4 IMPOSED LOADS ON BARRIERS

3.4.1 The horizontal force *F* (in kN), normal to and uniformly distributed over any length of 1.5m of a barrier for a car park, required to withstand the impact of a vehicle is given by:

$$F = \frac{0.5mv^2}{\delta_c + \delta_b}$$

where m Is the gross mass of the vehicle (in kg);
v is the velocity of the vehicle (in m/s) normal to the barrier;
δ_c is the ceformation of the vehicle (in mm);
δ_b is the deflection of the barrier (in mm).

Variables	Mass of vehicles <2500 kg	Mass of vehicles >2500 kg
m	1500	mass of vehicles
v	4.5	4.5
δ_c	10	100

Note : where δ_b = 0 use F = 150 kN for mass of vehicle = 2500 kg.

3.5 REFERENCES

1. SCI, Steelwork Design Guide to BS 5950 (Vol. 4) (1991)
2. OVE ARUP & PARTNERS, Metric Handbook (1970)
3. IStructE & ICE, Manual for the design of reinforced concrete building structures ("Green Book") (1985)
4. RICHARD LEES Ltd, Steel Deck Flooring Systems
5. BS 6399 - Parts 1 & 2

4.1 PROPERTIES OF STRUCTURAL MATERIALS

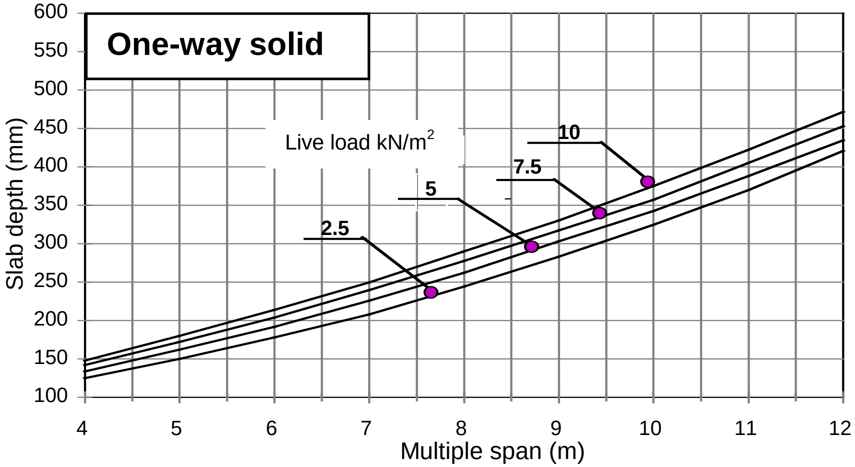
Material	Modulus of elasticity, E (kN/mm^2 or GPa)	Shear modulus (units of E)	Poisson's ratio	Thermal expansion (x 10^{-6} K^{-1})	Density
Concrete, f_{cu}=35	21 to 33 (at 28 days)	0.42 E	0.20	7 - 12	24
Concrete, f_{cu}=40 (e.g. prestressed)	22 to 34 (at 28 days)	0.42 E	0.20	7 - 12	24
Steel	205	0.38 E	0.30	12	78.5
Aluminium alloy	70	0.37 E	0.33	23	27.2
Stainless steel	See section 4.9				
Aluminium bronze	105	0.42 E	0.30	16 - 19	
Cast iron	65 - 95	0.4 E	0.25	11 - 13	70.7
Wrought iron	150 - 220	0.4 E	0.25	11 - 12	75.4
Timber (softwoods) C18 C24 C30	6.0 (min) 7.2 (min) 8.2 (min)	0.06 E 0.06 E 0.06 E	- - -	- - -	~3.8 ~4.2 ~4.6
Masonry	900 x f_k (f_k in kN/mm^2 or GPa)	-	-	4-8 (clay) 11-15 (CaSi)	
Water	-	-	-	60	9.8

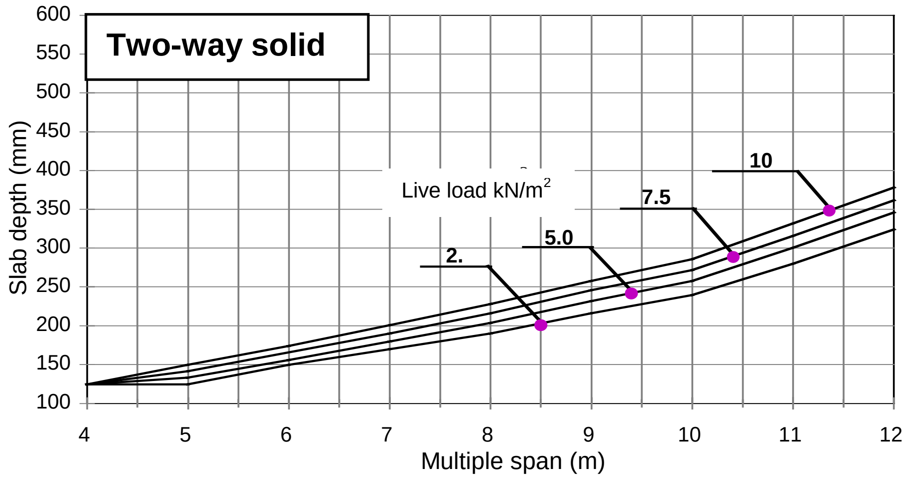
Note: The values given for concrete above are typical and vary with age, shrinkage and creep

4.2 REINFORCED CONCRETE
4.2.1 RULES OF THUMB

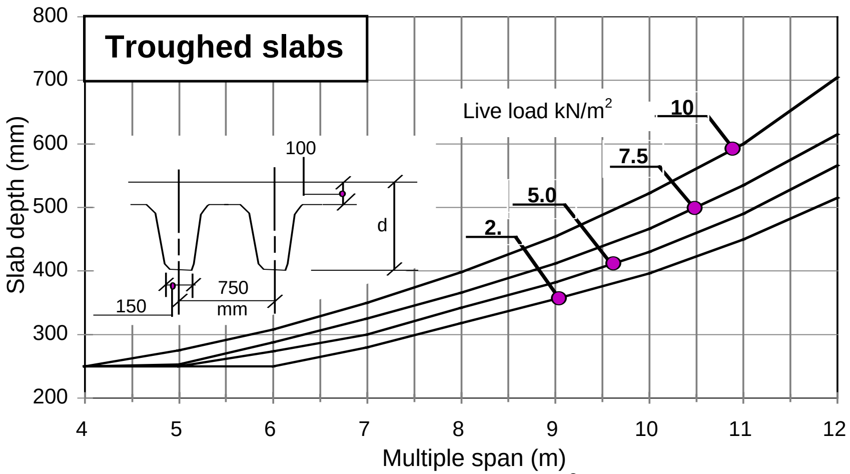
Span/depth ratios for slabs[1,7]

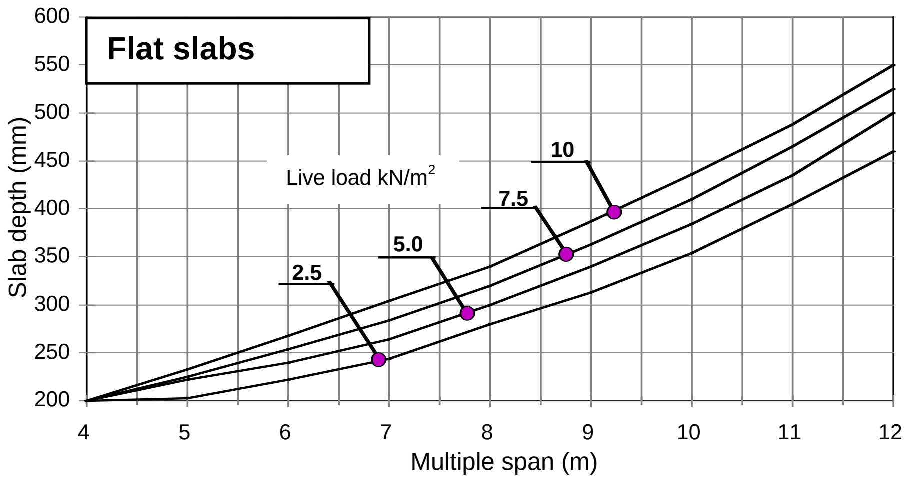
Slabs requiring support from beams





Slabs requiring support from columns only





Design assumptions : 3 spans. Loads: 1.5kN/m^2 has been allowed in addition to self-weight for finishes and services. Exposure: mild exposure conditions and one hour fire resistance. Materials in-situ: C35 concrete, main steel, fy = 460N/mm^2, mild steel links, fy = 250 N/mm^2

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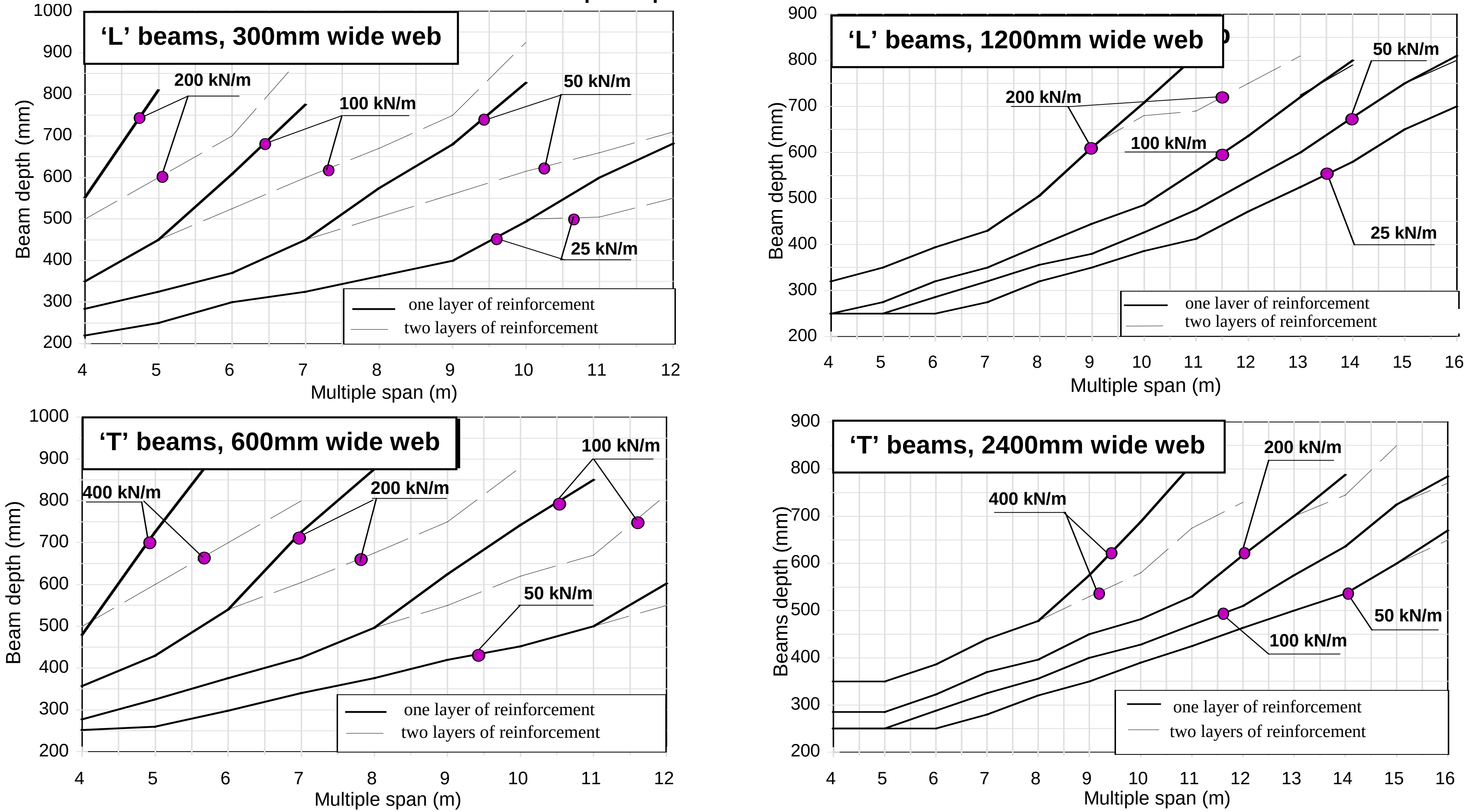
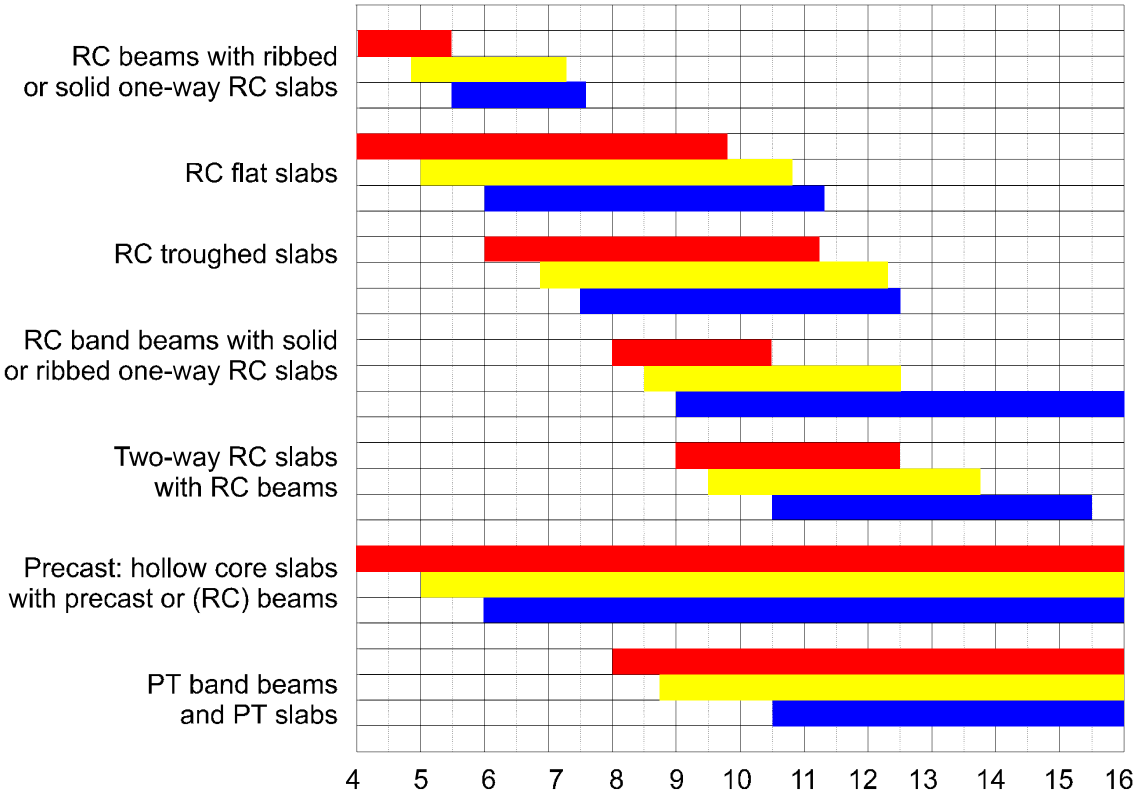
Span/depth ratios for beam[1,7]



For the depth of a single span look up size at span +2%

Design assumptions : Beam self weight (extra over an assumed 200mm depth of slab) allowed for and included. Exposure: mild exposure conditions and one hour fire resistance. Materials in-situ: C35 concrete, main steel, fy = 460N/mm^2. T beam width = Beam span / 3.5. Loads are Ultimate.

Concrete Floor Slabs: Typical Econmic Span Ranger



Key

- Square panels, aspect ratio 1.0
- Rectangular panels, aspect ratio 1.25
- Rectangular panels, aspect ratio 1.5

Note
all subject to market conditions and project specific requirements
RC=Reinforced concrete PT=Post-tensioned concrete

Typical column size^2 - also see section 4.2.6

Minimum column dimensions for 'stocky', braced column = clear height / 17.7

Column area where f_{cu} = 35 N/mm^2 and f_y = 460 N/mm^2 is as follows (N is axial force in Newtons):-

1% steel : Area = N/15
2% steel : Area = N/18
3% steel : Area = N/21

Approximate method for allowing for moments: multiply the axial load from the floor immediately above the column being considered) by:

1.25-interior columns
1.50-edge columns
2.00-corner columns

but keep the columns to constant size for the top two storeys.

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Typical wall thickness

At least 200mm thick (usually 300mm) for normal loads - if less than 1000mm high then 150mm thick is usually allowable.

Internal walls: Thickness > Height/15 (unrestrained at top)
Thickness > Height/30 (restrained at top)

Minimum size of elements[2]
Where different, values for Hong Kong[6] are in brackets.

Member	Minimum dimension, mm	Fire Rating		
		4h	2h	1h
Columns fully exposed to fire	width Cover	450 25 (35)	300 25 (35)	200 20 (25)
Beams	width cover	240 (280) 70 (80)	200 50	200 45
Slabs with plain soffit	thickness cover	170 45 (55)	125 35	100 35
Slabs with ribbed open soffit and no stirrups	thickness width of ribs cover	150 150 55	115 110 35	90 90 35

Cover to **main** reinforcement[2]

Conditions of exposure	Nominal cover				
Mild - protected from adverse conditions	25	20	20*	20*	20*
Moderate - condensation, soil	-	35	30	25	20
Severe - severe rain, occasional freezing	-	-	40	30	25
Very severe - sea water spray, severe freezing, salts	-	-	50†	40†	30
Extreme - abrasive action, acidic water, vehicles	-	-	-	60†	50
Maximum free water/cement ratio	0.65	0.60	0.55	0.50	0.45
Minimum cement content (kg/m^3)	275	300	325	350	400
Lowest grade of concrete	C30	C35	C40	C45	C50

Cover to **all** reinforcement[1]
*These covers may be reduced to 15mm provided that the nominal maximum size of aggregate does not exceed 15mm.
† Where concrete is subject to freezing whilst wet, air-entrainment should be used.
NOTE : This table relates to normal-weight aggregate of 20mm nominal size.

Reinforcement weights[2]

These values are approximate and should be used only as a check on the total estimated quantity:

Pile caps	-	110 - 150 kg/m^3
Rafts	-	60 - 70 kg/m^3
Beams	-	125 - 160 kg/m^3
Slabs	-	130 - 220 kg/m^3
Columns	-	220 - 300 kg/m^3
Walls	-	40 - 100 kg/m^3

Reinforcement availability

Standard sizes (mm): 6, 8, 10, 12, 16, 20, 25, 32, 40

Standard lengths: > 12mm diameter: 12 metres
< 12mm diameter: from a coil

4.2.2 LOAD FACTORS[3]

Partial safety factors for loads (Values in brackets are for H.K.)

Load combination (including earth and water loading where present)	Load type					
	Dead, G_k		Imposed, Q_k		Earth and water, E_n	Wind W_k
	adverse	beneficial	adverse	beneficial		
1. Dead and imposed	1.4 (1.5)	1.0	1.6 (1.7)	0	1.4*	-
2. Dead and wind	1.4	1.0	-	-	1.4*	1.4
3. Dead, wind and imposed	1.2	1.2	1.2	1.2	1.2	1.2

* For pressures arising from accidental head of water at ground level, a partial factor of 1.2 may be used.

Note : The HK dead & imposed factors can be reduced to 1.4 & 1.6 provided the procedure outlined in - PNAP 18F is followed.

The 'adverse' and 'beneficial' factors should be used so as to produce the most onerous condition.

4.2.3 BEAMS[3]

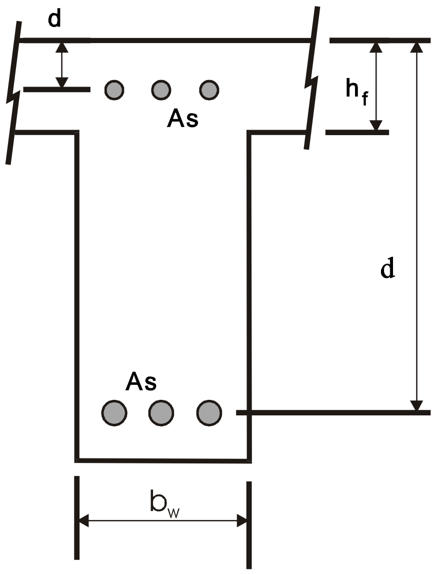
For high-tensile reinforcement: $f_y = 460$ N/mm^2
For mild steel: $f_y = 250$ N/mm^2

Bending

$M_u = 0.156 f_{cu} b d^2$

If: $M < M_u$ $\rightarrow$ no compression steel

$$A_s = \frac{M}{0.87 f_y 0.8 d}$$



If: $M > M_u$ $\rightarrow$ compression steel required

$$A_s' = \frac{M - 0.15 f_{cu} b d^2}{0.87 f_y (d - d')}$$

$$A_s = \frac{M_u}{0.87 f_y 0.8 d} + A_s'$$

where b equals:

	Simply supported	Continuous	Cantilever
T-Beam	$b_w + L / 5$	$b_w + L / 7.14$	b_w
L-Beam	$b_w + L / 10$	$b_w + L / 14.29$	b_w
and ≤ (i) actual flange width, (ii) beam spacing			

NOTE: If $M > 0.4 f_{cu} b_f h_f (d-0.5h_f)$ for flanged beams, then the neutral axis is in the web and the above formulae are not correct.

Maximum and minimum areas of longitudinal reinforcement for beams[2]

Minimum tension reinforcement (f_y = 460 N/mm²)

Rectangular beams with overall dimensions b and h		0.002 bh
Flanged beams (web in tension) :	$b_w/b < 0.4$ $b_w/b \geq 0.4$	0.0018 b_wh 0.0013 b_wh
Flanged beams (flange in tension over a continuous support):	T - beam L - beam	0.0026 b_wh 0.0020 b_wh
Transverse reinforcement in flanges of flanged beams (may be slab reinforcement)		0.0015 h_f per metre width

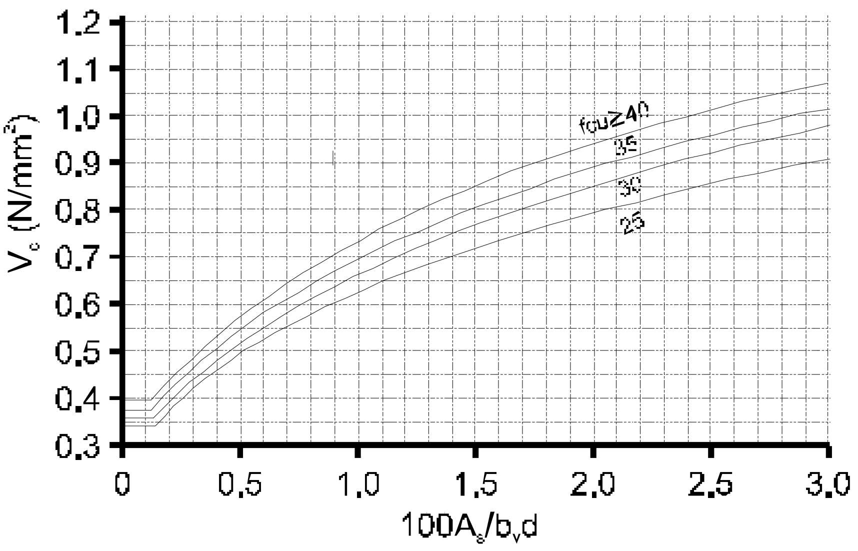
Minimum compression reinforcement:	Rectangular beam	0.002 bh
	Flanged beam web in compression:	0.002 b_wh

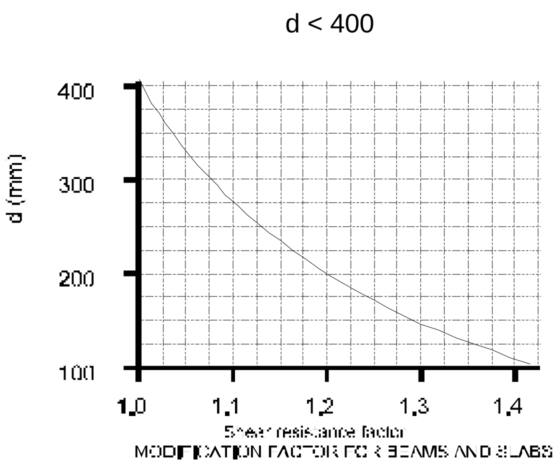
Maximum reinforcement (tension and compression): 0.04 b_wh
Normally main bars in beams should be not less than 16mm diameter.

Shear[3]

Minimum provision of links in beams	
Value of v (N/mm^2)	Area of shear reinforcement
Less than $0.5v_c$	Grade 250 (mild steel) links equal to 0.18% of the horizontal section throughout the beam, except in members of minor structural importance such as lintels
$0.5v_c<v<(v_c+0.4)$	Minimum links for whole length of beam $A_{sv} > \frac{0.4 b_w s_v}{0.95 f_{yv}}$
$(v_c+0.4)<v$	Links only provided $A_{sv} > b_w \frac{s_v(v - v_c)}{0.95 f_{yv}}$
$v < 0.8\sqrt{f_{cu}}$ and < 5 N/mm^2	For beams 2.0 N/mm^2 typical maximum For ribs 0.6 N/mm^2 typical maximum

NOTE: A_{sv} is the total cross-section of the link(s) in mm^2 (2 legs for a single closed link, 4 legs for double closed). s_v is the link spacing along the member.





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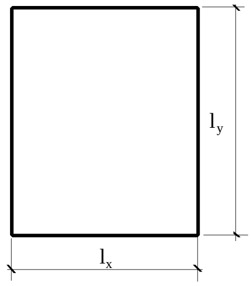
4.2.4 SLABS

Bending[3]

Simply supported on all sides:

$l_y > 1.5l_x$ then one-way spanning, else $M = \frac{wl_xl_y}{24}$ kNm/m

Design for bending as for beams (in 2 directions)



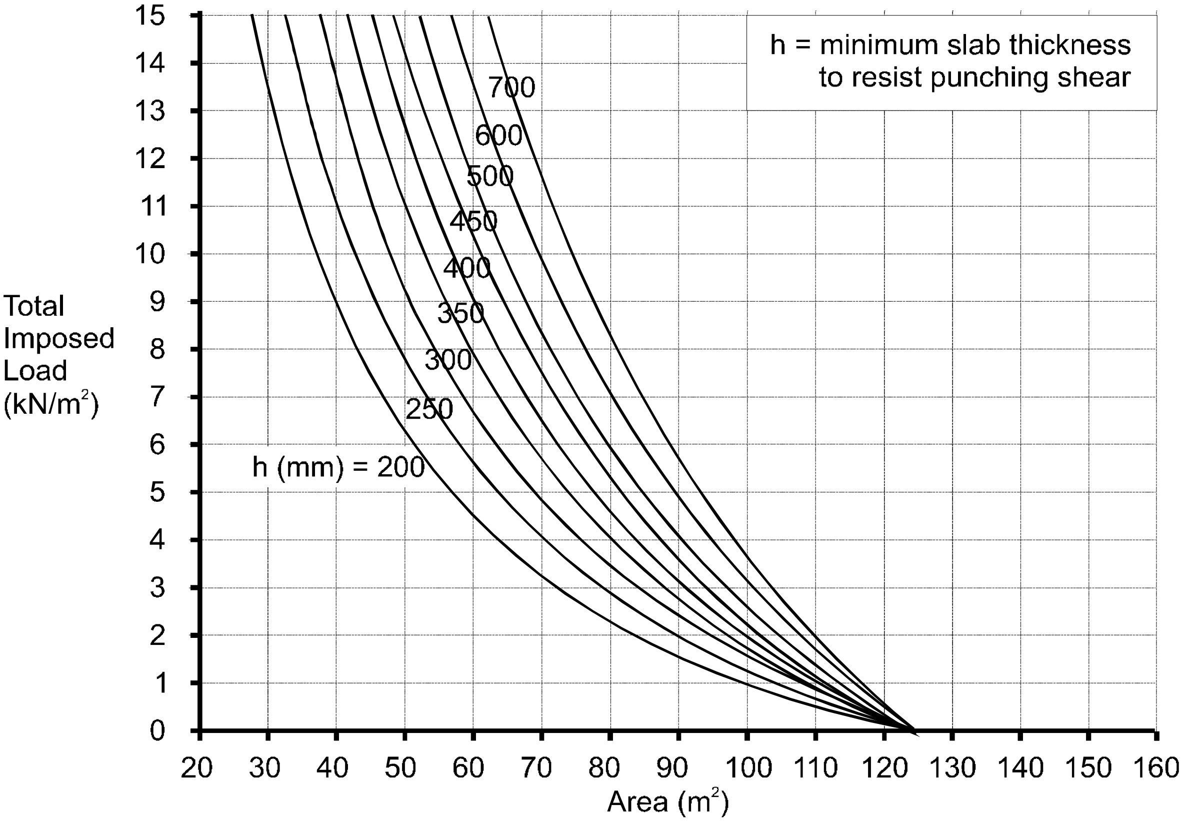
Continuous one-way spanning:

Bending moments and shear forces for one-way slabs					
	End support	End span	Penultimate support	Interior spans	Interior supports
Moment	0	0.086 Fl	-0.086 Fl	0.063 Fl	-0.063 Fl
Shear	0.4 F	-	0.6 F	-	0.5 F

Shear

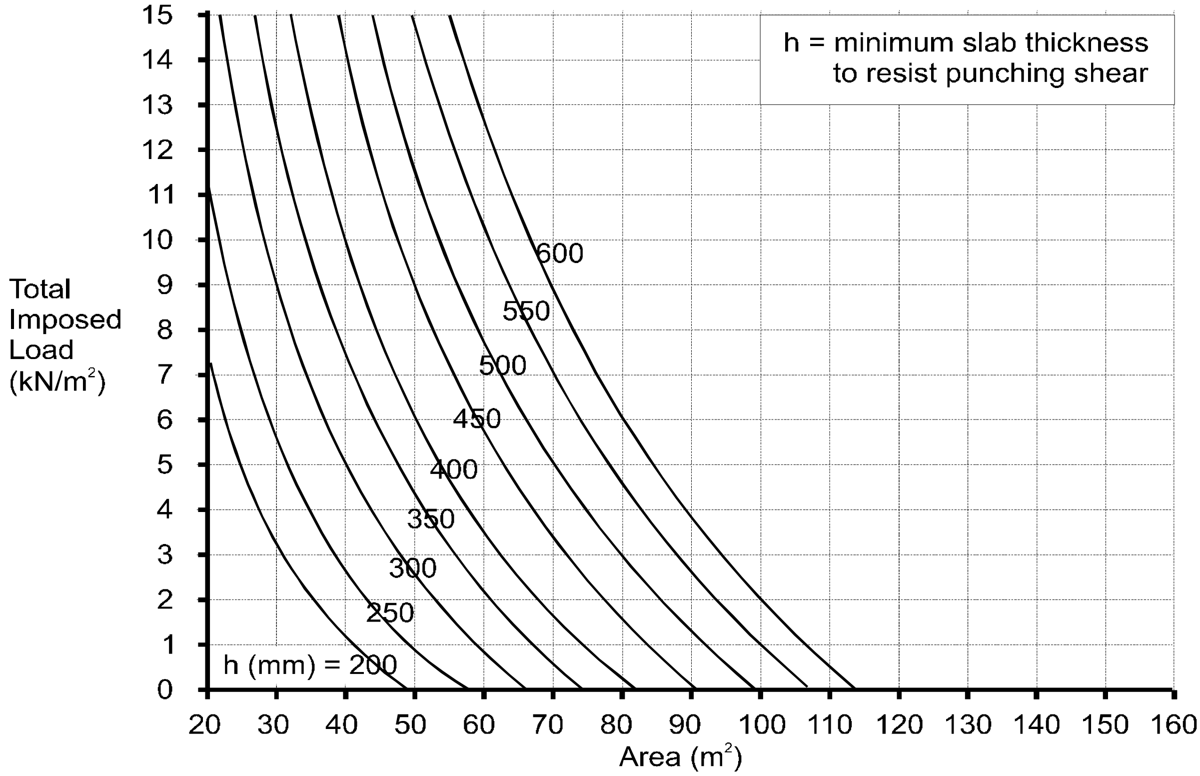
Ultimate shear check at column face
Column (inc. head) 300 x 300

Note: For column sizes other than 300 x 300 the slab depth should be multiplied by the factor = (column perimeter/1200)

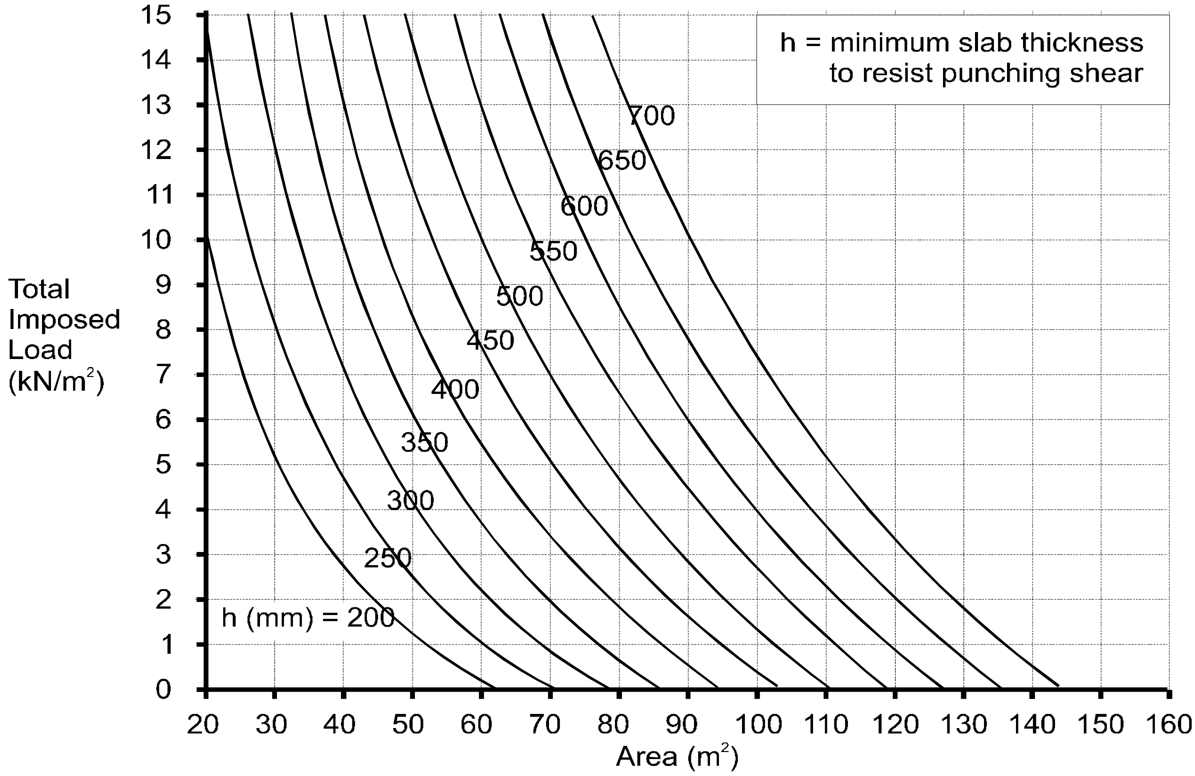


Notes:
1. f_{cu} = 35 N/mm²,
2. Dead load factor = 1.4,
3. Live load factor = 1.6,
4. The value of d/h is assumed to be 0.85,
5. The ratio of V_{eff}/V is assumed to be 1.15,

Column 300 x 300
Punching shear check at first perimeter for preliminary design (v_c = 0.6)



Column 500 x 500
Punching shear check at first perimeter for preliminary design (v_c = 0.6)



Notes:
1. f_{cu} = 35 N/mm²,
2. Dead load factor = 1.4,
3. Live load factor = 1.6,
4. The value of d/h is assumed to be 0.85,
5. The ratio of V_{eff}/V is assumed to be 1.15,

4.2.5 STIFFNESS[3]

Typically require :	Total deflection	< span/250
	Live Load + creep	< span/350
	and	< 20mm

Criterion satisfied if span / effective depth < (Basic x C_1 x C_2 x C_3)

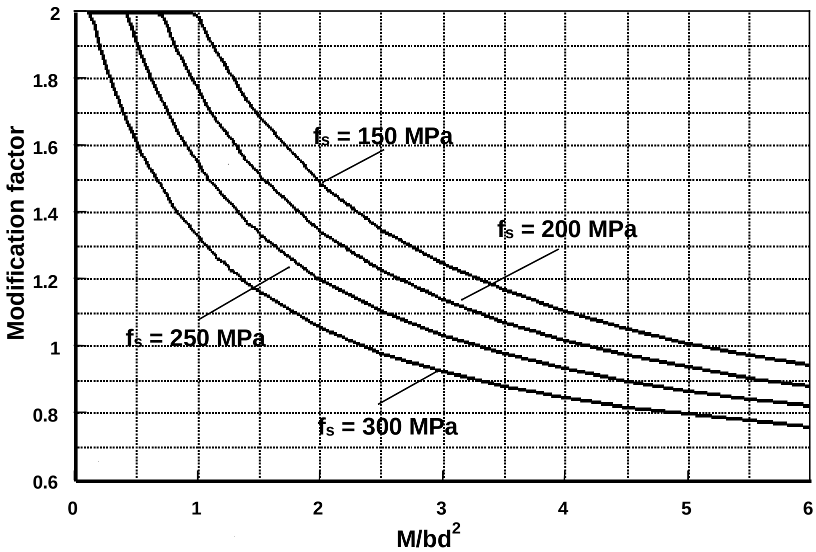
Typical multipliers (C1):
C1 = 0.8 for flanged beams with $b_w/b < 0.3$
C1 = 10/span(m) for spans beyond 10m
C1 = 0.9 for flat slabs (use longer span)

NOTE: For two-way slabs on continuous support, use shorter span.

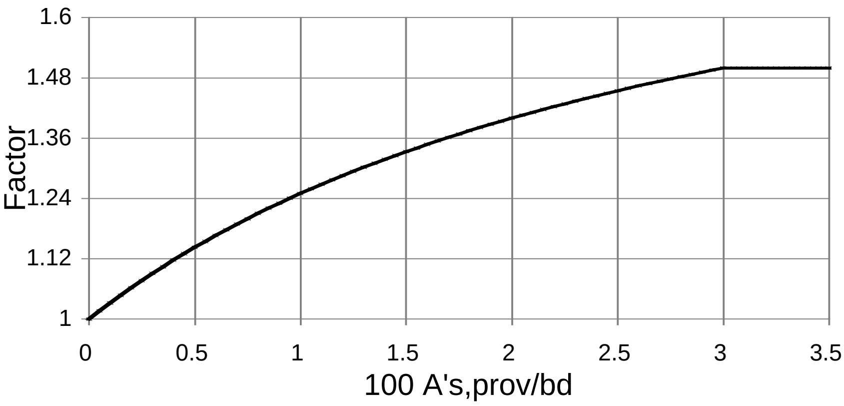
Basic span/effective depth ratios for rectangular beams	
Support conditions	Rectangular sections
Cantilever	7
Simple supported	20
Continuous	26

Tension reinforcement modification factor (C_2)[4]

f_S = service stress in reinforcement



Compression reinforcement modification factor (C_3)



4.2.6 COLUMNS

Typical design of columns[3]

For braced stocky columns use: $N_{cap} = 0.35\ f_{cu}A_c + 0.67\ f_yA_{sc}$

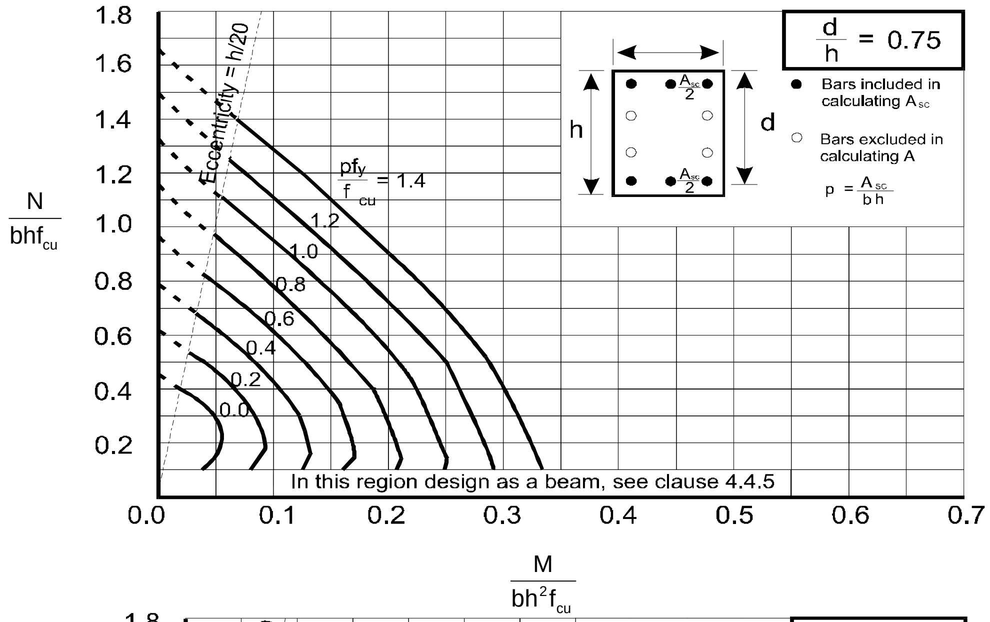
where: f_{cu} = characteristic strength of concrete (N/mm²)
A_c = area of concrete (mm²)
f_y = yield strength of reinforcement (N/mm²)
A_{sc} = area of rebars (mm²)

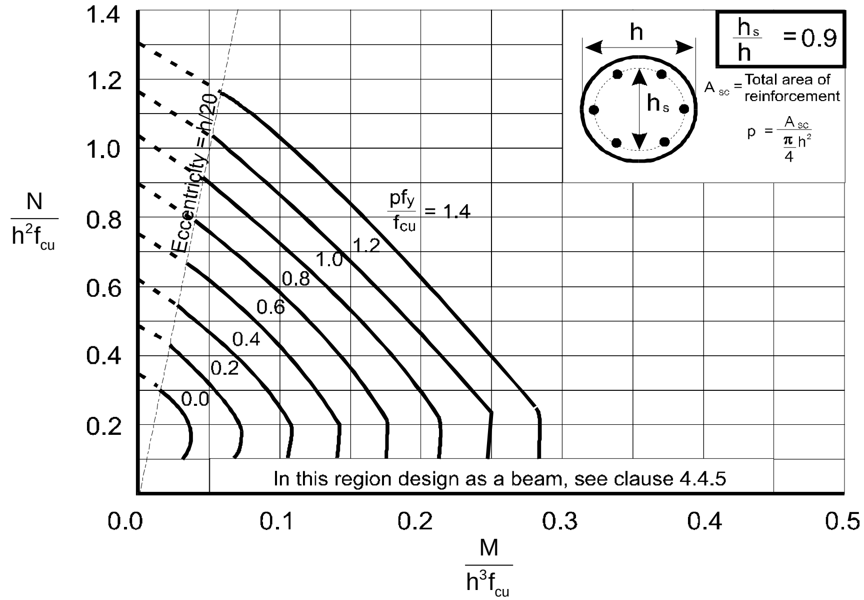
Ultimate resistance of braced stocky columns (f_{cu} = 35)

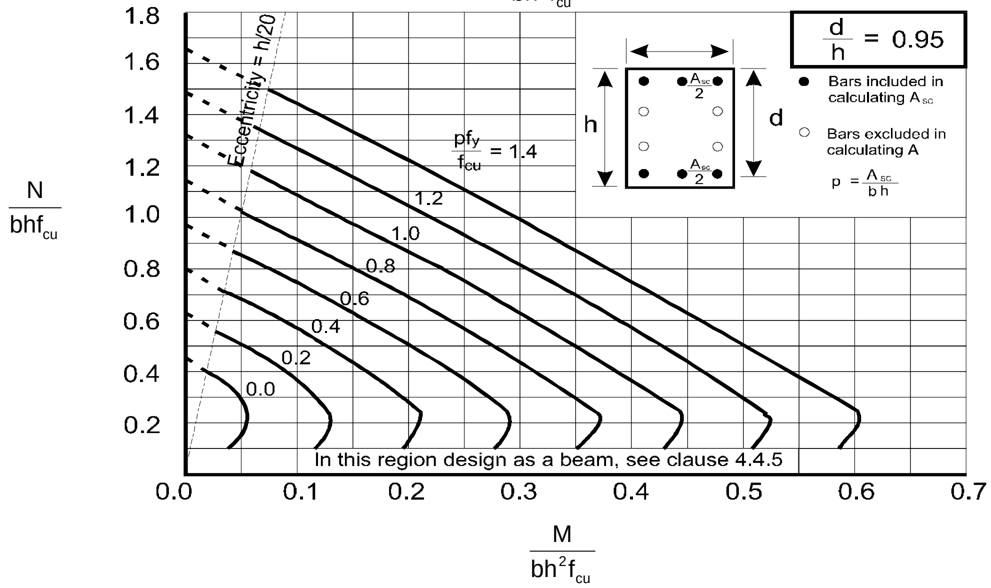
Column size & braced, clear storey height limit (mm)					Area of section ($mm^2 \times 10^3$)	p=1% (kN)	p=2% (kN)	p=3% (kN)	p=4%* (kN)
< 3530	< 4411	< 5294	< 6176	< 7059					
200 x 450	250 x 360	300 x 300			90	1369	1635	1901	2168
200 x 525	250 x 420	300 x 350			105	1597	1908	2218	2529
200 x 615	250 x 490	300 x 410	350 x 350		122.5	1863	2225	2588	2950
200 x 700	250 x 560	300 x 470	350 x 400		140	2129	2543	2958	3372
200 x 800	250 x 640	300 x 540	350 x 460	400 x 400	160	2433	2907	3380	3854
200 x 900	250 x 720	300 x 600	350 x 520	400 x 450	180	2737	3270	3803	4335
200 x1000	250 x 800	300 x 670	350 x 575	400 x 500	200	3041	3633	4225	4817
200 x1200	250 x 960	300 x 800	350 x 690	400 x 600	240	3650	4360	5070	5781

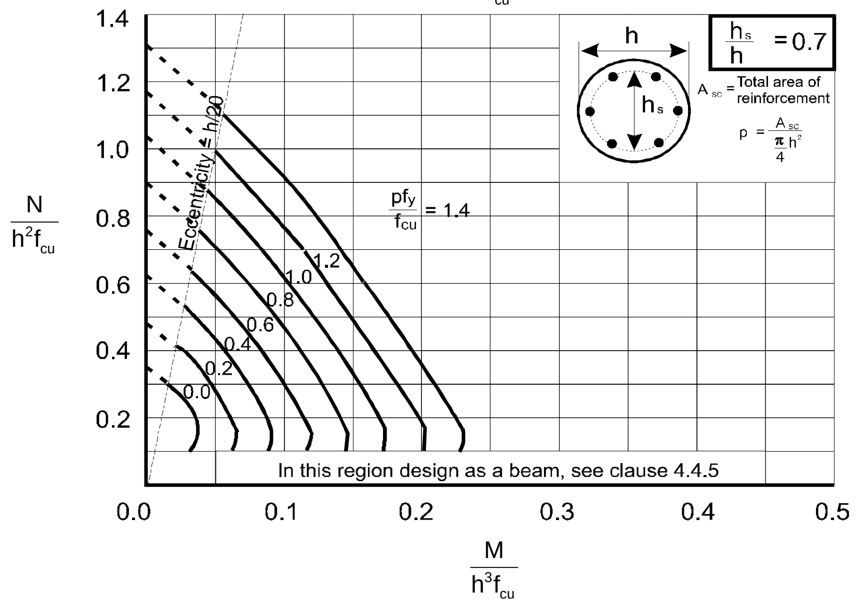
* Note : Scheme design based on 4% rebar should be avoided if possible.

Column interaction diagrams[2]









4.2.7 CREEP & SHRINKAGE

Shrinkage

For normal situations, assume long term shrinkage strain of 300 x 10 $^{-6}$

Creep

For normal situations, assume creep coefficient of $\phi = 2$

Hence long term E value: $E = \frac{E_{28}}{1+\phi}$

4.2.8 BAR AND MESH AREAS AND WEIGHTS[5]

ϕ = diameter (mm); p = pitch (mm)

Sectional area (mm²) per m. width									
φ p	6	8	10	12	16	20	25	32	40
50	566	1006	1570	2262	4022	6284	9818	16084	25132
75	376	669	1044	1504	2675	4179	6529	10696	16713
100	283	503	785	1131	2011	3142	4909	8042	12566
125	226	402	628	905	1609	2514	3927	6434	10053
150	189	335	523	754	1341	2095	3273	5361	8377
175	162	287	449	646	1149	1795	2805	4595	7180
200	142	252	393	566	1006	1571	2455	4021	6283
250	113	201	314	452	804	1258	1964	3217	5026
300	94	168	262	377	670	1047	1636	2681	4189

Weight (kg/m²)									
φ p	6	8	10	12	16	20	25	32	40
50	4.44	7.90	12.32	17.76	31.58	49.32	77.08	126.26	197.28
75	2.96	5.27	8.21	11.84	21.05	32.88	51.39	84.17	131.52
100	2.22	3.95	6.16	8.88	15.79	24.66	38.54	63.13	98.64
125	1.78	3.16	4.93	7.10	12.63	19.73	30.83	50.50	78.91
150	1.48	2.63	4.11	5.92	10.53	16.44	25.69	42.09	65.76
175	1.27	2.26	3.52	5.07	9.02	14.09	22.02	36.07	56.36
200	1.11	1.98	3.08	4.44	7.90	12.33	19.27	31.57	49.32
250	0.89	1.58	2.46	3.55	6.32	9.86	15.42	25.25	39.46
300	0.74	1.32	2.05	2.96	5.26	8.22	12.85	21.04	32.88

Sectional Area (mm^2)									
ϕ n	6	8	10	12	16	20	25	32	40
1	28	50	79	113	201	314	491	804	1257
2	57	101	157	226	402	628	982	1608	2513
3	85	151	236	339	603	943	1473	2413	3770
4	113	201	314	452	804	1257	1964	3217	5026
5	142	252	393	566	1006	1571	2455	4021	6283
6	170	302	471	679	1207	1885	2945	4825	7540
7	198	352	550	791	1408	2199	3436	5629	8796
8	226	402	628	905	1609	2514	3927	6434	10053
9	255	453	707	1018	1810	2828	4418	7238	11309
10	283	503	785	1131	2011	3142	4909	8042	12566
11	311	553	864	1244	2212	3456	5400	8846	13823
12	340	604	942	1357	2413	3770	5891	9650	15079
ϕ	6	8	10	12	16	20	25	32	40
Perim. (mm^2/mm)	18.8	25.1	31.4	37.7	50.2	62.8	78.5	100.5	125.6
Weight (kg/m)	0.222	0.395	0.616	0.888	1.579	2.466	3.854	6.313	9.864

n = number of bars

BS Fabric reference		Longitudinal wires			Cross wires			Nominal mass per square metre (kg)
		Nominal wire size (mm)	Pitch (mm)	Area (mm^2)	Nominal wire size (mm)	Pitch (mm)	Area (mm^2)	
Square mesh	A 393	10	200	393	10	200	393	6.16
	A 252	8	200	252	8	200	252	3.95
	A 193	7	200	193	7	200	193	3.02
	A 142	6	200	142	6	200	142	2.22
	A 98	5	200	98	5	200	98	1.54
Structural mesh	B 1131	12	100	1131	8	200	252	10.9
	B 785	10	100	785	8	200	252	8.14
	B 503	8	100	503	8	200	252	5.93
	B 385	7	100	385	7	200	193	4.53
	B 283	6	100	283	7	200	193	3.73
	B 196	5	100	196	7	200	193	3.05
Long mesh	C 785	10	100	785	6	400	70.8	6.72
	C 636	9	100	636	6	400	70.8	5.55
	C 503	8	100	503	5	400	49	4.34
	C 385	7	100	385	5	400	49	3.41
	C 283	6	100	283	5	400	49	2.61
Wrapping mesh	D 98	5	200	98	5	200	98	1.54
	D 49	2.5	100	49	2.5	100	49	0.77
Stock sheet size		Length 4.8m		Width 2.4m		Sheet area 11.52m^2		

Shear reinforcement A_{sv} / S_v values for links

No. of Legs	Bar Dia.---Area			Link Spacing Sv												
	8	10	12	100	125	150	175	200	225	250	275	300	325	350	375	400
2	101			1.005	0.804	0.670	0.574	0.503	0.447	0.402	0.366	0.335	0.309	0.287	0.268	0.251
		157		1.571	1.257	1.047	0.898	0.785	0.698	0.628	0.571	0.524	0.483	0.449	0.419	0.393
			226	2.262	1.810	1.508	1.293	1.131	1.005	0.905	0.823	0.754	0.696	0.646	0.603	0.565
3	151			1.508	1.206	1.005	0.862	0.754	0.670	0.603	0.548	0.503	0.464	0.431	0.402	0.377
		236		2.356	1.885	1.571	1.346	1.178	1.047	0.942	0.857	0.785	0.725	0.673	0.628	0.589
			339	3.393	2.714	2.262	1.939	1.696	1.508	1.357	1.234	1.131	1.044	0.969	0.905	0.848
4	201			2.011	1.608	1.340	1.149	1.005	0.894	0.804	0.731	0.670	0.619	0.574	0.536	0.503
		314		3.142	2.513	2.094	1.795	1.571	1.396	1.257	1.142	1.047	0.967	0.898	0.838	0.785
			452	4.524	3.619	3.016	2.585	2.262	2.011	1.810	1.645	1.508	1.392	1.293	1.206	1.131
6	302			3.016	2.413	2.011	1.723	1.508	1.340	1.206	1.097	1.005	0.928	0.862	0.804	0.754
		471		4.712	3.770	3.142	2.693	2.356	2.094	1.885	1.714	1.571	1.450	1.346	1.257	1.178
			679	6.786	5.429	4.524	3.878	3.393	3.016	2.714	2.468	2.262	2.088	1.939	1.810	1.696

4.2.9 REFERENCES

1. REINFORCED CONCRETE COUNCIL, Reinforcing Links Issue IIA, June 1997.
2. IStructE & ICE, Manual for the design of reinforced concrete building structures ("Green book") (1985)
3. BS 8110, Structural use of concrete, Part 1: 1985 Code of practice for design and construction
4. PALLADIAN PUBLICATIONS, Handbook to BS 8110 (1987)
5. OVE ARUP & PARTNERS, Reinforcement detailing manual (1990)
6. Code of Practice for Fire Resisting Construction, HK, 1996.
7. Goodchild C.H, Economic Concrete Frame Elements (1997),

4.3 PRESTRESSED CONCRETE

4.3.1 RULES OF THUMB

Advantages of using prestressed concrete

- Increased clear spans
- Thinner slabs
- Lighter structures
- Reduced cracking and deflections
- Reduced storey height
- Rapid construction
- Water tightness

Note: use of prestressed concrete does not significantly affect the ultimate limit state (except by virtue of the use of a higher grade of steel).

Maximum length of slab

50m, bonded or unbonded, stressed from both ends.
25m, bonded, stressed from one end only.

Mean prestress

Typically: $P/A \approx 1$ to $2\ N/mm^2$

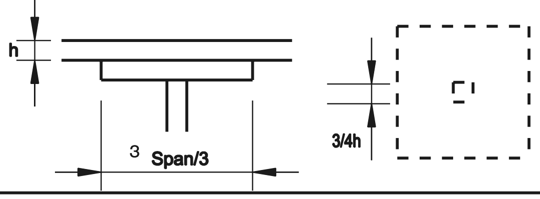
Cover

Take minimum cover to be 25mm.
Allow sufficient cover for (at least) nominal bending reinforcement over the columns, in both directions (typically T16 bars in each direction).

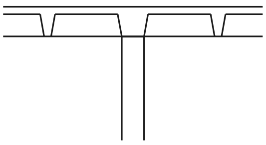
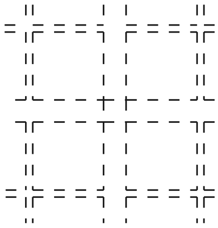
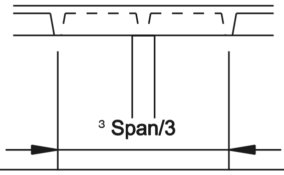
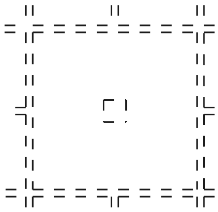
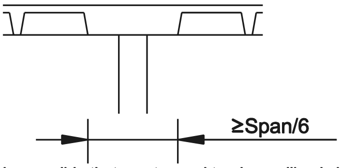
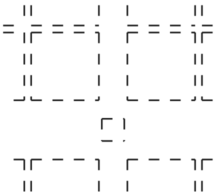
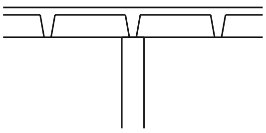
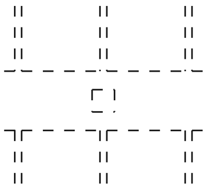
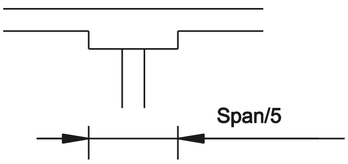
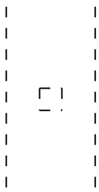
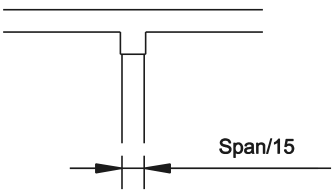
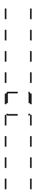
Effect of restraint to floor shortening

Post-tensioned floors must be able to shorten to enable the prestress to be applied to the floor.

Typical span/total depth ratios for a variety of section types of <u>multi-span</u> prestressed floors[2]

Section type	Total imposed loading kpa	Span/ depth ratio 6m – 13m	Additional requirement
1. Solid flat slab 	2.5 5.0 10.0	40 36 30	A
2. Solid flat slab with drop panel 	2.5 5.0 10.0	44 40 34	A

[Typical span/total depth ratios for <u>multi-span</u> prestressed floors (cont.)]

Section type	Total imposed loading kpa	Span/ depth ratio 6m≤ l ≤13m	Additional requirement
3. Coffered flat slab (not meeting the requirement of types 4 or 5)  	2.5 5.0 10.0	25 23 20	B
4. Coffered flat slab with solid panels  	2.5 5.0 10.0	28 26 23	B
5. Coffered flat slab with band beams   Note : It may be possible that prestressed tendons will only be required in the banded section and that untensioned reinforcement will surface in the nos. or vice versa	2.5 5.0 10.0	28 26 23	B
6. Ribbed slab   Note : The values of span/depth ratio can vary according to the width of the beam	2.5 5.0 10.0	30 27 24	B
7. one way slab with broad beam  	2.5 5.0 10.0	SLAB BEAM 45 25 40 22 35 18	A
8. One way slab with narrow beam  	2.5 5.0 10.0	SLAB BEAM 42 18 38 16 34 13	A

*Additional requirements if no vibration check to be carried out for normal office conditions

A ≥4 panels and ≥250mm thick slab or ≥8 panels and ≥200mm thick slab
B ≥4 panels and ≥400mm thick overall or ≥8 panels and ≥300mm thick overall

Note
1. All panels assumed to be square
2. Span/depth ratios not affected by column head

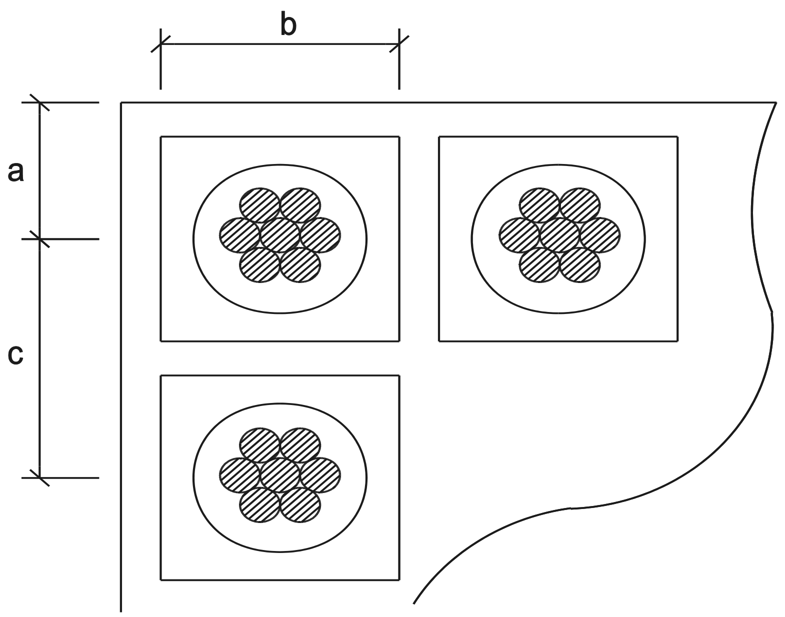
4.3.2 COMMON STRANDS[4]

	Nominal diameter (mm)	Steel area (mm^2)	Mass (kg/m)	Nominal tensile strength (N/mm^2)	Characteristic breaking load (kN)	Modulus of elasticity (kN/mm^2 or GPa)
Standard	15.2	139	1.090	1670	232	195 ± 10
	12.5	93	0.730	1770	164	195 ± 10
	11.0	71	0.557	1770	125	195 ± 10
	9.3	52	0.408	1770	92	195 ± 10
Super	15.7	150	1.180	1770	265*	195 ± 10
	12.9	100	0.785	1860	186	195 ± 10
	11.3	75	0.590	1860	139	195 ± 10
	9.6	55	0.432	1860	102	195 ± 10
	8.0	38	0.298	1860	70	195 ± 10
Compact/ Dyform	18.0	223	1.750	1700	380	195 ± 10
	15.2	165	1.295	1820	300	195 ± 10
	12.7	112	0.890	1860	209	195 ± 10

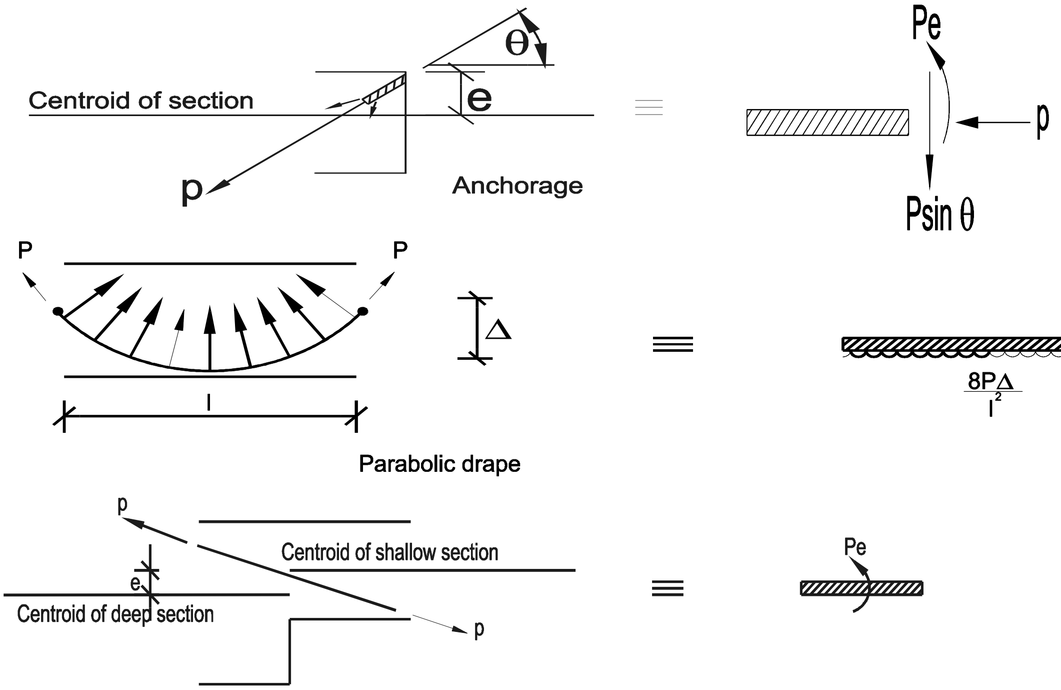
* 279 also available, details not yet published

4.3.3 COMMON TENDONS[1]

No. strands per duct for 15.7mm "super" strand	70% UTS (kN)	Internal sheath (mm)	Anchor sizes			Jack		
			a	b	c	Length (mm)	ϕ (mm)	Stroke (mm)
1	186	25						
7	1299	65	175	210	270	630	350	150
12	2226	75	200	245	300	750	390	250
15	2783	85				750	390	250
19	3525	95	250	315	375	900	510	250
27	5009	110	300	365	450	950	610	250
37	6864	130	375	450	525	1000	720	250



4.3.4 EQUIVALENT LOADS[6]

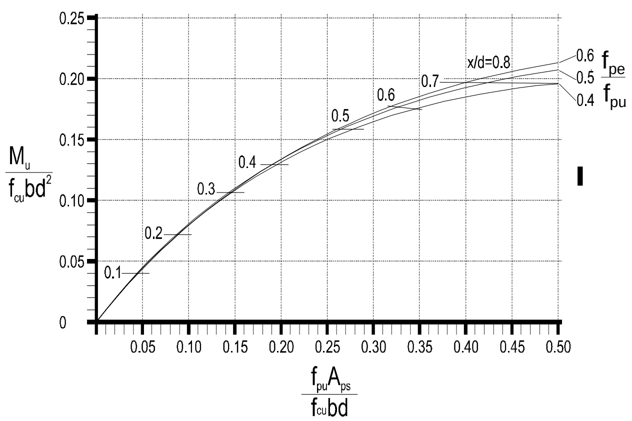


4.3.5 ALLOWABLE STRESSES AT SERVICE LOADS

	In service	At transfer
Compression	beams: $0.33f_{cu}$ ($0.4f_{cu}$ at supports for indeterminate beams) columns: $0.25f_{cu}$	bending: $0.5f_{ci}$ compression: $0.4f_{ci}$
Tension	Class 1: No tension Class 2: 2N/mm² post-tensioned 3N/mm² pre-tensioned Class 3: See BS 8110	1.0 N/mm² $0.45\sqrt{(f_{ci})}$ $0.36\sqrt{(f_{ci})}$

4.3.6 ULTIMATE BENDING STRENGTH[6]

For rectangular beams or T beams with neutral axis in flange:



4.3.7 SHEAR

Require that $v_u < 0.8\sqrt{(f_{cu})}$ and $5N/mm^2$

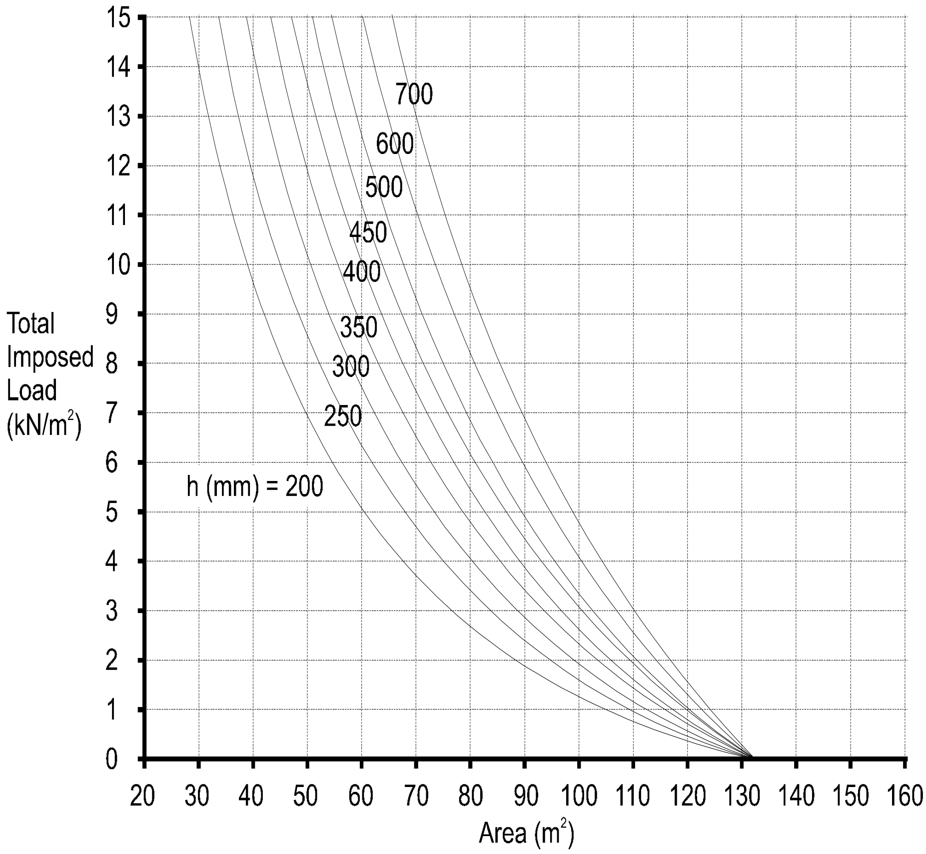
<u>Except</u> that inclined tendons may contribute to a reduced effective shear force on the concrete provided the shear zone is not cracked in bending at M_{ult}.

Ultimate shear check at column face

Column (inc. head) 300 x 300

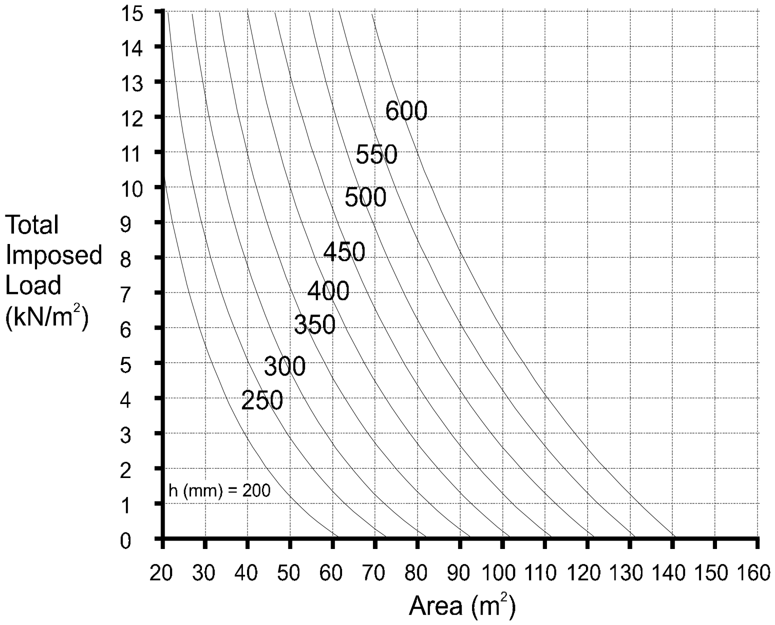
Note: For column sizes other than 300 x 300, the slab depth should be multiplied by the factor (column perimeter/1200)

Explanation

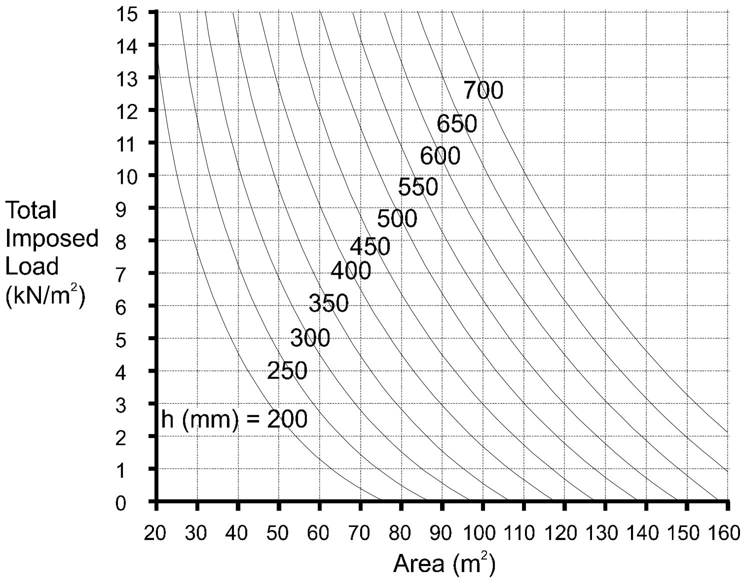


Information to be used in conjunction with the graph:
1. f_{cu} = 40 N/mm²
2. Dead load factor = 1.4
3. Live load factor = 1.6
4. The value of d/h is assumed to be 0.85
5. The ratio of V_{eff}/V is assumed to be 1.15
6. These curves do not take account of elastic distribution effects
7. The maximum shear stress for f_{cu} = 40 N/mm² and more is 5 N/mm².
   For f_{cu} < 40 N/mm² the maximum shear stress is $0.8\sqrt{f_{cu}}$
   For f_{cu} = 35 N/mm² increase slab depth by a factor of 1.06
   For f_{cu} = 30 N/mm² increase slab depth by a factor of 1.14

Column 300 x 300
Punching shear check for preliminary design (v_c = 0.75 N/mm²)



Column 500 x 500
Punching shear check for preliminary design (v_c = 0.75 N/mm²)



4.3.8 REFERENCES

1. PSC FREYSSINET, The 'K' Range
2. ARUP, Notes on Structures 29, June 1991
3. BRIDON ROPES, Ropes and Lifting Gear
4. BS 5896 : 1980, High tensile steel wire and strand for the prestressing of concrete
5. ARUP, Notes on Structures 18, June 1989
6. PALLADIAN PUBLICATIONS, Handbook to BS 8110 (1987)

4.4 STEEL (NON-COMPOSITE)

4.4.1 RULES OF THUMB

- **Choice of beam system**

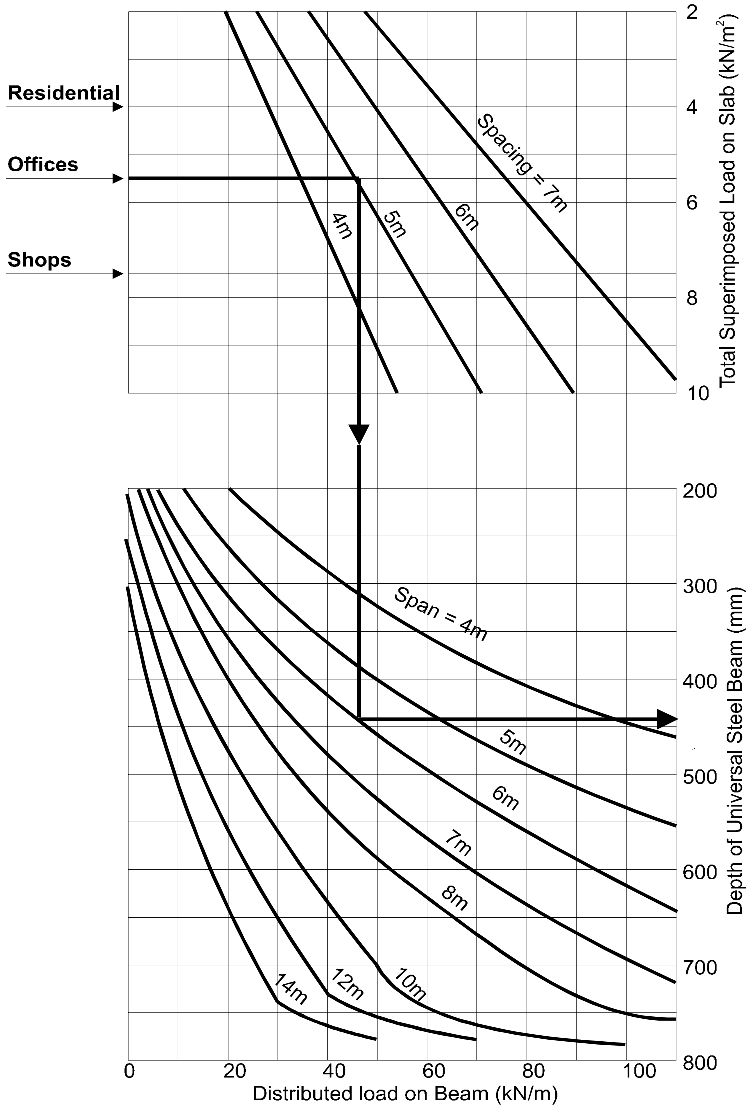
Element	Typical Span/depth	Typical Span (m)
Floor Beams (UB's) (including floor slab)	15-18	up to 12m
Plate girder	10-12	
Slimfloor (steel only)	25-28	6-9m
Castellated UB's*	14-17	12-20m
Lattice girders (RSA's)+	12-15	up to 35m
Lattice girders (Tubular)	15-18	up to 100m
Roof trusses (pitch>20^{O})	14-15	up to 17m
Space Frames	20-24	up to 60m

* Avoid if high point loads; increase Ireq by 1.3
\+ Precamber by L/250

- **Initial scheming chart**

One-or-two spans:
Read depth directly from chart

Multiple spans:
Deduct 50mm from depth estimated by chart



4.4.1 Rules of thumb (Cont'd)

- **Steel grades**

Generally grade 50 (Fe 510) (S 355)is most economical for quantities over 40 tonnes.

Note: Grade 50 not readily available from stockholders. Therefore expect a 6 week additional lead in time. Typically, grade 50B sections cost 5% by weight more than grade 43B --- see section 2.3.

- **Columns**

Preliminary design based on a concentric axial load (see section 4.4.4).

For top storey:
Prelim. design axial load = total axial load + 4 × difference in Y-Y axis load
+ 2 × difference in X-X axis load

For intermediate storey:
Prelim. design axial load = total axial load + 2 × difference in Y-Y axis load
+ 1 × difference in X-X axis load

Typical maximum column sizes for braced frames:

- 203 UC for buildings up to 3 storeys high.
- 254 UC for buildings up to 5 storeys high.
- 305 UC for buildings up to 8 storeys high.
- 356 UC for buildings from 8 to 12 storeys high.

- **Struts and ties**

Slenderness limits:

- members resisting load other than wind: $\lambda \leq 180$
- members resisting self weight and wind only: $\lambda \leq 250$
- members normally acting as a tie but subject to load reversal due to wind: $\lambda \leq 350$

Minimum CHS sections which satisfy slenderness limits

Slenderness Limit	Effective Length (m)				
	4	6	8	10	12
180	76.1 x 3.2	114.3 x 3.6	139.7 x 5.0	168.3 x 5.0	193.7 x 5.0
250	60.6 x 3.2	76.1 x 3.2	114.3 x 3.6	139.7 x 5.0	139.7 x 5.0
350	42.2 x 4.6	60.3 x 3.2	76.1 x 3.2	88.9 x 3.2	114.3 x 3.6

- **Portal Frames**

- Hauch length = span / 10
- Haunch depth = rafter depth (same section)
- Minimum rafter slope = 2.5^{o}
- Rafter depth = span / 60 (approx.)
- Stanchion depth = span / 50 (approx. --- not high bay)

4.4.2 LOAD FACTORS

Loadcase	Dead Load		Imposed Load		Wind	Temperature
	adverse	beneficial	adverse	beneficial		
1. Dead + imposed	1.4	1.0	1.6	0	-	(1.2)
2. Dead + Wind	1.4	1.0	-	-	1.4	(1.2)
3. Dead + imposed + Wind	1.2	1.0	1.2	1.0	1.2	(1.2)
4. Dead + imposed + notional horizontal*	1.4	1.4	1.3	1.3	-	-

* Notional horizontal load: 1% of factored dead load at each level or
0.5% of factored dead plus live load at each level, whichever is greater

4.4.3 DESIGN STRENGTH

Grade BS 4360 : 1986 (BS EN 10025 : 1990)	Thickness (mm)	p_y (N/mm²)	Grade BS 4360 : 1986 (BS EN 10025 : 1990)	Thickness (mm)	P_y (N/mm²)
43 (Fe 430) (S 275)	≤ 16	275	50 (Fe 510) (S 355)	≤ 16	355
	≤ 40	265		≤ 40	345
	≤ 63	255		≤ 63	340
	< 100	245		< 100	325

4.4.4 BEAM DESIGN

Ultimate strength in bending

Compression flange restrained

$M_{cx} = p_y S_x \ngtr 1.2\ p_y S_x$ (plastic & compact)

$M_{cx} = p_y S_x$ (semi-compact)

Requirement :

$M_{cx} \geq M_{max}$

Compression flange unrestrained:

$M_b = p_b S_x \ngtr M_{cx}$ (see restrained beam)

Note : Mb obtained directly from graph (P.5/23)

Requirement :

$M_b \geq mM_{max}$ (for beam not loaded between restrained points)

where $m = 0.57 + 0.33\beta + 0.1\beta^2 \nless 0.43$

β is positive for single curvature, β is negative for double curvature. Conservatively, (and for non equal flange beams) m = 1.0

BENDING

Universal Beams	GRADE 43						GRADE 50						
D×b×Mass (mm×mm ×Kg/m)	M_{cx} kNm	L_1 m (1.0)	L_2 m (0.75)	L_3 m (0.5)	L_4 m (0.35)	P_v kN	M_{cx} kNm	L_1 m (1.0)	L_2 m (0.75)	L_3 m (0.5)	L_4 m (0.35)	P_v kN	Intermediate masses (kg/m)
914×419×388	4680	3.9	7.7	12.5	-	3150	6020	3.4	6.8	10.8	15.0	4100	
914×419×343	4100	3.8	7.3	12.0	-	2810	5270	3.4	6.7	10.5	14.4	3660	
914×305×289	3340	2.7	5.1	8.2	11.5	2890	4280	2.4	4.5	7.5	10.1	3760	253, 224
914×305×201	2220	2.5	4.7	7.2	9.7	2180	2840	2.2	4.3	6.4	8.5	2840	
838×292×226	2430	2.5	4.8	7.7	10.7	2180	3110	2.3	4.3	6.8	9.2	2840	194
838×292×176	1800	2.4	4.6	7.0	9.4	1860	2320	2.1	4.2	5.3	8.2	2420	
762×267×197	1900	2.4	4.6	7.1	9.9	1910	2440	2.1	4.0	6.2	8.6	2490	173
762×267×147	1370	2.2	4.3	6.4	8.6	1550	1760	2.0	3.7	5.7	7.8	2010	
686×254×170	1490	2.3	4.3	6.9	9.7	1600	1910	2.0	4.1	6.1	8.4	2080	152, 140
686×254×125	1060	2.1	4.0	6.3	8.3	1260	1360	1.9	3.7	5.6	7.3	1640	
610×305×238	1980	3.0	6.0	10.2	15.0	1870	2540	2.6	5.3	9.0	13.0	2440	179
610×305×149	1460	2.8	5.6	9.0	13.0	1150	1550	2.5	4.9	7.5	10.3	1500	
610×229×140	1100	2.1	3.9	6.3	9.0	1290	1410	1.8	3.5	5.6	7.7	1670	125, 113
610×229×101	794	1.9	3.6	5.5	7.5	1050	1020	1.7	3.3	5.0	6.6	1360	
533×210×122	849	1.9	3.7	6.1	8.1	1110	1090	1.7	3.3	5.3	7.3	1440	109, 101, 92
533×210×82	566	1.8	3.3	5.2	7.0	837	731	1.5	3.0	4.6	6.1	1080	
457×191×98	592	1.8	3.5	5.8	7.6	847	777	1.6	2.9	5.0	7.0	1100	89, 82, 74
457×191×67	405	1.6	3.1	4.9	6.6	636	523	1.4	2.8	4.3	5.8	821	
457×152×82	477	1.3	2.5	4.3	6.3	791	622	1.1	2.4	3.8	5.3	1030	74, 67, 60
457×152×52	301	1.2	2.3	3.7	4.9	564	389	1.1	2.1	3.2	4.3	728	
406×178×74	415	1.6	3.2	5.1	7.3	661	536	1.4	2.8	4.5	6.3	853	67, 60
406×178×54	289	1.5	2.9	4.5	6.2	505	373	1.3	2.6	4.1	5.4	652	
406×140×46	245	1.2	2.3	3.5	4.9	458	316	1.1	2.1	3.2	4.2	591	
406×140×39	198	1.2	2.2	3.3	4.5	413	255	1.0	1.9	3.0	3.9	533	
356×171×67	334	1.6	3.1	5.3	7.7	547	430	1.4	2.8	4.5	6.5	706	57, 51
356×171×45	213	1.5	2.8	4.5	6.1	401	244	1.3	2.4	4.0	5.3	517	
356×127×39	180	1.1	2.0	3.3	4.4	378	232	0.9	1.7	2.9	3.8	488	
356×127×33	148	1.0	2.0	3.0	4.1	339	192	0.9	1.8	2.8	3.6	438	
305×165×54	232	1.6	3.1	5.2	7.8	395	300	1.4	2.8	4.5	6.5	510	46
305×165×40	172	1.5	2.9	4.7	6.5	306	222	1.3	2.6	4.1	5.6	395	
305×127×48	194	1.1	2.3	3.7	5.5	456	251	1.0	2.0	3.2	4.7	588	42
305×127×37	149	1.1	2.1	3.3	4.7	361	192	0.9	1.8	2.9	4.1	466	
305×102×33	132	0.9	1.7	2.7	3.7	341	170	0.8	1.5	2.3	3.3	440	28
305×102×25	92.4	0.8	1.5	2.3	3.2	292	120	0.7	1.3	2.1	2.7	377	
254×146×43	156	1.4	2.8	4.9	7.3	313	202	1.2	2.5	4.2	5.4	404	37
254×146×31	109	1.3	2.5	4.2	5.8	253	125	1.2	2.6	4.1	5.6	327	
254×102×28	97.4	0.9	1.7	2.8	4.0	275	127	0.8	1.6	2.5	3.5	355	25
254×102×22	71.6	0.8	1.6	2.5	3.4	243	93	0.7	1.4	2.3	3.0	314	
203×133×30	86.2	1.3	2.6	4.4	6.6	215	111	1.1	2.4	3.9	5.4	278	
203×133×25	71.2	1.3	2.4	4.1	5.9	194	82	1.1	1.7	2.8	4.0	251	

Universal Columns	GRADE 43						GRADE 50						
D×b×Mass (mm×mm ×Kg/m)	M_{cx} kNm	L_1 m (1.0)	L_2 m (0.75)	L_3 m (0.5)	L_4 m (0.35)	P_v kN	M_{cx} kNm	L_1 m (1.0)	L_2 m (0.75)	L_3 m (0.5)	L_4 m (0.35)	P_v kN	Intermediate masses (kg/m)
356×406×634	3490	8.7	-	-	-	3320	4520	6.8	-	-	-	4410	551, 467, 393,
356×406×235	1240	5.0	12.0	-	-	1120	1620	4.2	16.0	-	-	1460	& 340, 287
356×368×202	1050	4.8	10.5	-	-	1000	1370	3.9	9.0	15.0	-	1300	177, 153
356×368×129	601	4.1	9.8	-	-	605	782	4.8	8.7	14.0	-	788	
305×305×283	1300	4.8	14.0	-	-	1500	1730	4.4	11.5	-	-	2000	240, 198, 158
305×305×97	397	3.2	6.8	12.2	-	503	512	4.0	6.0	10.2	-	649	& 137, 118
254×254×167	641	3.3	10.3	-	-	883	834	3.0	8.7	-	-	1150	132, 107, 89
254×254×73	272	2.3	6.0	11.0	-	360	318	3.4	6.2	10.6	15.0	465	
203×203×86	259	2.7	7.0	14.0	-	459	338	2.2	5.9	12.0	-	598	71, 60, 52
203×203×46	137	2.2	4.8	8.7	13.7	245	159	2.7	5.0	8.2	12.5	316	
152×152×37	85	1.8	4.1	8.1	-	216	110	1.7	3.5	6.8	10.8	279	30
152×152×23	45.4	1.5	3.3	5.6	8.8	153	58.6	2.0	3.5	5.6	8.2	198	

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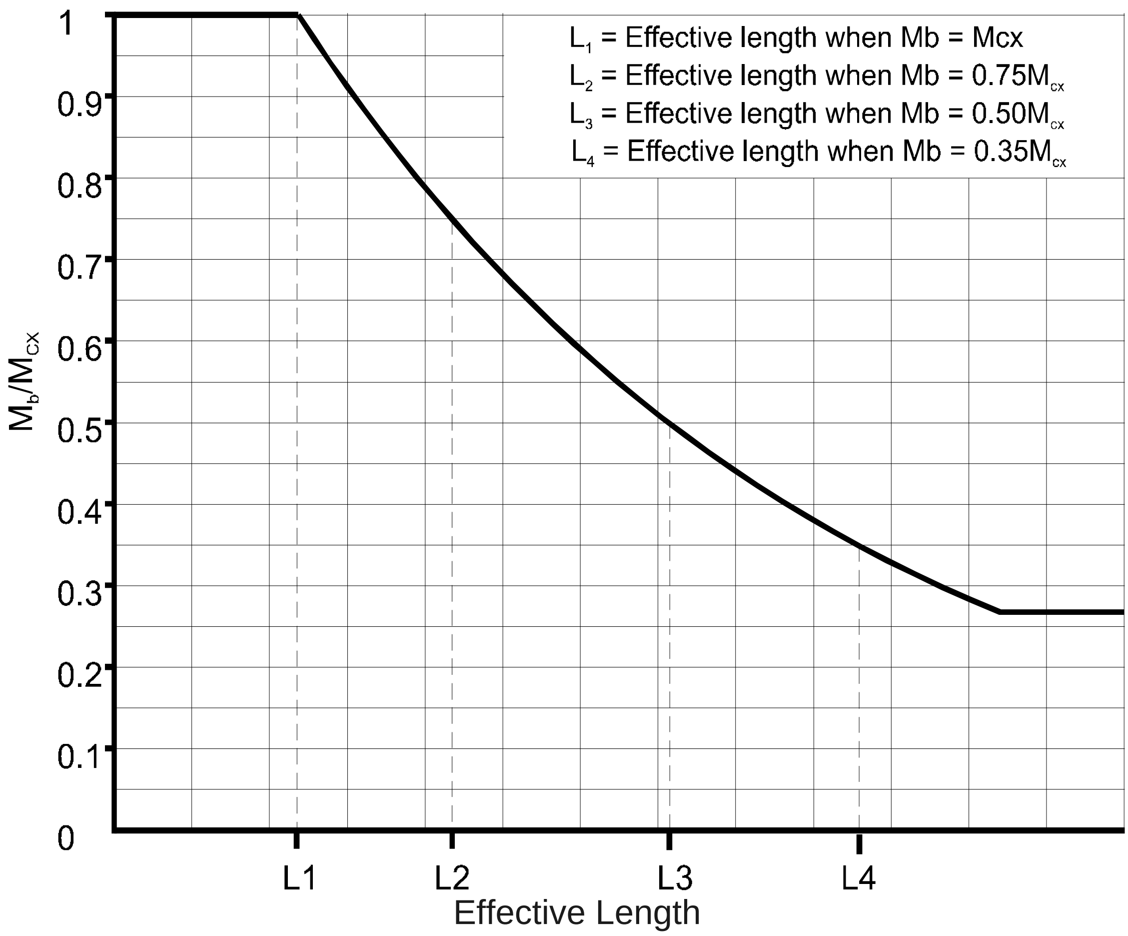
- **Approximate M_b calculation**

Table is to used in conjunction with the table on P. 4/23 to calculate approximate M_b.

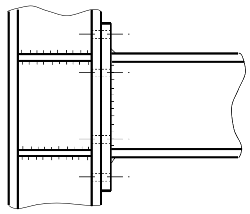


Example : 533x210x82UB (p_y = 275 Mpa) with Le compression flange = 6m.

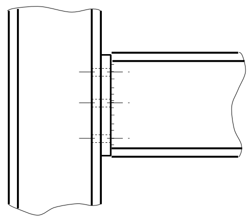
From table	L_4	= 7.0m = $0.35M_{cx}$
	L_3	= 5.2m = $0.50M_{cx}$
	M_{cx}	= 566 kNm
From graph	M_b	= $0.43M_{cx}$ (approx.), for Le = 6m.
		= <u>243</u> kNm

Effective lengths of beam compression flanges

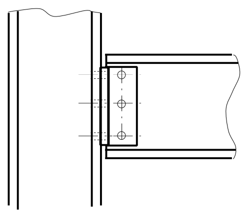
Rotational restraint on plan



1. Flanges fully restrained on plan



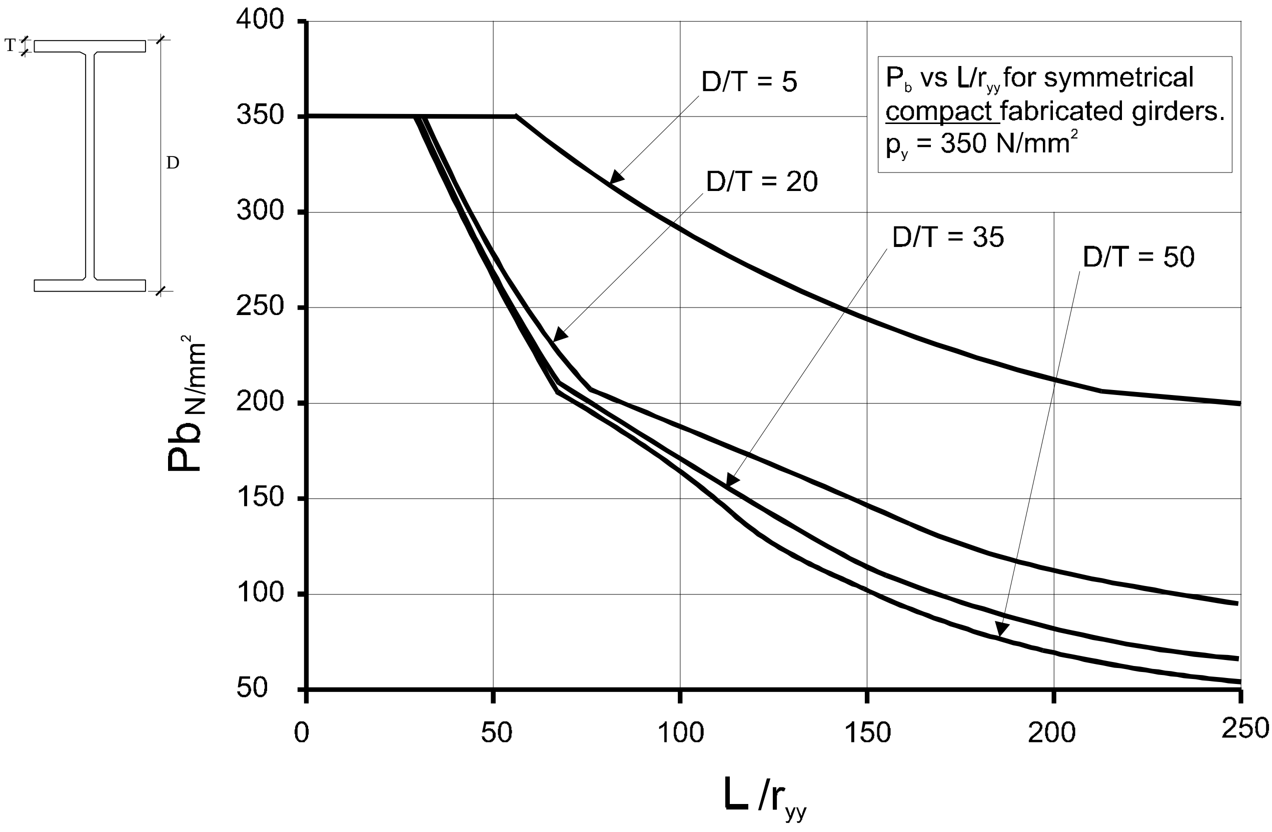
2. Flanges partially restrained on plan



3. Flanges free to rotate on plan

Conditions of restraint at the ends of the beams		Loading conditions: Normal	Loading conditions: Destabilizing
Compression flange laterally restrained; beam fully restrained against torsion	Both flanges fully restrained against rotation on plan	0.7L	0.85L
	Both flanges partially restrained against rotation on plan	0.85L	1.0L
	Both flanges free to rotate on plan	1.0L	1.2L
Compression flange laterally unrestrained; both flanges free to rotate on plan	Restraint against torsion provided only by positive connection of bottom flange to supports	1.0L+2D	1.2L+2D
	Restraint against torsion provided only by dead bearing of bottom flange on supports.	1.2L+2D	1.4L+2D

Lateral torsional buckling - Stress of fabricated girders



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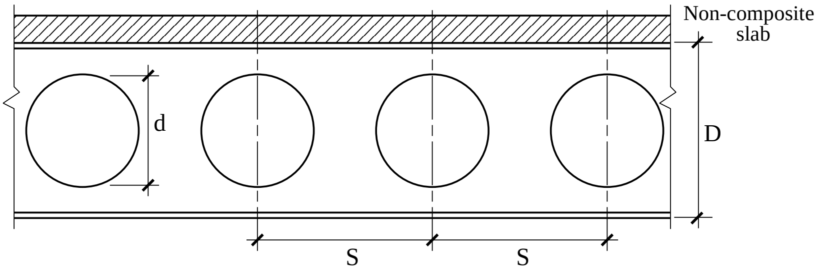
Castellated & cellular beams

Imposed loading 5+1 kN/m²



	SECONDARY BEAM SPAN (m)				
	6	**9**	**12**	**15**	**18**
Beam Size	**356 x 171 x 45**	**457 x 191 x 67**	**533 x 210 x 92**	**686 x 254 x 125**	**838 x 292 x 176**
Diameter	300	350	450	550	650
Spacing	450	525	675	825	975
0/A Depth	482	605	728	916	1116

	MAIN BEAM SPAN (m)														
	6			**9**			**12**			**15**			**18**		
Secondary Beam Span (m)	**Beam Size**			**Beam Size**			**Beam Size**			**Beam Size**			**Beam Size**		
	Dia.	Spacing	O/A Depth	Dia.	Spacing	O/A Depth	Dia.	Spacing	O/A Depth	Dia.	Spacing	O/A Depth	Dia.	Spacing	O/A Depth
6	**457 x 191 x 67**			**610 x 229 x 125**			**762 x 267 x 173**			**914 x 305 x 201**			**914 x 305 x 253**		
	400	600	627	500	750	828	700	1000	1078	700	1000	1219	700	1000	1235
9	**610 x 229 x 101**			**762 x 267 x 147**			**914 x 305 x 201**			**914 x 305 x 289**					
	500	750	819	500	750	970	700	1000	1219	700	1000	1243			
12	**610 x 229 x 113**			**838 x 292 x 194**			**914 x 305 x 289**								
	500	750	824	700	1000	1157	700	1000	1243						
15	**686 x 254 x 125**			**914 x 305 x 253**											
	550	750	934	700	1000	1235									
18	**762 x 267 x 173**			**914 x 305 x 289**											
	700	1000	1078	700	1000	1243									

Assumptions

1. Secondary beam spacing 3m
2. 150mm thick concrete slab of normal weight concrete
3. All beams grade Fe 510
4. Beams laterally restrained by concrete slab.

ARUP

4.4.5 COLUMNS (AND BEAM COLUMNS)

Local capacity check: $\frac{P}{P_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$

P_y = squash load

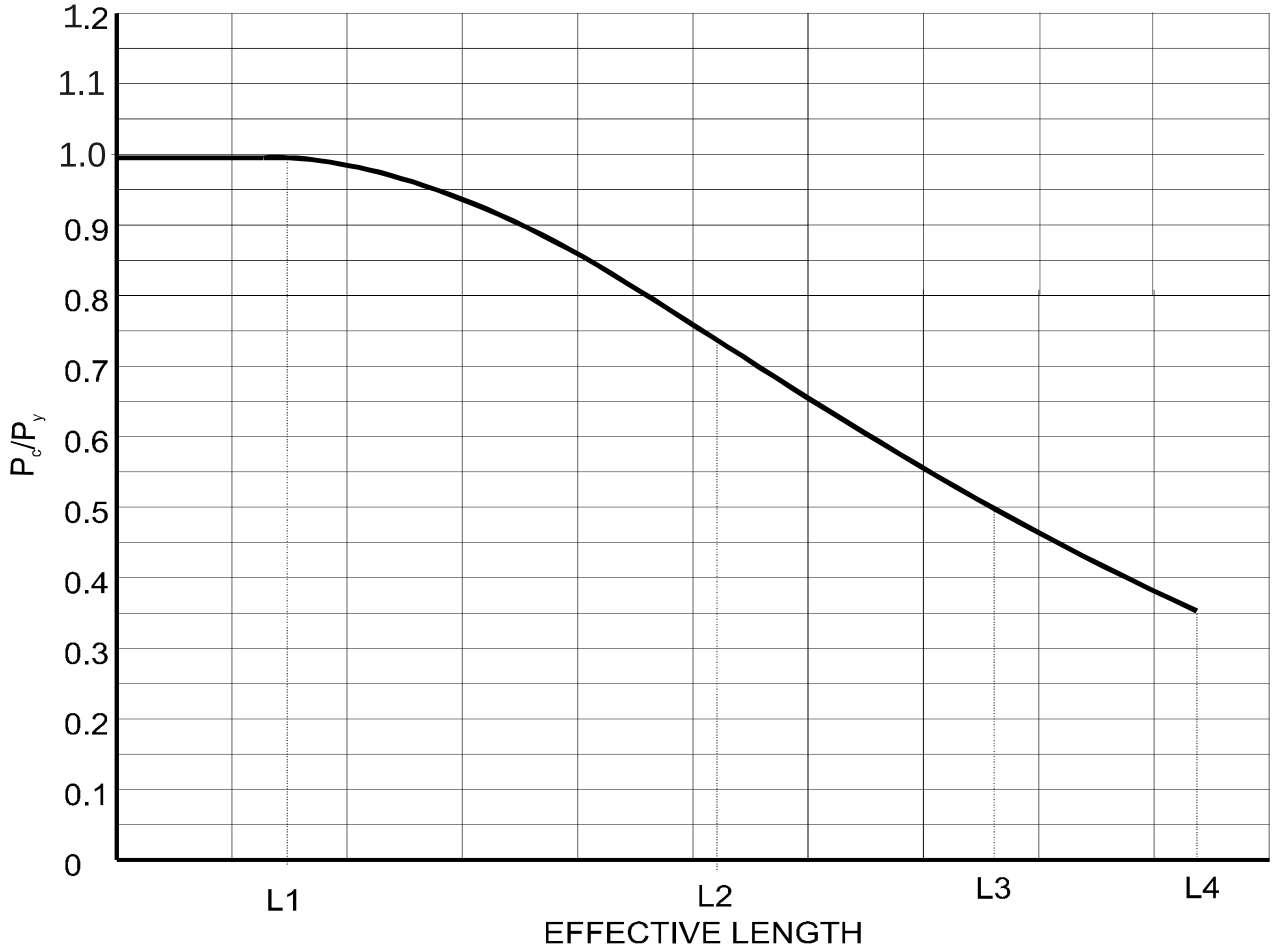
Buckling check: (minor axis failure) $\frac{P}{P_c} + \frac{m' M_x}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$

m' is the largest of m_x or m_{LT} from the equation in 4.4.4

M_b is obtained from the graph in 4.4.4 ($\not> 1.2\, p_y Z_x$)

P_c is the buckling capacity from table below

Note: For columns in simple construction use m' = 1.0; when determining M_b use L = 0.5 H , where H = column height



Note

This graph shows the approximate relationship between axial capacity and effective length. --- see following tables.
L_1 = Effective length when $P_c = P_y$. L_2 = Effective length when $P_c = 0.75P_y$.
L_3 = Effective length when $P_c = 0.50P_y$. L_4 = Effective length when $P_c = 0.35P_y$.

COMPRESSION

Circular Hollow Sections (CHS)		GRADE 43 (S275)					GRADE 50 (S355)					
Outside diameter (mm)	Thickness (mm)	$P_{c\,max}$ kN	L_{y1} m (1.0)	L_{y2} m (0.75)	L_{y3} m (0.5)	L_{y4} m (0.35)	$P_{c\,max}$ kN	L_{y1} m (1.0)	L_{y2} m (0.75)	L_{y3} m (0.5)	L_{y4} m (0.35)	Intermediate thicknesses * (mm)
88.9	3.2	237	0.4	2.3	3.3	4.1	306	0.4	2.1	3.0	3.7	4.0
	5.0	363	0.4	2.2	3.2	4.0	469	0.4	2.1	2.9	3.6	
114.3	3.6	344	0.6	3.1	4.3	5.3	444	0.6	2.8	3.8	4.8	5.0
	6.3	589	0.6	3.0	4.3	5.2	760	0.6	2.7	3.7	4.6	
139.7	5.0	583	0.7	3.7	5.2	6.4	753	0.7	3.4	4.6	5.8	6.3, 8.0
	10.0	1120	0.7	3.6	5.0	6.2	1440	0.7	3.3	4.5	5.7	
168.3	5.0	707	0.8	4.5	6.3	7.9	912	0.8	4.2	5.6	7.0	6.3, 8.0
	10.0	1370	0.8	4.4	6.1	7.5	1760	0.8	4.0	5.7	6.7	
193.7	5.0	814	1.0	5.2	7.3	9.0	1050	1.0	4.8	6.7	8.0	6.3, 8.0, 10.0
	12.5	1960	0.9	5.0	7.0	8.6	2530	0.9	4.5	6.3	7.7	
219.1	5.0	924	1.1	6.0	8.3	10.0	1190	1.1	5.4	7.3	9.1	6.3, 8.0, 10.0
	12.5	2230	1.1	5.7	8.0	9.9	2880	1.1	5.1	7.1	8.7	
244.5	6.3	1300	1.2	6.7	9.3	11.4	1670	1.2	6.0	8.2	10.1	8.0, 10.0, 12.5
	16.0	3160	1.2	6.5	8.9	11.0	4080	1.2	5.8	7.9	9.7	
273.0	6.3	1450	1.4	7.6	10.3	12.7	1870	1.4	6.8	9.2	11.3	8.0, 10.0, 12.5
	16.0	3550	1.3	7.2	9.9	12.3	4580	1.3	6.5	8.9	10.9	
323.9	6.3	1730	1.7	8.8	12.3	-	2230	1.7	8.0	11.0	13.5	8.0, 10.0, 12.5
	16.0	4260	1.6	8.6	12.0	-	5500	1.6	7.7	10.6	13.0	
355.6	8.0	2400	1.8	9.7	13.5	-	3100	1.8	8.7	12.0	-	10.0, 12.5
	16.0	4700	1.8	9.5	13.1	-	6070	1.8	8.5	11.7	-	

* Only part of the range is given. For the larger sections thicker tubes may be available.

Universal Columns	GRADE 43					GRADE 50				
D×b×Mass (mm×mm×Kg/m)	$P_{c\,max}$ kN	L_{y1} m (1.0)	L_{y2} m (0.75)	L_{y3} m (0.5)	L_{y4} m (0.35)	$P_{c\,max}$ kN	L_{y1} m (1.0)	L_{y2} m (0.75)	L_{y3} m (0.5)	L_{y4} m (0.35)
356×406×634	19800	2.0	5.5	9.2	12.8	26300	1.7	5.1	8.6	11.6
356×406×551	17200	2.0	5.4	9.3	12.7	22800	1.7	4.9	8.6	11.6
356×406×467	15200	1.9	5.3	9.1	12.3	20200	1.7	4.9	8.3	11.0
356×406×393	12800	1.9	5.6	9.5	12.6	17000	1.8	4.8	8.2	10.8
356×406×340	11000	1.9	5.6	9.4	12.5	14700	1.9	4.8	8.1	10.7
356×406×287	9690	1.8	5.9	9.6	12.7	12600	1.7	5.4	8.5	11.2
356×406×235	7950	1.8	5.9	9.6	12.5	10300	1.9	5.4	8.6	11.3
356×368×202	6840	1.8	5.6	9.0	11.8	89000	1.6	5.0	8.2	10.5
356×368×177	5980	1.7	5.7	8.9	11.7	7780	1.7	5.0	8.1	10.5
356×368×153	5180	1.8	5.5	8.9	11.6	6750	1.6	5.0	8.0	10.4
356×368×129	4380	1.9	5.7	8.8	11.5	5700	1.5	4.9	8.0	10.3
305×305×283	9190	1.5	4.6	7.5	9.9	12300	1.3	3.8	6.4	8.7
305×305×240	8090	1.5	4.7	7.7	10.0	10500	1.3	4.2	6.9	8.9
305×305×198	6690	1.5	4.7	7.6	9.8	8710	1.3	4.2	6.8	8.8
305×305×158	5320	1.4	4.7	7.4	9.7	6930	1.3	4.1	6.7	8.7
305×305×137	4620	1.4	4.5	7.3	9.6	6010	1.2	4.1	6.6	8.6
305×305×118	3970	1.4	4.5	7.3	9.6	5160	1.2	4.1	6.6	8.6
305×305×97	3390	1.3	4.4	7.2	9.4	4380	1.1	4.0	6.5	8.4
254×254×167	5630	1.3	3.9	6.3	8.3	7330	1.1	3.6	5.8	7.5
254×254×132	4470	1.2	3.9	6.3	8.3	5820	1.1	3.5	5.7	7.4
254×254×107	3620	1.2	3.8	6.2	8.1	4710	1.1	3.5	5.6	7.3
254×254×89	3010	1.2	3.8	6.2	8.1	3920	1.0	3.5	5.6	7.2
254×254×73	2560	1.1	3.7	6.0	7.9	3300	1.0	3.5	5.5	7.0
203×203×86	2920	0.9	3.1	5.0	6.6	3800	0.9	2.8	4.5	5.8
203×203×71	2410	0.9	3.1	4.9	6.4	3140	0.9	2.7	4.5	5.7
203×203×60	2090	0.9	3.0	4.8	6.3	2700	0.9	2.7	4.4	5.6
203×203×52	1830	0.9	2.9	4.7	6.2	2360	0.8	2.7	4.4	5.6
203×203×46	1620	0.9	2.9	4.7	6.2	2090	0.8	2.7	4.3	5.5
152×152×37	1300	0.7	2.1	3.5	4.7	1680	0.6	2.0	3.3	4.2
152×152×30	1060	0.7	2.2	3.5	4.6	1360	0.6	2.0	3.2	4.2
152×152×23	816	0.7	2.1	3.4	4.5	1050	0.6	2.0	3.1	4.0

NOTE: $L_x \approx 1.15 \left(\frac{I_x}{I_y}\right)^{½} L_y$

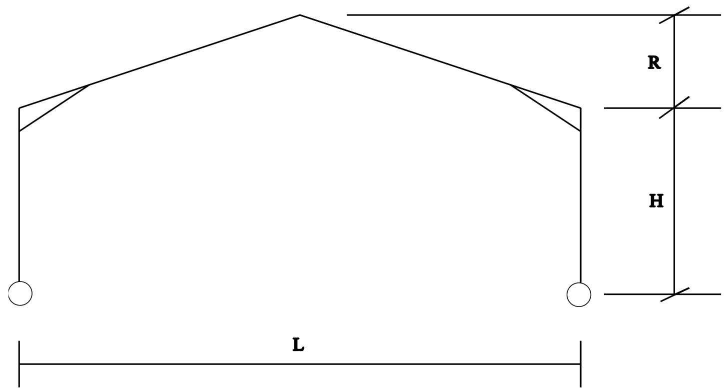
4.4.6 Portal Frame Sizing

The following are simple charts for the sizing of pinned base portals.

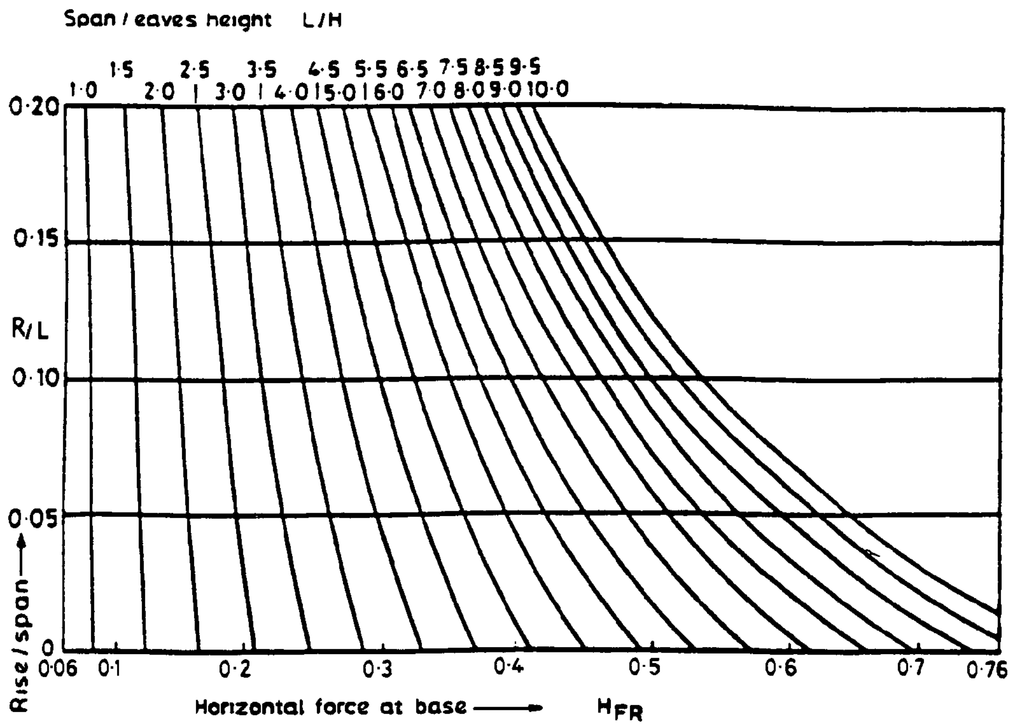
Assumptions :

- wind loading does not control design
- hinges formed at the eaves (in the stanchion) and near the apex.
- Moment at the end of the haunch is $0.87M_p$
- Stability of sections is not addressed

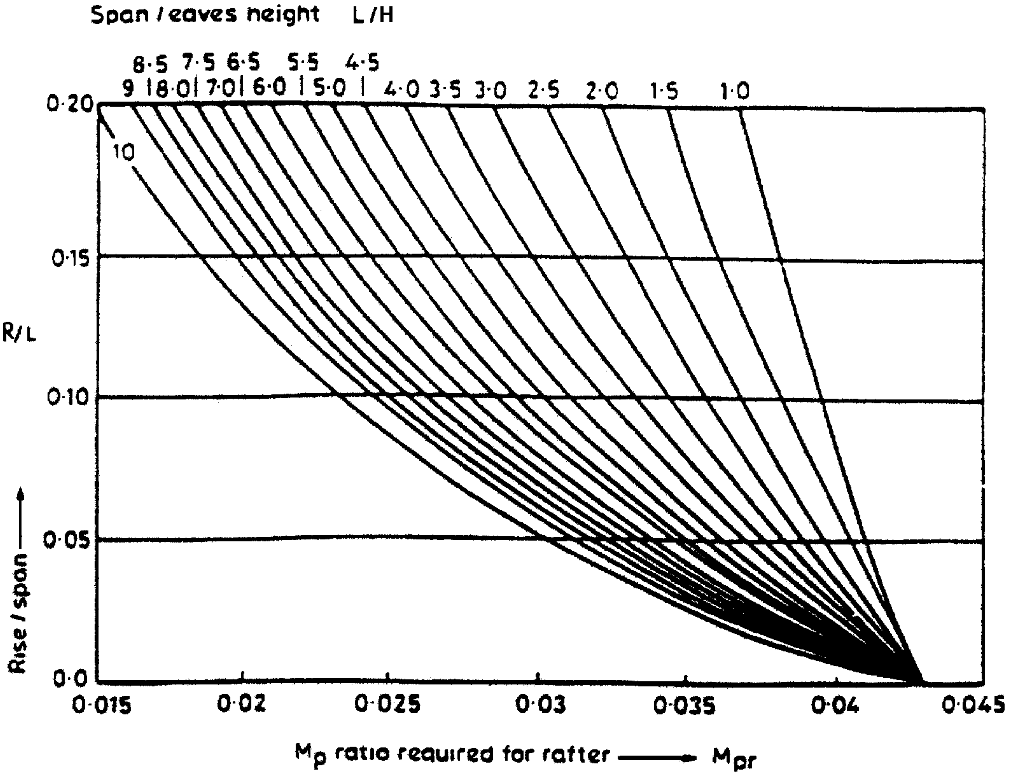
Load W = vertical load on rafter per meter



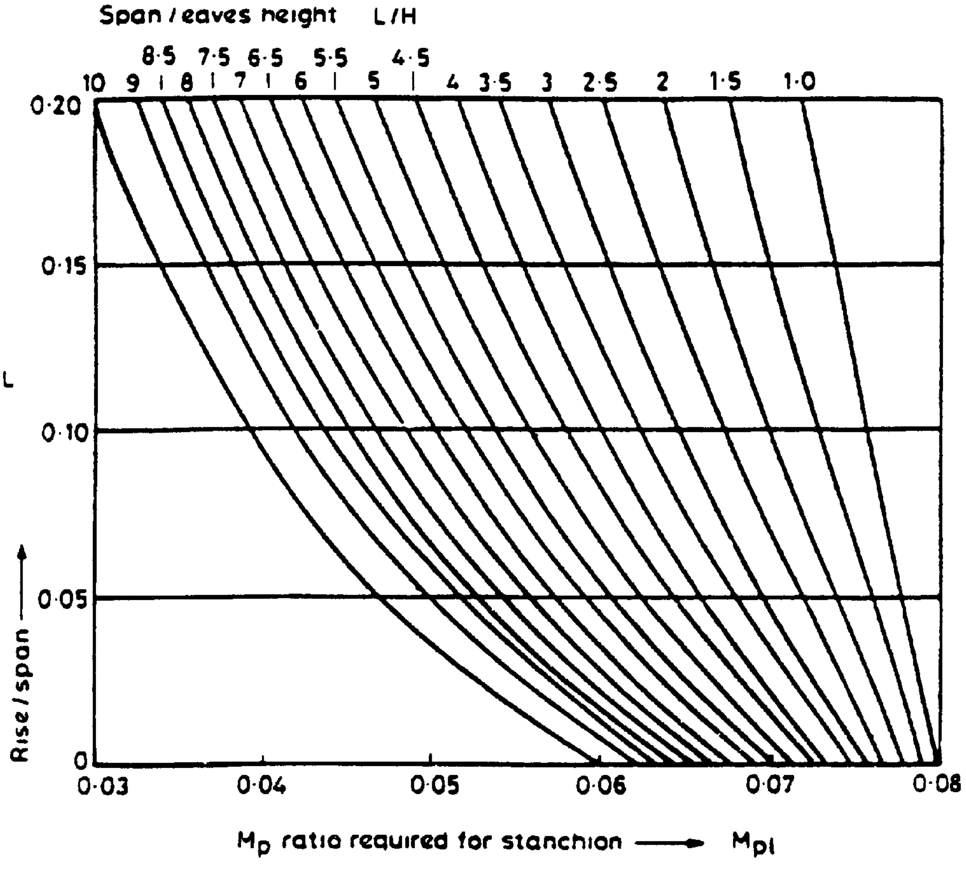
Horizontal base reaction H = H_{FR} WL



M_p required for rafter : $M_{prafter} = M_{pr} \, WL^2$



M_p required for stanchion : $M_{pstanchion} = M_{pl} \, WL^2$



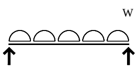
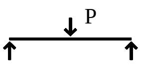
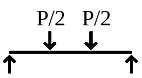
4.4.7 ELEMENT STIFFNESS

Serviceability check: unfactored dead + imposed
unfactored dead + 0.8 × (imposed + wind)

Deflection limits under imposed load:

Element	Limit
• Cantilever • Beam supporting plaster or brittle finish • Beams supporting masonry • Other beams • Crane beams	L/180 L/360 L/500 L/200 L/500
• Columns • Columns in multi-storey construction with movement sensitive cladding. Portal frames • Lateral at eaves • Vertical at apex	H/300 H/500 H/100 - H/300 * L/250 - L/500 *

* Depends on cladding system

Load case	Minimum I to satisfy deflection limit		
	L/200	L/360	L/500
	1.27 WL²	2.29 WL²	3.18 WL²
	2.03 PL²	3.66 PL²	5.08 PL²
	3.46 PL²	6.23 PL²	8.66 PL²

Note: For castellated beams, assume a 30% increase in deflection due to presence of web openings.
L in metres; W, P in kN; I in cm^4

4.4.8 CONNECTIONS

Bolted

- Assume S 275 fittings.
- Simple connections - use grade 8.8, 20mm diameter bolts
  fin plates}
  partial depth end plates}
  web cleats}
  t = 8mm for UB's < 457mm deep
  t = 10mm for UB's > 457mm deep
- Moment connections -use grade 8.8, 20mm or 24mm diameter. Assume end plate thickness equal to bolt diameter (25 thick with M24)
- Holding down bolts - assume grade 4.6 where possible.
  Standard sizes: M16 x 300
  M20 x 450, 600
  M24 x 450, 600
  M30 x 450, 600
  M36 x 450, 600, 750

See Appendices C12, C13, C14 for more information on bolts and fastening.
When carrying out design, it is important to consult new SCI/BCSA guidelines (Ref 3.4.5)

Bolts

Dia of Bolt mm	Tensile Stress Area mm2	Tensile Cap kN	Shear Value		Bearing Value of plate at 460N/mm2 and end distance equal to 2xbolt diameter Thickness in mm of Plate Passed Through											Bearing Value of plate at 550N/mm2 and end distance equal to 2xbolt diameter Thickness in mm of Plate Passed Through										
			Single Shear kN	Double Shear kN	5	6	7	8	9	10	12.5	15	20	25	30	5	6	7	8	9	10	12.5	15	20	25	30
12	84.3	37.9	31.6	63.2	27.6	33.1	38.6	44.2	49.7	55.2	69.0	-	-	-	-	33.0	39.6	46.2	52.8	59.4	66.0	-	-	-	-	-
16	157	70.7	58.9	118	36.8	44.2	51.5	58.9	66.2	73.6	92.0	110	147	-	-	44.0	52.8	61.6	70.4	79.2	88.0	110	132	-	-	-
20	245	110	91.9	184	46.0	55.2	64.4	73.6	82.8	92.0	115	138	184	230	-	55.0	66.0	77.0	88.0	99.0	110	138	165	220	-	-
22	303	136	114	227	50.6	60.7	70.8	81.0	91.1	101	126	152	202	253	-	60.5	72.6	84.7	96.8	109	121	151	182	242	-	-
24	353	159	132	265	55.2	66.2	77.3	88.3	99.4	110	138	166	221	276	-	66.0	79.2	92.4	106	119	132	165	198	264	330	-
27	459	207	172	344	62.1	74.5	86.9	99.4	112	124	155	186	248	310	373	74.2	89.1	104	119	134	148	186	223	297	371	-
30	561	252	210	421	69.0	82.8	96.6	110	124	138	172	207	276	345	414	82.5	99.0	116	132	148	165	206	248	330	412	495

Dia of Bolt mm	Proof Load of Bolt kN	Tensile Cap kN	Slip Value		Bearing Value of Plate at 825N/mm2 and end distance equal to 3xbolt diameter Thickness in mm of Plate Passed Through											Bearing Value of Plate at 1065N/mm2 and end distance equal to 2xbolt diameter Thickness in mm of Plate Passed Though										
			Single Shear kN	Double Shear kN	5	6	7	8	9	10	12.5	15	20	25	30	5	6	7	8	9	10	12.5	15	20	25	30
12	49.4	44.5	24.5	48.9	49.5	-	-	-	-	-	-	-	-	-	-	63.9	-	-	-	-	-	-	-	-	-	-
16	92.1	82.9	45.6	91.2	66.0	79.2	92.4	-	-	-	-	-	-	-	-	85.2	102	-	-	-	-	-	-	-	-	-
20	144	130	71.3	143	82.5	99.0	116	132	148	-	-	-	-	-	-	106	128	149	-	-	-	-	-	-	-	-
22	177	159	87.6	175	90.7	109	127	145	163	182	-	-	-	-	-	117	141	164	187	-	-	-	-	-	-	-
24	207	186	102	205	99	119	139	158	178	198	248	-	-	-	-	128	153	179	204	230	-	-	-	-	-	-
27	234	211	116	232	111	134	156	178	200	223	278	-	-	-	-	144	173	201	230	259	-	-	-	-	-	-
30	286	257	142	283	124	148	173	198	223	248	309	-	-	-	-	160	192	224	256	288	-	-	-	-	-	-

ARUP

Welded

Use 6mm fillet where possible.

Relative costs:	6mm fillet in downhand position	1.0
	6mm fillet in vertical position	2.0
	6mm fillet in overhead position	3.0

For each additional run multiply above by 1.75.

Note:	6mm weld	1 run
	8mm weld	2 runs
	10mm weld	3 runs

Single V butt weld in 10mm plate	6.0
Double V butt weld in 20mm plate	12.0
Single U butt weld in 20mm plate	10.0
Double U butt weld in 40mm plate	20.0
Single J butt weld in 20mm plate	9.0
Double J butt weld in 40mm plate	18.0
Single level butt weld in 10mm plate	5.0
Double level butt weld in 20mm plate	10.0

For each 5mm of plate thickness multiply above by 4.0.

Weld design

Fillet welds - **Grade 43 (Fe 430) (S 275) steel**, Grade E43 Electrodes

Leg length mm	Throat thickness mm	Capacity at 215 N/mm² kN/mm	Leg length mm	Throat thickness mm	Capacity at 215 N/mm² kN/mm
3.0	2.1	0.452	**12.0**	**8.4**	**1.81**
4.0	2.8	0.602	15.0	10.5	2.26
5.0	3.5	0.753	18.0	12.6	2.71
6.0	**4.2**	**0.903**	20.0	14.0	3.01
8.0	**5.6**	**1.2**	22.0	15.4	3.31
10.0	**7.0**	**1.51**	25.0	17.5	3.76

Fillet welds - **Grade 50 (Fe 510) (S 355) steel**, Grade E51 Electrodes

Leg length mm	Throat thickness mm	Capacity at 255 N/mm² kN/mm	Leg length mm	Throat thickness mm	Capacity at 255 N/mm² kN/mm
3.0	2.1	0.535	**12.0**	**8.4**	**2.14**
4.0	2.8	0.714	15.0	10.5	2.68
5.0	3.5	0.893	18.0	12.6	3.21
6.0	**4.2**	**1.07**	20.0	14.0	3.57
8.0	**5.6**	**1.43**	22.0	15.4	3.93
10.0	**7.0**	**1.79**	25.0	17.5	4.46

4.4.9 Corrosion protection

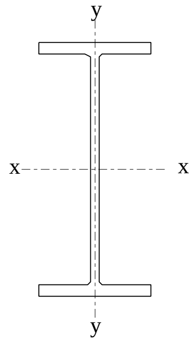
Notes : Define the environment correctly.
The information given is typical. There are many alternatives depending on the individual situations.
Avoid specifying too many schemes for any one job.
The table takes no account of fire resistance.
For further details, see Structural Guidance Note 5.1 (1992)

Environment		Typical protection solution
External	All	E-2 (three coat scheme)
Internal	Controlled (e.g. office)	Do nothing
	Cavity and perimeter	Galvanise to BS729
	Uncontrolled (e.g. warehouses)	Zinc rich primer to BS 4652
	Specials (e.g. swimming pools kitchens)	1-2

	External scheme E-2	Internal scheme I-2
Preparation	Blast clean to Sa 2.5 of BS7079 Pt A1	
Primer	Zinc rich epoxy 75µm DFT	2 pack epoxy zinc phosphate primer 50µm DFT
Barrier	Two pack Epoxy Micaceous Iron Oxide 75µm DFT	
Undercoat	Silicone Alkyd Enamel 35µm DFT	Acrylated rubber undrecoat 40µm DFT
Finish	Silicone Alkyd Enamel 35µm DFT	Acrylated rubber finish 25µm DFT

SECTION PROPERTIES

Universal Beams (1 of 2)

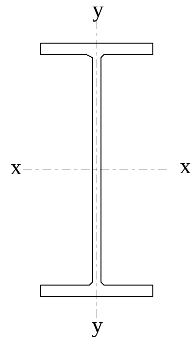


PROPERTIES

Designation		Moment of		Radius Of Gyration		Elastic Modulus		Plastic Modulus		Buck. Para.	Tors. Index	Warp. Const	Tors. Const	Area
Serial Size mm	**Mass per Metre**	Axis x-x cm^4	Axis y-y cm^4	Axis x-x cm	Axis y-y cm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	u	x	H dm^6	J cm^4	A cm^2
914x419	**388**	719300	45440	38.1	9.58	15630	2161	17670	3342	0.884	26.7	88.8	1739	495
	343	625200	39160	37.8	9.46	13720	1871	15470	2890	0.883	30.1	75.7	1193	437
914x305	**289**	504800	15610	37.0	6.50	10900	1015	12590	1603	0.866	31.9	31.2	930	369
	253	436400	13300	36.8	6.42	9503	871	10940	1371	0.866	36.2	26.4	626	323
	224	376300	1240	36.3	6.27	8268	739	9533	1163	0.861	41.3	22.1	422	286
	201	325900	9433	35.6	6.06	7217	622	8372	983	0.853	46.7	18.4	294	257
838x292	**226**	339700	11360	34.3	6.27	7985	773	9155	1212	0.870	35.0	19.3	514	289
	194	279200	9066	33.6	6.06	6641	620	7640	974	0.862	41.6	15.2	306	247
	176	246000	7791	33.1	5.90	5892	534	6806	841	0.856	46.5	13.0	221	224
762x267	**197**	239800	8175	30.9	5.71	6232	610	7164	959	0.869	33.2	11.3	404	251
	173	205200	6850	30.5	5.58	5385	514	6195	807	0.864	38.1	9.39	267	220
	147	168800	5462	30.0	5.39	4478	412	5169	648	0.857	45.1	7.40	160	188
686x254	**170**	170300	6630	28.0	5.53	4916	518	5631	811	0.872	31.8	7.42	308	217
	152	150400	5784	27.8	5.46	4375	455	5001	710	0.871	35.5	6.43	220	194
	140	136300	5183	27.6	5.39	3987	409	4558	638	0.868	38.7	5.72	169	178
	125	118000	4383	27.2	5.24	3481	346	3994	542	0.862	43.9	4.80	116	159
610x305	**238**	207700	15850	26.1	7.22	6564	1018	7462	1576	0.886	21.1	14.3	790	304
	179	151500	11400	25.8	7.08	4907	742	5515	1143	0.886	27.5	10.0	340	228
	149	124700	9308	25.6	6.99	4093	611	4575	938	0.886	32.5	8.10	201	190
610x229	**140**	111700	4499	25.0	5.03	3619	391	4139	611	0.875	30.6	3.98	216	178
	125	98500	3932	24.9	4.97	3219	343	3673	535	0.873	34.1	3.45	154	159
	113	87380	3434	24.6	4.88	2878	301	3287	470	0.869	37.9	2.99	112	144
	101	75820	2915	24.2	4.75	2518	256	2887	401	0.863	42.9	2.51	77.6	129
533x210	**122**	76180	3388	22.1	4.66	2798	320	3203	500	0.876	27.6	2.32	179	156
	109	66800	2939	21.9	4.60	2476	279	2827	435	0.875	30.9	1.99	126	139
	101	61650	2696	21.8	4.57	2297	257	2619	400	0.874	33.1	1.82	102	129
	92	55330	2389	21.7	4.50	2076	228	2366	356	0.871	36.4	1.60	76.3	118
	82	47520	2004	21.3	4.38	1799	192	2058	300	0.864	41.6	1.33	51.5	105
457x191	**98**	45770	2347	19.1	4.33	1959	243	2234	379	0.881	25.8	1.18	121	125
	89	41140	2093	19.0	4.28	1775	218	2020	339	0.879	28.2	1.04	91.3	114
	82	37090	1871	18.8	4.23	1612	196	1832	304	0.877	30.9	0.923	69.2	105
	74	33430	1674	18.7	4.20	1462	176	1659	273	0.876	33.8	0.820	52.2	95.1
	67	29410	1452	18.5	4.12	1297	153	1472	237	0.872	37.9	0.706	37.1	85.5
457x152	**82**	36250	1144	18.6	3.31	1559	149	1802	236	0.872	27.3	0.570	89.5	105
	74	32470	1013	18.5	3.26	1408	133	1624	209	0.870	30.0	0.500	66.8	95.1
	67	28600	879	18.3	3.21	1251	116	1442	183	0.867	33.5	0.430	47.6	85.3
	60	25450	795	18.3	3.24	1119	104	1283	163	0.869	37.6	0.387	33.5	75.8
	52	21370	645	17.9	3.11	950	84.6	1096	133	0.859	43.9	0.311	21.4	66.6

ARUP

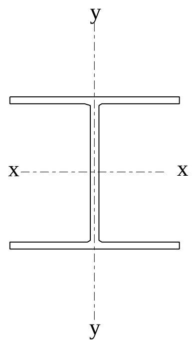
Universal Beams (2 of 2)



PROPERTIES

Designation		Second Moment of Area		Radius Of Gyration		Elastic Modulus		Plastic Modulus		Buck. Para.	Tors. Index	Warp. Const	Tors. Const	Area
Serial Size mm	**Mass per Metre kg**	Axis x-x cm^4	Axis y-y cm^4	Axis x-x cm	Axis y-y cm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	u	x	H dm^6	J cm^4	A cm^2
406x178	**74**	27430	1551	17.0	4.03	1329	173	1509	268	0.880	27.5	0.610	63.7	95.3
	67	24330	1365	16.9	3.99	1189	153	1346	237	0.880	30.5	0.533	46.1	85.5
	60	21540	1201	16.8	3.97	1060	135	1195	209	0.881	33.8	0.465	33.0	76.1
	54	18670	1019	16.5	3.86	927	115	1051	178	0.872	38.4	0.391	22.9	68.6
406x140	**46**	15670	540	16.3	3.03	779	75.9	889	119	0.870	38.8	0.207	19.2	59.0
	39	12410	410	15.9	2.89	625	57.8	718	90.7	0.859	47.6	0.155	10.5	49.2
356x171	**67**	19540	1362	15.1	3.99	1073	157	1213	243	0.886	24.4	0.413	55.7	85.5
	57	16060	1106	14.9	3.91	896	129	1009	198	0.883	28.9	0.330	33.1	72.2
	51	14160	968	14.8	3.87	796	113	895	174	0.882	32.2	0.287	23.6	64.6
	45	12080	810	14.6	3.77	686	94.7	773	146	0.875	37.0	0.237	15.7	57.0
356x127	**39**	10100	358	14.3	2.69	573	56.8	654	88.9	0.872	35.2	0.105	14.9	49.4
	33	8192	280	14.0	2.59	470	44.7	539	70.2	0.864	42.3	0.0810	8.65	41.8
305x165	**54**	11690	1061	13.1	3.94	752	127	843	195	0.891	23.7	0.234	34.3	68.2
	46	9935	896	13.0	3.90	647	108	722	166	0.891	27.2	0.195	22.2	58.8
	40	8551	766	12.9	3.85	563	92.8	626	142	0.888	31.0	0.165	14.9	51.6
305x127	**48**	9507	460	12.5	2.75	613	73.5	706	116	0.874	23.3	0.101	31.5	60.9
	42	8159	389	12.4	2.70	532	62.6	612	98.4	0.872	26.5	0.0843	21.1	53.4
	37	7162	337	12.3	2.67	471	54.6	540	85.6	0.871	29.6	0.0724	14.9	47.4
305x102	**33**	6501	194	12.5	2.15	416	37.9	481	60.0	0.866	31.6	0.0442	12.2	41.8
	28	5439	158	12.2	2.08	352	30.9	408	49.2	0.859	36.9	0.0355	7.69	36.4
	25	4364	119	11.8	1.96	286	23.5	336	37.8	0.844	44.1	0.0265	4.57	31.2
254x146	**43**	6554	677	10.9	3.51	505	92.0	568	141	0.890	21.1	0.103	24.0	55.0
	37	5547	571	10.8	3.47	433	78.0	435	119	0.889	24.3	0.0857	15.4	47.4
	31	4428	448	10.5	3.35	352	61.3	395	94.2	0.879	29.5	0.0660	8.65	39.9
254x102	**28**	4013	178	10.5	2.2l	308	34.9	354	54.8	0.873	27.4	0.0279	9.68	36.3
	25	3420	149	10.3	2.15	266	29.2	307	46.1	0.865	31.3	0.0230	6.52	32.3
	22	2853	119	10.0	2.06	225	23.5	260	37.3	0.854	36.1	0.0182	4.23	28.3
203x133	**30**	2888	384	8.72	3.18	279	57.4	313	88.0	0.882	21.5	0.0373	10.2	38.0
	25	2349	309	8.54	3.10	231	46.3	259	71.2	0.876	25.5	0.0295	6.05	32.2
203x102	**23**	2091	163	8.49	2.37	206	32.1	232	49.5	0.890	22.5	0.0153	6.87	29.0
178x102	**19**	1357	138	7.49	2.39	153	27.2	171	41.9	0.889	22.6	0.00998	4.37	24.2
152x89	**16**	838	90.4	6.40	2.10	110	20.3	124	31.4	0.889	19.5	0.00473	3.61	20.5
127x76	**13**	477	56.2	5.33	1.83	75.1	14.7	85.0	22.7	0.893	16.2	0.00200	2.92	16.8

Universal Columns



PROPERTIES

Designation		Second Moment of Area		Radius Of Gyration		Elastic Modulus		Plastic Modulus		Buck. Para.	Tors. Index	Warp. Const	Tors. Const	Area
Serial Size mm	**Mass per Metre kg**	Axis x-x cm^4	Axis y-y cm^4	Axis x-x cm	Axis y-y cm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	u	x	H dm^6	J cm^4	A cm^2
356x406	**634**	275000	98190	18.5	11.0	11590	4631	14240	7112	0.843	5.46	38.8	13730	808
	551	227000	82670	18.0	10.9	9964	3951	12080	6057	0.841	6.06	31.1	9232	702
	467	183100	67930	17.5	10.7	8388	3295	10010	5040	0.839	6.86	24.3	5817	595
	393	146700	55370	17.1	10.5	7001	2721	8225	4154	0.837	7.87	18.9	3545	501
	340	122500	46850	16.8	10.4	6029	2325	6997	3543	0.836	8.85	15.5	2340	433
	287	99930	38680	16.5	10.3	5077	1939	5814	2949	0.835	10.2	12.3	1441	366
	235	79150	31040	16.2	10.2	4155	1572	4691	2386	0.834	12.1	9.55	813	300
COLCORE	**477**	172500	68090	16.9	10.6	8078	3209	9704	4981	0.815	6.90	23.8	5705	607
356x368	**202**	66330	23630	16.0	9.57	3541	1262	3978	1917	0.843	13.4	7.14	561	258
	177	57110	20450	15.9	9.52	3101	1099	3455	1667	0.844	15.0	6.07	382	226
	153	48640	17510	15.8	9.46	2687	946	2970	1433	0.844	17.0	5.10	252	196
	129	40300	14580	15.6	9.39	2266	792	2485	1198	0.843	19.8	4.17	154	165
305x305	**283**	78800	24540	14.8	8.25	4314	1525	5101	2337	0.855	7.65	6.33	2034	360
	240	64150	20220	14.5	8.14	3639	1272	4243	1945	0.854	8.74	5.01	1270	305
	198	50860	16240	14.2	8.02	2993	1034	3438	1577	0.854	10.2	3.86	735	252
	158	38690	12500	13.9	7.89	2365	805	2675	1225	0.852	12.5	2.85	376	201
	137	32770	10650	13.7	7.82	2045	690	2293	1049	0.851	14.2	2.38	249	174
	118	27610	9006	13.6	7.76	1756	587	1952	892	0.851	16.2	1.97	160	150
	97	22200	7272	13.4	7.68	1443	477	1589	724	0.850	19.3	1.55	91.1	123
254x254	**167**	29920	9792	11.9	6.79	2070	740	2418	1131	0.852	8.49	1.62	625	212
	132	22550	7506	11.6	6.67	1632	575	1872	877	0.850	10.3	1.18	321	169
	10 7	17500	5894	11.3	6.57	1312	456	1484	695	0.848	12.4	0.893	173	137
	89	14280	4835	11.2	6.52	1097	378	1225	574	0.849	14.5	0.714	103	114
	73	11370	3880	11.1	6.46	895	306	990	463	0.849	17.3	0.558	57.5	92.9
203x203	**86**	9461	3114	9.27	5.32	851	298	979	455	0.849	10.2	0.317	138	110
	71	7634	2530	9.16	5.28	707	245	801	373	0.852	11.9	0.249	81.0	90.9
	60	6103	2047	8.96	5.19	582	199	654	303	0.847	14.1	0.195	46.9	76.0
	52	5254	1767	8.90	5.16	510	173	567	263	0.848	15.8	0.166	31.9	66.4
	46	4565	1539	8.81	5.12	449	151	497	230	0.846	17.7	0.142	22.2	58.8
152x152	**37**	2213	706	6.84	3.87	274	91.5	309	140	0.848	13.3	0.0399	19.3	47.3
	30	1748	560	6.75	3.82	222	73.3	248	112	0.848	16.0	0.0307	10.6	38.4
	23	1258	402	6.51	3.68	165	52.7	184	80.5	0.837	20.5	0.0213	4.82	29.7

ARUP

Circular Hollow Sections

DIMENSIONS AND PROPERTIES

Designation		Mass Per Metre	Area	Ratio For Local Buck.	Second Moment of Area	Radius Of Gyration	Elastic Modulus	Plastic Modulus	Tors. Const		Surf. Area Per Metre
Outside Dia. D(mm)	**Thickness t mm**	kg	A cm^2	D/t	I cm^4	r cm	Z cm^3	S cm^3	J cm^4	C cm^3	m^2
244.5	**6.3**	37.0	47.1	38.8	3346	8.42	274	358	6692	548	0.768
	8.0	46.7	59.4	30.6	4160	8.37	340	448	8320	680	0.768
	10.0	57.8	73.7	24.5	5073	8.30	415	550	10150	830	0.768
	12.5	71.5	91.1	19.6	6147	8.21	503	673	12290	1006	0.768
	I6.0	90.2	115	15.3	7533	8.10	616	837	15070	1232	0.768
	20.0@◆	111	141	12.2	8957	7.97	733	1011	17910	1466	0.768
	25.0+@◆	135	172	9.78	10520	7.81	860	1210	21040	1720	0.768
273.0	**6.3**	41.4	52.8	43.3	4696	9.43	344	448	9392	688	0.858
	8.0	52.3	66.6	34.1	5852	9.37	429	562	11700	858	0.858
	10.0	64.9	82.6	27.3	7154	9.31	524	692	14310	1048	0.858
	12.5	80.3	102	21.8	8697	9.22	637	849	17390	1274	0.858
	16.0	101	129	17.l	10710	9.10	784	1058	21420	1568	0.858
	20.0 @◆	125	159	13.6	12800	8.97	938	1283	25600	1876	0.858
	25.0 @◆	153	195	10.9	15130	8.81	1108	1543	30260	2216	0.858
323.9	**6.3**	49.3	62.9	51.4	7929	11.2	490	636	15860	980	1.02
	8.0	62.3	79.4	40.5	9910	11.2	612	799	19820	1224	1.02
	10.0	77.4	98.6	32.4	12160	11.1	751	986	24320	1502	1.02
	12.5	96.0	122	25.9	14850	11.0	917	1213	29700	1834	1.02
	16.0	121	155	20.2	18390	10.9	1136	1518	36780	2272	1.02
	20.0@ ◆	150	191	16.2	22140	10.8	1367	1850	44280	2734	1.02
	25.0@ ◆	184	235	13.0	26400	10.6	1630	2239	52800	3260	1.02
355.6	**8.0**	68.6	87.4	44.5	13200	12.3	742	967	26400	1484	1.12
	10.0	85.2	109	35.6	16220	12.2	912	1195	32440	1824	1.12
	12.5	106	135	28.4	19850	12.1	1117	1472	39700	2234	1.12
	16.0	134	171	22.2	24660	12.0	1387	1847	49320	2774	1.12
	20.0 @◆	166	211	17.8	29790	11.9	1676	2255	59580	3352	1.12
	25.0 @◆	204	260	14.2	35680	11.7	2007	2738	71360	4014	1.12
406.4	**10.0**	97.8	125	40.6	24480	14.0	1205	1572	48960	2410	1.28
	12.5	121	155	32.5	30030	13.9	1478	1940	60060	2956	1.28
	16.0	154	196	25.4	37450	l3.8	1843	2440	74900	3686	1.28
	20.0 @◆	191	243	20.3	45430	13.7	2236	2989	90860	4472	1.28
	25.0 @◆	235	300	16.3	54700	13.5	2692	3642	109400	5384	1.28
	32.0 @◆	295	376	12.7	66430	13.3	3269	4497	132900	6538	1.28
457.0	**10.0**	110	140	45.7	35090	15.8	1536	1998	70180	3072	1.44
	12.5	137	175	36.6	43140	15.7	1888	2470	86280	3776	1.44
	16.0	174	222	28.6	53960	15.6	2361	3113	107900	4722	1.44
	20.0@ ◆	216	275	22.9	65680	15.5	2874	3822	131400	5748	1.44
	25.0@ ◆	266	339	18.3	79420	15.3	3475	4671	158800	6950	1.44
	32.0 @◆	335	427	14.3	97010	15.1	4246	5791	194000	8492	1.44
	40.0@ ◆	411	524	11.4	114900	14.8	5031	6977	229800	10060	1.44
	10.0	123	156	50.8	48520	17.6	1910	2480	97040	3820	1. 60
508.0	**12.5**	153	195	40.6	59760	17.5	2353	3070	119500	4706	1.60
	16.0	194	247	31.7	74910	17.4	2949	3874	149800	5898	1.60
	20.0@◆	241	307	25.4	91430	17.3	3600	4766	182900	7200	1.60
	25.0@ ◆	298	379	20.3	110900	17.1	4367	5837	221800	8734	1.60
	32.0@ ◆	376	479	15.9	136100	16.9	5360	7261	272200	10720	1.60
	40.0@◆	462	588	12.7	162200	16.6	6385	8782	324400	12770	1.60
	50.0@ ◆	565	719	10.2	190900	16.3	75l5	10530	381800	15030	1.60

\+ Sections marked thus are not ncluded in BS4848: Part 2

@ Sections marked thus are seamless and rolled in grade 50B only

◆ Check availability of section

Rectangular Hollow Sections

DIMENSIONS AND PROPERTIES

Designation		Mass Per Metre	Area	Ratios for Local Buck.		Second Moment of Area		Radius Of Gyration		Elastic Modulus		Plastic Modulus		Tors. Const		Surf. Area
Size D B mm	Thickness kg	kg	A cm²	d/t	b/t	Axis x-x cm⁴	Axis y-y cm⁴	Axis x-x cm	Axis y-y cm	Axis x-x cm³	Axis y-y cm³	Axis x-x cm³	Axis y-y cm³	J cm⁴	C cm³	m²
150x100	**5.0**	18.7	23.9	27.0	17.0	747	396	5.59	4.07	99.5	79.1	121	90.8	806	127	0.489
	6.3	23.3	29.7	20.8	12.9	910	479	5.53	4.02	121	95.9	148	111	985	153	0.486
	8.0	29.1	37.1	15.7	9.50	1106	577	5.46	3.94	147	115	183	137	1202	184	0.483
	10.0	35.7	45.5	12.0	7.00	1312	678	5.37	3.86	175	136	220	164	1431	215	0.479
	12.5	43.6	55.5	9.00	5.00	1532	781	5.25	3.75	204	156	263	194	1680	246	0.473
160x80	**5.0**	18.0	22.9	29.0	13.0	753	251	5.74	3.31	94.1	62.8	117	71.7	599	106	0.469
	6.3	22.3	28.5	22.4	9.70	917	302	5.68	3.26	115	75.6	144	87.7	729	127	0. 466
	8.0	27.9	35.5	17.0	7.00	1113	361	5.60	3.19	139	90.2	177	107	882	151	0. 463
	10.0	34.2	43.5	13.0	5.00	1318	419	5.50	3.10	165	105	213	127	1041	175	0.459
	12.5	41.6	53.0	9.80	3.40	1536	476	5.38	3.00	192	119	254	150	1206	199	0.453
200x100	**5.0**	22.7	28.9	37.0	17.0	1509	509	7.23	4.20	151	102	186	115	1202	172	0.589
	6.3	28.3	36.0	28.7	12.9	1851	618	7.17	4.14	185	124	231	1473	1473	208	0.586
	8.0	35.4	45.1	22.0	9.50	2269	747	7.09	4.07	227	149	286	1802	1802	251	0.583
	10.0	43.6	55.5	17.0	7.00	2718	881	7.00	3.98	272	176	346	2154	2154	296	0.579
	12.5	53.4	68.0	13.0	5.00	3218	1022	6.88	3.88	322	204	417	2541	2541	342	0.573
	16.0	66.4	84.5	9.50	3.25	3808	1175	6.71	3.73	381	235	505	2988	2988	393	0.566
200x120	**5.0+**	24.2	30.9	37.0	21.0	1699	767	7.42	4.98	170	128	206	144	1646	210	0.629
	6.0+	28.9	36.8	30.3	17.0	2000	899	7.37	4.94	200	150	244	171	1940	245	0.627
	6.3 +	30.3	38.5	28.7	16.0	2087	937	7.36	4.93	209	156	255	178	2025	256	0.626
	8.0+	37.9	48.3	22.0	12.0	2564	1140	7.28	4.86	256	190	316	220	2491	310	0.623
	10.0+	46.7	59.5	17.0	9.00	3079	1356	7.19	4.77	308	226	384	266	2997	367	0.619
	12.5+	57.3	73.0	13.0	6.60	3658	1589	7.08	4.67	366	265	464	319	3567	429	0.613
250x150	**5.0+**	30.5	38.9	47.0	27.0	3382	1535	9.33	6.28	271	205	326	229	3275	337	0.789
	6.3	38.2	48.6	36.7	20.8	4178	1886	9.27	6.23	334	252	405	284	4049	413	0. 786
	8.0	48.0	61.1	28.2	15.7	5167	2317	9.19	6.16	413	309	505	353	5014	506	0. 783
	10.0	59.3	75.5	22.0	12.0	6259	2784	9.10	6.07	501	371	618	430	6082	606	0.779
	12.5	73.0	93.0	17.0	9.00	7518	3310	8.99	5.97	601	441	751	520	7317	717	0.773
	16.0	91.5	117	12.6	6.38	9089	3943	8.83	5.82	727	526	924	635	8863	851	0.766
300x200	**6.3**	48.1	61.2	44.6	28.7	7880	4216	11.3	8.30	525	422	627	475	8468	681	0. 986
	8.0	60.5	77.1	34.5	22.0	9798	5219	11.3	8.23	653	522	785	593	10550	840	0. 983
	10.0	75.0	95.5	27.0	17.0	11940	6331	11.2	8.14	796	633	964	726	12890	1016	0.979
	12.5	92.6	118	21.0	13.0	14460	7619	11.1	8.04	964	762	1179	886	15650	1217	0. 973
	16.0	117	149	15.7	9.50	17700	9239	10.9	7.89	1180	924	1462	1094	19230	1469	0.966
400x200	**8.0**	73.1	93.1	47.0	22.0	19710	6695	14.5	8.48	985	669	1210	746	15720	1135	1.18
	10.0	90.7	116	37.0	17.0	24140	8138	14.5	8.39	1207	814	1492	916	19240	1377	1.18
	12.5	112	143	29.0	13.0	29410	9820	14.3	8.29	1471	982	1831	1120	23410	1657	1.17
	16.0	142	181	22.0	9.50	36300	11950	14.2	8.14	1815	1195	2285	1388	28840	2011	1.17
450x250	**8.0+**	85.7	109	53.2	28.2	30270	12200	16.7	10.6	1345	976	1630	1086	27060	1629	1.38
	10.0	106	136	42.0	22.0	37180	14900	16.6	10.5	1653	1192	2013	1338	33250	1986	1.38
	12.5	132	168	33.0	17.0	45470	18100	16.5	10.4	2021	1448	2478	1642	40670	2407	1.37
	16.0	167	213	25.1	12.6	56420	22250	16.3	10.2	2508	1780	3103	2047	50480	2948	1.37
500x200	**8.0+**	85.7	109	59.5	22.0	34270	8170	17.7	8.65	1371	817	1716	900	21100	1430	1.38
	10.0+	106	136	47.0	17.0	42110	9945	17.6	8.57	1684	994	2119	1106	25840	1738	1.38
	12.5+	132	168	37.0	13.0	51510	12020	17.5	8.46	2060	1202	2609	1354	31480	2097	1.37
	16.0+	167	213	28.2	9.50	63930	14670	17.3	8.31	2557	1467	3267	1683	38830	2554	1.37
500x300	**10.0**	122	156	47.0	27.0	54120	24560	18.7	12.6	2165	1638	2609	1834	52400	2696	1.58
	12.5	152	193	37.0	21.0	66360	29970	18.5	12.5	2655	1998	3218	2257	64310	3282	1.57
	16.0	192	245	28.2	15.7	82670	37080	18.4	12.3	3307	2472	4042	2825	80220	4046	1.57
	20.0@	237	302	22.0	12.0	100100	44550	18.2	12.1	4006	2970	4942	3442	97310	4845	1.56

\+ Sections marked thus are not ncluded in BS4848: Part 2

@ Sections marked thus are seamless and rolled in grade 50B only

◆ Check availability of section

4.4.11 References

4. SCI, Guide to BS 5950: Part 1: 1990, Volume 1

5. ARBED, Structural shapes, 1990

6. Simple Connections, Volume 1: Design Rules, SCI/BCSA

7. Simple Connections, Volume 2: Practical Applications

8. Moment Connections, SCI BCSA

4.5 COMPOSITE STEEL AND CONCRETE

4.5.1 RULES OF THUMB

- **Typical starting point**

  Overall concrete depth 130mm (Grade 30)
  Depth of profiled decking 60mm
  Size beam with Z = (Z for non-composite beam) x F where F = 1.6 - 2.0

- **Typical maximum slab spans (m)**[1]

  Figures based on: "Ribdeck AL" (Richard Lees Ltd)
  Imposed load of 4+1 kN/m^2 (unfactored)
  (including floor, ceiling and services = 6.7 kN/m^2)
  Unpropped
  For other profiles see section D2

Decking gauge	Slab depth (mm)	Lightweight concrete		Normal Weight Concrete	
		Simply Supported	Continuous	Simply Supported	Continuous
0.9 (A142 mesh)	130 150	2.95 2.88	3.11 3.22	2.78 2.66	3.03 3.00
1.2 (A193 mesh)	130 150	3.20 3.08	3.73 3.62	3.02 2.89	3.55 3.41

Design assumes 60 minute fire resistance, provided that the slab is continious (decking need not be)

- **Choice of beam system**

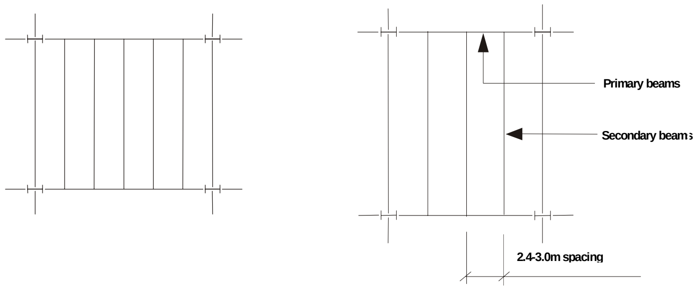
Scheme	Likely span range (m)		Economic and practical maximum ratios of span to structural depth	Accommodation of major services. Maximum x-sectional area for 15m span m²	Estimated unit cost index for fabricated and erected steelwork
	As primary beams	As secondary beams			
Simple construction with rolled sections	6-10.5	8-18	20 28	1.7 -	1.0 1.3 with reinforced openings
Fabricated sections	Above 12	Above 12	15 25	1.9 0.9	1.2
Haunched Beams	Above 12	Above 12	25 (support) 32(midspan)	5.3 3.6	1.3
Parallel Beam approach	Spans up to 10.5	Ribs up to 15	21 | 14 30 | 18	5.0 2.8	0.9
Castellated sections	N/A	up to 16	17 20	1.5 1.3	1.3
Stub girders	10-15	N/A	13 16	3.0 2.5	1.4
Composite trusses	Above 12	Above 12	12 16	1.5 1.0	1.5
Slimfloor	-	4.5 to 9	20	-	
Slimdek	-	5 to 7	-	-	

4.5.1 RULES OF THUMB (CONT'D)

- **Preferred beam layout**[2]

Inefficient

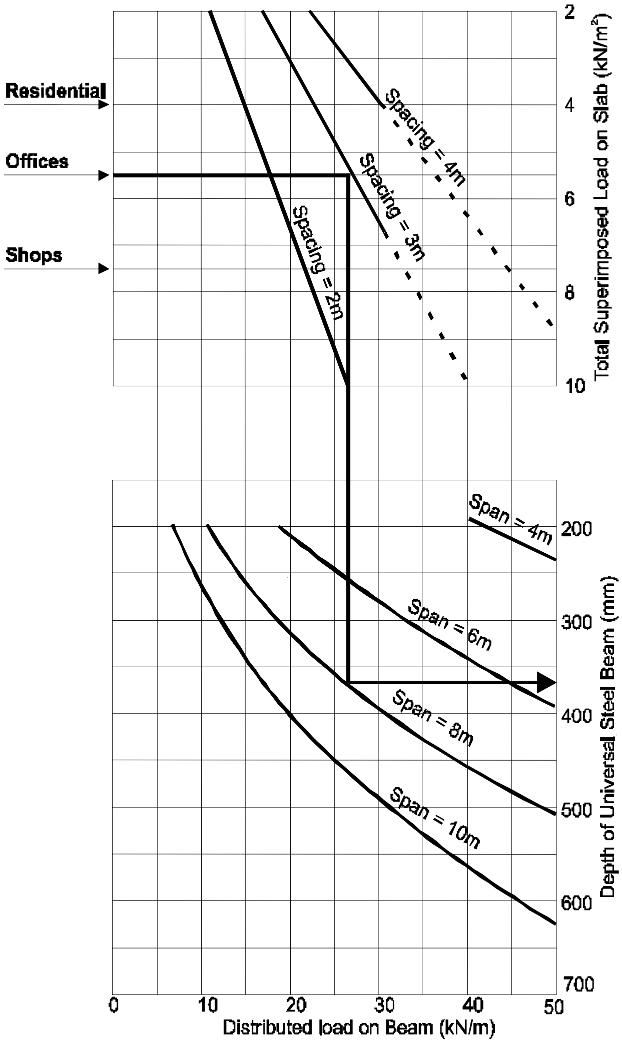
Efficient



For maximum structural efficiency:

$$\frac{L_{secondary}}{L_{primary}} = 4/3$$

- **Initial scheming chart**
  Universal beams, 125mm concrete slab
  (Dotted Line on upper graph indicates that a 150mm slab may be required).



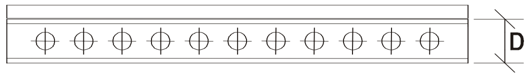
4.5.1 RULES OF THUMB (CONT'D)

Fabricated beams

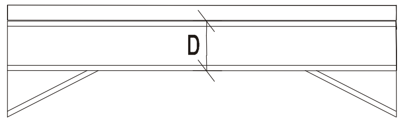
Castellated cellular beams (not very good for point loads):
Span/depth < 20

Castellated beams,	hole	= 0.67D
	centres	= 0.72D
Cellular beams holes	diameter	= 0.6D - 0.8D
	centres	= 1.1 -1.5

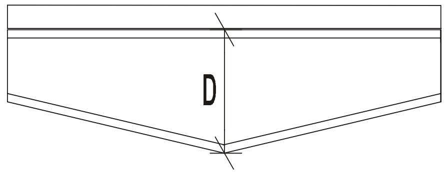
diameter



Haunched beams (use as part of frame action):
D = midspan depth
Span/depth ≤ 35 (span/depth including slab = 26 – 28)
Maximum overall depth at haunch = 2D
Haunch length typically 7 - 10% of span



Tapered beams:
D = midspan depth
Span/depth 15 - 25
Depth at support = 0.5D or maximum taper of 6 degrees



- **Openings in beams (non-seismic applications)**

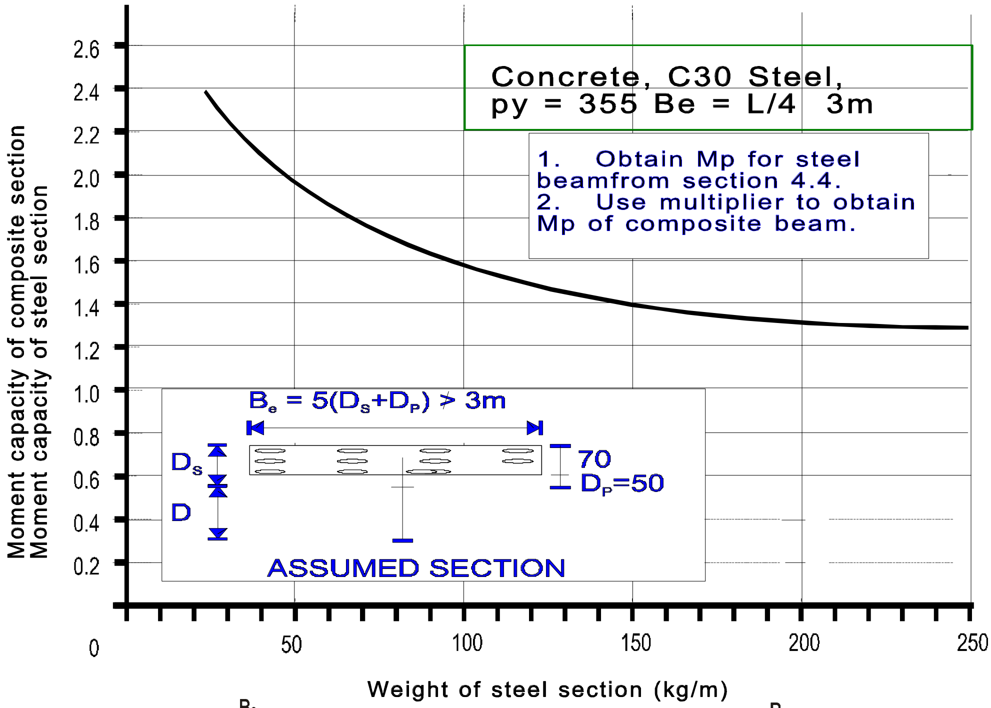
Geometrical constraints :
- Limit unstiffened openings to 0.6D depth by 1.5D length
- Limit stiffened openings to 0.7D depth by 2D length
- Space > D apart
- Ideally positioned between L/5 and L/3 from support for beams with UDL
- Position > D from any point load
- Position > 2D (or L/10) from support
- Openings should ideally be located mid-height. If not, the depths of the upper and lower sections of web should not differ by more than a factor of 2.

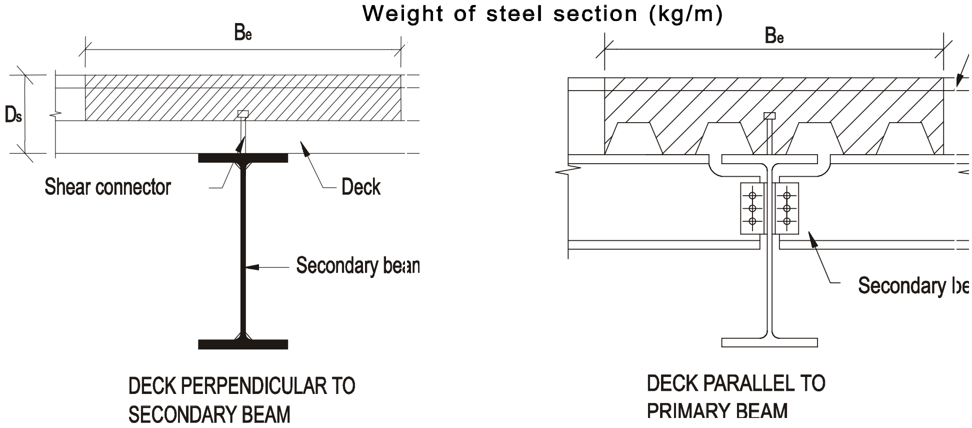
4.5.2 LOAD FACTORS

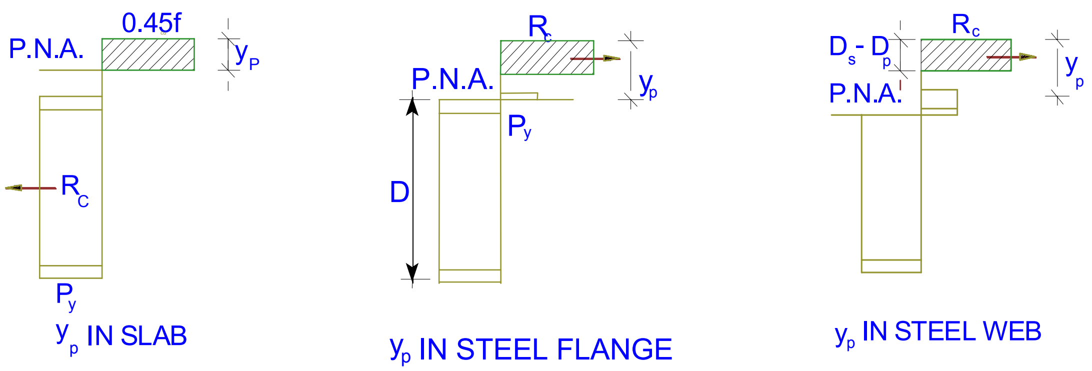
As for non-composite steel (see section 4.4.2)

4.5.3 BENDING RESISTANCE (composite condition)[3]

- **Approximate moment resistance calculation**







Case (c) **Case (b)** **Case(c)**

Bending Resistance Formulae (Assuming 100% interaction)

$R_s = p_y A$ $\qquad R_c = 0.45\, f_{cu}\,(D_s - D_p)B_e$ $\qquad B_e = 0.25\,L \not> $ beam spacing

- CASE (a) : $R_c > R_s$ (P.N.A. in concrete slab)

$$M_{pc} = R_s\left[\frac{D}{2} + D_s - \frac{R_s}{R_c}\left(\frac{D_s - D_p}{2}\right)\right]$$

- CASE (b) : $R_s > R_c > R_w$ (P.N.A. in steel flange)

$$M_{pc} = R_s\frac{D}{2} + R_c\left(\frac{D_s + D_p}{2}\right) - \frac{(R_s - R_c)^2}{R_f}\frac{T}{4}$$

where T = flange thickness
R_f = axial capacity of **one** steel flange

- CASE (c) : $R_c < R_w$ (P.N.A. lies in web)

$$M_{pc} = M_s + R_c\left(\frac{D_s + D_p + D}{2}\right) - \frac{R_c^2}{R_w}\frac{D}{4}$$

where M_s = plastic capacity of steel section
R_w = axial resistance of web only

4.5.4 SHEAR CONNECTORS[4]

Design strength of headed studs in normal weight concrete (kN)

Dimensions of stud shear connectors (mm)			Design strength of concrete (N/mm²)			
Diameter	Nominal height	As-welded height	25	30	35	40
25	100	95	117	123	129	134
22	100	95	95	101	106	111
19	100	95	76	80	83	87
19	75	70	66	70	73	77
16	75	70	56	59	62	66
13	65	60	35	38	39	42

For concrete of characteristic strength greater than 40 N/mm² use the values for 40 N/mm².
For connectors of heights greater than tabulated use the values for the greatest height tabulated.

r_{con} = 0.9 for lightweight concrete
= 1.0 for normal weight concrete

$$r_{profile} = \frac{0.85}{\sqrt{N}}\frac{b_a}{D_p}\frac{(h - D_p)}{D_p}$$

min 0.8 (N = 2)
min 0.6 (N = 3)

N = no studs/trough
h = stud height
b_a = average trough width
D_p = depth profile

Design resistance = Design strength x r_{con} x $r_{profile}$

- **Spacing**

Minimum longitudinal = 6φ
transverse = 4φ

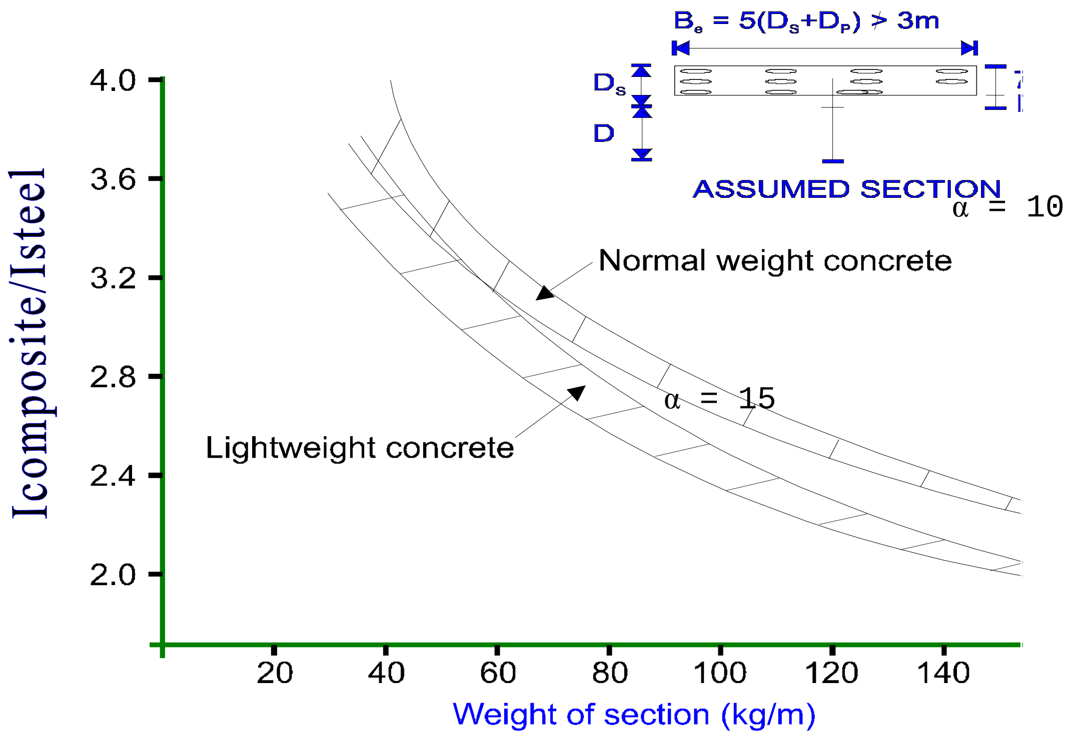
Maximum longitudinal = 600mm

4.5.5 BENDING STRENGTH (DURING CONSTRUCTION)

- Conform with requirements in section 4.4 for non-composite sections.
- Decking perpendicular to beam (secondary) provides restraint to top flange.
- Decking parallel to beam (primary) does not provide restraint.

4.5.6 STIFFNESS[3]

Approximate ratio of second moment of area of composite section to that of the steel section.



4.5.7 SAFE LOAD TABLES

Concrete grade	C35
Modular ratio	15
Overall concrete depth	130 mm
Depth of decking	60 mm
Partial interaction	60%
Flange width	as large as possible
Deflection limit	DL : 1/200 LL : 1/350
Dead Load	steelwork - self weight decking - 0.18 kPa slab (dense) - 3.12 kPa slab (lightweight) - 2.34 kPa services + ceiling - 1.00 kPa

4.5.8 REFERENCES

1. RICHARD LEES Ltd, Steel Deck Flooring Systems
2. STEEL CONSTRUCTION INSTITUTE, Steel Designers Manual
3. STEEL CONSTRUCTION INSTITUTE, SCI-P-055 Design of Composite Slabs and Beams with Steel Decking
4. BS 5950 Structural use of steelwork in building Part 3: Design in composite construction

SAFE LOAD TABLES (1)
GRADE 43 - DENSE CONCRETE SLAB
Imposed load = 4.0 + 1.0 kN/m^2

			Minimum Weight			Minimum Depth		
Bay size (m x m)	No. sec. Beams per grid	Spacing of sec. beams	Secondary Beams	Primary Beams	Weight (kg/m^2)	Secondary Beams	Primary Beams	Weight (kg/m^2)
6.0 x 6.0	2	3.00	305 x 102 x 28	406 x 140 x 46	17.00	203 x 203 x 46	254 x 254 x 89	30.17
6.0 x 7.2	2	3.00	356 x 127 x 39	457 x 152 x 52	20.22	203 x 203 x 60	254 x 254 x 107	34.86
6.0 x 7.5	2	3.00	356 x 127 x 39	457 x 152 x 60	21.00	203 x 203 x 71	254 x 254 x 107	37.93
6.0 x 8.0	2	3.00	406 x 140 x 39	457 x 152 x 60	20.50	203 x 203 x 86	254 x 254 x 132	45.17
6.0 x 9.0	2	3.00	457 x 152 x 52	457 x 191 x 74	25.56	254 x 254 x 89	254 x 254 x 132	44.33
6.0 x 10.0	2	3.00	457 x 152 x 60	533 x 210 x 82	28.20	254 x 254 x 107	254 x 254 x 167	52.37
6.0 x 12.0	2	3.00	533 x 210 x 82	533 x 210 x 92	35.00	254 x 254 x 167*	305 x 305 x 158	68.83
6.0 x 15.0	2	3.00	610 x 229 x 113 *	610 x 229 x 101	44.40	305 x 305 x 240*	305 x 305 x 198	93.20
6.0 x 18.0	2	3.00	762 x 267 x 147 *	610 x 229 x 125	55.94	356 x 406 x 340*	305 x 305 x 240	126.67
7.2 x 6.0	3	2.40	305 x 102 x 25	457 x 152 x 60	20.42	152 x 152 x 37	254 x 254 x 107	33.25
7.2 x 7.2	3	2.40	305 x 102 x 33	457 x 152 x 67	23.06	203 x 203 x 46	254 x 254 x 132	37.50
7.2 x 9.0	3	2.40	356 x 171 x 45	533 x 210 x 82	27.86	203 x 203 x 71	254 x 254 x 167	48.14
7.2 x 12.0	3	2.40	457 x 152 x 67	610 x 229 x 101	36.33	254 x 254 x132*	305 x 305 x 198	71.50
7.2 x 18.0	3	2.40	686 x 254 x 125 *	762 x 267 x 147	60.25	356 x 406 x 287*	356 x 406 x 287	135.53
7.5 x 6.0	3	2.50	305 x 102 x 25	457 x 152 x 60	20.00	203 x 203 x 46	254 x 254 x 132	40.40
7.5 x 7.5	3	2.50	356 x 127 x 33	533 x 210 x 82	24.13	203 x 203 x 52	254 x 254 x 167	43.07
7.5 x 9.0	3	2.50	356 x 171 x 45	533 x 210 x 92	28.22	203 x 203 x 86	305 x 305 x 158	51.96
7.5 x 12.0	3	2.50	457 x 152 x 67	610 x 229 x 113	36.22	254 x 254 x132*	305 x 305 x 240	72.80
7.5 x 15.0	3	2.50	610 x 229 x 101	686 x 254 x 125	48.73	305 x 305 x 198*	305 x 305 x 283	98.07
7.5 x 18.0	3	2.50	686 x 254 x 140 *	762 x 267 x 147	64.17	356 x 406 x 287*	356 x 406 x 340	133.69
8.0 x 6.0	3	2.67	305 x 102 x 25	457 x 152 x 74	21.71	203 x 203 x 46	254 x 254 x 132	39.25
8.0 x 8.0	3	2.67	356 x 127 x 39	533 x 210 x 82	24.88	203 x 203 x 71	305 x 305 x 158	46.38
8.0 x 9.0	3	2.67	406 x 140 x 46	610 x 229 x 101	28.47	203 x 203 x 86	305 x 305 x 198	54.25
8.0 x 10.0	3	2.67	457 x 152 x 52	610 x 229 x 101	29.60	254 x 254 x 89	305 x 305 x 198	53.18
8.0 x 12.0	3	2.67	457 x 191 x 74	610 x 229 x 125	38.17	254 x 254 x132*	305 x 305 x 240	69.50
8.0 x 15.0	3	2.67	610 x 229 x 101	762 x 267 x 147	47.68	305 x 305 x 198*	356 x 406 x 287	93.38
8.0 x 18.0	3	2.67	686 x 254 x 140 *	762 x 267 x 173	62.11	356 x 406 x 287*	356 x 406 x 393	129.46
9.0 x 6.0	3	3.00	305 x 102 x 28	533 x 210 x 82	23.00	203 x 203 x 46	254 x 254x 167	43.17
9.0 x 7.2	3	3.00	356 x 127 x 39	610 x 229 x 101	27.03	203 x 203 x 60	305 x 305 x 198	47.50
9.0 x 7.5	3	3.00	356 x 127 x 39	610 x 229 x 101	26.47	203 x 203 x 71	305 x 305 x 198	50.07
9.0 x 8.0	3	3.00	406 x 140 x 39	610 x 229 x 101	25.63	203 x 203 x 86	305 x 305 x 198	53.42
9.0 x 9.0	3	3.00	457 x 152 x 52	610 x 229 x 113	29.89	254 x 254 x 89	305 x 305 x 240	56.33
9.0 x 10.0	3	3.00	457 x 152 x 60	610 x 229 x 125	32.50	254 x 254 x 107	305 x 305 x 240	59.67
9.0 x 12.0	3	3.00	533 x 210 x 82	686 x 254 x 140	39.00	254 x 254 x 167*	356 x 406 x 287	79.58
9.0 x 15.0	3	3.00	610 x 229 x 113 *	762 x 267 x 173	49.20	305 x 305 x 240*	356 x 406 x 393	106.20
9.0 x 18.0	3	3.00	762 x 267 x 147 *	838 x 292 x 194	59.78	356 x 406 x 340*	COLCORE x 477	139.83
10.0 x 6.0	4	2.50	305 x 102 x 25	610 x 229 x 101	26.83	203 x 203 x 46	305 x 305 x 198	51.40
10.0 x 8.0	4	2.50	356 x 127 x 39	686 x 254 x 140	33.10	203 x 203 x 71	356 x 406 x 287	64.28
10.0 x 9.0	4	2.50	356 x 171 x 45	762 x 267 x 147	34.33	203 x 203 x 86	356 x 406 x 287	66.29
10.0 x 10.0	4	2.50	457 x 152 x 52	762 x 267 x 147	35.50	254 x 254 x 89	356 x 406 x 340	69.60
10.0 x 12.0	4	2.50	457 x 152 x 67	838 x 292 x 176	41.47	254 x 254 x 132*	356 x 406 x 393	85.55
10.0 x 15.0	4	2.50	610 x 229 x 101	914 x 305 x 201	53.80	305 x 305 x 198*	356 x 406 x 551	115.93
10.0 x 18.0	4	2.50	686 x 254 x 140 *	914 x 305 x 253	70.06	356 x 406 x 287*	356 x 406 x 634	150.02
12.0 x 6.0	4	3.00	305 x 102 x 28	686 x 254 x 140	32.67	203 x 203 x 46	406 x 406 x 287	63.17
12.0 x 7.2	4	3.00	356 x 127 x 39	686 x 254 x 170	36.61	203 x 203 x 60	356 x 406 x 340	67.22
12.0 x 7.5	4	3.00	356 x 127 x 39	762 x 267 x 173	36.07	203 x 203 x 71	356 x 406 x 393	76.07
12.0 x 8.0	4	3.00	406 x 140 x 39	762 x 267 x 173	34.63	203 x 203 x 86	356 x 406 x 393	77.79
12.0 x 9.0	4	3.00	457 x 152 x 52	838 x 292 x 194	38.89	254 x 254 x 89	COLCORE x 477	82.67
12.0 x 10.0	4	3.00	457 x 152 x 60	914 x 305 x 201	40.10	254 x 254 x 107	356 x 406 x 467	82.37
12.0 x 12.0	4	3.00	533 x 210 x 82	914 x 305 x 224	46.00	254 x 254 x 167*	356 x 406 x 551	101.58
12.0 x 15.0	4	3.00	610 x 229 x 113 *	914 x 305 x 289	56.93	305 x 305 x 240*	914 x 419 x 343	102.87
12.0 x 18.0	4	3.00	762 x 267 x 147 *	914 x 419 x 388	70.56	356 x 406 x 340*	914 x 419 x 388	134.89
15.0 x 6.0	5	3.00	305 x 102 x 28	838 x 292 x 176	38.67	203 x 203 x 46	COLCORE x 477*	94.83
15.0 x 7. 5	5	3.00	356 x 127 x 39	914 x 305 x 224	42.87	203 x 203 x 71	356 x 406 x 551	97.13
15.0 x 8.0	5	3.00	406 x 140 x 39	914 x 305 x 224	41.00	203 x 203 x 86	356 x 406 x 551	97.54
15. 0 x 9.0	5	3.00	457 x 152 x 52	914 x 305 x 253	45.44	254 x 254 x 89	356 x 406 x 634*	100.11
15.0 x 10.0	5	3.00	457 x 152 x 60	914 x 305 x 289	48.90	254 x 254 x 107	914 x 305 x 289*	64.57
15. 0 x 12.0	5	3.00	533 x 210 x 82	914 x 419 x 343 *	55.92	254 x 254 x 167*	914 x 419 x 388*	88.00
15.0 x 15.0	5	3.00	610 x 229 x 113 *	FAIL		305 x 305 x 240*	FAIL	
15.0 x 18.0	5	3.00	762 x 267 x 147 *	FAI L		356 x 406 x 340*	FAIL	
18.0 x 6.0	6	3.00	305 x 102 x 28	914 x 305 x 253 *	51.50	203 x 203 x 46	356 x 406 x 634*	121.00
18.0 x 7.2	6	3.00	356 x 127 x 39	914 x 419 x 343 *	60.64	203 x 203 x 60	914 x 419 x 343*	67.64
18.0 x 7.5	6	3.00	356 x 127 x 39	914 x 419 x 343 *	58.73	203 x 203 x 71	914 x 419 x 343*	69.40
18.0 x 8. 0	6	3.00	406 x 140 x 39	914 x 419 x 343 *	55.88	203 x 203 x 86	914 x 419 x 388*	77.1 7
18.0 x 9.0	6	3.00	457 x 152 x 52	FAIL		254 x 254 x 89	FAIL	
18.0 x 10.0	6	3.00	457 x 152 x 60	FAIL		254 x 254 x 107	FAIL	
18.0 x 12. 0	6	3.00	533 x 210 x 82	FAIL		254 x 254 x 167*	FAIL	
18.0 x 15.0	6	3.00	610 x 229 x 113 *	FAIL		305 x 305 x 240*	FAIL	
18.0 x 18.0	6	3.00	762 x 267 x 347 *	FAIL		356 x 406 x 340*	FAIL	

(*) Natural frequency of the beam is less then 4.5Hz.

SAFE LOAD TABLES (2)
GRADE 43 - LIGHTWEIGHT CONCRETE SLAB
Imposed load = 4.0 + 1.0 kN/m^2

			Minimum Weight			Minimum Depth		
Bay size (m x m)	No. sec. beams per grid	Spacing of sec. beams	Secondary Beams	Primary Beams	Weight (kg/m^2)	Secondary Beams	Primary Beams	Weight (kg/m^2)
6.0 x 6.0	2	3.00	305 x 102 x 25	406 x 140 x 46	16.00	203 x 203 x 46	203 x 203 x 86	29.67
6.0 x 7.2	2	3.00	356 x 127 x 33	457 x 152 x 52	18.22	203 x 203 x 52	254 x 254 x 89	29.69
6.0 x 7.5	2	3 00	305 x 102 x 37	457 x 152 x 52	19.27	203 x 203 x 60	254 x 254 x 107	34.27
6.0 x 8.0	2	3.00	356 x 127 x 39	457 x 152 x 60	20.50	203 x 203 x 71	254 x 254 x 107	37.04
6.0 x 9.0	2	3.00	406 x 140 x 46	457 x 152 x 67	22.78	203 x 203 x 86	254 x 254 x 132	43.33
6.0 x 10.0	2	3.00	457 x 152 x 52	457 x 191 x 74	24.73	254 x 254 x 107	254 x 254 x 132	48.87
6.0 x 12.0	2	3.00	457 x 191 x 74	533 x 210 x 82	31.50	254 x 254 x 167	254 x 254 x 167	69.58
6.0 x 15.0	2	3.00	610 x 229 x 101	610 x 229 x 101	40.40	305 x 305 x 198*	305 x 305 x 198	79.20
6.0 x 18.0	2	3.00	686 x 254 x 140*	610 x 229 x 113	52.94	356 x 406 x 340*	305 x 305 x 240	126.67
7.2 x 6.0	3	2.40	254 x 102 x 22	457 x 152 x 52	17.83	152 x 152 x 37	254 x 254 x 107	33.25
7.2 x 7.2	3	2.40	305 x 102 x 28	457 x 152 x 67	20.97	203 x 203 x 46	254 x 254 x 132	37.50
7.2 x 9.0	3	2.40	356 x 127 x 39	533 x 210 x 82	25.36	203 x 203 x 71	254 x 254 x 167	48.14
7.2 x 12.0	3	2.40	457 x 152 x 60	610 x 229 x 101	33.42	254 x 254 x 107	305 x 305 x 198	61.08
7.2 x 18.0	3	2.40	610 x 229 x 125*	686 x 254 x 140	59.86	356 x 406 x 287*	305 x 305 x 287	135.53
7.5 x 6.0	3	2.50	305 x 102 x 25	457 x 152 x 60	20.00	152 x 152 x 37	254 x 254 x 107	32.63
7.5 x 7.5	3	2.50	305 x 102 x 33	457 x 191 x 74	23.07	203 x 203 x 46	254 x 254 x 132	36.00
7.5 x 9.0	3	2.50	406 x 140 x 39	533 x 210 x 82	24.71	203 x 203 x 71	254 x 254 x 167	46.96
7.5 x 12.0	3	2.50	457 x 152 x 60	610 x 229 x 101	32.42	254 x 254 x 132	305 x 305 x 198	69.30
7.5 x 15.0	3	2.50	533 x 210 x 92	610 x 229 x 125	45.13	305 x 305 x 198*	305 x 305 x 283	98.07
7.5 x 18.0	3	2.50	610 x 229 x 125*	762 x 267 x 147	58.17	356 x 406 x 287*	356 x 406 x 287	130.74
8.0 x 6.0	3	2.67	305 x 102 x 25	457 x 152 x 67	20.54	152 x 152 x 37	254 x 254 x 132	35.88
8.0 x 8.0	3	2.67	356 x 127 x 39	533 x 210 x 82	24.88	203 x 203 x 60	254 x 254 x 167	43.38
8.0 x 9.0	3	2.67	406 x 140 x 39	533 x 210 x 92	24.85	203 x 203 x 86	305 x 305 x 158	49.81
8.0 x 10.0	3	2.67	457 x 152 x 52	610 x 229 x 101	29.60	254 x 254 x 89	305 x 305 x 198	53.18
8.0 x 12.0	3	2.67	457 x 152 x 67	610 x 229 x 113	34.54	254 x 254 x 132	305 x 305 x 240	69.50
8.0 x 15.0	3	2.67	610 x 229 x 101	686 x 254 x 140	47.21	305 x 305 x 198*	356 x 406 x 287	93.38
8.0 x 18.0	3	2.67	686 x 254 x 125*	686 x 254 x 170	56.32	356 x 406 x 287*	356 x 406 x 340	126.51
9.0 x 6.0	3	3.00	305 x 102 x 25	533 x 210 x 82	22.00	203 x 203 x 46	254 x 254 x 167	43.17
9.0 x 7.2	3	3.00	356 x 127 x 33	533 x 210 x 92	23.78	203 x 203 x 52	305 x 305 x 158	39.28
9.0 x 7.5	3	3.00	305 x 102 x 37	533 x 210 x 92	24.60	203 x 203 x 60	305 x 305 x 198	46.40
9.0 x 8.0	3	3.00	356 x 127 x 39	610 x 229 x 101	25.63	203 x 203 x 71	305 x 305 x 198	48.42
9.0 x 9.0	3	3.00	406 x 140 x 46	610 x 229 x 101	26.56	203 x 203 x 86	305 x 305 x 198	50.67
9.0 x 10.0	3	3.00	457 x 152 x 52	610 x 229 x 125	29.83	254 x 254 x 107	305 x 305 x 240	59.67
9.0 x 12.0	3	3.00	457 x 191 x 74	686 x 254 x 140	36.33	254 x 254 x 167	356 x 406 x 287	79.58
9.0 x 15.0	3	3.00	610 x 229 x 101	686 x 254 x 170	45.00	305 x 305 x 198*	356 x 406 x 340	88.67
9.0 x 18. 0	3	3.00	686 x 254 x 140*	838 x 292 x 176	56.44	356 x 406 x 340*	COLCORE x 477	139.83
10.0 x 6.0	4	2.50	305 x 102 x 25	610 x 229 x 101	26.83	152 x 152 x 37	305 x 305 x 198	47.80
10.0 x 8.0	4	2.50	356 x 127 x 33	610 x 229 x 125	28.83	203 x 203 x 60	305 x 305 x 283	59.38
10.0 x 9.0	4	2.50	406 x 140 x 39	686 x 254 x 140	31.16	203 x 203 x 71	356 x 406 x 287	60.29
10.0 x 10.0	4	2.50	406 x 140 x 46	762 x 267 x 147	33.10	203 x 203 x 86	356 x 406 x 287	63.10
10.0 x 12.0	4	2.50	457 x 152 x 60	762 x 267 x 173	38.42	254 x 254 x 132	356 x 406 x 393	85.55
10.0 x 15.0	4	2.50	533 x 210 x 92	914 x 305 x 201	50.20	305 x 305 x 198*	356 x 406 x 467	110.33
10.0 x 18.0	4	2.50	610 x 229 x 125*	914 x 305 x 253	64.06	356 x 406 x 287*	356 x 406 x 634	150.02
12.0 x 6.0	4	3.00	305 x 102 x 25	686 x 254 x 125	29.17	203 x 203 x 46	305 x 305 x 283	62.50
12.0 x 7.2	4	3.00	356 x 127 x 33	762 x 267 x 147	31.42	203 x 203 x 52	356 x 406 x 287	57.19
12.0 x 7.5	4	3.00	305 x 102 x 37	762 x 267 x 147	31.93	203 x 203 x 60	356 x 406 x 340	65.33
12.0 x 8.0	4	3.00	356 x 127 x 39	762 x 267 x 173	34.63	203 x 203 x 71	356 x 406 x 340	66.17
12.0 x 9.0	4	3.00	406 x 140 x 46	838 x 292 x 176	34.89	203 x 203 x 86	356 x 406 x 393	72.33
12. 0 x10.0	4	3.00	457 x 152 x 52	838 x 292 x 194	36.73	254 x 254 x 107	COLCORE x 477	83.37
12.0 x 12.0	4	3.00	457 x 191 x 74	914 x 305 x 224	43.33	254 x 254 x 167	356 x 406 x 511	98.25
12.0 x 15.0	4	3.00	610 x 229 x 101	914 x 305 x 289	52.93	305 x 305 x 198*	356 x 406 x 634	108.27
12.0 x 18.0	4	3.00	686 x 254 x 140*	914 x 419 x 343	65.72	356 x 406 x 340*	914 x 419 x 388	134.89
15.0 x 6.0	5	3.00	305 x 102 x 25	762 x 267 x 173	37.37	203 x 203 x 46	356 x 406 x 393*	80.83
15.0 x 7.5	5	3.00	305 x 102 x 37	914 x 305 x 201	39.13	203 x 203 x 60	356 x 406 x 551	93.47
15.0 x 8.0	5	3.00	356 x 127 x 39	934 x 305 x 224	41.00	203 x 203 x 71	356 x 406 x 551	92.54
15.0 x 9.0	5	3.00	406 x 140 x 46	914 x 305 x 253	43.44	203 x 203 x 86	356 x 406 x 634*	99.11
15.0 x 10.0	5	3.00	457 x 152 x 52	914 x 305 x 289	46.23	254 x 254 x 107	356 x 406 x 634*	99.07
15.0 x 12.0	5	3.00	457 x 191 x 74	914 x 419 x 343	53.25	254 x 254 x 167	914 x 419 x 343	84.25
15.0 x 15.0	5	3.00	610 x 229 x 101	FAIL		305 x 305 x 198*	FAIL	
15.0 x 18.0	5	3.00	686 x 254 x 140*	FAIL		356 x 406 x 340*	FAIL	
18.0 x 6.0	6	3.00	305 x 102 x 25	914 x 305 x 253 *	50.50	203 x 203 x 46	356 x 406 x 634*	121.00
18.0 x 7.2	6	3.00	356 x 127 x 33	914 x 305 x 289 *	51.14	203 x 203 x 52	914 x 305 x 289*	57.47
18.0 x 7.5	6	3.00	305 x 102 x 37	914 x 419 x 343 *	58.07	203 x 203 x 60	914 x 419 x 343*	65.73
18.0 x 8.0	6	3.00	356 x 127 x 39	914 x 419 x 343*	55.88	203 x 203 x 71	914 x 419 x 34 *	66.54
18.0 x 9.0	6	3.00	406 x 140 x 46	914 x 419 x 388*	58.44	203 x 203 x 86	914 x 419 x 388*	71.78
18.0 x 10.0	6	3.00	457 x 152 x 52	FAIL		254 x 254 x 107	FAIL	
18.0 x 12.0	6	3.00	457 x 191 x 74	FAIL		254 x 254 x 167	FAIL	
18.0 x 15.0	6	3.00	610 x 229 x 101	FAIL		305 x 305 x 198*	FAIL	
18.0 x 18.0	6	3.00	686 x 254 x140*	FAIL		356 x 406 x 340*	FAIL	

(*) Natural frequency of the beam is less then 4.5Hz.

SAFE LOAD TABLES (3)
GRADE 50 - DENSE CONCRETE SLAB
Imposed load = 4.0 + 1.0 kN/m^2

			Minimum Weight			Minimum Depth		
Bay size (m x m)	No. sec. beams per grid	Spacing of sec. beams	Secondary Beams	Primary Beams	Weight (kg/m^2)	Secondary Beams	Primary Beams	Weight (kg/m^2)
6.0 x 6.0	2	3.00	305 x 102 x 25	406 x 140 x 39	14.83	152 x 152 x 37	203 x 203 x 86	26.67
6.0 x 7.2	2	3.00	305 x 102 x 33	406 x 140 x 46	17.39	203 x 203 x 46	254 x 254 x 89	27.69
6.0 x 7.5	2	3.00	305 x 102 x 33	457 x 152 x 52	17.93	203 x 203 x 52	254 x 254 x 89	29.20
6.0 x 8.0	2	3.00	356 x 127 x 33	457 x 152 x 52	17.50	203 x 203 x 60	254 x 254 x 89	31 .13
6.0 x 9.0	2	3.00	406 x 140 x 39	457 x 152 x 60	19.67	203 x 203 x 86	254 x 254 x 107	40.56
6.0 x 10.0	2	3.00	457 x 152 x 52	457 x 152 x 67	24.03	254 x 254 x 89	254 x 254 x 132	42.87
6.0 x 12.0	2	3.00	457 x 191 x 67	533 x 210 x 82	29.17	254 x 254 x132*	254 x 254 x 167	57.92
6.0 x 15.0	2	3.00	533 x 210 x 92	533 x 210 x 92	36.80	305 x 305 x 198*	305 x 305 x 158	76.53
6.0 x 18.0	2	3.00	686 x 254 x 125	610 x 229 x 101	47.28	356 x 406 x 340*	305 x 305 x 198	124.33
7.2 x 6.0	3	2.40	254 x 102 x 22	457 x 152 x 52	17.83	152 x 152 x 30	254 x 254 x 89	27.33
7.2 x 7.2	3	2.40	305 x 102 x 25	457 x 152 x 60	18.75	203 x 203 x 46	254 x 254 x 107	34.03
7.2 x 9.0	3	2.40	305 x 127 x 37	457 x 152 x 74	23.64	203 x 203 x 60	254 x 254 x 132	39.67
7.2 x 12.0	3	2.40	457 x 152 x 52	533 x 210 x 92	29.33	254 x 254 x 107*	254 x 254 x 167	58.50
7.2 x 18.0	3	2.40	610 x 229 x 101	610 x 229 x 125	49.03	356 x 406 x 287*	305 x 305 x 283	135.31
7.5 x 6.0	3	2.50	254 x 102 x 22	457 x 152 x 52	17.47	152 x 152 x 30	254 x 254 x 89	26.83
7.5 x 7.5	3	2.50	305 x 102 x 28	457 x 152 x 67	20.13	203 x 203 x 46	254 x 254 x 132	36.00
7.5 x 9.0	3	2.50	356 x 127 x 39	457 x 152 x 74	23.82	203 x 203 x 60	254 x 254 x 167	42.56
7.5 x 12.0	3	2.50	457 x 152 x 52	533 x 210 x 92	28.47	254 x 254 x 107*	305 x 305 x 198	59.30
7.5 x 15.0	3	2.50	533 x 210 x 82	610 x 229 x 113	40.33	305 x 305 x 198*	305 x 305 x 240	95.20
7.5 x 18.0	3	2.50	610 x 229 x 113 *	686 x 254 x 125	52.14	356 x 406 x 287*	305 x 305 x 283	130.52
8.0 x 6.0	3	2.67	254 x 102 x 22	457 x 152 x 60	18.25	152 x 152 x 37	254 x 254 x 107	31.71
8.0 x 8.0	3	2.67	305 x 102 x 33	457 x 152 x 74	21.63	203 x 203 x 52	254 x 254 x 167	40.38
8.0 x 9.0	3	2.67	356 x 127 x 39	533 x 210 x 82	23.74	203 x 203 x 71	254 x 254 x 167	45.18
8.0 x 10.0	3	2.67	406 x 140 x 46	533 x 210 x 92	26.45	203 x 203 x 86	305 x 305 x 158	48.05
8.0 x 12.0	3	2.67	457 x 152 x 60	610 x 229 x 101	30.92	254 x 254 x 132*	305 x 305 x 198	66.00
8.0 x 15.0	3	2.67	533 x 210 x 82	610 x 229 x 125	39.08	305 x 305 x 198*	305 x 305 x 240	90.25
8.0 x 18.0	3	2.67	610 x 229 x 125*	762 x 267 x 147	55.04	356 x 406 x 287*	356 x 406 x 287	123.57
9.0 x 6.0	3	3.00	305 x 102 x 25	457 x 191 x 74	20.67	152 x 152 x 37	254 x 254 x 132	34.33
9.0 x 7.2	3	3.00	305 x 102 x 33	533 x 210 x 82	22.39	203 x 203 x 46	254 x 254 x 167	38.53
9.0 x 7.5	3	3.00	305 x 102 x 33	533 x 210 x 82	21.93	203 x 203 x 52	254 x 254 x 167*	39.60
9.0 x 8.0	3	3.00	356 x 127 x 33	533 x 210 x 92	22.50	203 x 203 x 60	305 x 305 x 158	39.75
9.0 x 9.0	3	3.00	406 x 140 x 39	610 x 229 x 101	24.22	203 x 203 x 86	305 x 305 x 198	50.67
9.0 x 10.0	3	3.00	457 x 152 x 52	610 x 229 x 101	27.43	254 x 254 x 89	305 x 305 x 198	49.47
9.0 x 12.0	3	3.00	457 x 152 x 67	610 x 229 x 125	32.75	254 x 254 x 132*	305 x 305 x 240*	64.00
9.0 x 15.0	3	3.00	533 x 210 x 92	762 x 267 x 147	40.47	305 x 305 x 198*	356 x 406 x 287*	85.13
9.0 x 18.0	3	3.00	686 x 254 x 125*	762 x 267 x 173	51.28	356 x 406 x 340*	356 x 406 x 340*	132.22
10.0 x 6.0	4	2.50	254 x 102 x 22	533 x 210 x 92	24.13	152 x 152 x 30	305 x 305 x 158*	38.33
10.0 x 8.0	4	2.50	305 x 102 x 33	610 x 229 x 113	27.33	203 x 203 x 52	305 x 305 x 240*	50.80
10.0 x 9.0	4	2.50	356 x 127 x 39	610 x 229 x 125	29.49	203 x 203 x 60	305 x 305 x 240*	50.67
10.0 x 10.0	4	2.50	406 x 140 x 39	686 x 254 x 140	29.60	203 x 203 x 86	305 x 305 x 283*	62.70
10.0 x 12.0	4	2.50	457 x 152 x 52	762 x 267 x 147	33.05	254 x 254 x 107*	3% x 406 x 340*	71.13
10.0 x 15.0	4	2.50	533 x 210 x 82	838 x 292 x 176	44.53	305 x 305 x 198*	356 x 406 x 393*	1 05.40
10.0 x 18.0	4	2.50	610 x 229 x 113	914 x 305 x 201	56.37	356 x 406 x 287*	COLCORE x 477*	141.30
12.0 x 6.0	4	3.00	305 x 102 x 25	610 x 229 x 125	29.17	152 x 152 x 37	305 x 305 x 240*	52.33
12.0 x 7.2	4	3.00	305 x 102 x 33	686 x 254 x 140	30.44	203 x 203 x 46	305 x 305 x 283*	54.64
12.0 x 7.5	4	3.00	305 x 102 x 33	686 x 254 x 140	29.67	203 x 203 x 52	305 x 305 x 283	55.07
12.0 x 8.0	4	3.00	356 x 127 x 33	762 x 267 x 147	29.38	203 x 203 x 60	356 x 406 x 287*	55.88
12.0 x 9.0	4	3.00	406 x 140 x 39	686 x 254 x 170	31.89	203 x 203 x 86	356 x 406 x 340*	66.44
12.0 x 10.0	4	3.00	457 x 152 x 52	762 x 267 x 173	34.63	254 x 254 x 89	356 x 406 x 340*	63.67
12.0 x 12.0	4	3.00	457 x 152 x 67	838 x 292 x 194	38.50	254 x 254 x 332*	COLCORE x 477*	83.75
12.0 x 15.0	4	3.00	533 x 210 x 92	914 x 305 x 253	47.53	305 x 305 x198*	356 x 406 x 551	102.73
12.0 x 18.0	4	3.00	686 x 254 x 125	914 x 305 x 289	57.72	356 x 406 x 340*	914 x 419 x 343	132.39
15.0 x 6.0	5	3.00	305 x 102 x 25	762 x 267 x 147 *	32.83	152 x 152 x 37	356 x 406 x 393*	77.83
15.0 x 7.5	5	3.00	305 x 102 x 33	838 x 292 x 176 *	34.47	203 x 203 x 52	COLCORE x 477*	80.93
15.0 x 8.0	5	3.00	356. x 127 x 33	838 x 292 x 194 *	35.25	203 x 203 x 60	356 x 406 x 467*	78.38
15.0 x 9.0	5	3.00	406 x 140 x 39	914 x 305 x 201 *	35.33	203 x 203 x 86	356 x 406 x 551	89.89
15.0 x 10.0	5	3.00	457 x 152 x 52	914 x 305 x 224 *	39.73	254 x 254 x 89	356 x 406 x 634*	93.07
15.0 x 12.0	5	3.00	457 x 152 x 67	914 x 305 x 289 *	46.42	254 x 254 x132*	914 x 305 x 289*	68.08
15.0 x 15.0	5	3.00	533 x 210 x 92	914 x 419 x 343 *	53.53	305 x 305 x198*	914 x 419 x 343*	88.87
15.0 x 18.0	5	3.00	686 x 254 x 125	FAIL		356 x 406 x 340*	FAIL	
18.0 x 6.0	6	3.00	305 x 102 x 25	914 x 305 x 201 *	41.83	152 x 152 x 37	356 x 406 x 634 *	118.00
18.0 x 7.2	6	3.00	305 x 102 x 33	914 x 305 x 253 *	46.14	203 x 203 x 46	914 x 305 x 253*	50.47
18.0 x 7.5	6	3.00	305 x 102 x 33	914 x 305 x 253 *	44.73	203 x 203 x 52	914 x 305 x 253*	51.07
18.0 x 8.0	6	3.00	356 x 127 x 33	914 x 305 x 289 *	47.13	203 x 203 x 60	914 x 305 x 289*	56.13
18.0 x 9.0	6	3.00	406 x 140 x 39	914 x 419 x 343 *	51.11	203 x 203 x 86	914 x 419 x 343*	66.78
18.0 x 10.0	6	3.00	457 x 152 x 52	914 x 419 x 343 *	51.63	254 x 254 x 89	914 x 419 x 343*	63.97
18.0 x 12.0	6	3.00	457 x 152 x 67	FAIL		254 x 254 x 132*	FAIL	
18.0 x 15.0	6	3.00	533 x 210 x 92	FAIL		305 x 305 x 198*	FAIL	
18.0 x 18.0	6	3.00	686 x 254 x 125	FAIL		356 x 406 x 340*	FAIL	

(*) Natural frequency of the beam is less then 4.5Hz.

SAFE LOAD TABLES (4)
GRADE 50 - LIGHTWEIGHT CONCRETE SLAB
Imposed load = 4.0 + 1.0 kN/m^2

			Minimum Weight			Minimum Depth		
Bay size (m x m)	No. sec. beams per grid	Spacing of sec. beams	Secondary Beams	Primary Beams	Weight (kg/m^2)	Secondary Beams	Primary Beams	Weight (kg/m^2)
6.0 x 6.0	2	3.00	254 x 102 x 22	356 x 127 x 39	13.83	152 x 152 x 37	203 x 203 x 71	24.17
6.0 x 7.2	2	3.00	305 x 102 x 28	406 x 140 x 46	15.72	203 x 203 x 46	203 x 203 x 86	27.28
6.0 x 7.5	2	3.00	305 x 102 x 28	406 x 140 x 46	15.47	203 x 203 x 46	254 x 254 x 73	25.07
6.0 x 8.0	2	3.00	305 x 102 x 33	457 x 152 x 52	17.50	203 x 203 x 52	254 x 254 x 89	28.46
6.0 x 9.0	2	3.00	356 x 127 x 39	457 x 152 x 52	18.78	203 x 203 x 71	254 x 254 x 107	35.56
6.0 x 10.0	2	3.00	406 x 140 x 46	457 x 191 x 60	21.33	254 x 254 x 73	254 x 254 x 107	35.03
6.0 x 12.0	2	3.00	457 x 191 x 60	457 x 191 x 74	26.17	254 x 254 x132*	254 x 254 x 132	55.00
6.0 x 15.0	2	3.00	533 x 210 x 82	533 x 210 x 82	32.80	305 x 305 x 198*	254 x 254 x 167	77.13
6.0 x 18.0	2	3.00	610 x 229 x 125*	610 x 229 x 101	47.28	356 x 406 x 340*	305 x 305 x 198	124.33
7.2 x 6.0	3	2.40	254 x 102 x 22	406 x 140 x 46	16.83	152 x 152 x 30	254 x 254 x 73	24.67
7.2 x 7.2	3	2.40	305 x 102 x 25	457 x 152 x 52	17.64	152 x 152 x 37	254 x 254 x 107	30.28
7.2 x 9.0	3	2.40	305 x 102 x 33	457 x 152 x 67	21.19	203 x 203 x 52	254 x 254 x 132	36.33
7.2 x 12.0	3	2.40	457 x 152 x 52	533 x 210 x 82	28.50	254 x 254 x 107*	254 x 254 x 167	58.50
7.2 x 18.0	3	2.40	610 x 229 x 101	610 x 229 x 125	49.03	356 x 406 x 287*	305 x 305 x 240	132.92
7.5 x 6.0	3	2.50	254 x 102 x 22	457 x 152 x 52	17.47	152 x 152 x 30	254 x 254 x 89	26.B3
7.5 x 7.5	3	2.50	305 x 102 x 25	457 x 152 x 60	18.00	203 x 203 x 46	254 x 254 x 107	32.67
7.5 x 9.0	3	2.50	356 x 127 x 33	457 x 152 x 74	21.42	203 x 203 x 60	254 x 254 x 132	38.67
7.5 x 12.0	3	2.50	457 x 152 x 52	533 x 210 x 92	28.47	254 x 254 x132*	305 x 305 x 158	65.97
7.5 x 15.0	3	2.50	533 x 210 x 82	610 x 229 x 101	39.53	305 x 305 x 198*	305 x 305 x 198	92.40
7.5 x 18.0	3	2.50	610 x 229 x 101	610 x 229 x 125	47.34	356 x 406 x 287*	305 x 305 x 283	130.52
8.0 x 6.0	3	2.67	254 x 102 x 22	457 x 152 x 52	16.92	152 x 152 x 30	254 x 254 x 107	29.08
8.0 x 8.0	3	2.67	305 x 102 x 33	457 x 152 x 74	21.63	203 x 203 x 46	254 x 254 x 132	33.75
8.0 x 9.0	3	2.67	356 x 127 x 33	533 x 210 x 82	21.49	203 x 203 x 60	254 x 254 x 167	41.06
8.0 x 10.0	3	2.67	406 x 140 x 39	533 x 210 x 82	22.83	203 x 203 x 86	254 x 254 x 167	48.95
8.0 x 12.0	3	2.67	457 x 152 x 52*	610 x 229 x 101	27.92	254 x 254 x132*	305 x 305 x 198	66.00
8.0 x 15.0	3	2.67	533 x 210 x 82*	610 x 229 x 125	39.08	305 x 305 x198*	305 x 305 x 240	90.25
8.0 x 18.0	3	2.67	610 x 229 x 101*	686 x 254 x 140	45.65	356 x 406 x 287*	305 x 305 x 283	123.35
9.0 x 6.0	3	3.00	254 x 102 x 22	457 x 191 x 67	18.50	152 x 152 x 37	254 x 254 x 132	34.33
9.0 x 7.2	3	3.00	305 x 102 x 28	533 x 210 x 82	20.72	203 x 203 x 46	254 x 254 x 167	38.53
9.0 x 7.5	3	3.00	305 x 102 x 28	533 x 210 x 82	20.27	203 x 203 x 46	254 x 254 x 167	37.60
9.0 x 8.0	3	3.00	305 x 102 x 33	533 x 210 x 82	21.25	203 x 203 x 52	254 x 254 x 167	38.21
9.0 x 9.0	3	3.00	356 x 127 x 39	533 x 210 x 92	23.22	203 x 203 x 71	305 x 305 x 158	41.22
9.0 x 10.0	3	3.00	406 x 140 x 46	610 x 229 x 101	25.43	254 x 254 x 73	305 x 305 x 198	44.13
9.0 x 12.0	3	3.00	457 x 152 x 60	610 x 229 x 113	29.42	254 x 254 x132*	305 x 305 x 240	'64.00
9.0 x 15.0	3	3.00	533 x 210 x 82	686 x 254 x 140	36.67	305 x 305 x198*	305 x 305 x 283	84.87
9.0 x 18.0	3	3.00	610 x 229 x 125	686 x 254 x 170	51.11	356 x 406 x 340*	356 x 406 x 340	1 32.22
10.0 x 6.0	4	2.50	254 x 102 x 22	533 x 210 x 82	22.47	152 x 152 x 30	254 x 254 x 167*	39.83
10.0 x 8.0	4	2.50	305 x 102 x 28	610 x 229 x 101	23.83	203 x 203 x 46	305 x 305 x 198*	43.15
10.0 x 9.0	4	2.50	356 x 127 x 33	610 x 229 x 125	27.09	203 x 203 x 60	305 x 305 x 240	50.67
10.0 x 10.0	4	2.50	356 x 127 x 39	686 x 254 x 125	28.10	203 x 203 x 86	305 x 305 x 283	62.70
10.0 x 12.0	4	2.50	457 x 152 x 52	762 x 267 x 147	33.05	254 x 254 x 107*	356 x 406 x 287*	66.72
10.0 x 15.0	4	2.50	533 x 210 x 82	762 x 267 x 173	44.33	305 x 305 x 198*	356 x 406 x 393	105.40
10.0 x 18.0	4	2.50	610 x 229 x 101	838 x 292 x 194	51.18	356 x 406 x 287*	COLCORE x 477*	141.30
12.0 x 6.0	4	3.00	254 x 102 x 22	610 x 229 x 101	24.17	152 x 152 x 37	305 x 305 x 240*	52.33
12.0 x 7.2	4	3.00	305 x 102 x 28	686 x 254 x 125	26.69	203 x 203 x 46	305 x 305 x 283*	54.64
12.0 x 7.5	4	3.00	305 x 102 x 28	686 x 254 x 125	26.00	203 x 203 x 46	305 x 305 x 283*	53.07
12.0 x 8.0	4	3.00	305 x 102 x 33	686 x 254 x 140	28.50	203 x 203 x 52	356 x 406 x 287*	53.21
12.0 x 9.0	4	3.00	356 x 127 x 39	762 x 267 x 147	29.33	203 x 203 x 71	356 x 406 x 287	55.56
12.0 x 10.0	4	3.00	406 x 140 x 46	686 x 254 x 170	32.33	254 x 254 x 73	356 x 406 x 340*	58.33
12.0 x 12.0	4	3.00	457 x 152 x 60	838 x 292 x 176	34.67	254 x 254 x132*	356 x 406 x 393*	76.75
12.0 x 15.0	4	3.00	533 x 210 x 92	914 x 305 x 224	45.60	305 x 305 x198*	356 x 406 x 551	102.73
12.0 x 18.0	4	3.00	610 x 229 x 125	914 x 305 x 289	57.72	356 x 406 x 340*	356 x 406 x 634*	148.56
15.0 x 6.0	5	3.00	254 x 102 x 22	762 x 267 x 147*	31.83	152 x 152 x 37	356 x 406 x 393*	77.83
15.0 x 7.5	5	3.00	305 x 102 x 28	762 x 267 x 173*	32.40	203 x 203 x 46	COLCORE x 477*	78.93
15.0 x 8.0	5	3.00	305 x 102 x 33	838 x 292 x 176*	33.00	203 x 203 x 52	356 x 406 x 467*	75.71
15.0 x 9.0	5	3.00	356 x 127 x 39	838 x 292 x 194*	34.56	203 x 203 x 71	356 x 406 x 551	84.89
15.0 x 10.0	5	3.00	406 x 140 x 46	914 x 305 x 224*	37.73	254 x 254 x 73	356 x 406 x 634*	87.73
15.0 x 12.0	5	3.00	457 x 152 x 60	914 x 305 x 253*	41.08	254 x 254 x 132*	914 x 305 x 289	68.08
15.0 x 15.0	5	3.00	533 x 210 x 82*	914 x 419 x 343*	50.20	305 x 305 x 198*	914 x 419 x 343*	88.87
15.0 x 18.0	5	3.00	610 x 229 x 125*	914 x 419 x 388*	63.22	356 x 406 x 340*	914 x 419 x 388*	134.89
18.0 x 6.0	6	3.00	254 x 102 x 22	838 x 292 x 194*	39.67	152 x 152 x 37	356 x 406 x 634*	118.00
18.0 x 7.2	6	3.00	305 x 102 x 28	914 x 305 x 224*	40.44	203 x 203 x 46	914 x 305 x 224*	46.44
18.0 x 7.5	6	3.00	305 x 102 x 28	914 x 305 x 253*	43.07	203 x 203 x 46	914 x 305 x 253*	49.07
18.0 x 8.0	6	3.00	305 x 102 x 33	914 x 305 x 253*	42.63	203 x 203 x 52	914 x 305 x 253*	48.96
18.0 x 9.0	6	3.00	356 x 127 x 39	914 x 305 x 289*	45.11	203 x 203 x 71	914 x 305 x 289*	55.7B
18.0 x 10.0	6	3.00	406 x 140 x 46	914 x 419 x 343*	49.63	254 x 254 x 73	914 x 419 x 343*	58.63
18.0 x 12.0	6	3.00	457 x 152 x 60	914 x 419 x 388*	52.33	254 x 254 x132*	914 x 419 x 388*	76. 33
18.0 x 15.0	6	3.00	533 x 210 x 82	FAIL		305 x 305 x 198*	FAIL	
18.0 x 18.0	6	3.00	610 x 229 x 125	FAIL		356 x 406 x 340*	FAIL	

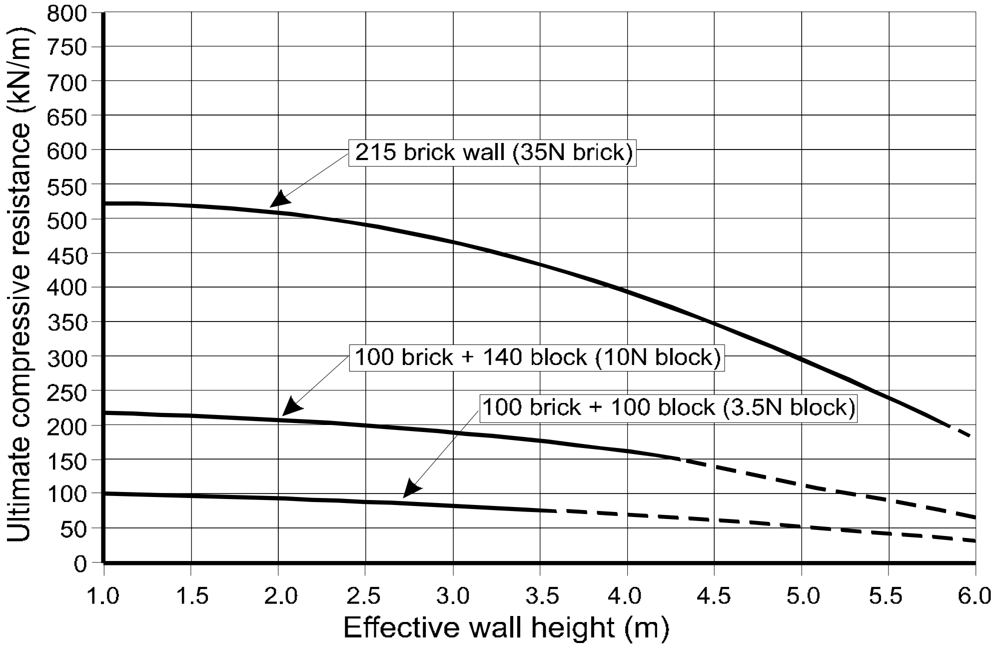
(*) Natural frequency of the beam is less then 4.5Hz.

4.7 MASONRY

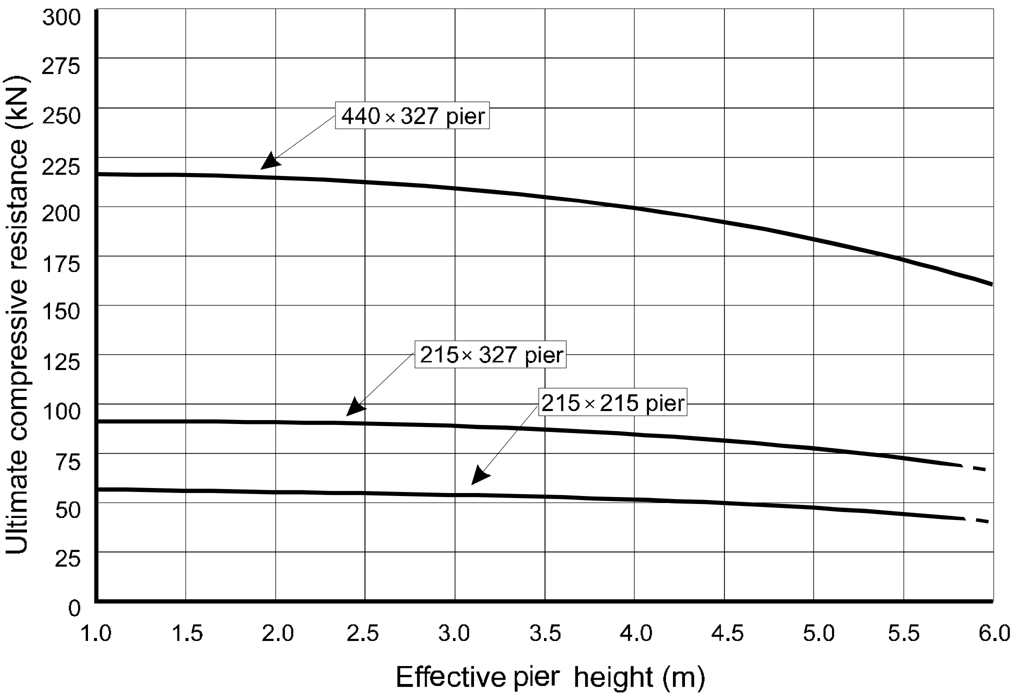
4.7.1 RULES OF THUMB

Ultimate resistances in compression

Wall sizing: e < 0.05 t ; grade (iii) mortar
(Note: For cavity walls load is applied to inner leaf only.)
BS 5628 : Pt 1 Cl 28.1. limits slenderness ratio to 27



Pier sizing : e < 0.05 t ; 20N brick ; grade (iii) mortar
BS 5628 : Pt 1 Cl 28.1. limits slenderness ratio to 27



Initial sizing rules

Trial wall thicknesses:
For <u>compressive</u> loading only:

	Supported top and bottom	Supported at base only
Solid	H/16	H/8
Cavity*	H/11	H/5.5

H is wall height   Min. leaf thickness 100mm
* Wall thickness is sum of leaf thickness

For <u>lateral</u> loading:
solid walls, Height = 1/40 distance between supports
cavity walls, Height = 1/30 distance between supports

4.7.2 LOAD FACTORS (From BS 5628 Part 1 Clause 22)

Load Combination	Load Type					
(Including Earth and Water Loading Where Present)	Dead, G_k		Imposed, Q_k		Earth and Water, E_n	Wind, W_k
	Adverse	Beneficial	Adverse	Beneficial		
1. Dead and Imposed	1.4	0.9	1.6	0	1.4	-
2. Dead and Wind	1.4	0.9	-	-	1.4	1.4*†
3. Dead, Imposed and Wind	1.2	1.2	1.2	1.2	1.2	1.2†

† Use $0.015G_k$ if greater than factored W_k.
* A partial factor of 1.2 may be used for freestanding walls and laterally loaded walls panel, whose removal would in no way affect the stability of the remaining structure.

4.7.3 MATERIAL FACTORS (From BS 5628 Part 1 Table 4)

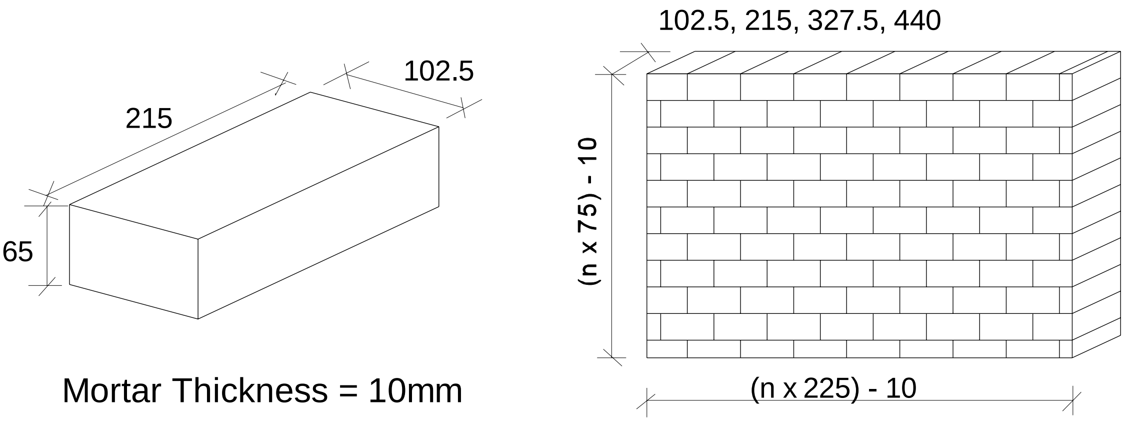
Partial safety factors for material strength

		Construction Control	
		Special	Normal
Manufacturing Control	Special	2.5	3.1
	Normal	2.8	3.5*

* Use for initial sizing
Note particular requirements for use of 'Special' catogory

ARUP

4.7.4 MODULAR DIMENSIONS (Brickwork)



Mortar Thickness = 10mm

4.7.5 TYPICAL UNIT STRENGTHS

Material and BS	Class	Typical unit compressive strength (N/mm^2)
Fired-clay bricks (BS 3921)	Engineering A† Engineering B† Facing bricks† Common bricks	> 70 > 50 10 - 50 10 - 30
Calcium silicate bricks (BS187)	Class 7 Class 6 Class 5 Class 4 Class 3	48.5 41.5 34.5 27.5 20.5
Concrete bricks (BS 6073: Part 1)		7 - 20
Concrete blocks (BS 6073: Part 1)	Dense solid† Dense hollow† Lightweight†	7, 10 - 35 3.5, 7, 10 2.8, 3.5, 4, 7 (10)
Reconstructed stone† (BS 6457)	Dense solid	As dense solid concrete blocks
Natural stone† (BS 5390 and BS 8298)	Structural quality	15 - 100 (dependent on stone type, bed, location, etc.)
† These are often selected by client or architect for appearance or thermal performance - check this, and establish strength, before starting to size members.		

4.7.6 MASONRY COMPRESSIVE STRENGTH (BS 5628, Pt. 1, Table 2)

Characteristic compressive strength of masonry, f_k, in N/mm^2

(a) Constructed with standard format bricks

Mortar designation	Compressive strength of unit (N/mm^2)								
	5	**10**	**15**	**20**	**27.5**	**35**	**50**	**70**	**100**
(i)	2.5	4.4	6.0	7.4	9.2	11.4	15.0	19.2	24.0
(ii)	2.5	4.2	5.3	6.4	7.9	9.4	12.2	15.1	18.2
(iii)	2.5	4.1	5.0	5.8	7.1	8.5	10.6	13.1	15.5
(iv)	2.2	3.5	4.4	5.2	6.2	7.3	9.0	10.8	12.7

(b) Constructed with blocks having a ratio of height to least horizontal dimension of 0.6

Mortar designation	Compressive strength of unit (N/mm^2)							
	2.8	**3.5**	**5.0**	**7.0**	**10**	**15**	**20**	**35** or greater
(i)	1.4	1.7	2.5	3.4	4.4	6.0	7.4	11.4
(ii)	1.4	1.7	2.5	3.2	4.2	5.3	6.4	9.4
(iii)	1.4	1.7	2.5	3.2	4.1	5.0	5.8	8.5
(iv)	1.4	1.7	2.2	2.8	3.5	4.4	5.2	7.3

(c) Constructed from hollow blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0

Mortar designation	Compressive strength of unit (N/mm^2)							
	2.8	**3.5**	**5.0**	**7.0**	**10**	**15**	**20**	**35** or greater
(i)	2.8	3.5	5.0	5.7	6.1	6.8	7.5	11.4
(ii)	2.8	3.5	5.0	5.5	5.7	6.1	6.5	9.4
(iii)	2.8	3.5	5.0	5.4	5.5	5.7	5.9	8.5
(iv)	2.8	3.5	4.4	4.8	4.9	5.1	5.3	7.3

(d) Constructed from solid concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0

Mortar designation	Compressive strength of unit (N/mm^2)							
	2.8	**3.5**	**5.0**	**7.0**	**10**	**15**	**20**	**35** or greater
(i)	2.8	3.5	5.0	6.8	8.8	12.0	14.8	22.8
(ii)	2.8	3.5	5.0	6.4	8.4	10.6	12.8	18.8
(iii)	2.8	3.5	5.0	6.4	8.2	10.0	11.6	17.0
(iv)	2.8	3.5	4.4	5.6	7.0	8.8	10.4	14.6

NOTE TO TABLE OF f_k

1. For piers, columns, and short walls with plan area A (in m^2) ≤ 0.2m^2, multiply f_k by (0.7 + 1.5A).

2. For 'half-brick thick' brick walls, multiply Table (a) values by 1.15.

3. For 90 x 90mm section modular bricks, multiply the Table (a) values by:
1.25 if wall thickness = brick width, 1.1 otherwise

4. For unfilled hollow blocks, interpolate between Tables (b) and (c) as necessary.

5. For solid and concrete-filled hollow blocks, with height:least horizontal dimension between 0.6 and 2.0, interpolate between Tables (b) and (d) as necessary.

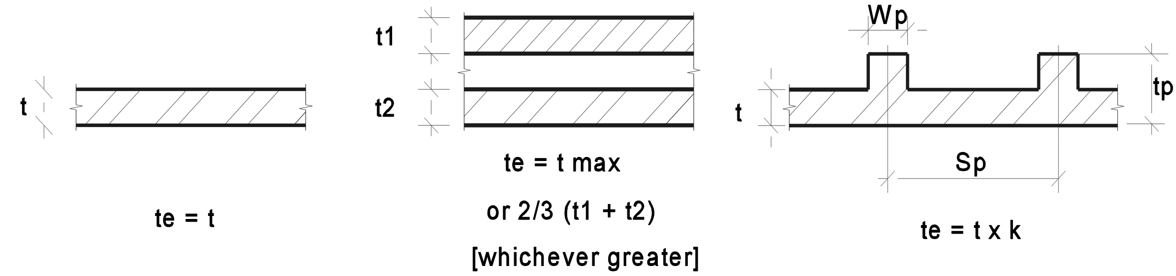
6. For squared natural stone and reconstructed stone, interpolate between Tables (b) and (d) as necessary.

7. For random rubble natural stone, take 75% of squared natural stone values. If using lime mortar, take 50% of strength for grade (iv) mortar.

MORTAR STRENGTHS

Designation	Cement:Lime:Sand
(i)	1 : 0 - ¼ : 3
(ii)	1 : ½ : 4 - 4½
(iii)	1 : 1 : 5-6
(iv)	1 : 2 : 8-9
Pure lime	0 : 1 : 3

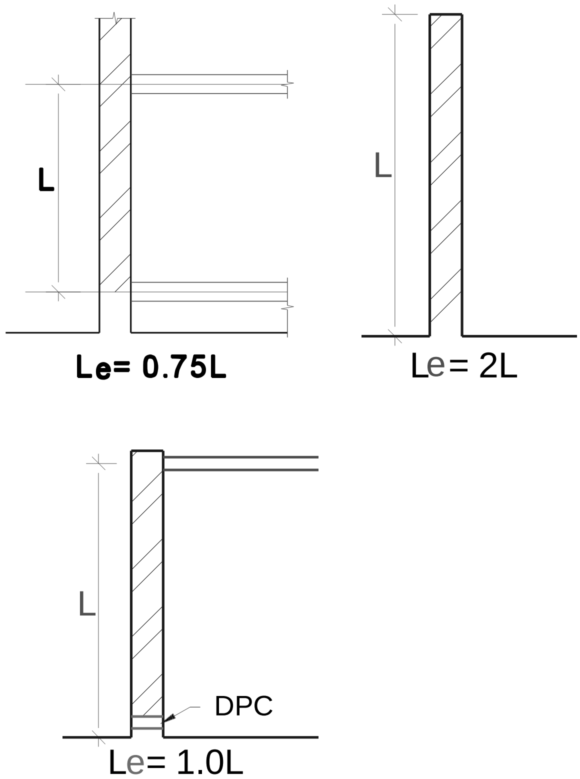
See also Section 4.7.12, and BS 5628, Pt 1, Table 1.



Values of K for the design of piers (From BS 5628, Pt. 1, Table 5)			
Ratio of pier spacing (centre-to-centre) to pier width (s_p / w_p)	Ratio of pier thickness to actual thickness of wall or leaf (t_p / t)		
	1	2	3 and thicker
6 (or less)	1	1.4	2
10	1	1.2	1.4
20 (or more)	1	1	1

Reduction factor β (From BS 5628, Pt. 1, Table 7)

Capacity reduction factor, β †				
Slenderness ratio: l_e/t_e	Eccentricity at top of wall, e			
	Up to 0.05t	0.1t	0.2t	0.3t
0	1.00	0.88	0.66	0.44
6	1.00	0.88	0.66	0.44
8	1.00	0.88	0.66	0.44
10	0.97	0.88	0.66	0.44
12	0.93	0.87	0.66	0.44
14	0.89	0.83	0.66	0.44
16	0.83	0.77	0.64	0.44
18	0.77	0.70	0.57	0.44
20	0.70	0.64	0.51	0.37
22	0.62	0.56	0.43	0.30
24	0.53	0.47	0.34	
26	0.45	0.38		
27	0.40	0.33		
† Linear interpolation between eccentricities and slenderness ratios is permitted				



Vertical load resistance of wall or column per unit length:

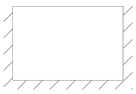
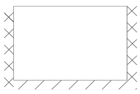
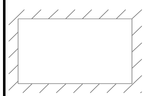
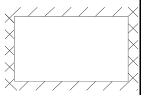
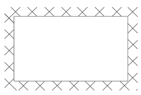
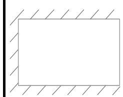
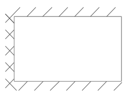
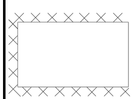
$$P = \frac{\beta t f_k}{\gamma_m}$$

where β = capacity reduction factor from above table
t = actual wall, column, or leaf thickness
f_k = characteristic compressive strength from table
γ_m = partial safety factor for material from Table 4.7.3 - use 3.5 for sizing.

4.7.7 SIZING EXTERNAL WALL PANELS

- Walls in buildings up to four storeys high and subject only to lateral loads may be sized as below. Gravity stresses generally improve capacity to resist wind, and so thickness may be guesstimated for higher loadbearing walls.
- Applicable only in areas with many windbreaks (cities, towns, woodland etc.) within the defined wind zones.
- Thickness of wall should be at least:
  For solid wall: 1/40th of distance between supports
  For cavity wall: total thickness 1/30th of distance between supports; each leaf min. 100mm thick; cavity width 100mm max; wall ties 900 x 450mm spacing; mortar grade (i), (ii) or (iii)
- Treat pitched gable walls as rectangular panels with height taken at mid-height of roof slope.
- Openings (windows, doors, etc.) only if either:
  - Openings are entirely framed by lateral restraints (floors, roof, crosswalls, etc.)
  or
  - (a) the total area of openings is less than the lesser of
    10% of the maximum tabulated area
    25% of the actual wall area
  and
  - (b) no opening is less than half its maximum dimension from any edge of the wall panel (other than its base) and from any adjacent opening.
- If above conditions not satisfied, calculate wind forces and use Table in 4.7.8 or design to BS 5628: Part 1.

Maximum permitted areas of certain walls

Wind zone	Height	 A		 B		 C		 D		 E		 F		 G		 H		 I	
		Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall	Cavity wall	190mm solid wall
	m	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2
1	5.4	11.0	13.5	17.5	19.0	26.5	28.5	20.5	29.0	32.0	41.0	32.0	41.0	8.5	10.0	14.0	19.0	19.5	30.5
	10.8	9.0	11.5	13.0	15.5	17.5	21.5	15.5	23.5	24.0	32.5	32.0	41.0	7.0	8.0	10.0	14.5	15.5	21.5
2	5.4	9.5	12.0	14.0	17.0	21.0	24.0	17.5	25.5	27.0	35.5	32.0	41.0	7.5	8.5	10.5	16.5	17.0	24.5
	10.8	8.0	9.5	11.5	14.0	13.5	17.5	13.0	20.5	19.0	28.5	28.0	36.5	6.0	7.0	9.0	11.0	13.0	17.5
3	5.4	8.5	10.5	12.5	15.0	15.5	20.0	14.5	22.5	22.0	31.0	30.5	40.5	6.5	7.5	9.5	13.5	14.5	20.0
	10.8	7.0	8.5	10.0	12.0	11.5	15.5	11.0	17.5	14.5	24.5	24.5	31.5	5.0	6.0	7.5	9.0	11.5	15.0
4	5.4	8.0	9.5	11.0	13.5	13.0	17.0	12.5	19.5	18.0	27.5	27.0	35.0	6.0	6.5	8.5	10.5	12.5	17.0
	10.8	6.5	7.5	9.0	11.0	10.5	13.5	9.5	14.5	12.5	21.0	21.5	27.5	4.0	5.5	6.5	7.5	10.0	12.5

Notes:
1. Cavity wall: 100mm outer leaf (any bricks or blocks not less than 14.0 N/mm²)
   100mm inner leaf (any bricks or blocks not less than 3.5 N/mm²).
   If either leaf is increased to 140mm, increase the areas by 20%
2. Solid walls: Single leaf, collar-jointed, grouted cavity.
   Any bricks or blocks not less than 3.5 N/mm²
3. Wind zones: As BS 5628 Part 3 Figure 1.

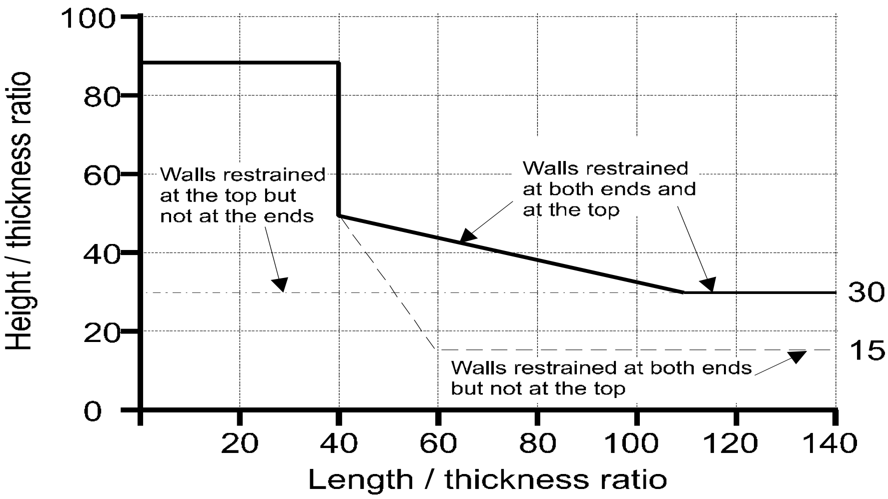
4.7.8 FLEXURAL STRENGTH OF MASONRY

Characteristic Flexural Strength of Masonry, f_{kx}, in N/mm^2						
	Plane of failure parallel to bed joints (spanning vertically)			Plane of failure perpendicular to bed joints (spanning horizontally)		
Mortar designation	(i)	(ii) and (iii)	(iv)	(i)	(ii) and (iii)	(iv)
Clay bricks having a water absorption:						
less than 7%	0.7	0.5	0.4	2.0	1.5	1.2
between 7% and 12%	0.5	0.4	0.35	1.5	1.1	1.0
over 12%	0.4	0.3	0.25	1.1	0.9	0.8
Calcium silicate bricks	0.3		0.2	0.9		0.6
Concrete bricks	0.3		0.2	0.9		0.6
Concrete blocks (solid or hollow) of compressive strength in N/mm^2:						
2.8 used in wall	0.25		0.2	0.40		0.4
3.5 thickness* up				0.45		0.4
7.0 to 100mm				0.60		0.5
2.8 used in wall	0.15		0.1	0.25		0.2
3.5 thickness* of				0.25		0.2
7.0 250mm				0.35		0.3
10.5 used in walls of	0.25		0.2	0.75		0.6
14.0 and over any thickness*				0.90†		0.7†

* The thickness should be taken to be the thickness of the wall, for a single leaf wall, or the thickness of the leaf, for a cavity wall. For concrete blocks 100-250mm thick, interpolate.
† When used with flexural strength in parallel direction, assume the orthogonal ratio μ=0.3
Note: Mortar designation as in Table 4.7.6

4.7.9 INTERNAL NON-LOADBEARING MASONRY WALLS

For single-leaf wall of length L and height H, with adequate lateral restraint. calculate the minimum thickness required from the graph:



Extract from BS5628: Part 3, figure 6.

Note:
This graph only applies where significant internal wind pressures cannot occur.

For cavity wall with wall ties, sum of leaf thicknesses to be not less than 1½t where t is calculated as above.
Note that the presence of openings, chases, and movement joints may demand greater thickness and/or additional intermediate restraints.

4.7.10 FREESTANDING MASONRY WALLS

Thickness of freestanding walls (Single leaf, unstiffened by piers)

Wind zone	Max. ratio of height (above lateral restraint): actual thickness	Max. ratio of height (above d.p.c.†): actual thickness
1	8.5	6.4
2	7.5	5.6
3	6.5	4.9
4	6.0	4.5

† Assume d.p.c. cannot resist flexure.

Notes:
1. Unit compressive strength ≥ 3.5 N/mm^2, density ≥ 1400 kg/m^3.
2. Applicable only in areas with many windbreaks (cities, towns, woodland, etc.) - elsewhere calculate wind forces and design as gravity wall or to BS 5628: Part 1.
3. Wind zones as BS 5628 Part 3 Figure 1

4.7.11 JOINTS

Recommended Vertical Joints in Masonry			
Material	Max. joint spacing (m)†	Joint width (mm)	Max. aspect ratio*
Fired-clay bricks	15 12 (preferable)	1.3 x spacing in metres (minimum)	3:1 (suggested)
Calcium silicate (sand-lime) bricks	7.5 - 9	10 (typical)	3:1
Concrete blocks and bricks	6	10 (suggested)	2:1
Natural stone cladding in cement-based mortar	6	10	3:1 (suggested)

† Use max of half these values for joint nearest corner (Internal or External)

* Ratio of panel length:panel height for solid panel; if openings, check each sub-panel separately and consider reinforcement for ratios beyond max. value.

Horizontal joints in non-loadbearing masonry† (BS 5628 Part 1 Cl 29.2.2)		
Uninterrupted wall height	Joint spacing (m)	Joint width (m)
Multi-storey	9m or every third storey (whichever is less), but can omit if building is less than 12m with four or fewer storeys	Allow 1mm per metre between masonry support and top of masonry below; minimum 10mm
Storey-high	At head of wall	Allow 1mm per metre

† Consider also other requirements for joint (acoustic and thermal insulation, weathertightness, fire separation, etc) when selecting joint filler.

4.7.12 OTHER ISSUES

Non-structural issues influencing decisions on material strength, wall thickness, and mortar grade:

Issue	Influence on	Recommendation
Weathertightness	Wall thickness	Use cavity construction (min. 90mm thick outer leaf), or assume min. solid wall thickness for Sheltered/Moderate exposure (Table 11, BS 5628: Part 3): Rendered Clay/calcium silicate/dense concrete/reconstructed stone - 190mm; Lightweight concrete - 140mm. Unrendered 440mm
Durability	Material, strength, mortar grade. Conservatively, for sizing, choose lowest unit strength and mortar grade to satisfy durability	See Table 13 BS 5628: Part 3. For unrendered external walls with high [and low] risk of saturation: Fired-clay units - FL,FN [ML,MN] in (i), (ii),[iii] grade mortar; Calcium silicate units - classes 2-7 in (iii),[iv] mortar *; Concrete bricks ≥ 15 [7] N/mm^2 in (iii) mortar; Concrete blocks (any strength) in (iii), [iv] mortar*. For internal walls and inner leaves of cavity walls: Fired-clay units - any in (i)-(iv) mortar; Calcium silicate units - classes 2-7 in (iii) or (iv) mortar; Concrete bricks - ≥ 7N/mm^2 in (iv) mortar; Concrete blocks (any strength) in (iii) or (iv) mortar. * See remarks on table 13C for mortar grade (iv).
Fire resistance	Material and whether solid/perforated/hollow; thickness	See Table 16, BS 5628: Part 3. A 100mm unplastered wall or leaf of a cavity wall will give 2 hour fire resistance in all materials and loading conditions (sometimes conservatively) except: Fired-clay bricks/blocks with voids or perforations (75-100% solid - use min. 170mm thickness); Hollow concrete blocks with gravel or natural stone aggregate (limestone OK) - min. 200mm thickness with vermiculite-gypsum plaster. Pay attention to joints around panels.
Thermal insulation (and avoidance of condensation)	Material, strength, thickness of external walls	This often dictates use of cavity wall with lightweight/hollow - hence WEAK - concrete blocks, typically 2.8 - 7 N/mm^2 and 100-150mm min. thickness; this may be a problem on multi-storey loadbearing wall construction. Applied insulation in cavity or on inner [or outer] face may be used. This must be resolved with architect/service engineer EARLY in design.
Sound absorption and noise reduction	Material, strength, thickness	See Building Regulations Approved Document E1 Airborne sound resistance where necessary (e.g. between dwellings) is typically achieved by: Single leaf walls - 215mm plastered brickwork (min. density 1610kg/m^3) or dense blockwork (min. density 1840kg/m^3), or 190mm unplastered concrete (min. density 2200kg/m^3); Cavity walls - two 102mm leaves of plastered brickwork (min.density 1970kg/m^3), two 100mm leaves (50mm cavity) of plastered dense blockwork (min. density 1990kg/m^3), or two 100mm leaves (75mm cavity) of plastered dry-lined lightweight blockwork (max. density 1600 kg/m^3). Pay attention to joints aroud panels.
Appearance	Material, strength	Architect's choice - must be resolved EARLY as it profoundly influences structural design.
Health and safety	Thickness of unit	Units weighing more than 20kg should not be used if one-man laying is intended (which is normal). E.g. max. thickness dense blockwork at 2000kg/m^3 is 105mm (standard 440x215 block). Consider collar-jointed wall or blocks laid on side† if thicker wall required (†check strength with manufacturer).

4.8 ALUMINIUM

4.8.1 MAIN STRUCTURAL ALLOYS

Typical uses: Curtain walling
Rainscreen cladding
Glazing arms/rails

	Alloy	Condition	Product	Range of thickness (mm)	Dura-bility *	Limiting stress (N/mm²)		
						p_0	p_a	p_v
Heat-treatable	6063 (H9)	T4 T6	Extruded Extruded	0 - 150 0 - 150	B	65 [65] 160 [80]	85 [85] 175 [87]	40 [40] 95 [47]
	6082 (H30)	T4 T6	Extruded Extruded	0 - 150 20 - 150	B	115 [115] 270 [135]	145 [145] 290 [145]	70 [70] 160 [80]
Non-heat-treatable	5083 (N8)	O H22	Sheet, plate Sheet, plate	0.2 - 80 0.2 - 6	A	105 [105] 235 [105]	150 [150] 270 [121]	65 [65] 140 [63]

where: p_0 is the limiting unfactored stress for bending and overall yielding
p_a is the limiting unfactored stress for local capacity of the section in tension or compression
p_v is the limiting unfactored stress in shear
Note : A material factor up to 1.3 must be used with these numbers

Figures in square brackets [ ] apply to all material within 25mm of a weld zone.
* For durability see corrosion protection table below.

4.8.2 DURABILITY (General corrosion protection of aluminium structures)

P = Protection is required (see BS 8118 : Part 2)

Alloy durability rating	Material thickness (mm)	Protection needed according to environment							
		Atmospheric						Immersed	
		Rural	Industrial/urban		Marine			Fresh water	Sea water
			Moderate	Severe	Non-industrial	Moderate	Severe		
A	All	None	None	P	None	None	P	None	None
B	< 3	None	P	P	P	P	P	P	P
	≥ 3	None	None	P	None	None	P	P	P

4.8.3 TYPICAL PHYSICAL PROPERTIES

Density 2710 kg/m^3
Young's modulus 70 kN/mm^2
Thermal coefficient 23 x 10^{-6} ^{O}C

4.8.4 DESIGN

Design in accordance with **BS 8118 : 1991**
BS 8118 : 1991 uses the limit state for design.

Aluminium comes in the following forms:

- extrusion
- cast
- plate
- sheet

Usually buckling in compression is critical.

4.9 STAINLESS STEEL

As described in Notes on Materials: 190 the system of designation for stainless steel has been changed by the introduction of BS EN 10088. The mechanical properties given below are for the grades in BS EN 10088. The nearest equivalent old designation is also given.

4.9.1 MATERIAL GRADES

For structural use with high resistance to corrosion: use austenitic or duplex stainless steels.

Suggested grades for atmospheric applications												
Steel grade	Location											
	Rural			Urban			Industrial			Marine		
	L	M	H	L	M	H	L	M	H	L	M	H
304L	✓	✓	✓	✓	✓	(✓)	(✓)	(✓)	X	✓	(✓)	X
316L	O	O	O	O	✓	✓	✓	✓	(✓)	✓	✓	(✓)
duplex 2205	O	O	O	O	O	O	O	O	✓	O	O	✓

L - Least corrosive conditions within that category.
M - Typical of that category.
H - Corrosion higher than typical.

O - Potentially over-specified for corrosion.
✓ - The optimum choice for corrosion resistance.
X - Likely to suffer excess corrosion.
(✓) - Can be considered if precautions are taken.

WARNING: Consult Arup Swimming Pool Design Guide where appropriate.

4.9.2 MECHANICAL PROPERTIES

Old designation	Material Name	Material number	0.2% proof stress (N/mm^2)		UTS (N/mm^2)		Elongation (%)	
			Hot Rolled Plate	Bars, rods +sections	Hot Rolled Plate	Bars, rods +sections	Hot Rolled Plate	Bars, rods +sections
304L 304 S11	X2CrNi19-11	1.4306	200	180	500 to 650	460 to 680	45	45
316L 316S11	X2CrNiMo17-12-2	1.4404	220	200	520 to 670	500 to 700	45	40
316L 316S13	X2CrNiMo18-14-3	1.4435	220	200	520 to 670	500 to 700	45	40
Duplex 2205	X2CrNiMoN22-5-3	1.4462	460	450	640 to 840	650 to 880	25	25

4.9.3 PHYSICAL PROPERTIES

Old designation	Material Number	Density (kg/m^3)	Thermal expansion 20 - 100°C (10^{-6}/ °C)	Thermal conductivity (W/m°C)	Heat capacity (J/kg°C)
304L	1.4306	7900	16	15	500
316L	1.4404	8000	16	15	500
duplex 2205	1.4462	7800	13	15	500

4.9.4 DESIGN STRENGTH

The basic design strength, p_y, may generally be taken as the 0.2% proof stress given in 4.9.2 as those are minimum values. The exception is Duplex 2205 where a maximum of 450N/mm² should be used and this should be verified by mill certificates. For duplex 2205 with thickness 10<t<20mm a material safety factor of 1.05 should be used.

Alternatively based on tensile tests $p_y=\sigma_{0.2}/1.1$ where $\sigma_{0.2}$ is the average test value of the 0.2% proof stress. If mill certificates are used $p_y=\sigma_{m0.2}/1.2$ where $\sigma_{m0.2}$ is the average value of the 0.2% proof stress as given on the mill certificate or release note.

4.9.5 ELASTIC PROPERTIES

	Design values of elastic properties			Values of constants to be used for determining secant modulus (see over)			
Grade	Young's modulus, E (N/mm^2)		Shear modulus, G (N/mm^2)	Transverse direction		Longitudinal direction	
	Transverse direction	Longitudinal direction		k	m	k	m
304L	200 000	200 000	76 900	2.22	7.50	2.22	5.50
316L	195 000	190 000	74 000	2.05	8.00	2.00	6.00
duplex 2205	205 000	200 000	77 900	0.91	4.00	0.89	4.00

Deflection calculations

For estimating deflections, use the secant modulus:

$$E_s = \frac{E_{st} + E_{sc}}{2}$$

where

$$E_{st} = \frac{E}{1 + k\left(\frac{p_t}{p_y}\right)^m}$$

and

$$E_{sc} = \frac{E}{1 + k\left(\frac{p_c}{p_y}\right)^m}$$

p_t and p_c are the values of p in the tension and compression flange respectively.
k and m are constants obtained from the previous table.

4.9.6 AVAILABILITY

Sheet, plate, bar and tubes widely available for 304L and 316L.
Similar for duplex 2205 but not as widely stocked.

Certain rolled sections available for 304L and 316L. None for duplex 2205.

	f_y	UTS	Weldable	Sizes (mm)
High tensile rod		1350 1100 950	N N N	4 - 11 ϕ 12 - 19 ϕ 19 - 25 ϕ
Reinforcing bar and plain rod	300 460 180	500 625	N N Y	6 - 50 ϕ plain 6 - 32 ϕ deformed 6 - 50 ϕ
Structural sections	180+		Y	I, ⊏, ⌊ 250 - 300 □ 100 ϕ ○ 400 ϕ

4.9.7 REFERENCES

1. SCI, Concise guide to the structural design of stainless steel.
2. BS EN 10088 : 1995, Stainless steels, Parts 1 - 3

ARUP

5. FOUNDATIONS

5.1 GENERAL PRINCIPLES

! All foundations should be taken down to an adequate bearing stratum, which ensures the settlement under load will be acceptable to the structure.

! Settlement under loads should always be considered. This may be done by calculation and/or by reference to successful use of similar foundations in similar materials, preferably in the local neighbourhood of the site. Advice from Building Control Engineers is helpful in this respect.

! In assessing settlement the interaction between foundations needs to be considered plus the overall load of the complete structure as well as the loading of an individual foundation.

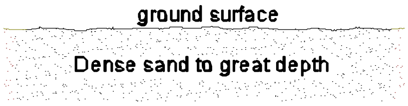
! Settlement arises from the following:
- Undrained elastic settlement which occurs on loading and hence during construction
- Consolidation settlement of clays as porewater pressures dissipate (time dependant)
- secondary consolidation of soft clays and peat (time dependant)
- creep of fill (time dependant)
- settlement induced by construction vibration, seismic loading or inondation
- creep of natural granular deposits (time dependant but usually small)

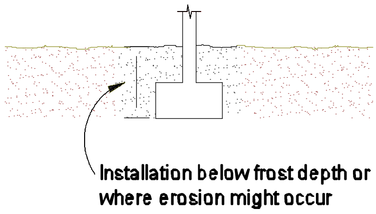
! Foundations should be taken to a depth at which they will not be affected by seasonal changes, including both frost and action and swelling and shrinkage due to changes of water content. Frost action is particularly important in silty soils, including chalk, and shrinkage is important in many clays, especially if there are trees nearby. BRE Digests and NHBC guidelines provide advice on foundations in clay deposits which have become desiccated due to vegetation.

! It is important that all foundation designs are reviewed by a geotechnical engineer - preferably in advance of any design decisions. In addition advice may be required to determine the geological character of the founding strata and whether any unusual features may be present.

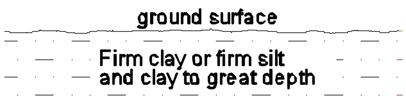
5.2 APPROPRIATE FOUNDATION SOLUTIONS

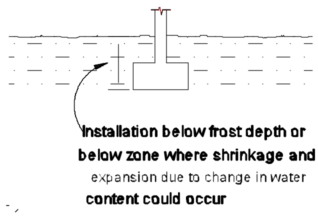
<table>
<tr><th>SOIL CONDITIONS</th><th>APPROPRIATE FOUNDATION TYPE AND LOCATION</th><th>DESIGN COMMENTS</th></tr>
<tr><td>1.



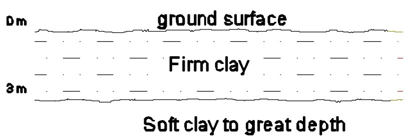
</td><td>


</td><td>Spread footings most appropriate for conventional foundation needs. A deep foundation such as piles could be required if uplift forces were to act.</td></tr>
<tr><td>2.



</td><td>


</td><td>Spread footings most appropriate solution in many cases, depending on settlement considerations</td></tr>
<tr><td>3.



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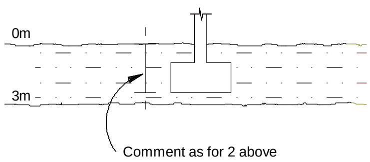
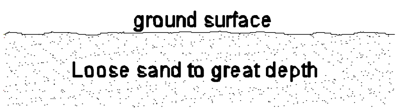


</td><td>Spread footings would be appropriate for low to medium range of loads if not installed too close to soft clay. Take care to not overstress the soft clay. If settlements become excessive deep foundation might be required. Cyclic loading may cause larger settlements.</td></tr>
<tr><td>4.



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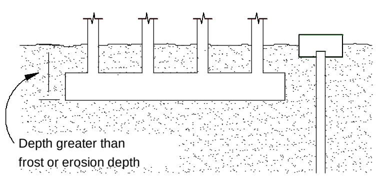
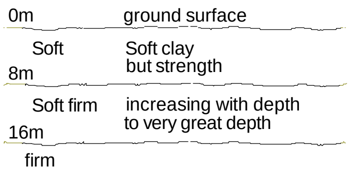
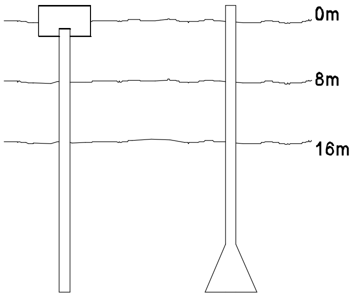


</td><td>Spread footings may settle excessively or require use of very low bearing pressures. Any later disturbance to the sand by vibration, groundwater changes or seismic loading for example, may cause large settlements. Consider mat (raft) foundations or consider compacting sand by vibroflotation or other method then use spread footings. Driven piles could be used and would densify the sand. Also consider continuous flight auger piles.</td></tr>
</table>

SOIL CONDITIONS	APPROPRIATE FOUNDATION TYPE AND LOCATION	DESIGN COMMENTS

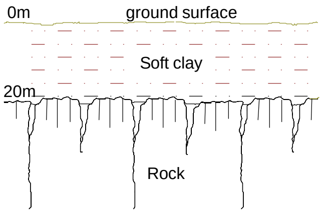
5.

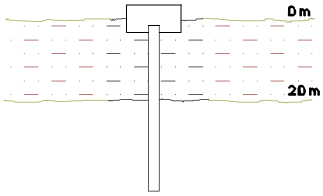




Spread footings probably not appropriate. Friction piles or piers would be satisfactory if some settlement could be tolerated. Long piles would reduce settlement problems. Also consider mat or floating foundation.

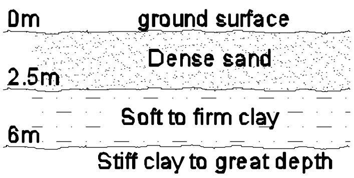
6.

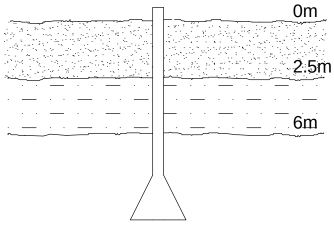




Deep foundations - piles, piers, caissons - bearing directly on or in the rock. Downdrag (negative skin friction) may add to the loads on the piles. The weathering, infill etc. of the rock may be critical in the design of the socket

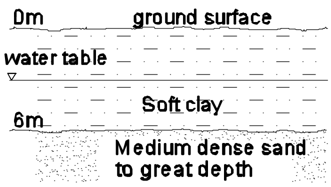
7.

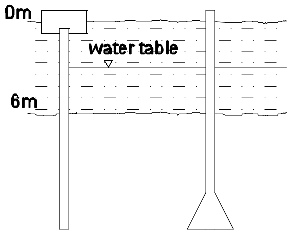




For heavy loads, spread footings in upper sand layer would probably experience large settlement because of underlying soft clay layer. Consider straight shafted piles or piles with bells in the stiff clay layer. Bells may be difficult to form in some clay strata. If time is available preloading might make it possible to use shallow foundations.

8.

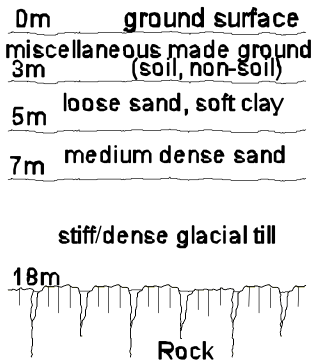


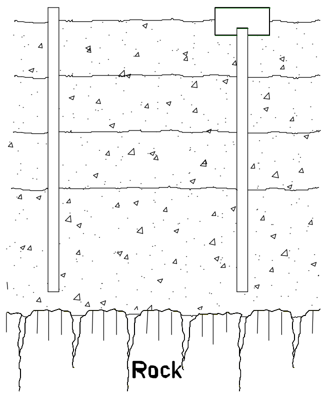


Deep foundations best, continuous flight auger piles suitable. Expanded base piles into sand layer not common. Bored piles require water (if cased) or bentonite (if not) to balance water pressures.

SOIL CONDITIONS	APPROPRIATE FOUNDATION TYPE AND LOCATION	DESIGN COMMENTS

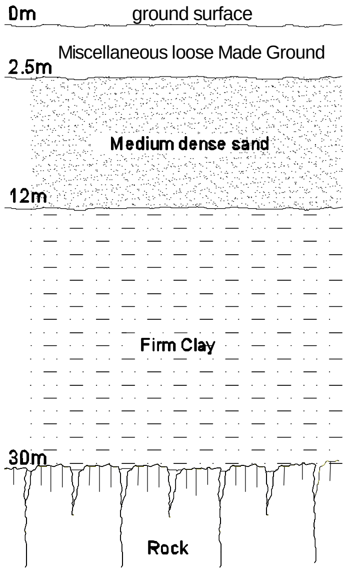
9.

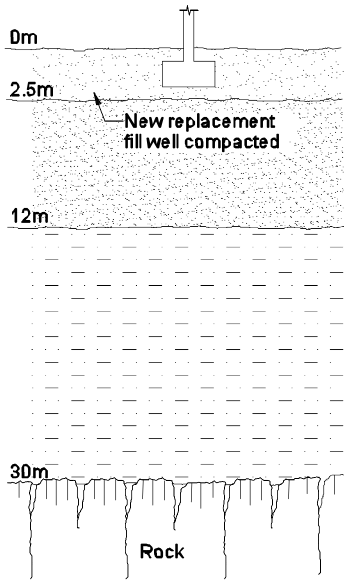




Deep foundation types extending into medium dense sand, or preferably into compact glacial till. Strong possibility for drilled pile bored under bentonite. Also consider cast-in-place and driven concrete pile, steel piles,CFA piles. (Cannot underream in till.) Negative skin frcition should be considered

10.

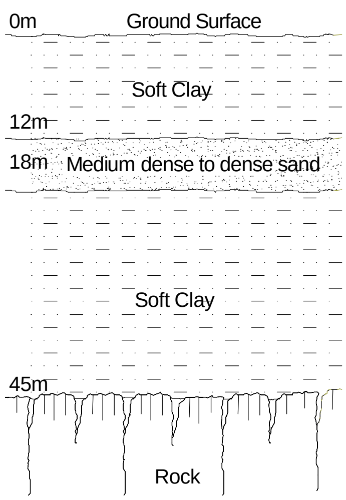


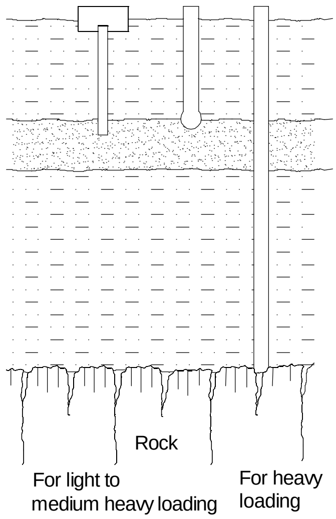


Deep foundations penetrating through fill are appropriate. With piles or piers consider stopping in upper zone of sand layer to limit consolidation of clay layer. Also consider replacing poor fill with new imported, compacted, fill, then use spread footings in the new fill. Calculate settlements due to consolidation of clay under complete load of new structure.

SOIL CONDITIONS	APPROPRIATE FOUNDATION TYPE AND LOCATION	DESIGN COMMENTS

11.

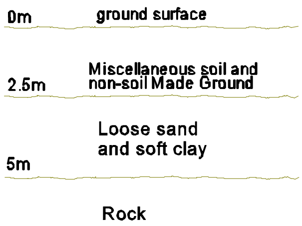


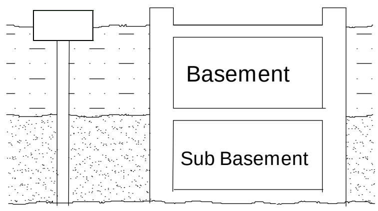


If foundation loads are not too heavy, consider using piles or piers bearing in the upper zone of sand layer and check for settlement. If foundation loads are heavy, consider driven piles (steel) or caissons to rock. Also consider floating foundation. Nature of rock is very important. Driving can induce positive pore presures and negative skin friction.

.

12.





Foundations should bear directly on the rock which is relatively close to the ground surface. If no basement areas are needed for the building consider piers. If basement areas are useful, consider full excavation to rock and construction of two basement levels.

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5.3 PRESUMED ALLOWABLE BEARING VALUES UNDER STATIC, NON-ECCENTRIC STATIC LOADING

Bearing values relate to characteristic loads.
Further values are given in BS8004.
This information is given for preliminary assessment purposes only.

Foundations in non-cohesive soils at a minimum depth of 0.75m below ground level

Description of soil	N-value in standard penetration test	Presumed bearing value (kN/m^2 or kgf/cm^2 x 100) for foundation of width		
		1m	2m	4m
Very dense sands and gravels	>50	600	500	400
Dense sands and gravals	30-50	350-600	300-500	250-400
Medium-dense sands and gravels	10-30	150-350	100-300	100-250
Loose sands and gravals	5-10	50-150	50-100	50-100

The allowable bearing pressure is defined as that causing 25mm settlement under the foundation width.

If the water table is within a depth equal to the width of the foundation and the depth of the foundation is small in relation to its width, the settlements will be doubled.
If settlements must not exceed 25mm, the allowable bearing values should be halved.

Foundations in conhesive soils at a minimum depth of 1m below ground level

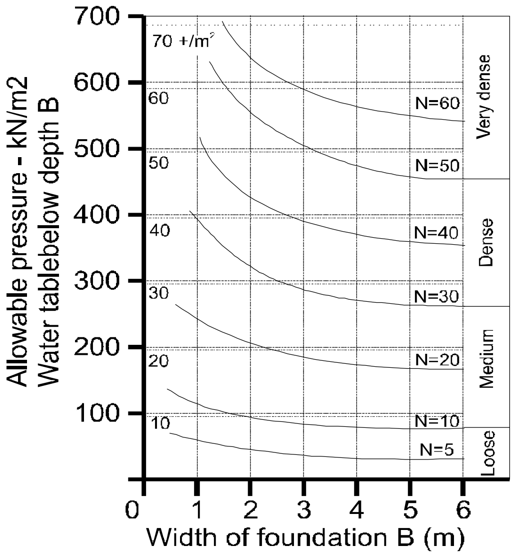
Description	Cohesive strength (kN/m^2 or kgf/cm^2 x 100)	Presumed bearing value (kN/m2 or kgf/cm2 x 100) for foundation of width		
		1m	2m	4m
Hard boulder clays, hard fissured clays (e.g. deeper London and Gault clays)	>300	800	600	400
Very stiff boulder clay, very stiff 'blue' London Clay	150-300	400-800	300-500	150-250
Stiff fissured clays (e.g. stiff 'blue' and brown London clay), stiff weathered boulder clay	75-150	200-400	150-250	75-125
Firm normally consolidated clays (at depth), fluvio-glacial and lake clays, upper weathered 'brown' London clay	40-75	100-200	75-100	50-75
Soft normally consolidated alluvial clays (e.g. marine, river and estuarine clays)	20-40	50-100	25-50	Negligible

Chart for estimating allowable bearing pressure for foundations in sands

SPT ‘N’ values are shown as belows per 300mm

If the water table is within a depth equal to the width of the foundation and the depth of the foundation is small in relation to its width, the settlements will be doubled.

If settlements must not exceed 25mm, the allowable bearing values should be halved.



5.4 SHALLOW FOUNDATIONS

$$\textit{Area of foundation} \;'\; \frac{\textit{Characteristic load}}{\textit{Allowable bearing pressure}}$$

5.5 PILED FOUNDATIONS

Working load on pile < 0.25fcu (0.1fcu for continuous flight auger)

Warning: The following relationships apply only to bored cast in place concrete piles in London clay. For all other piles check with Geotechnics (which should always be done anyway).

$$\textit{Working bearing capacity of straight shafted piles} \;'\; \left(\frac{0.5\overline{c_u}\ x\ perimeter}{3}\right)\%\left(\frac{9c_{u,base}\ x\ base\ area}{3}\right)$$

$$\textit{Working bearing capacity of large under\&reamed piles} \;'\; \left(\frac{0.35\overline{c_u}\ x\ perimeter}{f_1}\right)\%\left(\frac{9c_{u,base}\ x\ base\ area}{f_2}\right)$$

For straight sided piles higher capacities may be available by following the guidelines for Site Investigations and pile tests in the London District Surveyors Association Publication, Guide Notes for the Design of Straight Shafted Piles in London Clay (1996)

C_u = undrained shear strength of London Clay
Typically diameter of under-ream = 3 x diameter of shaft

Factor of safety : $f_1 = f_2 = 2.5$
or $f_1 = 1$ $f_2 = 3$ whichever gives the lower capacity

Minimum spacing of pile shafts = 3 x diameter (ensure under-reams do not encroach)

6. WATER RESISTANT BASEMENTS

6.1 RULES OF THUMB

Minimum thickness

Preferred minimum thickness of walls and slabs: 300mm
Where thicker consider surface zones of 200mm each face for reinforcement to control shrinkage/thermal cracking.

Reinforcement

Typically for water resistant walls: T16 @ 200 c/c in both faces and in both directions
or T12 @ 150 c/c in both faces and in both directions

Standard cover

Assumed concrete grade 35 (This should be a minimum)
Put the horizontal reinforcement furthest from earth face.

Face	Cover (mm)
Earth face of walls where shuttered	50
Earth face of walls (cast against earth)	75
External exposed faces of walls	40
Bottom and sides to base	75
Internal faces	Greater of 25 or bar diameter

Waterstops / waterbars

- Required by BS 8102 for grade 1 basements with concrete design to BS 8110
- Give extra "comfort" at construction joints, otherwise total reliance on workmanship
- Not essential but often desirable
- Use external waterstop for basements (preferred)
- Can use centrestop in vertical construction if necessary (e.g. swimming pool), must be carefully supported/kept in place.

6.2 ESTABLISH CLIENT'S REQUIREMENTS / EXPECTATIONS

These can vary even for the same type of space. Tables 6.1 and 6.2 (from CIRIA Report 139) will help.

Establish (for example): a). Does small amount of leaking (liquid) matter (for people and contents)?
b). Do stains matter? (aesthetics)
c). What level of (vapour) ingress is acceptable/tolerable (for people and contents)?

Note. Some of the requirements for a particular performance will not be within our control (heating, ventilation etc).

6.3 CONSTRUCTION OPTIONS

Structural concrete can prevent ingress of liquid water, except at joints and cracks. It will **not**, generally, prevent the passage of moisture vapour.

Steel sheet piling can prevent ingress of liquid water, except at joints. It will also reduce the passage of moisture vapour. Consider welded sheet piling – low carbon type.

Construction option	Advantages	Disadvantages
Cut & cover	• Allows easy inclusion of membrane external to the structure • Enhanced quality of concrete elements • Continuous construction • Good finish • Straightness of line of walls	• Deep basements not easy • Not always sufficient room (e.g. inner city sites)
Sheet piling Post and panel	• Provides restraint to the ground • Provides restraint to water flow (both short and long term) • Can be used as a shutter for the concrete	• Provides restraint to concrete - increased risk of cracking • Difficult to install a membrane on external face of structure
Diaphragm wall & Secant piles	• Provides restraint to the ground • Provides some restraint to water flow • Can build deep basements	• Difficult to install a membrane on external face of structure • Allows water through the joints (use drained cavity?) • Difficult to get an effective connection with the slab • Poor appearance • Expensive
Contiguous piles	• Provides restraint to the ground • Cost	• Little restraint to water flow • Difficult to get an effective connection with the slab • Difficult to install a membrane • Poor appearance • Expensive

Table 6.2 (from CIRIA report 139) gives examples of types of basement.

6.4 WATERPROOFING OPTIONS (Combined with options of structure)

Tanking (Type A)

- Preformed membranes or liquid applied
- Can prevent liquid and vapour passage
- Best installed by open cut construction
- Best installed external to construction (outside face of structural wall)

Structurally Integral Protection (Type B)

- Reinforced concrete with calculated crack widths to BS8110 Part 2 possible for Type 1
- Concrete design to BS8007 required for type 2 and 3
- If used, particularly for type 2 and 3 basements, there must be careful consideration of mix design and the workmanship required as well as a strategy for dealing with leaks.

Drained cavity (Type C)

- Provide channels to allow drainage of water
- Ventilate cavity externally to reduce vapour and build up of other gases
- Ventilate basement to reduce vapour
- Automatic pump may be required in sump
- Design inner leaf as free-standing or restrained at top by slab
- Beware vermin

6.5 CRITICAL POINTS

- Re-entrant corners – keep plan form simple
- Penetrations e.g. pipe services (group together), earthing pits
- Wall/slab junctions - particularly in non-open excavation
- Changes in section/depth e.g. lift pits
- Pile/slab junctions
- "One column per pile" junctions, e.g. steel columns into top of pile.

6.6 CONSTRUCTION JOINTS

- Need to control the effects of temperature and shrinkage
- The fewer, the better
- Arrange the sequence of castings to reduce restraint from adjacent pours
- Recommended spacing of joints (principally to control workmanship, not cracking):

Construction	Max. area (m?)	Max. dimension (m)
Watertight walls	25	5
Watertight slabs	100	10

May be reviewed for particular cases

6.7 MOVEMENT JOINTS

- Rarely necessary below ground level
- Potential weak points. Only consider providing them if <u>essential</u> to control movements e.g. between tower and podium blocks above.

6.8 REFERENCES

CIRIA Report 139 Water – resisting basements 1995
CIRIA, Guide 5, Guide to the design of waterproof basements
BS 8007: 1987: Design of concrete structures for retaining aqueous liquids
BS8102: 1990: Protection of structures against water from the ground
BS8110: Part 1: 1997: Structural use of concrete: Code of Practice for design and construction
BS8110: Part 2: 1985: Structural use of concrete: Code of Practice for special circumstances
OVE ARUP PARTNERSHIP: Structural Typical details for use in buildings
OVE ARUP & PARTNERS, Reinforcement detailing manual
Notes on Materials 86, 138, 145
Notes on Structures 4, 24, 29

Table 6.1 Guide to level of protection to suit basement use from table 2.1 of CIRIA 139
(The first four columns are from table 1 of BS8102)

Grade of basement	**Basement usage**	**Performance level**	**Form of protection***	**Commentary on Table 1 of BS8102: 1990**
Grade 1 (basic utility)	Car parking; plant rooms (excluding electrical equipment); workshops	Some seepage and damp patches tolerable	Type B. Reinforced concrete design in accordance with BS8110	Unless there is good ventilation, or local drainage, visible water may not be acceptable even for the suggested uses. Calculated crack widths less than 0.3 mm to BS8110 Part 2 BS8110: Part 1 contains only limited guidance on crack control and lacks consideration of early thermal movement. Using Part 1 may result in the formation of cracks with widths unacceptable in permeable ground. There is no guidance on control of thermal cracking in BS8110. Groundwater should be checked for chemicals, which may have a deleterious effect on the structure or internal finishes. The performance level defined in BS8102 for workshops is unlikely to meet the requirements of the Building Regulations, approved Document C for workshops, which are more likely to require a Grade 3 (habitable) environment.
Grade 2 (better utility)	Workshops and Plantrooms requiring drier environment ; retail storage areas	No water penetration but moisture vapour tolerable	Type A Type B. Reinforced concrete design in accordance with BS8007	Membranes may be applied in multiple layers with well-lapped joints. The performance level assumes no serious defects in workmanship, although these may be masked in dry conditions or impermeable ground. Groundwater should be checked as for Grade 1. A high level of supervision of all stages of construction is necessary.
Grade 3 (habitable)	Ventilated residential and working areas including offices, restaurants etc., leisure centres	Dry environment	Type A. Type B. With reinforced concrete design to BS8007. Type C. with wall and floor cavity and DPM	As Grade 2 In highly permeable ground multi-element systems (possibly including active precautions) will probably be necessary.
Grade 4 (special)	Archives and stores requiring controlled environment	Totally dry environment	Type A. Type B. With reinforced concrete design to BS8007 plus a vapour-proof membrane. Type C. With ventilated wall cavity and vapour barrier to inner skin and floor cavity with DPM	As Grade 3

Table 6.2 Guidance on the functional environments requirements for basement usage (Table 2.2 of CIRIA 139)

Grade of basement	Relative humidity	Temperature	Performance level: Dampness	Performance level: Wetness
Grade 1 (basic utility)	>65% normal UK external range	Car parks: atmospheric Workshops: 15~ 29°C. Mechanical plantrooms: 32°C max, at ceiling level	Visible damp patches may be acceptable	Minor seepage may be acceptable
Grade 2 (better utility)	35~50%	Retail storage: 15°C max Electrical plantrooms 42°C max	No visible damp patches, construction materials to contain less than the air-dry moisture content	None acceptable
Grade 3 (habitable)	40~60% 55~60% for a restaurant in summer	Offices: 21~25°C Residential: 18~22°C Leisure centres: 18°C for spectators 10°C for squash courts 22°C for changing rooms 24~29°C for swimming pools Restaurants: 18~25°C Kitchens 29°C max	None acceptable Active measures to control internal humidity may be necessary	
Grade 4 (special)	50% for art storage >40% for microfilms and tapes 35% for books	Art storage: 18~22°C Book archives: 13~18°C	Active measures to control internal humidity probably essential	

(N.B. The limits for a particular basement application should be agreed with the client and defined at the design approval stage).

Table 6.3 Construction methods and examples of passive precautions available to achieve the required Grade of internal environment in deep or shall basements. (Table 3.1 of CIRIA 139)

Basement depth and construction materials	Target internal environment / examples of construction methods and passive precautions			
	Grade 1 (basic utility)	Grade 2 (better utility)	Grade 3* (habitable)	Grade 4* (special)
	Limited environment control ***Complete*** ***environment control*** *possibly* adequate normally required (Low cost, low reliability) (High cost, high reliability)			
	Some water penetration Acceptable	Water penetration Unacceptable	Increasing requirements for vapour control	
Shallow (assumed no hydrostatic pressure, i.e. groundwater level below basement floor or drainage provided) likely to be residential Masonry, reinforced masonry, plain or reinforced (pre-cast or in-situ) concrete or steel sheet piling	Grade not usually acceptable for residential basements	Masonry or plain concrete plus tanking (Type A) or drained cavity (Type C) protection Reinforced concrete box (Type B) protection	Masonry or plain concrete plus tanking (Type A) protection and/or Type C protection Reinforced concrete box (type B) plus tanking vapour barrier (Type A) or drained (type C) protection	If grade required the methods and precautions for shallow basements with permanent hydrostatic pressure should be followed
Shallow (with permanent hydrostatic pressure) Masonry, reinforced masonry, plain or reinforced (pre-cast or in-situ) concrete or steel sheet piling	Masonry, plain or reinforced concrete box construction plus tanking (Type A) or drained (Type C) protection Reinforced concrete box (Type B) protection Steel sheet piling in conjunction plus drained (Type C) protection	Masonry, plain or reinforced concrete box construction plus tanking (Type A) or drained (type C) protection Reinforced concrete box (Type B) protection	Masonry or plain concrete plus tanking (vapour barrier, Type A) *and* drained (Type C) protection Reinforced concrete box (Type B) plus tanking (vapour barrier, Type A) or drained (Type C) protection	Reinforced concrete box (type B) with tanking (vapour barrier, Type A), plus drained (Type C) protection Passive precautions alone are not likely to be sufficient
Deep (with permanent hydrostatic pressure) Reinforced concrete including piled or in-site perimeter wall.	Reinforced concrete box (Type B) protection Concrete piled wall possibly requiring drained cavity (type C) protection	Reinforced concrete box (Type B) protection Concrete piled wall or reinforced concrete box (Type B) plus drained (Type C) protection	Concrete piling or reinforced concrete box (Type B) plus an internal vapour barrier (Type A) or drained (Type C) protection Passive precautions alone are not likely to be sufficient	Concrete piling or reinforced concrete box (Type B) plus tanking (vapour barrier, Type A) and drained (Type C) protection Achieved only at high cost Passive precautions alone are not likely to be sufficient

Notes: When tanking is required, external or sandwich tanking systems are recommended for both new and existing basements where it is possible to use them. Such systems become feasible either by virtue of an existing permanent external surface (including faced sheet piling) or where working space is created through open excavation. The choice of tanking system also requires an assessment of the external hydrostatic pressure and its effect on the basement wall design and construction. For deeper basements, or where excavation is impracticable, internal protection by cavity construction with internal or reverse tanking may be used. This implies a reduction in usable volume or increased excavation volume. Integral protection must not be damaged by wall fixings. The costs of available options and associated risks will need to be evaluated. Where significant quantities of water are likely to accrue in sumps on a regular basis the drainage authority should be approached at an early stage to request acceptance of the discharge.

* The design for Grade 3 or Grade 4 should take account of the contribution of active precautions (heating and ventilation, etc.) in achieving the required internal environment.

7. FIRE

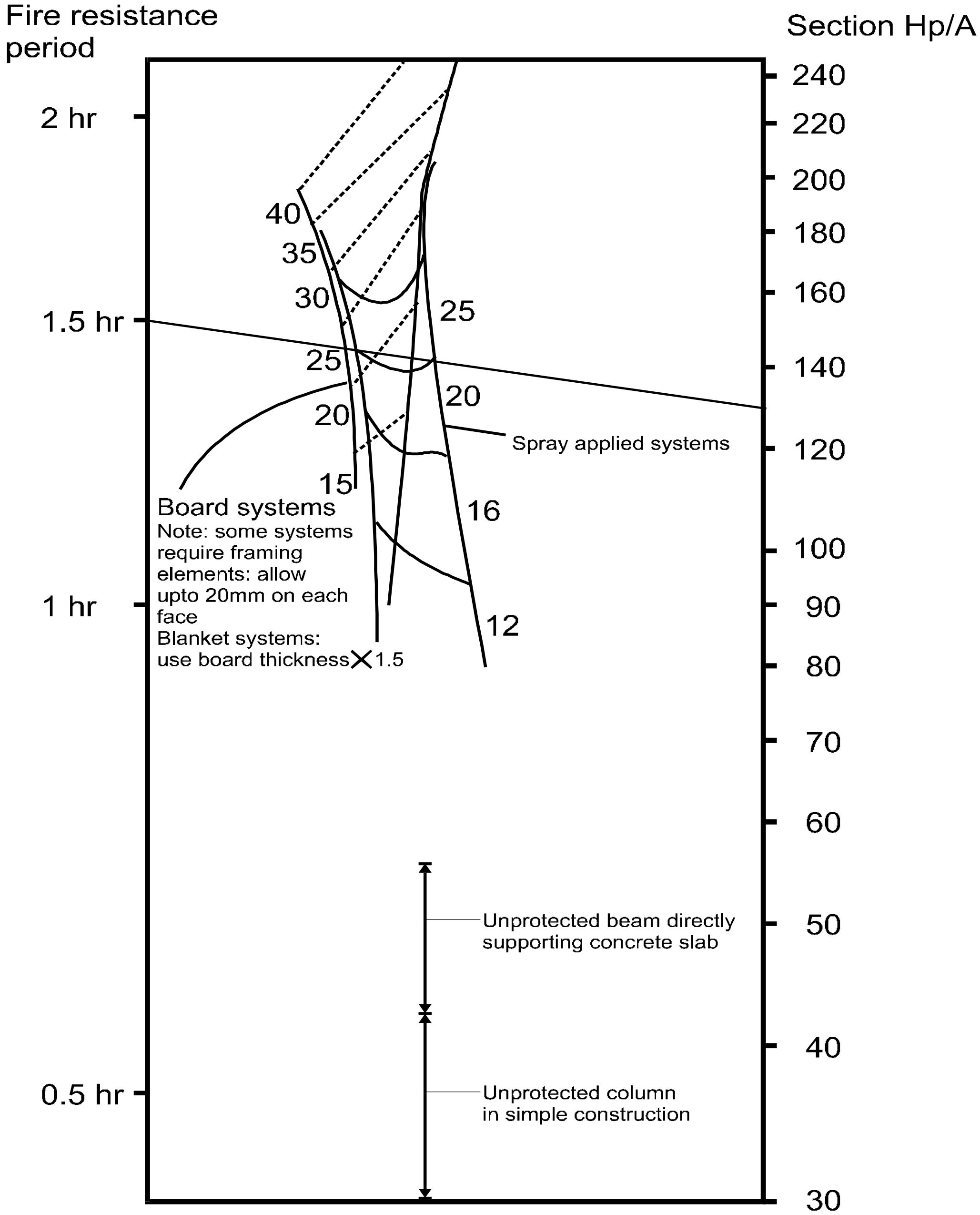
7.1 MINIMUM PERIODS OF FIRE RESISTANCE. (UK Practice only)

Table A2 from the approved document B to Building Regulations (1991). **Other British Standards or Local Acts may set <u>higher</u> standards**.

Purpose group of building	Minimum periods (hours) for elements of structure in a:					
	Basement storey(●) including floor over		Ground or upper storey			
	Depth (m) of a lowest basement		Height (m) of top floor above ground, in building or separating part of building.			
	more than 10	not more than 10	not more than 5	not more than 20	not more than 30	more than 30
1. Residential (domestic):						
(a) flats and maisonettes	1½	1	½*	1**	1½**	2**
(b) & (c) dwelling houses	not relevant	½*	½*	1	not relevant	not relevant
2. Residential:						
(a) Institutional (~)	1½	1	½*	1	1½	2#
(b) other residential	1½	1	½*	1	1½	2#
3. Office:						
- not sprinklered	1½	1	½*	1	1½	not permitted
- sprinklered (2)	1	1	½*	½*	1	2#
4. Shop and commercial:						
- not sprinklered	1½	1	1	1	1½	not permitted
- sprinklered (2)	1	1	½*	1	1	2#
5. Assembly and recreation:						
- not sprinklered	1½	1	1	1	1½	not permitted
- sprinklered (2)	1	1	½*	1	1	2#
6. Industrial:						
- not sprinklered	2	1½	1	1½	2	not permitted
- sprinklered(2)	1	1	½*	1	1½	2#
7. Storage & other non-residential:						
a. building or part not described above:						
- not sprinklered	2	1½	1	1½	2	not permitted
- sprinklered (2)	1½	1	½*	1	1½	2#
b. Car park for light vehicles:						
i) open sided park (3)	not applicable	not applicable	¼*+	¼*+	¼*+	1
ii) any other park	1½	1	½*	1	1½	2#

- ● The floor over a basement (or if there is more than 1 basement, the floor over the topmost basement) should meet the provisions for the ground and upper storeys if that period is higher.
- * Increased to a minimum of 1 hour for compartment walls separating buildings
- ** Reduced to ½ hour for any floor within a maisonette, but not if the floor contributes to the support of the building
- # Reduced to 1½ hours for elements not forming part of the structural frame
- \+ Increased to ½ hour for elements protecting the means of escape
- ~ Multi-storey hospitals designed in accordance with the NHS Firecode documents should have a minimum 1 hour standard

7.2 FIRE PROTECTION TO STEEL ELEMENTS (UK Practice only)



Approximate thickness (mm) of protection for fully loaded steel members based on a **range** of manufacturers' test data (Fire protection for structural steel in buildings, ASFPCM, (1988), also see revised 2nd edition (1992))

For the example line given:	H_p / A = 130
	Fire resistance period = 1½ hours
Line intersects zones:	Board 20 and 25
	Spray 20 and 25
Solution:	Spray 20mm to 25mm depending on system used
	Board 25mm to 30mm depending on system used
	Blanket 38mm to 45mm depending on system used

7.3 FIRE PROTECTION FOR REINFORCED CONCRETE

For cover details, see Section 4.2 Reinforced Concrete

7.4 FIRE PROTECTION FOR MASONRY (UK Practice only)

See Table 16, BS 5628: Part 3.
A 100mm unplastered wall or leaf of a cavity wall will give 2 hour fire resistance in all materials and loading conditions (sometimes conservatively) except:

- Fired-clay bricks/blocks with voids or perforations (75-100% solid - use min. 170mm thickness);
- Hollow concrete blocks with gravel or natural stone aggregate (limestone OK) - min. 200mm thickness with vermiculite-gypsum plaster.

7.5 FIRE REQUIREMENTS FOR TIMBER (UK Practice only)

The requirement of the Building Regulations with respect to timber fall under two headings:

- (B2) Spread of flame
- (B3 - (1)) Period of fire resistance

Spread of flame
The Regulations define spread of flame classes for walls and ceilings for various building purpose groups and sizes. Spread of flame is determined by tests described in BS 476: Parts 6 & 7 which allocate materials into classes, related to the extent of travel of a flame front under standard conditions in a given time. Most timber (>400kg/m^3) falls into Class 3. A lower class rating can be achieved by impregnation, or by surface treatment. Structural elements, because of their size, are generally given surface coatings. Many are moisture sensitive, and can discolour if they get wet.

Period of fire resistance
The Regulations also define specific periods of fire resistance for elements of structure (although generally no period is required for roofs). This requirement is often satisfied for walls and floors by applying protective materials to the frame, and these are described in BS 5268: Part 4; Section 4.2.

Alternatively, the fire resistance of the members themselves may be calculated by the method given in BS 5268: Part 4; Section 4.1, based on charring rates. Timber will ignite when subjected to temperatures of around 270°C, if a pilot flame is present to ignite the gases given off during the 'cooking' process. The insulation value of the outer charred layer, however, means that timber which is just a few millimetres inside the burning zone is only warm. Thus timber burns at a predictable speed, known as the 'charring rate', which, for common softwoods with a density of about 450kg/m^3 is defined in section 4.1 as 20mm (or 25mm for columns), in 30 minutes.

The reduced section (ie. the full section minus the charred zone) is checked for strength and deflection. Increased stresses are allowed (of the order x2 to x2.25), together with more generous deflection limits (1/30 span). The charring rates quoted for solid timber may be applied without modification to glulams made with the conventional adhesives.

In addition, it is necessary to look at the overall stability of the charred structure, and to protect any metal (including bolts) which forms part of the structural system, either by ensuring that the component lies with the residual section, or that it is suitably protected by a fire resistant cladding or sacrificial timber.

7.6 FURTHER INFORMATION

The requirements above relate to standard furnace tests, and assume the member is fully stressed. If the fire load is small and/or the member is lightly stressed, significant improvements may be obtained. Contact Arup Fire for more information.

APPENDIX A – MATHEMATICAL FORMULAE

Version 3.1. Jan 99. A.5. corrected equation for trapezium inertia.
Version 3.2. May 2000. A.5. corrected equation for trapezium inertia.

A.1 **Trigonometric functions**

$$\sin x = \frac{e^{ix} - e^{-ix}}{2i}$$

$$\cos x = \frac{e^{ix} + e^{-ix}}{2}$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \quad \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \quad \tan A \tan B}$$

$$\sin A - \sin B = 2\cos\frac{A+B}{2}\sin\frac{A-B}{2}$$

$$\sin A + \sin B = 2\sin\frac{A+B}{2}\cos\frac{A-B}{2}$$

$$\cos A - \cos B = -2\sin\frac{A+B}{2}\sin\frac{A-B}{2}$$

$$\cos A + \cos B = 2\cos\frac{A+B}{2}\cos\frac{A-B}{2}$$

$$\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

$$\sin A \ \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$

$$\sin A \ \cos B = \frac{1}{2}\left[\sin(A+B) + \sin(A-B)\right]$$

$$\cos^2 x = \frac{1}{2}\left[1 + \cos 2x\right]$$

$$\sin^2 x = \frac{1}{2}\left[1 - \cos 2x\right]$$

$$\cos^3 x = \frac{1}{4}\left[3\cos x + \cos 3x\right]$$

$$\sin^3 x = \frac{1}{4}\left[3\sin x - \sin 3x\right]$$

A.2 **Hyperbolic functions**

$$\cosh x = \frac{e^{x} + e^{-x}}{2}$$

$$\sinh x = \frac{e^{x} - e^{x}}{2}$$

$$\cosh ix = \cos x$$

$$\cos ix = \cosh x$$

$$\sinh ix = i \sin x$$

$$\sin ix = i \sinh x$$

$$\cosh^2 x - \sinh^2 x = 1$$

$$\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y$$

$$\sinh(x \pm y) = \sinh x \cosh y \pm \cosh x \sinh y$$

$$\cosh(x \pm iy) = \cosh x \cos y \pm i \sinh x \sin y$$

$$\sinh(x \pm iy) = \sinh x \cos y \pm i \cosh x \sin y$$

A.3 **Standard indefinite integral**

Integrand	Integral	Integrand	Integral
$\sin x$	$-\cos x$	$\sinh x$	$\cosh x$
$\cos x$	$\sin x$	$\cosh x$	$\sinh x$
$\tan x$	$-\ln(\cos x)$	$\tanh x$	$\ln(\cosh x)$
$\operatorname{cosec} x$	$\ln(\tan x/2)$	$\operatorname{cosech} x$	$\ln(\tanh x/2)$
$\sec x$	$\ln(\tan x + \sec x)$	$\operatorname{sech} x$	$2\tan^{-1}(e^x)$
$\cot x$	$\ln(\sin x)$	$\coth x$	$\ln(\sinh x)$
$\sec^2 x$	$\tan x$	$\operatorname{sech}^2 x$	$\tanh x$
$\tan x \sec x$	$\sec x$	$\tanh x \operatorname{sech} x$	$-\operatorname{sech} x$
$\cot x \operatorname{cosec} x$	$-\operatorname{cosec} x$	$\coth x \operatorname{cosech} x$	$-\operatorname{cosech} x$
$\dfrac{1}{\sqrt{a^2-x^2}}$	$\sin^{-1}\left(\dfrac{x}{a}\right)$ *or* $-\cos^{-1}\left(\dfrac{x}{a}\right)$		
$\dfrac{1}{\sqrt{x^2+a^2}}$	$\sinh^{-1}\left(\dfrac{x}{a}\right)$ *or* $\ln\left(x+\sqrt{x^2+a^2}\right)$		
$\dfrac{1}{\sqrt{x^2-a^2}}$	$\cosh^{-1}\left(\dfrac{x}{a}\right)$ *or* $\ln\left(x+\sqrt{x^2-a^2}\right)$		
$\dfrac{1}{x^2+a^2}$	$\dfrac{1}{a}\tan^{-1}\left(\dfrac{x}{a}\right)$		

A.4 **Standard substitutions for integration**

If the integrand is a function of :	Substitute:
(a^2-x^2) *or* $\sqrt{a^2-x^2}$	$x = a\sin\theta$ *or* $x = a\cos\theta$
(a^2+x^2) *or* $\sqrt{a^2+x^2}$	$x = a\tan\theta$ *or* $x = a\sinh\theta$
(x^2-a^2) *or* $\sqrt{x^2-a^2}$	$x = a\sec\theta$ *or* $x = a\cosh\theta$

or of the form:

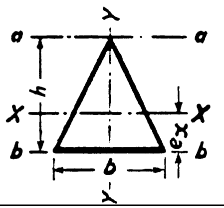
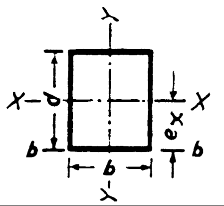
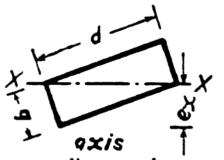
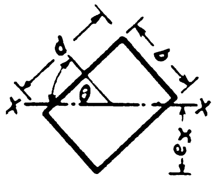
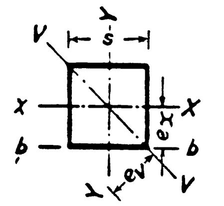
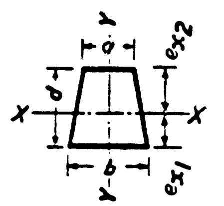
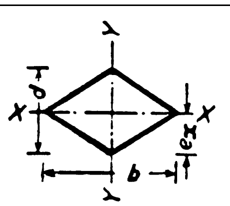
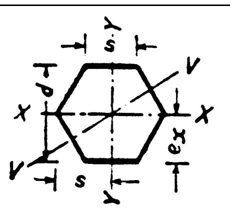
$\left\{(ax+b)\sqrt{px+q}\right\}^{-1}$	$px+q = u^2$
$\left\{(ax+b)\sqrt{px^2+qx+r}\right\}^{-1}$	$ax+b = \dfrac{1}{u}$

or a rational function of:

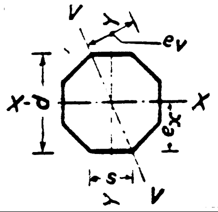
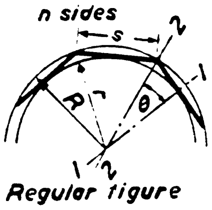
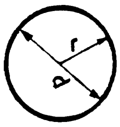
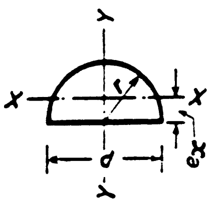
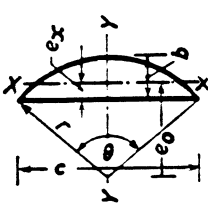
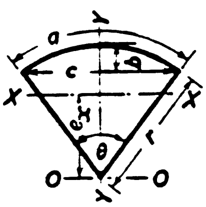
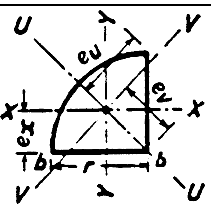
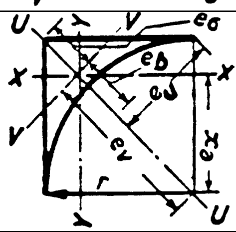
$\sin x$ *and/or* $\cos x$	$t = \tan\dfrac{x}{2}$

$$\left[\textit{whence} \quad \sin x = \frac{2t}{1+t^2} \qquad \cos x = \frac{1-t^2}{1+t^2} \qquad dx = \frac{2\,dt}{1+t^2}\right]$$

A.5 **Geometric properties of plane sections**

section		Area	Position of centroid	Moments of inertia	Section Moduli
Triangle		$A = \frac{bh}{2}$	$e_x = \frac{h}{3}$	$I_{xx} = bh^3/36$ $I_{yy} = hb^3/48$ $I_{aa} = bh^3/4$ $I_{bb} = bh^3/12$	Z_{xx} $base = bh^2/12$ $apex = bh^2/24$ $Z_{yy} = bh^2/24$
Rectangle		$A = bd$	$e_x = \frac{h}{2}$	$I_{xx} = bd^3/12$ $I_{yy} = db^3/12$ $I_{bb} = bd^3/3$	$Z_{xx} = bd^2/6$ $Z_{yy} = db^2/6$
Rectangle		$A = bd$	$e_x = \frac{bd}{\sqrt{b^2 + d^2}}$	$I_{xx} = \frac{b^3 d^3}{6(b^2 + d^2)}$	$Z_{xx} = \frac{b^2 d^2}{6\sqrt{b^2 + d^2}}$
Rectangle		$A = bd$	$e_x = \frac{b\sin\theta + d\cos\theta}{2}$	$I_{xx} = \frac{bd(b^2\sin^2\theta + d^2\cos^2\theta)}{12}$	$Z_{xx} = \frac{bd\left(b^2\sin^2\theta + d^2\cos^2\theta\right)}{6(b\sin\theta + d\cos\theta)}$
Square		$A = s^2$	$e_x = \frac{s}{2}$ $e_v = \frac{s}{\sqrt{2}}$	$I_{xx} = I_{yy} = s^4/12$ $I_{bb} = s^4/3$ $I_{vv} = s^4/12$	$Z_{xx} = Z_{yy} = \frac{s^3}{6}$ $Z_{vv} = \frac{s^3}{6\sqrt{2}}$
Trapezium		$A = \frac{d(a+b)}{2}$	$e_{x1} = \frac{d(2a+b)}{3(a+b)}$	$I_{xx} = \frac{d^3(a^2 + 4ab + b^2)}{36(a+b)}$ $I_{yy} = \frac{d(a^3 + a^2 b + ab^2 + b^3)}{48}$	$Z_{xx} = \frac{I_{xx}}{d - e_x}$ (*two values*) $Z_{yy} = \frac{2I_{yy}}{b}$
Diamond		$A = \frac{bd}{2}$	$e_x = \frac{d}{2}$	$I_{xx} = \frac{bd^3}{48}$ $I_{yy} = \frac{db^3}{48}$	$Z_{xx} = \frac{bd^2}{24}$ $Z_{yy} = \frac{db^2}{24}$
Hexagon		$A = 0.866d^2$	$e_x = 0.866s$ $= \frac{d}{2}$	$I_{xx} = I_{yy} = I_{vv}$ $= 0.0601d^4$	$Z_{xx} = 0.1203d^3$ $Z_{yy} = Z_{vv}$ $= 0.1042d^3$

Geometric properties of plane sections (cont.)

Section		Area	Position of centroid	Moments of inertia	Section Moduli
Octagon		$A = 0.8284d^2$ $s = 0.4142d$	$e_x = \frac{d}{2}$ $e_v = 0.541d$	$I_{xx} = I_{yy} = I_{vv}$ $= 0.0547d^4$	$Z_{xx} = Z_{yy}$ $= 0.1095d^3$ $Z_{vv} = 0.1011d^3$
Polygon		$A = \frac{n s^2 \cot\theta}{4}$ $A = n r^2 \tan\theta$ $A = \frac{n R^2 \sin 2\theta}{2}$	$e = r$ or R depending on the axis and value of n	$I_1 = I_2$ $= \frac{A(6R^2 - s^2)}{24}$ $= \frac{A(12r^2 + s^2)}{48}$	$Z = \frac{I}{e}$
Circle		$A = \pi r^2$ $A = 0.7854d^2$	$e = r = \frac{d}{2}$	$I = \frac{\pi d^4}{64}$ $I = 0.7854r^2$	$Z = \frac{\pi d^3}{32}$ $Z = 0.7854r^3$
Semi-Circle		$A = 1.5708r^2$	$e_x = 0.424r$	$I_{xx} = 0.1098r^4$ $I_{yy} = 0.3927r^4$	$Z_{xx} =$ $base = 0.2587r^3$ $crown = 0.1907r^3$ $Z_{yy} = 0.3927r^3$
Segment		$A =$ $\frac{r^2}{2}\left(\frac{\pi\theta°}{180°} - \sin\theta\right)$	$e_0 = \frac{c^3}{12A}$ $e_x = e_0 - r\cos\frac{\theta}{2}$	$I_{xx} = \frac{r^4}{16}\left(\frac{\pi\theta°}{90°} - \sin 2\theta\right)$ $- \frac{20r^4(1-\cos\theta)^3}{\pi\theta° - 180°\sin\theta}$ $I_{yy} = \frac{r^4}{48}\left(\frac{\pi\theta°}{30°} - 8\sin\theta + \sin 2\theta\right)$	Z_{xx} $base = I_{xx}/e_I$ $crown = \frac{I_{xx}}{b - e_I}$ $Z_{vv} = \frac{2I_{yy}}{c}$
Sector		$A = \frac{\theta°}{360°}\pi r^2$	$e_x = \frac{2}{3}r\frac{c}{a}$ $e_x = \frac{r^2 c}{3A}$	$I_{xx} = I_o - \frac{360°}{\theta°\pi}\sin^2\frac{\theta}{2}\frac{4r^4}{9}$ $I_{yy} = \frac{r^4}{8}\left(\frac{\pi\theta°}{180°} - \sin\theta\right)$ $I_0 = \frac{r^4}{8}\left(\frac{\pi\theta°}{180°} + \sin\theta\right)$	Z_{xx} $centre = \frac{I_{xx}}{e_x}$ $crown = \frac{I_{xx}}{r - e_x}$ $Z_{yy} = \frac{2I_{yy}}{c}$
Quadrant		$A = \frac{\pi r^2}{4}$	$e_x = 0.424r$ $e_v = 0.6r$ $e_u = 0.707r$	$I_{xx} = I_{yy} = 0.0549r^4$ $I_{bb} = 0.1963r^4$ $I_{uu} = 0.0714r^4$ $I_{vv} = 0.0384r^4$	*Minimum Values* $Z_{xx} = Z_{yy} = 0.0953r^3$ $Z_{uu} = 0.1009r^3$ $Z_{vv} = 0.064r^3$
Complement		$A = 0.2146r^2$	$e_x = 0.777r$ $e_v = 1.098r$ $e_u = 0.707r$ $e_\sigma = 0.316r$ $e_b = 0.391r$	$I_{xx} = I_{yy} = 0.0076r^4$ $I_{uu} = 0.012r^4$ $I_{vv} = 0.0031r^4$	*Minimum Values* $Z_{xx} = Z_{yy} = 0.0097r^3$ $Z_{uu} = 0.017r^3$ $Z_{vv} = 0.0079r^3$

A.6 **Conversion Factors**
Imperial : Metric conversion factors

Mass

1 kg	= 2.205 lb	1 lb	= 0.4536 kg
1 tonne	= 0.9842 ton	1 ton	= 1.016 tonne

Length

1 mm	= 0.03937 in	1 in	= 25.40 mm
1 m	= 3.281 ft	1 ft	= 0.3048 m
1 m	= 1.094 yd	1 yd	= 0.9144 m

Area

1 mm^2	= 0.00155 in^2	1 in^2	= 645.2 mm^2
1 m^2	= 10.76 ft^2	1 ft^2	= 0.09290 m^2
1 m^2	= 1.196 yd^2	1 yd^2	= 0.8361 m^2

Volume

1 mm^3	= 0.000061 in^3	1 in^3	= 16390 mm^3
1 m^3	= 35.32 ft^3	1 ft^3	= 0.02832 m^3
1 m^3	= 1.308 yd^3	1 yd^3	= 0.7646 m^3

Density

1 kg/m^3	= 0.06242 lb/ft^3	1 lb/ft^3	= 16.02 kg/m^3
1 tonne/m^3	= 0.7524 ton/yd^3	1 ton/yd^3	= 1.329 tonne/m^3

Force

1 N	= 0.102 kgf	1 kgf	= 9.807 N
1 N	= 0.2248 lbf	1 lbf	= 4.448 N
1 kN	= 0.1004 tonf	1 tonf	= 9.964 kN

Stress

1 N/mm^2	= 145.0 lbf/in^2	1 lbf/in^2	= 0.006895 N/mm^2
1 N/m^2	= 0.102 kgf/m^2	1 kgf/m^2	= 9.807 N/m^2
1 kgf/m^2	= 0.2048 lbf/ft^2	1 lbf/ft^2	= 4.882 kgf/m^2
1 N/m^2	= 0.02089 lbf/ft^2	1 lbf/ft^2	= 47.88 N/m^2
1 kN/m^2	= 0.009324 tonf/ft^2	1 tonf/ft^2	= 107.3 kN/m^2
1 N/mm^2	= 0.06475 tonf/in^2	1 tonf/in^2	= 15.44 N/mm^2

Strip Loading

1 N/m	= 0.102 kgf/m	1 kgf/m	= 9.807 N/m
1 kgf/m	= 0.6720 lbf/ft	1 lbf/ft	= 1.488 kgf/m
1 kN/m	= 68.53 lbf/ft	1 lbf/ft	= 0.0146 kN/m
1 kN/m	= 0.03059 tonf/ft	1 tonf/ft	= 32.69 kN/m

Moment

1 Nm	= 0.102 kgf.m	1 kgf.m	= 9.807 Nm
1 kgf.m	= 86.80 lbf.in	1 lbf.in	= 0.01152 kgf.m
1 Nm	= 8.851 lbf.in	1 lbf.in	= 0.1130 Nm
1 Nm	= 0.7376 lbf.ft	1 lbf.in	= 1.356 Nm
1 kNm	= 3.951 tonf.in	1 tonf.in	= 0.2531 kNm

Modulus of Elasticity

1 N/mm^2	= 145.00 lbf/in^2	1 lbf/in^2	= 6.895 x 10^{-3} N/mm^2

Section Modulus

1 mm^3	= 61.01 x 10^{-6} in^3	1 in^3	= 16390 mm^3

Second Moment of Area

1 mm^4	= 2.403 x 10^{-6} in^4	1 in^4	= 416200 mm^4

APPENDIX B – ANALYSIS FORMULAE

B.1 **Elastic bending formulae**

Bending about a principle axis:

$$\frac{s}{y} = \frac{M}{I} = E\,k \quad ; \qquad \text{curvature-change} \quad k = \frac{1}{R} - \frac{1}{R_0}$$

In general, bending moment is *section modulus* Z times maximum bending stress.
Longitudinal shear force S on material of area A_s , due to transverse shear force F on the beam.

$$S = \frac{F}{I}\int_{A_S} y\,dA = \frac{F\,A_S\,\bar{y}}{I} \qquad \text{per unit length of beam.}$$

B.2 **Elastic torsion formulae**

Round shafts: $\frac{t}{r} = \frac{T}{J} = G\,f$ where ϕ is the angle of twist per unit length

and $J = \int r^2 dA$ is the polar moment of area.

Circular area, radius R: $J = \frac{p\,R^4}{2}$

Thin circular tube, radius R thickness t: $J = 2p\,R^3\,t$

Thin walled tube of arbitrary cross-section:

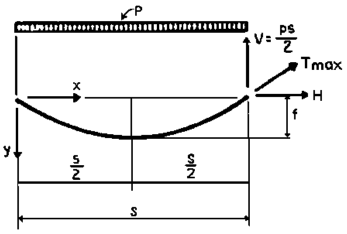
$$t = \frac{T}{2A_e t} \quad : \quad T = G\frac{4A_e^2}{\oint \frac{ds}{t}} f$$

where A_e is the enclosed area to mid thickness, t is the wall thickness. and s is the distance round the permiter.

B.3 **Taut wires, cables or chains**

s = span length
f = cable sag
n = *f/s* = sag ratio
L = length of cable curve
ΔL_s = cable elongation due to axial stress
ΔL_t = cable elongation due to temperature change, *t*
A = area of cable
E = modulus of elasticity of cable
ε = thermal coefficient of linear expansion
t = temperature change in °F
p = load per unit length

Uniformly loaded cables with horizontal chords



$a.\ y = \frac{4f}{s^2}\left(sx - x^2\right)$

$b.\ H = \frac{ps^2}{8f}$

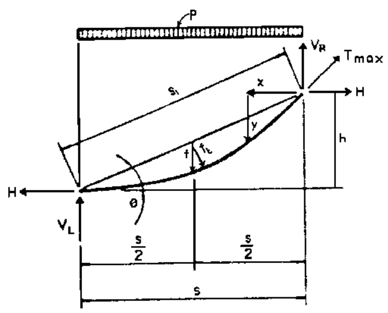
$c.\ T_{max} = H\sqrt{1+16n^2}$

$d.\ L = s\left(1 + \frac{8}{3}n^2 - \frac{32}{5}n^4 + \ldots\right)$

$e.\ \Delta L_s \cong \frac{Hs}{AE}\left(1 + \frac{16}{3}n^2\right)$

$f.\ \Delta L_t = \varepsilon t L \cong \varepsilon t s\left(1 + \frac{8}{3}n^2\right)$

Uniformly loaded cables
With inclined chords



$a.\ y = \frac{4f}{s^2}\left(sx - x^2\right)$

$b.\ H = ps^2/8f$

$c.\ T_{max} = H\sqrt{1 + \left(\frac{h}{s} + 4n\right)^2}$

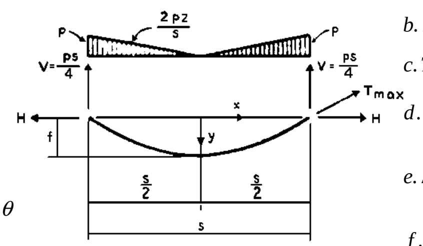
$d.\ L \cong s\left(1 + \frac{8n^2}{3\sec^4\theta}\right)\sec\theta$

$e.\ \Delta L_s \cong \frac{Hs}{AE}\left(1 + \frac{16n^2}{3\sec^4\theta}\right)\sec\theta$

$f.\ \Delta L_t \cong \varepsilon ts\left(1 + \frac{8n^2}{3\sec^4\theta}\right)\sec\theta$

$g.\ V_s = \frac{Hh}{s} + \frac{ps}{2}$

Triangular loading on cables
with horizontal chords



$a.\ y = f\left(1 - 8\frac{x^3}{s^3}\right)$

$b.\ H = ps^2/24f$

$c.\ T_{max} = \sqrt{1+36n^2}$

$d.\ L = s\left(1 + \frac{18}{5}n^2 - 18n^4 + \ldots\right)$

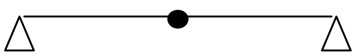
$e.\ \Delta L_s \cong \frac{Hs}{AE}\left(1 + \frac{36}{5}n^2\right)$

$f.\ \Delta L_t \cong \varepsilon ts\left(1 + \frac{18}{5}n^2\right)$

B.4 **Vibration**

Typically $f = \frac{18}{\sqrt{y}}$ for most structures

Where: f is in cycles per second
y is the static deflection in mm

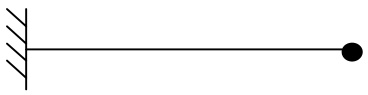


Simply supported
Mass concentrated in centre

$f = \frac{15.8}{\sqrt{y}}$

Simply Supported
Mass and stiffness distributed

$f = \frac{18}{\sqrt{y}}$



Cantilever
Mass concentrated at end

$f = \frac{15.8}{\sqrt{y}}$

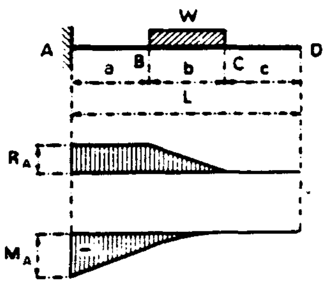
Cantilever
Mass and stiffness distributed

$f = \frac{19.7}{\sqrt{y}}$

ARUP

B.5 **Design formulae for beams - cantilever**

CANTILEVER



UNIFORM LOAD ON PART OF SPAN

Span = L

Uniform Load = W

R_A = W

$M_A = -W\left(a+\frac{b}{2}\right)$

$i_C = i_D = \frac{W}{6EI}(3a^2+3ab+b^2)$

$\delta_D = \frac{W}{24EI}[8a^3+18a^2b+12ab^2+3b^3+4c(3a^2+3ab+b^2)]$

SPECIAL CASE: UNIFORM LOAD ON FULL SPAN

Span = L = b

a = c = 0

Uniform Load = W

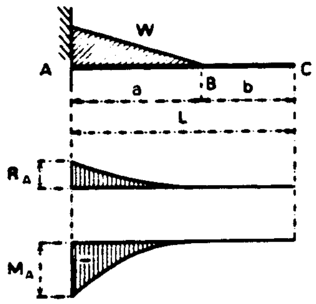
R_A = W

$M_A = -\frac{WL}{2}$

$i_D = \frac{WL^2}{6EI}$

$\delta_D = \frac{WL^3}{8EI}$

CANTILEVER



TRIANGULAR LOAD ON PART OF SPAN

Span = L

Triangular Load = W

R_A = W

$M_A = -\frac{Wa}{3}$

$\delta_C = \frac{Wa^2}{15EI}\left(L+\frac{b}{4}\right)$

$i_B = i_C = \frac{Wa^2}{12EI}$

SPECIAL CASE: TRIANGULAR LOAD ON FULL SPAN

Span = L = a

b = 0

Triangular Load = W

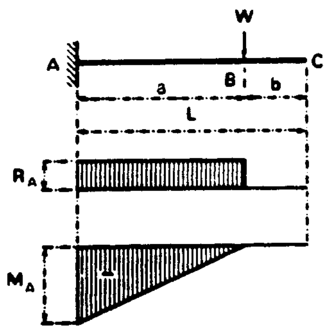
R_A = W

$M_A = -\frac{WL}{3}$

$\delta_C = \frac{WL^3}{15EI}$

$i_C = \frac{WL^2}{12EI}$

CANTILEVER



POINT LOAD AT ANY POSITION

Span = L

Point Load = W

R_A = W

$M_A = -Wa$

$\delta_C = \frac{Wa^2}{3EI}\left(L+\frac{b}{2}\right)$

$i_B = i_C = \frac{Wa^2}{2EI}$

SPECIAL CASE: POINT LOAD AT FREE END

Span = L = a

b = 0

Point Load = W

R_A = W

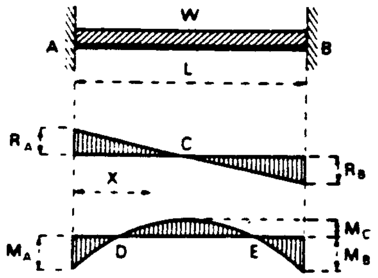
$M_A = -WL$

$\delta_C = \frac{WL^3}{3EI}$

$i_C = \frac{WL^2}{2EI}$

B.6 **Design formulae for beams - fixed both ends**

BEAM FIXED AT BOTH ENDS



at 0·211L from either end $M_D = M_E = 0$

UNIFORM LOAD ON FULL SPAN

Span = L

Total Uniform Load = W

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

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

at mid-span:
- $M_C = \frac{WL}{24}$
- $\delta_{max} = \frac{WL^3}{384EI}$

at X from A:
- $M_X = -\frac{W}{12L}(L^2 - 6LX + 6X^2)$
- $\delta_X = \frac{WX^2}{24EIL}(L - X)^2$
- $i_X = \frac{WX}{12EIL}(L^2 - 3LX + 2X^2)$

POINT LOAD AT MID-SPAN

Span = L

Point Load = W

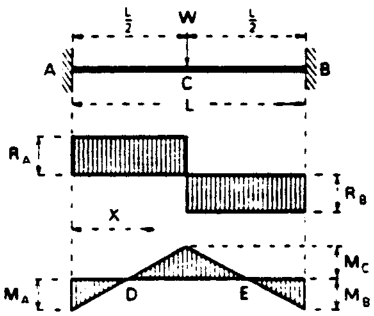
$R_A = R_B = \frac{W}{2}$

$M_A = M_B = -\frac{WL}{8}$

at mid-span:
- $M_C = \frac{WL}{8}$
- $\delta_{max} = \frac{WL^3}{192EI}$

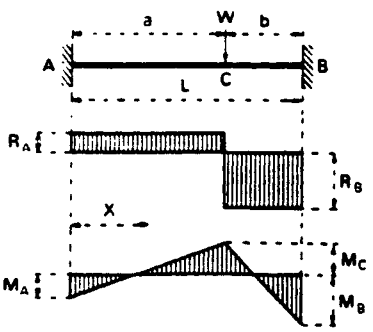
at X from A between A & C:
- $M_X = \frac{W}{8}(4X - L)$
- $\delta_X = \frac{WX^2}{48EI}(3L - 4X)$
- $i_X = \frac{WX}{8EI}(L - 2X)$

BEAM FIXED AT BOTH ENDS



at 0·25L from either end $M_D = M_E = 0$

BEAM FIXED AT BOTH ENDS



When a > b the maximum deflection is at $X = \frac{2La}{L + 2a}$

POINT LOAD AT ANY POSITION

Span = L

Point Load = W

$R_A = \frac{Wb^2(L + 2a)}{L^3}$ $\quad R_B = \frac{Wa^2(L + 2b)}{L^3}$

$M_A = -\frac{Wab^2}{L^2}$ $\quad M_B = -\frac{Wa^2b}{L^2}$

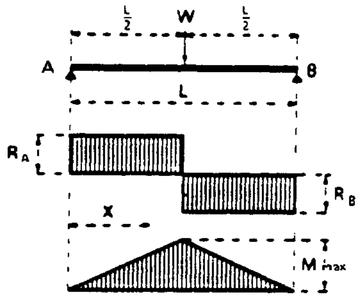
at C, under load, $M_C = \frac{2Wa^2b^2}{L^3}$

at X from A between A & C:
- $M_X = -\frac{Wab^2}{L^2} + \frac{Wb^2(L + 2a)X}{L^3}$
- $\delta_X = \frac{Wb^2X^2[3La - (L + 2a)X]}{6EIL^3}$
- $i_X = \frac{Wb^2X[2La - (L + 2a)X]}{2EIL^3}$

$\delta_{max} = \frac{2Wa^3b^2}{3EI(L + 2a)^2}$

B.7 **Design formulae for beams - simply supported**

SIMPLY SUPPORTED BEAM



POINT LOAD AT MID-SPAN

Span $= L$

Point Load $= W$

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

at mid-span: $M_{max} = \frac{WL}{4}$; $\delta_{max} = \frac{1}{48}\cdot\frac{WL^3}{EI}$

$i_A = i_B = \frac{WL^2}{16EI}$

at X from A between A & centre: $M_X = \frac{WX}{2}$; $\delta_X = \frac{WX}{48EI}(3L^2 - 4X^2)$; $i_X = \frac{W}{16EI}(L^2 - 4X^2)$

POINT LOAD AT ANY POSITION

Span $= L$

Point Load $= W$

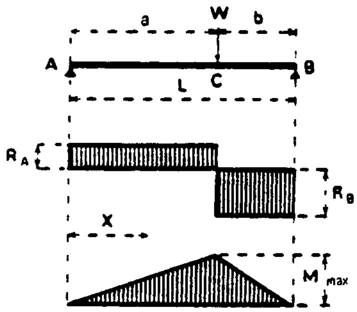
$R_A = \frac{Wb}{L}$ $R_B = \frac{Wa}{L}$

at C under load: $M_{max} = \frac{Wab}{L}$; $\delta_C = \frac{Wa^2b^2}{3EIL}$

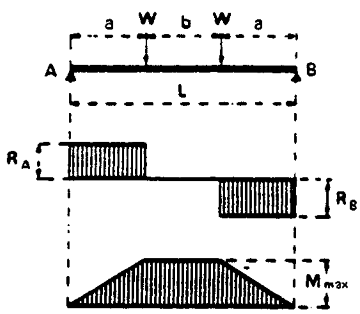
$i_A = \frac{Wab}{6EIL}(L+b)$; $i_B = \frac{Wab}{6EIL}(L+a)$

When $a > b$, δ_{max} is at X from A: $\delta_{max} = \frac{Wab(L+b)}{27EIL}\sqrt{3a(L+b)}$; $X = \sqrt{\frac{a(L+b)}{3}}$

SIMPLY SUPPORTED BEAM



SIMPLY SUPPORTED BEAM



TWO EQUAL SYMMETRICAL POINT LOADS

Span $= L$

Two Point Loads, each $= W$

$R_A = R_B = W$

M_{max} over length b $= Wa$

δ_{max} at mid-span $= \frac{Wa}{24EI}(3L^2 - 4a^2)$

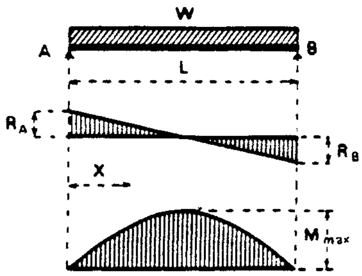
δ under either load $= \frac{Wa^2}{6EI}(3L - 4a)$

$i_A = i_B = \frac{Wa}{2EI}(L - a)$

If $a = b = \frac{L}{3}$, $\delta_{max} = \frac{23}{648}\cdot\frac{WL^3}{EI}$

[B.7 **Design formulae for beams - simply supported** (cont..)]

SIMPLY SUPPORTED BEAM



UNIFORM LOAD ON FULL SPAN

Span $= L$

Total Uniform Load $= W$

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

at mid-span: $M_{max} = \frac{WL}{8}$; $\delta_{max} = \frac{5}{384} \cdot \frac{WL^3}{EI}$

$i_A = i_B = \frac{WL^2}{24EI}$

at X from A:

$M_X = \frac{WX}{2L}(L-X)$

$\delta_X = \frac{WX}{24EIL}(X^3 - 2X^2L + L^3)$

$i_X = \frac{W}{24EIL}(4X^3 - 6X^2L + L^3)$

UNIFORM LOAD ON PART OF SPAN

Span $= L$

Total Uniform Load $= W$

Let $r = \frac{0{\cdot}5b + c}{L}$

$R_A = Wr$; $R_B = W(1-r)$

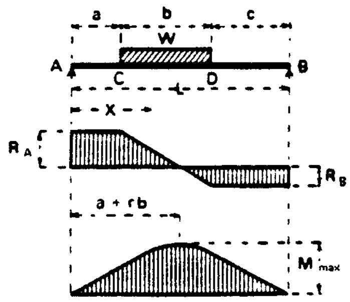
at $X = a + rb$ $M_{max} = Wr(a + 0{\cdot}5rb)$

$i_A = \frac{Wr}{6EI}(L^2 - c^2 - Lbr)$; $i_B = \frac{W(1-r)}{6EI}(L^2 - a^2 - Lb(1-r))$

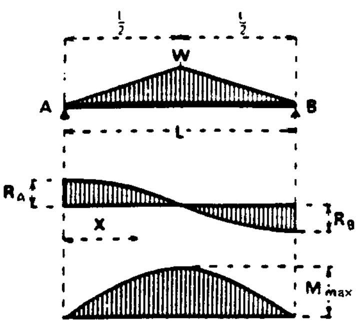
Equation to elastic line between C and D, i.e. $a \leq X \leq a+b$

$$\delta_x = \frac{W}{24EIb}\left[X^4 - 4(a+rb)X^3 + 6a^2X^2 + 4\left\{rb\left(L^2 - c^2 - cb - \frac{b^2}{2}\right) - a^3\right\}X + a^4\right]$$

SIMPLY SUPPORTED BEAM



SIMPLY SUPPORTED BEAM



TRIANGULAR LOAD ON FULL SPAN

Span $= L$

Total Load $= W$

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

at mid-span: $M_{max} = \frac{WL}{6}$; $\delta_{max} = \frac{WL^3}{60EI}$

$i_A = i_B = \frac{5WL^2}{96EI}$

at X from A between A & centre:

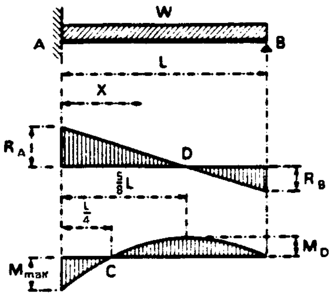
$M_X = \frac{WX}{6L^2}(3L^2 - 4X^2)$

$\delta_X = \frac{WX}{480EIL^2}(16X^4 - 40X^2L^2 + 25L^4)$

$i_X = \frac{W}{96EIL^2}(16X^4 - 24X^2L^2 + 5L^4)$

B.8 **Design formulae for beams - propped cantilever**

PROPPED CANTILEVER



at $\frac{1}{4}L$ from A, $M_C = 0$

UNIFORM LOAD ON FULL SPAN

Span = L

Total Uniform Load = W

$R_A = \frac{5}{8}W$ $\quad R_B = \frac{3}{8}W$

at A $\quad M_{max} = -\frac{WL}{8}$

at $\frac{5}{8}L$ from A $\quad M_D = \frac{9}{128}WL$

at 0·5785L from A $\quad \delta_{max} = \frac{WL^3}{185EI}$

at B $\quad \theta_B = \frac{WL^2}{48EI}$

at X from A:

$M_X = -\frac{W}{8L}(L^2-5LX+4X^2)$

$\delta_X = \frac{WX^2}{48EIL}(3L^2-5LX+2X^2)$

$\theta_X = \frac{WX}{48EIL}(6L^2-15LX+8X^2)$

POINT LOAD AT MID-SPAN

Span = L

Point Load = W

$R_A = \frac{11}{16}W$ $\quad R_B = \frac{5}{16}W$

at A $\quad M_{max} = -\frac{3}{16}WL$

at mid-span under load:

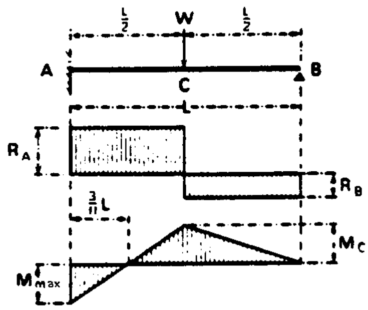
$M_C = \frac{5}{32}WL$

$\delta_C = \frac{7WL^3}{768EI}$

at 0·5528L from A, $\delta_{max} = \frac{WL^3}{107EI}$

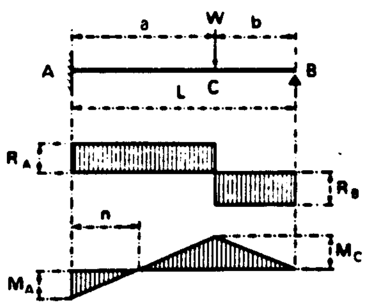
at B $\quad \theta_B = \frac{WL^2}{32EI}$

PROPPED CANTILEVER



at $\frac{3}{11}L$ from A, M = 0

PROPPED CANTILEVER



at $n = aL\frac{L+b}{3L^2-b^2}$ from A, M = 0

POINT LOAD AT ANY POSITION

Span = L

Point Load = W

$R_A = \frac{Wb(3L^2-b^2)}{2L^3}$ $\quad R_B = \frac{Wa^2(2L+b)}{2L^3}$

$M_A = -\frac{Wab(L+b)}{2L^2}$ $\quad M_C = \frac{Wa^2b(2L+b)}{2L^3}$

$\theta_B = \frac{Wa^2b}{4EIL}$

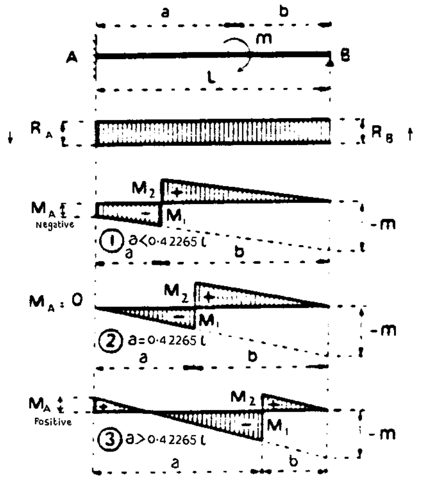
Absolute max deflection is under the load when $a = b\sqrt{2} = 0{\cdot}5858L$ $\quad \delta_{max\ max} = \frac{WL^3}{102EI}$

When $a > b\sqrt{2}$ max deflection is between A and C $\quad \delta_{max} = \frac{Wa^3b}{3EI}\cdot\frac{(L+b)^3}{(3L^2-b^2)^2}$

When $a < b\sqrt{2}$ max deflection is between C and B $\quad \delta_{max} = \frac{Wa^2b}{6EI}\sqrt{\frac{b}{2L+b}}$

[B.8 **Design formulae for beams - propped cantilever** (cont..)]

PROPPED CANTILEVER



MOMENT APPLIED AT ANY POINT

Span = L Applied Moment = m

$M_A = \frac{L^2 - 3b^2}{2L^2} m$ $\theta_B = \frac{ma}{4EIL}(2b - a)$

$R_A = -R_B = -\frac{3(L^2 - b^2)}{2L^3} m = -\frac{m + M_A}{L}$

① $M_1 = -\frac{m}{L^3}\left(a^3 + \frac{3}{2}a^2 b + b^3\right)$

$M_2 = \frac{3\,mab}{L^3}\left(b + \frac{a}{2}\right) = m + M_1$

② $M_1 = -0.42265\ m$

$M_2 = 0.57735\ m$

③ $M_1 =$, $M_2 =$ } as for ①

UNIFORM LOAD ON LENGTH BEYOND PROP

Span = L Full Length = S

Uniform Load = W

$R_A = -\frac{3Wa}{4L}$ $R_B = \frac{W}{L}\left(S - \frac{a}{4}\right)$

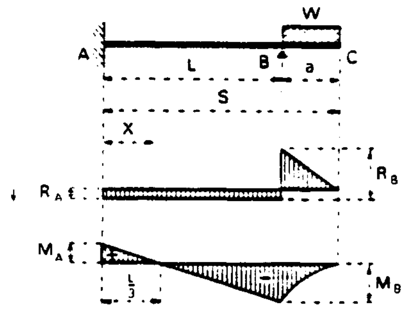
$M_A = \frac{Wa}{4}$ $M_B = -\frac{Wa}{2}$

Deflection at C = $\delta_{max} = \frac{Wa^2 S}{8EI}$

Max. Negative Deflection at $X = \frac{2}{3}L$ } $\delta_{neg} = -\frac{WL^2 a}{54EI}$

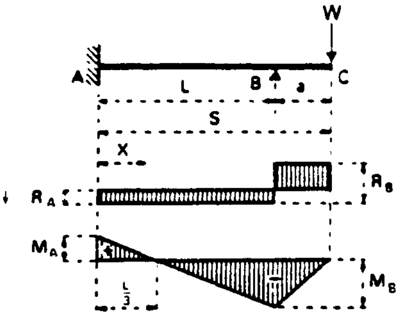
Slope at C = $\theta_C = \frac{Wa}{8EI}\left(S + \frac{a}{3}\right)$

PROPPED CANTILEVER



at $X = \frac{L}{3}$ from A, M = 0

PROPPED CANTILEVER



at $X = \frac{L}{3}$ from A, M = 0

POINT LOAD AT FREE END

Span = L Full Length = S

Point Load = W

$R_A = -\frac{3Wa}{2L}$ $R_B = \frac{W}{L}\left(S + \frac{a}{2}\right)$

$M_A = \frac{Wa}{2}$ $M_B = -Wa$

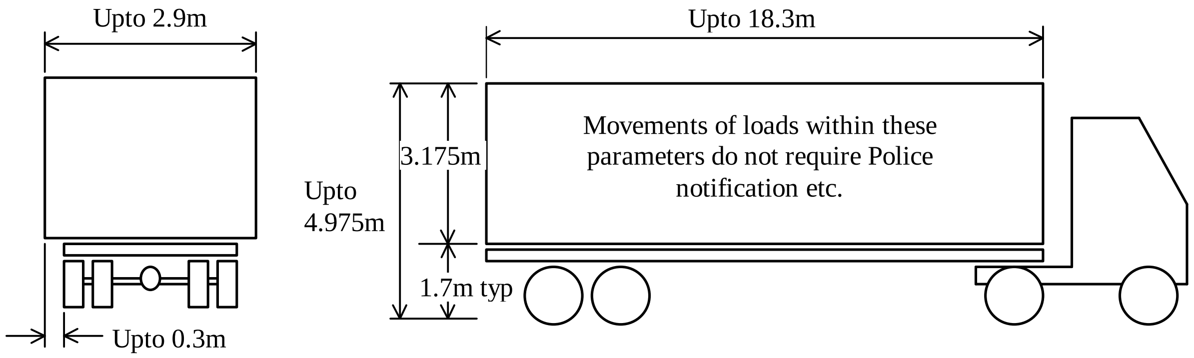
Deflection at C = $\delta_{max} = \frac{Wa^2}{4EI}\left(S + \frac{a}{3}\right)$

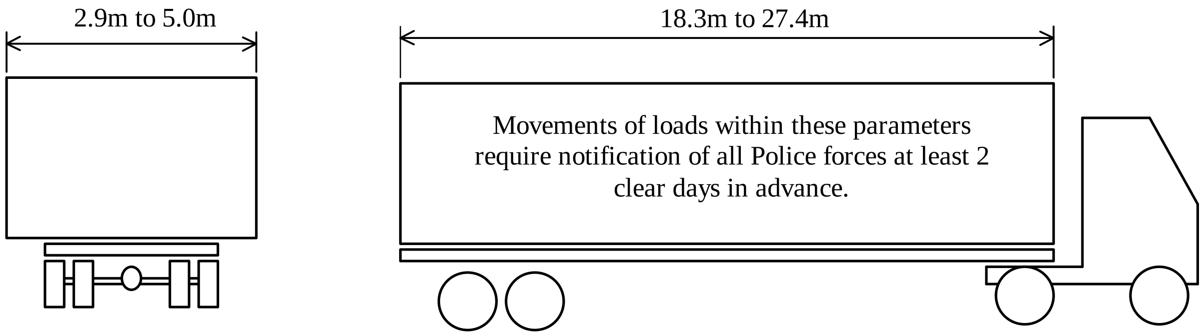
Max. Negative Deflection at $X = \frac{2}{3}L$ } $\delta_{neg} = -\frac{WL^2 a}{27EI}$

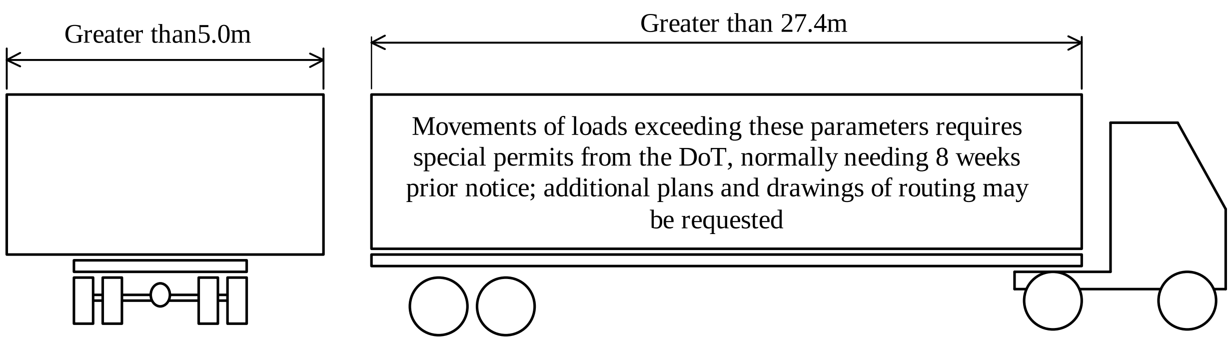
Slope at C = $\theta_C = \frac{Wa}{4EI}(S + a)$

APPENDIX C – USEFUL DESIGN DATA

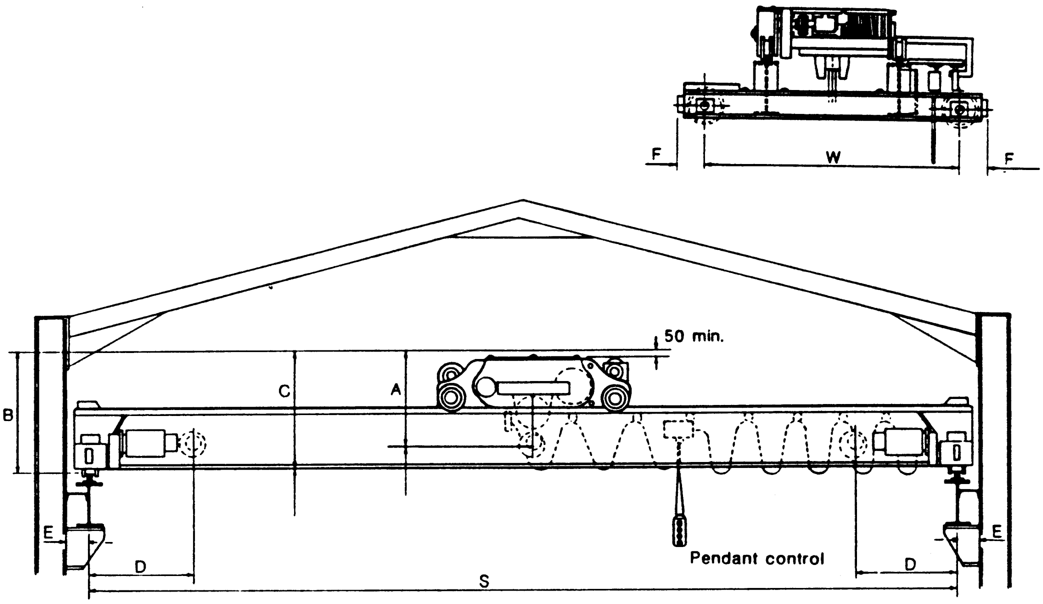
C.1 **Road transport limitations (simplified) (in the UK)**







C.2 **Craneage data – double girder**

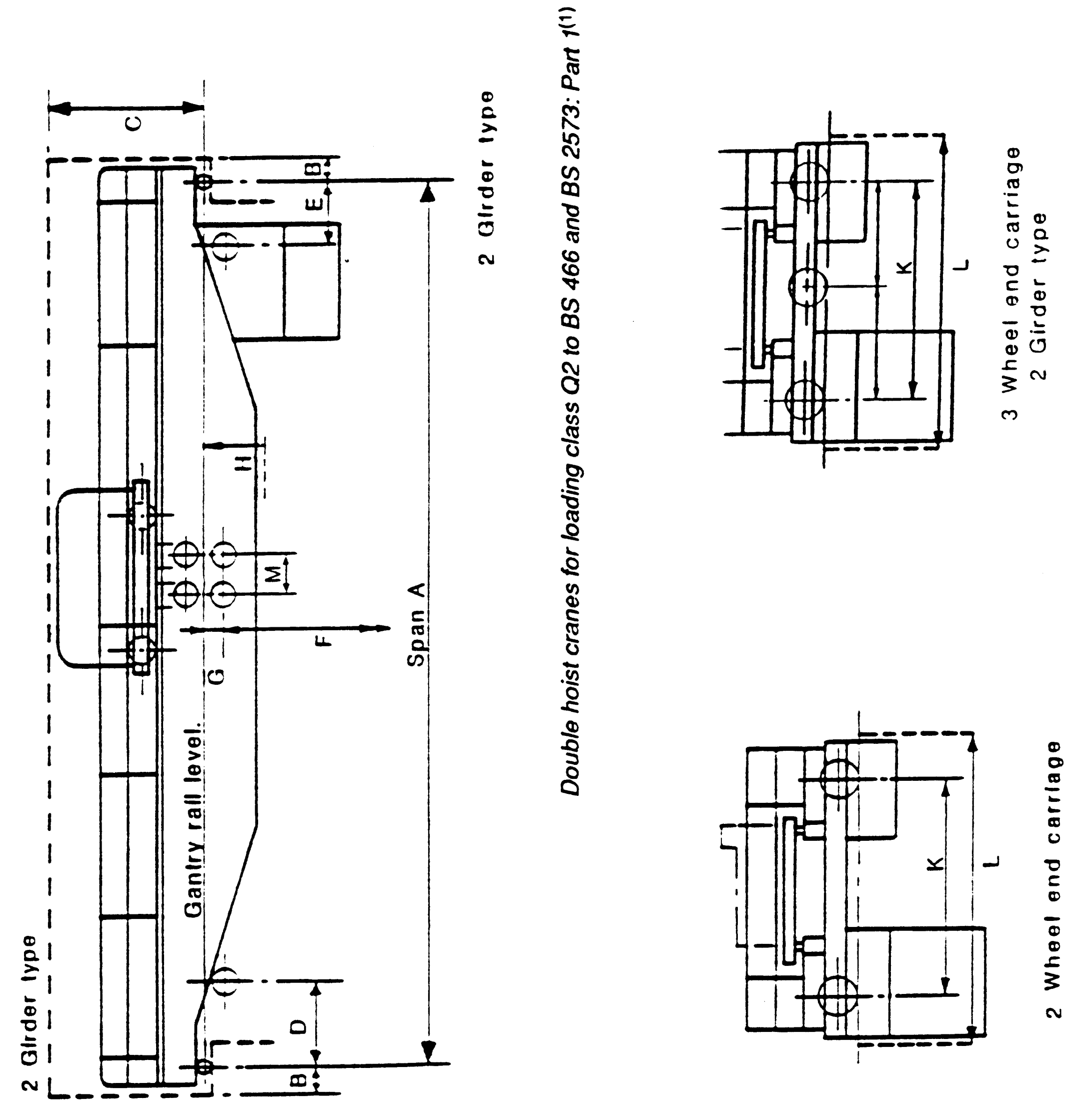


Double girder pendant controlled cranes for loading class Q2 to BS 446 and BS 2573: Part 1[1]

Capacity tonnes	Span S metres	A mm	B mm	C mm	D mm	E mm	F mm	H mm	W mm	Crab wt. tonnes	Crane wt. tonnes	Wheel load tonnes
10	8	920	1250	1225	970	200	430	9700	2500	1.70	5.18	6.19
	10	920	1250	1225					2500		5.84	6.47
	12	920	1278	1255					2500		7.98	6.98
	14	920	1280	1255					3100		8.82	7.26
	16	920	1375	1325					3700		10.68	7.77
	18	920	1375	1325					3700		11.60	8.04
	20	950	1535	1485					3700		11.11	7.91
	22	950	1715	1665					3700		12.67	8.30
	24	950	1715	1665					4300		13.65	8.61
	26	950	1865	1815					4300		15.17	8.99
25	8	1650	1650	1540	1150	220	500	8000	4300	4.00	11.40	14.90
	10		1650	1540		220	500		4300		11.97	15.04
	12		1650	1540		220	500		4300		13.14	15.62
	14		1800	1690		220	500		4300		14.36	16.13
	16		1800	1690		220	500		4300		15.22	16.49
	18		1950	1840		220	500		4300		18.83	17.52
	20		1950	1840		220	500		4300		20.03	17.92
	22		2100	1990		220	520		4900		22.54	18.64
	24		2100	1990		235	600		4900		24.53	19.20
	26		2125	2035		235	600		4900		27.78	20.08

1. Dimension B is based upon construction where end carriages are built into bridges member for maximum rigidity and compact headroom dimension. Alternative end constructions can be provided to either increase or reduce dimension B to suit existing building condition
2. The height of lift, H or hook path dimension, is based upon a standard crab unit. Alternative crabs are available in all capacities for extended heights of lift.
3. Crane weights include the crab.
4. Weights of crane and crab are with unloaded hooks.
5. Wheel loads are for static conditions with maximum working load and minimum crab approach.
6. Above information is approximate only and is intended for guidance. Exact information should be obtained from manufactures' publication.

C.3 **Craneage data – double hoist**



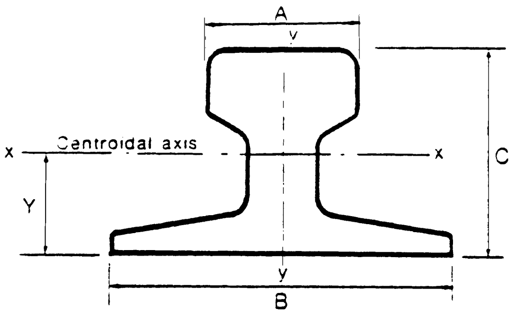
Capacity tonnes	A m	B mm	C m	D m	E m	F m	G m	H m	K m	L m	M M	Crab wt. tonnes	Crane wt. tonnes	Wheel load tonnes	Wheels in end carriage
50/10	10	330	2.6	1.5	2.0	16	0.6	0.8	4.3	5.5	1.1	20	21.0	30.0	2
	12.5	330	2.6					1.0	4.6	5.8			35.0	32.0	
	16	330	2.6					1.1	4.7	5.9			30.0	34.2	
	20	340	2.7					1.3	4.9	6.1			35.0	37.0	
	25	340	2.7					1.4	5.0	6.2			41.0	40.0	
	32	340	2.7					1.6	5.2	6.4			50.0	43.0	

1. Crane weights include the weight of the crab.
2. Weights of crane and crab are with unloaded hooks.
3. Wheel loads are for static conditions with maximum working load and minimum crab approach.
4. Above information is approximate only and is intended for guidance. Exact information should be obtained from manufactures' publication.

C.4 **Standard rail sections**

Section	Mass/ unit length Kg/m	Dimension mm			Area	Y	I_{xx}	I_{yy}	Z_{xx}	Z_{yy}
		Head width A	Base width B	Height C	cm^2	mm	cm^4	cm^4	cm^3	cm^3
13 bridge	13.31	36.0	92	47.5	16.95	21.5	39.01	74.38	14.70	16.17
16 bridge	15.97	44.5	108	54.0	20.34	24.3	64.01	116.34	21.55	21.54
20 bridge	19.86	50.0	127	55.5	25.30	25.8	82.10	192.76	27.66	30.36
28 bridge	28.62	50.0	152	67.0	36.46	28.9	167.45	371.37	44.05	48.86
35 bridge	35.38	58.0	160	76.0	45.06	34.4	265.67	505.23	63.79	63.15
50 bridge	50.18	58.5	165	76.0	63.92	29.3	325.83	719.67	69.81	87.23
56 bridge	55.91	76.0	171	102.0	71.22	43.8	794.38	685.90	141.24	80.67
89 crane	88.93	102.0	178	114.0	113.29	53.3	1493.04	1415.91	245.91	159.09
101 crane	100.38	100.0	165	155.0	127.88	73.9	3410.78	1266.34	420.47	153.50
164 crane	165.92	140.0	230	150.0	211.37	67.7	4776.95	5121.70	580.59	445.37

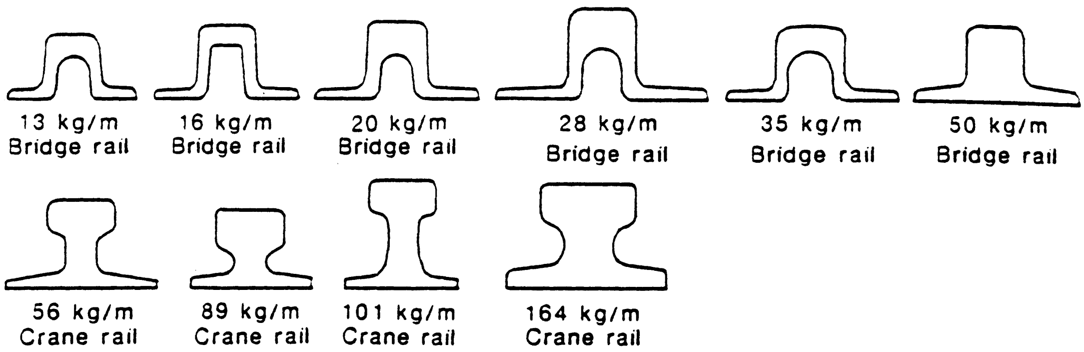
For A, B and C see figure below



Rail dimensions

Maximum lengths for individual
Bridge and crane rail sections

Section	Length (m)
13 bridge	9.144
16 bridge	9.144
20 bridge	9.144
28 bridge	15.000
35 bridge	15.000
50 bridge	15.000
56 bridge	15.000
89 crane	15.000
101 crane	12.192
164 crane	9.144



Profiles of bridge and crane rails

ARUP

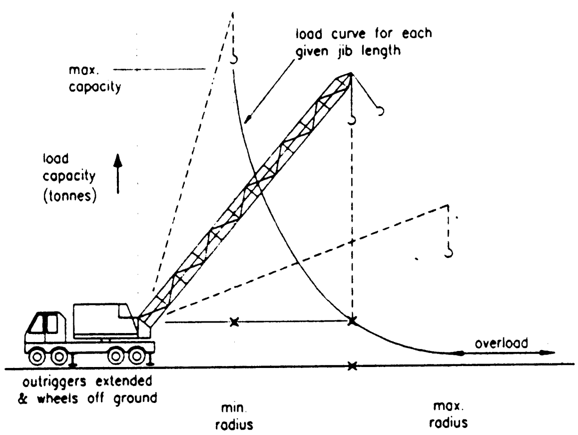
C.5 **Typical bend radii – rolled sections**

Typical recommended bend radii

Serial size	Typical possible bend radii	
	X-X Axis (metres)	Y-Y Axis (meters)
533 x 210 x 122 UB	25	2.5
406 x 178 x 74 UB	18	2.25
305 x 165 x 54 UB	7	2
254 x 146 x 43 UB	5	1.75
203 x 133 x 30 UB	4	1.5
178 x 102 x 19 UB	4	1.25
152 x 89 x 16 UB	2.5	1
127 x 76 x 13 UB	2	1
254 x 203 x 81.85 RSJ	4	2.25
203 x 152 x 52.09 RSJ	2.5	1.75
152 x 127 x 37.20 RSJ	1.5	1.5
305 x 305 x 283 UC	6	3.5
254 x 254 x 167 UC	4.5	3
203 x 203 x 86 UC	3	2.25
152 x 127 x 37 UC	2	1.75
250 x 250 x 16 SHS	10	10
200 x 200 x 12.5 SHS	7	7
200 x 100 x 10 RHS	4	6
150 x 100 x 10 RHS	2.5	4
120 x 80 x 10 RHS	2	3
219.1 x 12.5 CHS	3	3
168.3 x 10 CHS	1.5	1.5
114.3 x 6.3 CHS	1.25	1.25
60.3 x 5 CHS	0.75	0.75

The examples shown are not the minimum radii possible

C.6 **Safe load for 25 tonne capacity mobile crane**



Main boom capacities (tonnes) – through full 360 ° circle slew – with outriggers fully extended

Radius in meters	Boom length						
	10.07m fully retracted	10.07m to 12.50m	12.50m to 15.00m	15.00m to 17.50m	17.50m to 20.00m	20.00m to 22.50m	22.50m to 24.57m
3.0m	25.40	20.70	20.10	20.10			
3.5m	22.00	20.00	19.00	18.80	16.00		
4.0m	19.50	18.00	17.80	17.60	15.50		
4.5m	17.00	16.80	16.70	16.50	14.90	12.70	
5.0m	15.30	15.30	15.30	15.00	13.90	12.30	10.40
6.0m	13.00	12.80	12.40	12.40	12.20	11.60	9.80
7.0m	10.50	10.50	10.50	10.50	10.50	10.50	9.40
8.0m		8.30	8.30	8.30	8.30	8.30	8.30
10.0m		5.35	5.35	5.35	5.35	5.35	5.35
12.0m			3.85	3.85	3.85	3.85	3.85
14.0m				2.80	2.80	2.80	2.80
16.0m					2.15	2.15	2.15
18.0m						1.70	1.70
20.0m						1.30	1.30
22.0m							0.90

C.7 **Standard durbar plate sections**

Standard Sizes

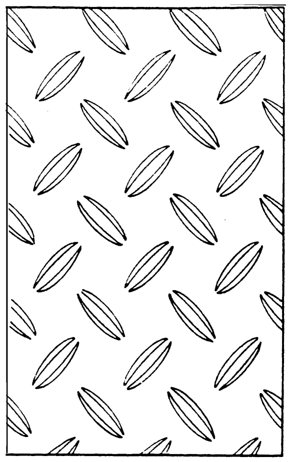
Width mm	Thickness range on plain mm				
1000	4.5	6.0	8.0	10.0	12.5
1250	4.5	6.0	8.0	10.0	12.5
1500	4.5	6.0	8.0	10.0	12.5
1750	4.5	6.0	8.0	10.0	12.5
1830	-	6.0	8.0	10.0	12.5

Consideration will be given to requirements other than standard sizes where they represent a reasonable tonnage per size, i.e. in one length and one width. Lengths up to 10 meters can be supplied for plate 6mm & over

Mass per square metre of durbar plates

Thickness on plain mm*	Kg/m^2
4.5	37.97
6.0	49.74
8.0	65.44
10.0	81.14
12.5	100.77

Depth of pattern ranging from 1.9 mm to 2.4 mm.
*Thickness as measured through body of the plate



Ultimate load capacity (kN/m^2) for plates simply supported on two sides, stressed to 275 N/mm^2

Thickness on plain mm	Span (mm)							
	600	800	1000	1200	1400	1600	1800	2000
4.5	20.48	11.62	7.45	5.17	3.80	2.95	2.28	1.87
6.0	36.77	20.68	13.28	9.20	6.73	5.20	4.07	3.30
8.0	65.40	36.87	23.48	16.38	11.97	9.23	7.23	5.93
10.0	102.03	57.42	36.67	25.55	18.70	14.45	11.30	9.25
12.5	159.70	89.85	57.40	39.98	29.27	22.62	17.68	14.50

Stiffeners should be used for spans in excess of 1100mm to avoid excessive deflections

C.8 **RHS sections – standard lengths**

Length ranges and tolerances for rectangular hollow sections (RHS)

Size		Welded		Seamless		Length tolerance mm
Square mm	Rectangular mm	Standard mill lengths m	Special mill lengths m	Standard lengths m	Maximum exact lengths m	
20 x 20	-	6.4	5.4 – 7.5			+150 - 0
25 x 25 & 30 x 30	-	6.4 & 7.5				
	50 x 25	7.5				
40 x 40 up to 100 x 100 x 8	50 x 30 up to 120 x 80 x 8	7.5, 10 & 12	5.4 – 13.7			
100 x 100 x 10 up to 150 x 150 x 12.5	120 x 80 x 10 up to 200 x 100 x 12.5	7.5, 10 & 12	6.1 – 14.6			
150 x 150 x 16	200 x 100 x 16			10 - 11.2	5.6 - 11.2	+300 – 0
180 x 180 up to 400 x 400 x 16	250 x 150 up to 500 x 300 x 16	10 & 12	9 – 14.8			+300 – 0
400 x 400 x 20	500 x 300 x 20	8.5-9.0 random				

C.9 **CHS sections – standard lengths**

Length ranges and tolerances for circular hollow section (CHS)

Size (mm)		Welded		Seamless	Length tolerance mm
O.D.	Thickness	Standard mill lengths m	Special mill lengths m	Standard mill lengths m	
21.3 & 26.9	All	6.0 & 6.4	5.4 – 7.5		+150 – 0
33.7 - 48.3	All	6.0, 6.4 & 7.5	5.4 – 7.5		+150 – 0
60.3 – 114.3	All	6.0, 6.4, 7.5 & 10	5.4 – 12		+150 – 0
139.7 – 168.3	All	7.5, 10 & 12	6.1 – 14.6		+150 – 0
193.7	Up to 12.5	7.5, 10, & 12	6.1 – 14.6		+150 – 0
	16.0			8, 10 & 12	+300 – 0
219.1	Up to 12.5	10 & 12	9 – 14.8		+300 - 0
	16.0 20.0			8, 10 6, 8 & 10	
244.5	6.3 – 16 8 – 12.5	10 & 12	9 – 14.8	8, 10 & 12 10, 12 & 14	+300 - 0
	20.0			6, 8 & 10	
273	6.3 – 16	10 & 12	9 – 14.8		+300 - 0
	20.0 25.0			6, 8 & 10 4, 6 & 8	
323.9	6.3 – 16.0	10 & 12	9 – 14.8		+300 - 0
	20.0 25.0			6, 8 & 10 4, 6 & 8	
355.6	8.0 – 16.0	10 & 12	9 – 14.8		+300 - 0
	20.0 25.0			6, 8 & 10 4, 6 & 8	
406.4	10.0 – 16.0	10 & 12	9 – 14.8		+300 - 0
	20.0 25.0 32.0			8, 10 & 12 4, 6 & 8 2, 4 & 6	
457	10.0 – 16.0	10 & 12	9 – 14.8		+300 - 0
	20.0 25.0 32.0 40.0			8, 10 & 12 6, 8 & 10 4, 6 & 8 2, 4 & 6	
508	10.0 – 16.0	10 & 12	9 – 14.8		+300 - 0
	20 & 25 32 40 50			6, 8 & 10 4, 6 & 8 2, 4 & 6 3, 4 & 5	

C.10 **Carbon steel plate sections – British Steel standard sizes**

Typical size range of carbon steel plates (maximum length in m)

Width (mm) Thickness	1220 - 1250	1250 - 1300	1300 - 1500	1500 - 1600	1600 - 1750	1750 - 1800	1800 - 2000	2000 - 2100	2100 - 2250	2250 - 2500	2500 - 2750	2750 - 3000	3000 - 3050	3050 - 3250	3250 - 3460	3460 - 3500	3500 - 3750	3750 - 3960
5	12	12	12	12	12	12	12	12	12	12	-	-	-	-	-	-	-	-
6	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	12.5	12.5	-	-	-	-	-	-
7	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	-	-	-	-	-
8	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	11	-	-	-	-
9	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	-	-	-	-
10	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	10	-	-	-
12.5	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	-
15	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	-
20	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
25	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
30	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
35	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
40	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
45	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
50	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	16.3	15.4
60	15.3	17	17	17	17	17	17	17	17	17	17	16.9	15.6	15.6	14.6	14.6	13.6	12.8
65	13.1	17	17	17	17	17	17	17	17	17	15.9	14.6	13.4	13.4	12.5	12.5	11.6	11
70	13.1	17	17	17	17	17	17	17	17	17	15.9	14.6	13.4	13.4	12.5	12.5	11.6	11
75	8.4	17	17	16.8	16.8	17	17	17	17	15.3	13.9	12.7	11.6	11.6	10.9	10.9	10.2	9.7
80	7.9	17	17	16.8	16.8	17	17	17	17	15.3	13.9	12.7	11.6	11.6	10.9	10.9	10.2	9.7
90	-	17	17	15	15	17	17	15.1	15.1	13.6	12.4	11.3	10.5	10.5	9.7	9.7	9.1	8.6
100	-	15.7	15.7	13.5	15.3	15.3	13.6	13.6	12.2	11.1	10.2	9.4	9.4	8.7	8.7	8.7	8.2	7.7
120	-	13.1	13.1	11.2	11.2	12.7	12.7	11.3	11.3	10.2	9.3	8.5	7.8	7.8	7.3	7.3	6.8	6.4
140	-	11.2	11.2	9.6	9.6	10.9	10.9	9.7	9.7	8.7	7.9	7.3	6.7	6.7	6.2	6.2	5.8	-
160	-	9.8	9.8	8.4	9.6	9.6	8.5	8.5	8.5	7.6	6.9	6.4	5.9	5.9	5.5	5.5	5.1	-
180	-	8.7	8.7	7.5	7.5	8.5	8.5	7.5	7.5	6.8	6.2	5.7	5.2	5.2	4.9	4.9	4.5	-
200	-	7.9	7.9	6.7	6.7	7.6	7.6	6.8	6.8	6.1	5.6	5.1	4.7	4.7	4.4	4.4	4.1	-
250	-	4	4	4	4	4	4	4	4	3.9	3.5	3.2	-	-	-	-	-	-
300	-	4	4	4	4	4	4	3.6	3.6	3.2	-	-	-	-	-	-	-	-
350	-	4	4	4	4	3.5	3.5	3.1	3.1	-	-	-	-	-	-	-	-	-

- indicates size not available

C.11 **Carbon and carbon manganese wide flats – British Steel standard sizes**

Typical size range of carbon and carbon-manganese wide flats (max length in m)

Thickness (mm) / Width	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80	90	100
150				13	13	13	15	15	15	15	15	15						
180		12	13	13	15	15	15	15	15	15	15	16	16	16	16			
200		12	13	14	15	15	15	15	15	16	16	16	16	16	16			
220		12	13	14	15	15.5	16.5	17	17	17.5	18	18	18	18	18			
250		12	13.5	14	15	15.5	16	16.5	17.5	17.5	17.5	18	18	18	18			
275		12	14	14	15	15.5	16.5	17	17	17.5	18	18	18	18	18			
300		12	14	15	16	18	18	18	18	18	19	19	19	19	19			
325		12	12	15	16	18	18	18	18	18	19	19	19	19	19			
350			12	15	16	18	18	18	18	20	20	20	20	20	20			
375			12	16	16.5	20	20	20	20	20	20	21	21	21	21			
400			12	16	17	21	21	22	22	22.5	22.5	23	23	23	23			
425			12	16	18	21	23	23	23	23	23	23	23	23	23			
450				16	18	21	23	23	23	23	23	23	23	23	23			
475				15	18	21	23	23	23	23	23	23	23	23	23			
500				15	18	21	23	23	23	23	23	23	23	23	23			
525					18	21	23	23	23	23	23	23	23	23	22			
550					18	21	23	23	23	23	23	23	23	22	20			
575					18	21	23	23	23	23	23	23	23	21	19			
600					18	21	23	23	23	23	23	23	22	21	19			
625					18	21	23	23	23	23	23	23	21	20	19			
650					18	21	23	23	23	23	23	22	21	19	18			

Not available

Development range – please consult

May be available with dimensions and material properties by arrangement

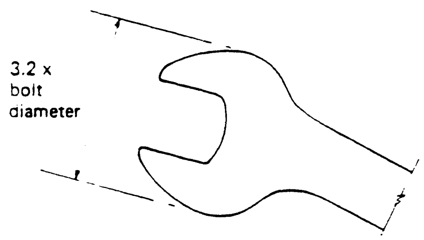
Not normally available except by special arrangement on straightness and flatness tolerances

C.12 **Fasteners – mechanical properties and dimensions of ordinary bolts**

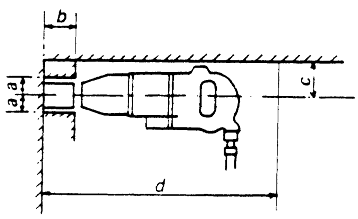
Metric coarse threads		M12	M16	M20	M24	M30	M36
Pitch (mm)		1.74	2.00	2.50	3.00	3.50	4.00
Tensile stress area		84.3	157	245	353	561	817
Basic effective diameter (pitch diameter) (mm)		10.863	14.701	18.376	22.051	27.727	33.402
Grade 4.6	Ultimate load kN	33.1	61.6	96.1	138	220	321
	Proof load	18.7	34.8	54.3	78.2	124	181
Grade 8.8	Ultimate load kN	66.2	123	192	277	439	641
	Proof load	48.1	89.6	140	201	321	466
Length of threads							
= 125mm		30	38	46	54	66	78
> 125mm and = 200mm		36	44	52	60	72	84
> 200mm		49	57	65	73	85	97
= 125mm (short thread length)		-	24	30	36	-	-
Dimensions (mm)							
Maximum width across flats		19.0	24.0	30.0	36.0	46.0	55.0
Maximum width across corners		21.9	27.7	34.6	41.6	53.1	63.5
Nominal head depth of bolts		8.0	10.0	13.0	15.0	19.0	23.0
Nominal depth of nuts		10.0	13.0	16.0	19.0	24.0	29.0

C.13 **Fasteners – clearance for tightening**

Up to and including M20 diameter, tightening is usually best done by hand

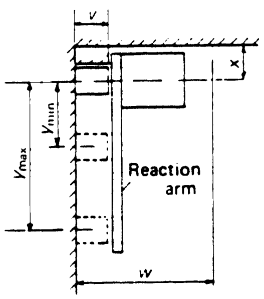


Hand Spanner for Ordinary Bolts



Size of bolt	a	b	c	d- power
M12	23	27	30	500
M16	30	46	60	500
M20	30	46	60	600
M24	36	65	60	600
M30	49	78	70	700
M36	49	97	100	700

Impact wrench for HSFG bolts



Size of bolt	v	w*	x	min. y to max. y
M24	65	250	60	82
		500		210
M30	78	270	65	89
		600		260
M36	97	300	65	89
		600		260

Note that the clearances given are the minimum values for convenient working. Lesser values than these may be used where necessary, after consultation with the equipment manufacturer.

Torque multiplier for HSFG bolts

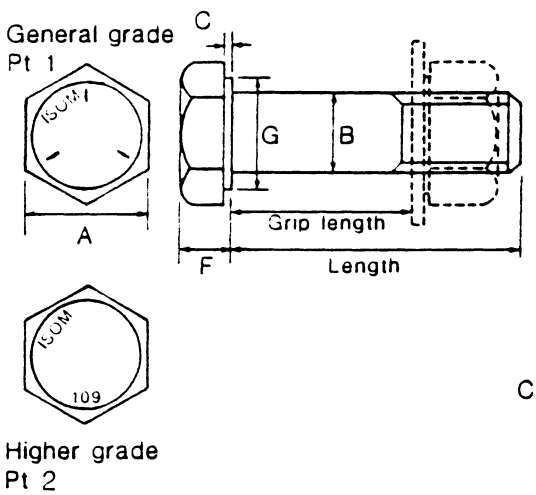
C.14 **Fasteners – high strength friction grip bolts**

Dimensions for high strength friction grip bolts and nuts to BS 4395 parts 1 and 2

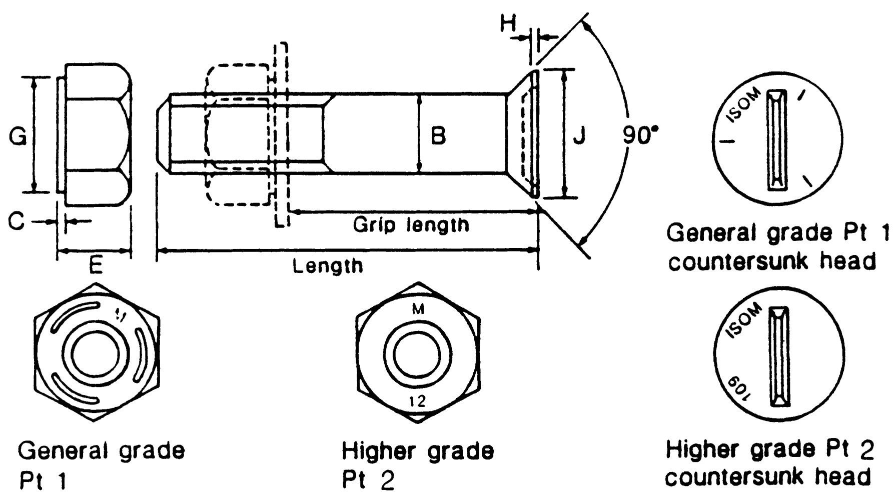
Nominal diameter	Diameter of unthreaded shank B		Pitch (coarse pitch series)	Width across flats A		Depth of washer face C	Thickness of hexagon head F		*Dia of Csk. Head J	Diameter of washer face G		*Depth of Csk. Flash H	Thickness of nuts E		Addition to grip length to give length of bolt required**
mm	Max mm	Min mm	mm	Max mm	Min mm	mm	Max. mm	Min. mm	mm	Max. mm	Min. mm	mm	Max. mm	Min. mm	mm
(M12)	12.70	11.30	1.75	22	21.16	0.4	8.45	7.55	24	22	19.91	2.0	11.55	10.45	22
M16	16.70	15.30	2.0	27	26.16	0.4	10.45	9.55	32	27	24.91	2.0	15.55	14.45	26
M20	20.84	19.16	2.5	32	31.00	0.4	13.90	12.10	40	32	29.75	3.0	18.55	17.45	30
M22	22.84	21.16	2.5	36	35.00	0.4	14.90	13.10	44	36	33.75	3.0	19.65	18.35	34
M24	24.84	23.16	3.0	41	40.00	0.5	15.90	14.10	48	41	38.75	4.0	22.65	21.35	36
M27	27.84	26.16	3.0	46	45.00	0.5	17.90	16.10	54	46	43.75	4.0	24.65	23.35	39
M30	30.84	29.16	3.5	50	49.00	0.5	20.05	17.95	60	50	47.75	4.5	26.65	25.35	42
M33	34.00	32.00	3.5	55	53.80	0.5	22.05	19.95	66	55	52.55	5.0	29.65	28.35	45
M36	37.00	35.00	4.0	60	58.80	0.5	24.05	21.95	72	60	57.75	5.0	31.80	30.20	48

See figures below for the dimensions used in the table
Size shown in brackets is non-preferred
* Countersunk head
** Allows for nut, one flat round washer and sufficient thread protrusion beyond nut.

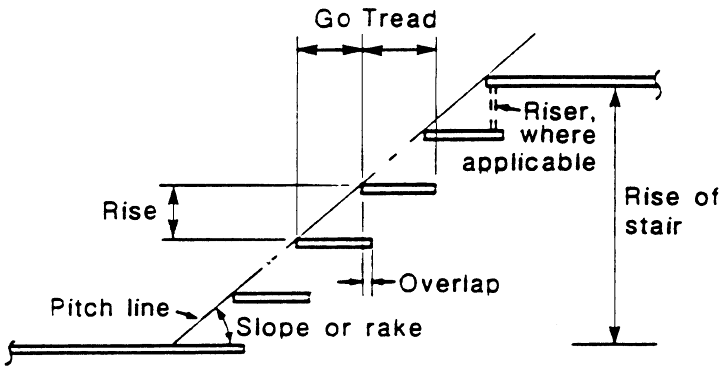
HEXAGON HEAD



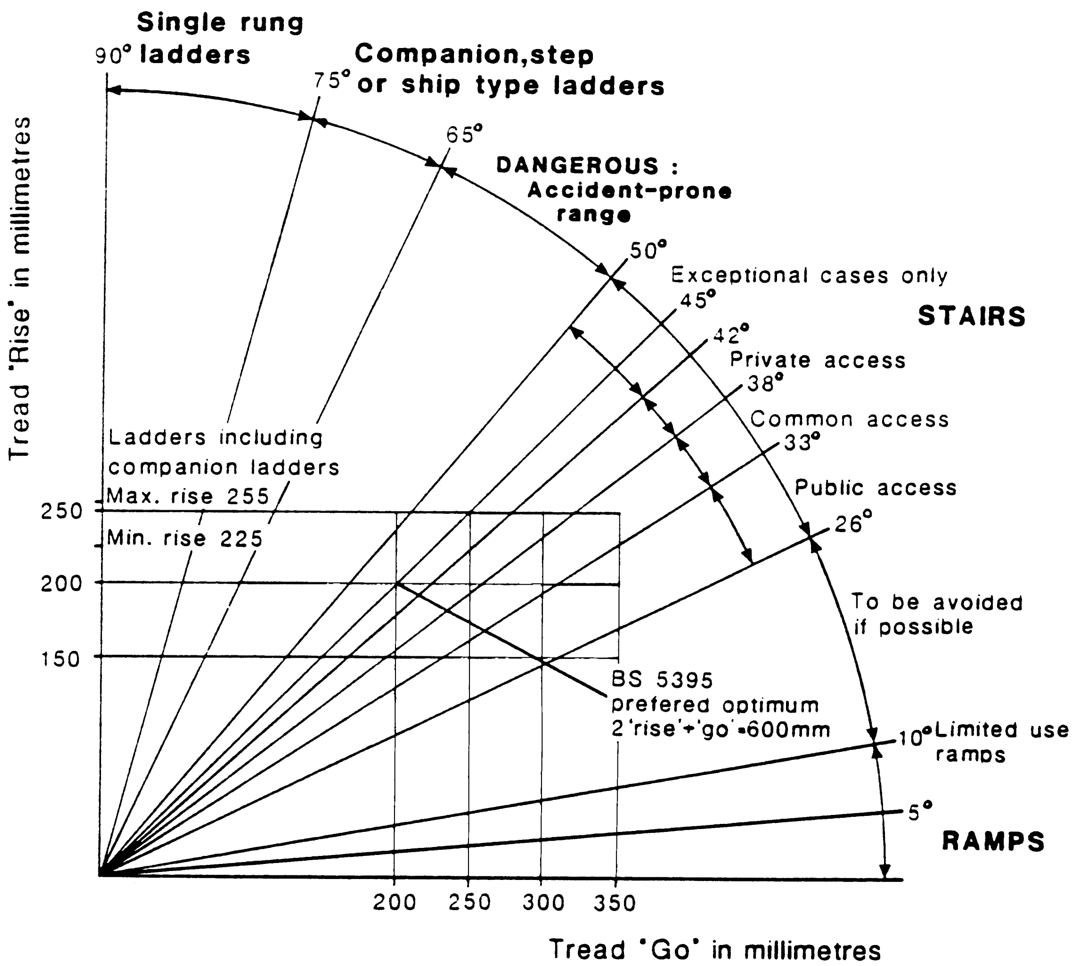
COUNTERSUNK HEAD



C.15 **Staircase dimensions**



Stairway terms



APPENDIX D

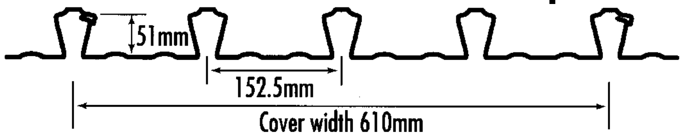
D.1 **Macalloy Bars**

Bar dia. mm	Stressing ties	Stainless steel stressing ties	Stainless steel architectural ties	High strength precision ties	Tie rods grades		
					43	50	17m
18			79	80	36	49	58
20		147					
22					52	71	83
24			92	153			
25	241	232					
26.5	270						
27			112	187	82	114	132
30			138	230			
32	394	379					
36	500		195	322	144	198	229
40	618	591					
45					219	303	351
50	959						
60					398	525	636
72					574	758	918
75	2056						
90					709	1022	
100					892	1286	

Approximate safe working loads (kN)

D.2 **Composite decking [Richard Lees ltd.]**

Super Holorib Z28



Load Span Table - Normal Weight Concrete

SUPPORT CONDITION (Δ Permanent, ▲ Temporary)	SLAB DEPTH mm	0.9mm GAUGE IMPOSED LOAD (kN/m²)				1.0MM GAUGE IMPOSED LOAD (kN/m²)				1.2mm GAUGE IMPOSED LOAD (kN/m²)			
		*	5.0	6.7	10.0	*	5.0	6.7	10.0	*	5.0	6.7	10.0
SINGLE	100	2.55	2.55	2.55	2.55	2.79	2.79	2.79	2.79	3.09	3.09	3.09	3.09
	120	2.41	2.41	2.41	2.41	2.63	2.63	2.63	2.63	2.92	2.92	2.92	2.92
	130	2.35	2.35	2.35	2.35	2.57	2.57	2.57	2.57	2.85	2.85	2.85	2.85
	150	2.23	2.23	2.23	2.23	2.44	2.44	2.44	2.44	2.71	2.71	2.71	2.71
	175	2.12	2.12	2.12	2.12	2.31	2.31	2.31	2.31	2.57	2.57	2.57	2.57
	200	2.02	2.02	2.02	2.02	2.20	2.20	2.20	2.20	2.45	2.45	2.45	2.45
MULTIPLE	100	3.00	3.00	3.00	3.00	3.22	3.22	3.22	3.22	3.51	3.51	3.51	3.51
	120	2.82	2.82	2.82	2.82	3.07	3.07	3.07	3.07	3.35	3.35	3.35	3.35
	130	2.75	2.75	2.75	2.75	3.00	3.00	3.00	3.00	3.28	3.28	3.28	3.28
	150	2.61	2.61	2.61	2.61	2.85	2.85	2.85	2.85	3.14	3.14	3.14	3.14
	175	2.47	2.47	2.47	2.47	2.70	2.70	2.70	2.70	2.99	2.99	2.99	2.99
	200	2.35	2.35	2.35	2.35	2.56	2.56	2.56	2.56	2.84	2.84	2.84	2.84
PROPPED	100	3.55	3.55	3.55	3.17	3.55	3.55	3.55	3.34	3.55	3.55	3.55	3.44
	120	4.25	4.25	4.16	3.50	4.25	4.25	4.25	3.68	4.25	4.25	4.25	4.01
	130	4.60	4.60	4.33	3.65	4.60	4.60	4.53	3.83	4.60	4.60	4.60	4.18
	150	5.30	5.18	4.63	3.92	5.30	5.30	4.83	4.11	5.30	5.30	5.22	4.47
	175	5.04	5.04	4.96	4.23	5.44	5.44	5.17	4.42	5.95	5.95	5.56	4.79
	200	4.82	4.82	4.82	4.50	5.20	5.20	5.20	4.70	5.69	5.69	5.69	5.08

Load Span Table - Lightweight Concrete

SUPPORT CONDITION (Δ Permanent, ▲ Temporary)	SLAB DEPTH mm	0.9mm GAUGE IMPOSED LOAD (kN/m²)				1.0MM GAUGE IMPOSED LOAD (kN/m²)				1.2mm GAUGE IMPOSED LOAD (kN/m²)			
		*	5.0	6.7	10.0	*	5.0	6.7	10.0	*	5.0	6.7	10.0
SINGLE	100	2.74	2.74	2.74	2.74	3.00	3.00	3.00	3.00	3.05	3.05	3.05	3.05
	120	2.60	2.60	2.60	2.60	2.84	2.84	2.84	2.84	3.14	3.14	3.14	3.14
	130	2.53	2.53	2.53	2.53	2.77	2.77	2.77	2.77	3.08	3.08	3.08	3.08
	150	2.42	2.42	2.42	2.42	2.65	2.65	2.65	2.65	2.94	2.94	2.94	2.94
	175	2.30	2.30	2.30	2.30	2.52	2.52	2.52	2.52	2.80	2.80	2.80	2.80
	200	2.19	2.19	2.19	2.19	2.40	2.40	2.40	2.40	2.67	2.67	2.67	2.67
MULTIPLE	100	3.05	3.05	3.05	3.04	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
	120	3.05	3.05	3.05	3.05	3.28	3.28	3.28	3.28	3.57	3.57	3.57	3.57
	130	2.97	2.97	2.97	2.97	3.21	3.21	3.21	3.21	3.50	3.50	3.50	3.50
	150	2.83	2.83	2.83	2.83	3.09	3.09	3.09	3.09	3.37	3.37	3.37	3.37
	175	2.69	2.69	2.69	2.69	2.94	2.94	2.94	2.94	3.22	3.22	3.22	3.22
	200	2.56	2.56	2.56	2.56	2.80	2.80	2.80	2.80	3.10	3.10	3.10	3.10
PROPPED	100	3.05	3.05	3.05	3.04	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
	120	3.65	3.65	3.65	3.55	3.65	3.65	3.65	3.64	3.65	3.65	3.65	3.65
	130	3.95	3.95	3.95	3.71	3.95	3.95	3.95	3.89	3.95	3.95	3.95	3.95
	150	4.55	4.55	4.55	4.55	4.00	4.55	4.55	4.19	4.55	4.55	4.55	4.55
	175	5.30	5.30	5.12	4.32	5.30	5.30	5.30	4.52	5.30	5.30	5.30	4.89
	200	5.21	5.21	5.21	4.61	5.62	5.62	5.62	4.82	6.05	6.05	6.05	5.20

Notes (On tables to left)

1. *depicts maximum spans when deck used as permanent shuttering only.
2. The spans indicated assume clear span + 100mm to the centreline of supports.
3. A span to depth ratio of 35:1 for normal weight and 30:1 for lightweight concrete is imposed in deriving the above spans.
4. For calculating deflections an additional loading of 0.5 kN/m² is included by RLSD Ltd to allow for non-recoverable deflection due to construction personnel. Maximum deflections are limited to span/130 after taking account of ponding.
5. All other construction stage design checks include an allowance of 1.5 kN/m² for construction loading.
6. Tables are based on grade C30 concrete of wet density 2,400 kg/m³ and 1900 kg/m² for lightweight.
7. The dead weight of the slab has been included in the development of the spans shown. However, consideration should be given to finishes, partition walls, etc when reading from these tables.
8. Composite slabs are designed as simply supported irrespective of the deck support configuration. A nominal crack control mesh is required over the supports in accordance with clause 6.7, 6.8 and 6.9 of BS 5950:Part 4.
9. Decking is manufactured from material meeting the following specification: BS EN 10147 designated in accordance with BS EN 10025 S280 GD + Z275 NA-C.

Simplified Fire Design Method - Continuous spans only

FIRE RATING hrs	SLAB DEPTH mm	NORMAL WEIGHT CONCRETE SPAN (m) FOR GIVEN INPOSED LOAD (kN/m²)									LIGHTWEIGHT CONCRETE SPAN (m) FOR GIVEN IMPOSED LOAD (kN/m²)								
		A142			A193			A252			A142			A193			A252		
		5.0	6.7	10.0	5.0	6.7	10.0	5.0	6.7	10.0	5.0	6.7	10.0	5.0	6.7	10.0	5.0	6.7	10.0
1.0	100	2.78	2.50	2.14	2.78	2.50	2.14	2.78	2.50	2.14	2.79	2.50	2.12	2.79	2.50	2.12	2.79	2.50	2.12
	120	3.31	3.00	2.58	3.31	3.00	2.58	3.31	3.00	2.58	3.43	3.08	2.63	3.60	3.60	3.07	3.60	3.60	3.07
	130	3.38	3.07	2.64	4.01	3.64	3.14	4.01	3.64	3.14	3.50	3.16	2.70	3.90	3.69	3.15	3.90	3.69	3.15
	150	3.49	3.19	2.76	4.10	3.78	3.28	4.10	3.78	3.28	3.50	3.30	2.84	4.10	3.85	3.31	4.10	3.85	3.31
	175	-	-	-	4.10	3.94	3.44	4.10	3.94	3.44	-	-	-	4.10	4.02	3.48	4.10	4.02	3.48
	200	-	-	-	4.10	4.08	3.58	4.10	4.08	3.58	-	-	-	4.10	4.02	3.63	4.10	4.10	3.63
1.5	105	-	-	-	-	-	-	-	-	-	2.79	2.50	2.12	2.79	2.50	2.12	2.79	2.50	2.12
	110	2.77	2.50	2.14	2.77	2.50	2.14	2.77	2.50	2.14	2.83	2.54	2.16	2.83	2.54	2.16	2.83	2.54	2.16
	130	3.30	3.00	2.59	3.30	3.00	2.59	3.30	3.00	2.59	3.41	3.07	2.63	3.90	3.64	3.12	3.90	3.64	3.12
	150	3.42	3.12	2.71	4.06	3.71	3.22	4.06	3.71	3.22	3.50	3.20	2.76	4.10	3.80	3.27	4.10	3.80	3.27
	175	-	-	-	4.10	3.86	3.38	4.10	3.86	3.38	-	-	-	4.10	3.98	3.44	4.10	3.98	3.44
	200	-	-	-	4.10	4.00	3.52	4.10	4.00	3.52	-	-	-	4.10	4.10	3.59	4.10	4.10	3.59
2.0	130	-	-	-	-	-	-	-	-	-	-	-	-	3.33	3.00	2.57	3.90	3.60	3.08
	140	-	-	-	3.30	3.00	2.59	3.30	3.00	2.59	-	-	-	3.40	3.07	2.63	4.08	3.68	3.16
	150	-	-	-	3.35	3.06	2.65	3.98	3.63	3.15	-	-	-	3.46	3.13	2.69	4.10	3.76	3.23
	175	-	-	-	3.48	3.19	2.79	4.10	3.79	3.31	-	-	-	3.50	3.28	2.84	4.10	3.93	3.40
	200	-	-	-	3.50	3.30	2.90	4.10	3.93	3.45	-	-	-	3.50	3.41	2.96	4.10	4.09	3.56

Notes (on table above)

1. The simplified fire design method is based on fire tests on composite slabs incorporating steel meshes with 15-45mm top cover. This method is applicable for any construction where the mesh may act in tension over a supporting beam or wall (negative bending). This includes all end bay conditions.
2. All figures in the table are derived strictly in accordance with guidance given in SCI publication 056-'The fire resistance of composite floors with steel decking' (2nd edition), 1991.
3. Loads shown here are unfactored working loads and should include all imposed dead and live loads, excluding only the self weight of the slab. An ultimate load factor of 1.0 is assumed throughout.]
4. The mesh should satisfy the minimum elongation requirement given in BS4449 : 1998.
5. For conditions outside the scope of these tables , including all isolated spans, consult the appropriate fire engineering chart.

Composite Decking cont. [Ward Multideck 60 – Normal weight concrete]

LIGHTWEIGHT CONCRETE — **MAXIMUM PERMISSIBLE SPAN (m)**

Span Type (Support Condition)	Slab Depth (mm)	Min Mesh Size	t = 0.9 Total Applied Load (kN/m²) (See note 6)						t = 1.0 Total Applied Load (kN/m²) (See note 6)						t = 1.1 Total Applied Load (kN/m²) (See note 6)						t = 1.2 Total Applied Load (kN/m²) (See note 6)					
			4.0	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**
Single span	120	A98	2.48	2.48	2.48	2.48	2.48	2.39	3.01	3.01	3.01	3.01	2.81	2.54	3.36	3.36	3.36	3.31	2.93	2.65	3.50	3.50	3.50	3.32	2.94	2.65
	130	A142	2.40	2.40	2.40	2.40	2.40	2.40	2.90	2.90	2.90	2.90	2.90	2.73	3.26	3.26	3.26	3.26	3.16	2.86	3.40	3.40	3.40	3.40	3.15	2.85
	140	A142	2.32	2.32	2.32	2.32	2.32	2.32	2.80	2.80	2.80	2.80	2.80	2.80	3.17	3.17	3.17	3.17	3.17	3.05	3.31	3.31	3.31	3.31	3.31	3.05
	150	A142	2.25	2.25	2.25	2.25	2.25	2.25	2.71	2.71	2.71	2.71	2.71	2.71	3.09	3.09	3.09	3.09	3.09	3.09	3.22	3.22	3.22	3.22	3.22	3.22
	160	A142	2.19	2.19	2.19	2.19	2.19	2.19	2.63	2.63	2.63	2.63	2.63	2.63	3.01	3.01	3.01	3.01	3.01	3.01	3.14	3.14	3.14	3.14	3.14	3.14
	175	A193	2.10	2.10	2.10	2.10	2.10	2.10	2.53	2.53	2.53	2.53	2.53	2.53	2.89	2.89	2.89	2.89	2.89	2.89	3.03	3.03	3.03	3.03	3.03	3.03
	200	A193	1.98	1.98	1.98	1.98	1.98	1.98	2.37	2.37	2.37	2.37	2.37	2.37	2.71	2.71	2.71	2.71	2.71	2.71	2.85	2.85	2.85	2.85	2.85	2.85
	250	A252	1.79	1.79	1.79	1.79	1.79	1.79	2.14	2.14	2.14	2.14	2.14	2.14	2.44	2.44	2.44	2.44	2.44	2.44	2.56	2.56	2.56	2.56	2.56	2.56
Double span	120	A98	2.88	2.88	2.88	2.85	2.65	2.39	3.31	3.31	3.31	3.15	2.80	2.53	3.66	3.66	3.63	3.31	2.93	2.65	3.82	3.82	3.77	3.32	2.94	2.65
	130	A142	2.78	2.78	2.78	2.78	2.78	2.58	3.22	3.22	3.22	3.22	3.03	2.72	3.55	3.55	3.55	3.51	3.16	2.86	3.71	3.71	3.71	3.57	3.15	2.85
	140	A142	2.68	2.68	2.68	2.68	2.68	2.68	3.13	3.13	3.13	3.13	3.13	2.92	3.45	3.45	3.45	3.45	3.38	3.05	3.60	3.60	3.60	3.60	3.38	3.05
	150	A142	2.60	2.60	2.60	2.60	2.60	2.60	3.05	3.05	3.05	3.05	3.05	3.05	3.36	3.36	3.36	3.36	3.36	3.23	3.51	3.51	3.51	3.51	3.51	3.24
	160	A142	2.52	2.52	2.52	2.52	2.52	2.52	2.96	2.96	2.96	2.96	2.96	2.96	3.28	3.28	3.28	3.28	3.28	3.28	3.42	3.42	3.42	3.42	3.42	3.42
	175	A193	2.42	2.42	2.42	2.42	2.42	2.42	2.84	2.84	2.84	2.84	2.84	2.84	3.16	3.16	3.16	3.16	3.16	3.16	3.30	3.30	3.30	3.30	3.30	3.30
	200	A193	2.28	2.28	2.28	2.28	2.28	2.28	2.67	2.67	2.67	2.67	2.67	2.67	3.00	3.00	3.00	3.00	3.00	3.00	3.13	3.13	3.13	3.13	3.13	3.13
	250	A252	2.06	2.06	2.06	2.06	2.06	2.06	2.40	2.40	2.40	2.40	2.40	2.40	2.69	2.69	2.69	2.69	2.69	2.69	2.83	2.83	2.83	2.83	2.83	2.83

LIGHTWEIGHT CONCRETE PROPPED — **MAXIMUM PERMISSIBLE SPAN (m)**

Span Type (Support Condition)	Slab Depth (mm)	Min Mesh Size	t = 0.9 Total Applied Load (kN/m²) (See note 6)						t = 1.0 Total Applied Load (kN/m²) (See note 6)						t = 1.1 Total Applied Load (kN/m²) (See note 6)						t = 1.2 Total Applied Load (kN/m²) (See note 6)					
			4.0	6.0	8.0	10.0	12.0	14.0	4.0	6.0	8.0	10.0	12.0	14.0	4.0	6.0	8.0	10.0	12.0	14.0	4.0	6.0	8.0	10.0	12.0	14.0
Single prop (or)	120	A98	4.19	3.54	3.03	*	*	*	4.20	3.75	*	*	*	*	4.20	3.91	*	*	*	*	4.20	3.91	*	*	*	*
	130	A142	4.42	3.78	3.23	*	*	*	4.55	3.99	3.42	*	*	*	4.55	4.15	3.56	*	*	*	4.55	4.15	*	*	*	*
	140	A142	4.61	4.00	3.43	*	*	*	4.90	4.21	3.62	3.20	*	*	4.90	4.37	3.76	3.33	*	*	4.90	4.37	3.76	*	*	*
	150	A142	4.78	4.18	3.62	3.20	2.89	*	5.09	4.40	3.80	3.37	*	*	5.25	4.50	3.95	3.57	*	*	5.25	4.58	3.95	*	*	*
	160	A142	4.94	4.33	3.79	3.36	3.04	*	5.25	4.61	3.98	3.53	3.19	*	5.53	4.78	4.13	3.67	3.32	*	5.60	4.78	4.13	3.67	*	*
	175	A193	4.79	4.53	4.04	3.59	3.25	2.98	5.47	4.82	4.23	3.76	3.41	3.13	5.76	5.06	4.39	3.90	3.54	*	5.98	5.06	4.38	3.90	3.54	3.25
	200	A193	4.56	4.56	4.40	3.94	3.57	3.27	5.34	5.14	4.61	4.11	3.37	343	6.00	5.40	4.77	4.26	3.87	3.56	6.26	5.47	4.77	4.26	3.87	3.56
	250	A252	4.12	4.12	4.12	4.12	4.12	3.81	4.80	4.80	4.80	4.73	4.31	3.97	5.38	5.38	5.38	4.88	4.45	4.11	5.66	5.66	5.42	4.88	4.45	4.11
Two props (or)	200	A193	5.45	4.83	4.40	3.93	3.55	3.27	5.79	*	*	*	*	*	6.07	*	*	*	*	*	6.32	*	*	*	*	*
	250	A252	5.91	5.30	4.87	4.52	*	*	6.27	5.63	5.15	*	*	*	6.58	5.92	5.42	*	*	*	6.86	6.16	*	*	*	*

Notes:

1 All tabulated figures include the self weight of the slab.

2 All tabulated figures include a construction allowance of 1.5kN/m² for spans of 3m and over, or 4.5/span kN/m² for spans less than 3m in accordance with the recommendations of BS 5950: Part 4 1994.

3 The suggested maximum ratios of slab span to slab depth are 30 for LWC and 35 for NWC to control deflections. Deflection under construction loading (wet concrete etc.) has been limited to that stipulated in BS 5950: Part 4 1994. For the purpose of calculating the span/depth ratio, the distance between the centre-lines of the supports of an end span may be used.

4 Minimum reinforcement mesh sizes provide 0.1% of the gross cross-sectional areas of the concrete at the support.

5 The composite slabs should meet the requirements of BS 5950: Part 4 1994 with regard to their composite behaviour under normal imposed loads.

6 Total applied load referred to in the above table is a working Load based on factored combinations of live loads, finishes, ceilings, services and partitions, divided by a load factor of 1.60 (excluding slab self weight).

7 Temporary supports should remain in place until the concrete has achieved its 28 day cub strength.

8 * The addition of props gives no further benefit in these cases.

9 Propped loads assume props are equally spaced.

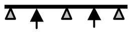
10 Deck must lie flat on all support beams. Point only contact will affect design loading.

Composite Decking cont. [Ward Multideck 60 - Lightweight concrete]

LIGHTWEIGHT CONCRETE **MAXIMUM PERMISSIBLE SPAN (m)**

Span Type (Support Condition)	Slab Depth (mm)	Min Mesh Size	t = 0.9 Total Applied Load (kN/m²) (See note 6)						t = 1.0 Total Applied Load (kN/m²) (See note 6)						t = 1.1 Total Applied Load (kN/m²) (See note 6)						t = 1.2 Total Applied Load (kN/m²) (See note 6)					
			4.0	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**
	120	A98	2.67	2.67	2.67	2.39	2.65	2.39	3.19	3.19	3.19	3.17	2.81	2.54	3.55	3.55	3.55	3.32	2.94	2.66	3.71	3.60	3.60	3.32	2.94	2.65
	130	A142	2.58	2.58	2.58	2.58	2.58	2.58	3.10	3.10	3.10	3.10	3.03	2.73	3.44	3.44	3.44	3.44	3.16	2.86	3.61	3.61	3.61	3.57	3.16	2.86
	140	A142	2.50	2.50	2.50	2.50	2.50	2.50	3.03	3.03	3.03	3.03	3.03	2.92	3.38	3.38	3.38	3.38	3.38	3.05	3.52	3.52	3.52	3.52	3.38	3.05
	150	A142	2.43	2.43	2.43	2.43	2.43	2.43	2.95	2.95	2.95	2.95	2.95	2.95	3.30	3.30	3.30	3.30	3.30	3.24	3.44	3.44	3.44	3.44	3.44	3.24
	160	A142	2.37	2.37	2.37	2.37	2.37	2.37	2.86	2.86	2.86	2.86	2.86	2.86	3.22	3.22	3.22	3.22	3.22	3.22	3.36	3.36	3.36	3.36	3.36	3.36
	175	A193	2.28	2.28	2.28	2.28	2.28	2.28	2.75	2.75	2.75	2.75	2.75	2.75	3.12	3.12	3.12	3.12	3.12	3.12	3.26	3.26	3.26	3.26	3.26	3.26
	200	A193	2.15	2.15	2.15	2.15	2.15	2.15	2.59	2.59	2.59	2.59	2.59	2.59	2.97	2.97	2.97	2.97	2.97	2.97	3.10	3.10	3.10	3.10	3.10	3.10
	250	A252	1.79	1.96	1.96	1.96	1.96	1.96	2.35	2.35	2.35	2.35	2.35	2.35	2.72	2.72	2.72	2.72	2.72	2.72	2.82	2.82	2.82	2.82	2.82	2.82
	120	A98	3.08	3.08	3.08	2.39	2.65	2.39	3.51	3.51	3.51	3.17	2.81	2.54	3.87	3.60	3.60	3.30	2.94	2.66	3.97	3.60	3.60	3.32	2.94	2.65
	130	A142	3.00	3.00	3.00	2.58	2.85	2.58	3.42	3.42	3.42	3.40	3.03	2.72	3.77	3.77	3.77	3.57	3.16	2.86	3.94	3.94	3.94	3.57	3.16	2.86
	140	A142	2.91	2.9	2.91	2.77	2.91	2.77	3.33	3.33	3.33	3.33	3.24	2.92	3.68	3.68	3.68	3.68	3.68	3.05	3.84	3.84	3.84	3.84	3.38	3.05
	150	A142	2.82	2.82	2.82	2.82	2.82	2.82	3.25	3.25	3.25	3.25	3.25	3.11	3.59	3.59	3.59	3.59	3.59	3.24	3.75	3.75	3.75	3.75	3.75	3.24
	160	A142	2.74	2.74	2.74	2.74	2.74	2.74	3.18	3.18	3.18	3.18	3.18	3.18	3.51	3.51	3.51	3.51	3.51	3.43	3.67	3.67	3.67	3.67	3.67	3.43
	175	A193	2.63	2.63	2.63	2.63	2.63	2.63	3.08	3.08	3.08	3.08	3.08	3.08	3.40	3.40	3.40	3.40	3.40	3.40	3.55	3.55	3.55	3.55	3.55	3.55
	200	A193	2.48	2.48	2.48	2.48	2.48	2.48	2.92	2.92	2.92	2.92	2.92	2.92	3.23	3.23	3.23	3.23	3.23	3.23	3.38	3.38	3.38	3.38	3.38	3.38
	250	A252	2.25	2.25	2.25	2.25	2.25	2.25	2.63	2.63	2.63	2.63	2.63	2.63	2.96	2.96	2.96	2.96	2.96	2.96	2.96	3.10	3.10	3.10	3.10	3.10

LIGHTWEIGHT CONCRETE PROPPED **MAXIMUM PERMISSIBLE SPAN (m)**

Span Type (Support Condition)	Slab Depth (mm)	Min Mesh Size	t = 0.9 Total Applied Load (kN/m²) (See note 6)						t = 1.0 Total Applied Load (kN/m²) (See note 6)						t = 1.1 Total Applied Load (kN/m²) (See note 6)						t = 1.2 Total Applied Load (kN/m²) (See note 6)					
			4.0	6.0	8.0	10.0	12.0	14.0	4.0	6.0	8.0	10.0	12.0	14.0	4.0	6.0	8.0	10.0	12.0	14.0	4.0	6.0	8.0	10.0	12.0	14.0
 or 	120	A98	3.66	*	*	*	*	*	3.79	3.60	*	*	*	*	3.90	*	*	*	*	*	3.95	*	*	*	*	*
	130	A142	3.92	3.89	*	*	*	*	4.05	3.90	3.53	*	*	*	4.15	3.90	3.66	*	*	*	4.21	3.90	*	*	*	*
	140	A142	4.20	4.13	3.55	*	*	*	4.31	4.20	3.74	3.33	*	*	4.41	4.20	3.88	3.43	*	*	4.47	4.20	*	*	*	*
	150	A142	4.50	4.32	3.76	3.30	*	*	4.56	4.47	3.95	3.47	*	*	4.67	4.50	4.10	3.61	*	*	4.73	4.50	4.10	*	*	*
	160	A142	4.94	4.80	4.48	3.95	3.48	*	4.81	4.77	4.14	3.65	3.29	*	4.92	4.80	4.30	3.79	*	*	4.98	4.80	4.30	3.79	*	*
	175	A193	5.25	4.71	4.23	3.72	3.35	*	5.25	5.01	4.42	3.90	3.51	3.21	5.28	5.25	4.58	4.04	3.65	3.34	5.35	5.24	4.57	4.03	3.63	*
	200	A193	4.95	4.95	4.55	4.11	3.70	3.38	5.84	5.31	4.82	4.29	3.87	3.54	5.98	5.63	5.01	4.44	4.01	3.67	6.00	5.82	5.01	4.43	4.01	3.67
	250	A252	4.50	4.50	4.50	4.50	4.20	3.71	-	-	-	-	-	-	5.92	5.92	5.66	5.14	4.52	4.00	6.20	6.20	5.76	5.12	4.65	4.11
 or 	200	A193	5.76	5.05	*	*	*	*	6.00	5.36	4.83	4.28	3.87	3.54	6.00	*	*	*	*	*	*	*	*	*	*	*
	250	A252	6.30	5.59	5.06	4.68	*	*	6.51	5.93	5.38	4.97	4.37	3.87	7.02	6.23	5.65	*	*	*	7.32	6.50	*	*	*	*

NOTES

1. All tabulated figures include the self weight of the slab.
2. All tabulated figures include a construction allowance of 1.5kN/m² for spans of 3m and over, or 4.5kN/m² for spans less than 3m in accordance with the recommendations of BS5950: Part 4 1994.
3. The suggested maximum ratios of slab span to slab depth are 30 for LWC and 35 for NWC to control deflection. Deflection under construction loading (wet concrete etc.) has been limited to that stipulated in BS5950: Part 4 1994. For purpose of calculating the span /depth ratio, the distance between the centre-lines of the supports of an end span may be used.
4. Minimum reinforcement mesh sizes provide 0.1% of the gross cross –sectional area of the concrete at the support.
5. The composite slabs should meet the requirements of BS 5950: Part 4 1994 with regard to their composite behaviour under normal imposed loads.
6. Total applied load referred to in the above table is a working load based on factored combinations of live loads, ceilings, finished, services and partitions, divided by a load factor of 1.60 (excluding slab self weight).
7. Temporary supports should remain in place until the concrete has achieved its 28 day cube strength.
8. * The addition of props gives no further benefit in these cases.
9. Propped loads assume props are equally spaced.
10. Deck must lie flat on all support beams. Point only contact will affect design loading.

Composite Decking cont. [Ward Multideck 60 - Fire resistance]

NORMAL WEIGHT CONCRETE **MAXIMUM PERMISSIBLE SPAN (m)**

Slab Depth (mm)	Min Mesh Size	Fire rating: 1.0 hour(s) Total Applied Load (kN/m²) See note 6 (page 8)					Fire rating: 1.5 hour(s) Total Applied Load (kN/m²) See note 6 (page 8)					Fire rating: 2.0 hour(s) – end span Total Applied Load (kN/m²) See note 6 (page 8)					Fire rating: 2.0 hour(s) – internal span Total Applied Load (kN/m²) See note 6 (page 8)				
		4.00	6.00	8.00	10.00	12.00	4.00	6.00	8.00	10.00	12.00	4.00	6.00	8.00	10.00	12.00	4.00	6.00	8.00	10.00	12.00
130	142	3.85	3.43	3.15	2.92	2.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
130	193	4.18	3.74	3.41	3.16	2.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
130	252	4.51	4.03	3.68	3.41	3.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
140	142	4.01	3.60	3.30	3.06	2.87	3.63	3.25	2.98	2.77	2.60	-	-	-	-	-	-	-	-	-	-
140	193	4.36	3.91	3.58	3.32	3.12	3.95	3.54	3.25	3.02	2.83	-	-	-	-	-	-	-	-	-	-
140	252	4.71	4.23	3.87	3.59	3.37	4.28	3.84	3.51	3.26	3.06	-	-	-	-	-	-	-	-	-	-
150	142	4.06	3.67	3.37	3.14	2.95	3.78	3.40	3.13	2.91	2.73	3.13	2.82	2.59	2.41	2.27	3.73	3.36	3.09	2.87	2.70
150	193	4.44	3.99	3.66	3.41	3.20	4.13	3.72	3.41	3.17	2.98	3.48	3.14	2.88	2.68	2.52	4.16	3.75	3.44	3.20	3.01
150	252	4.80	4.32	3.97	3.69	3.46	4.47	4.02	3.69	3.43	3.22	3.85	3.47	3.18	2.96	2.78	4.60	4.14	3.80	3.53	3.31
160	142	4.13	3.73	3.43	3.20	3.00	3.89	3.52	3.23	3.01	2.83	3.26	2.95	3.72	2.53	2.38	3.95	3.56	3.28	3.06	2.87
160	193	4.49	4.05	3.72	3.47	3.26	4.26	3.85	3.54	3.29	3.10	3.65	3.30	3.03	2.83	2.66	4.42	3.99	3.67	3.42	3.21
160	252	4.86	4.39	4.03	3.75	3.53	4.62	4.17	3.83	3.57	3.36	4.03	3.64	3.35	3.12	2.93	4.87	4.40	4.04	3.75	3.54
175	142	4.19	3.80	3.51	3.27	3.08	3.95	3.58	3.31	3.09	2.91	3.38	3.07	2.83	2.65	2.49	4.15	3.76	3.47	3.24	3.05
175	193	4.55	4.13	3.81	3.55	3.35	4.33	3.92	3.62	3.38	3.18	3.78	3.43	3.17	2.96	2.79	4.66	4.22	3.90	3.64	3.43
175	252	4.93	4.47	4.12	3.84	3.62	4.69	4.25	3.92	3.65	3.45	4.19	3.80	3.50	3.27	3.08	5.15	4.67	4.31	4.02	3.78
200	*142	4.29	3.92	3.63	3.40	3.21	4.04	3.69	3.42	3.21	3.03	3.45	3.15	2.92	2.74	2.59	4.31	3.94	3.65	3.42	3.23
200	193	4.65	4.25	3.94	3.69	3.48	4.42	4.03	3.74	3.50	3.31	3.86	3.53	3.27	3.06	2.89	4.86	4.44	4.11	3.85	3.64
200	252	5.03	4.59	4.25	3.98	3.76	4.79	4.38	4.05	3.80	3.58	4.28	3.90	3.62	3.39	3.20	5.40	4.93	4.56	4.27	4.03
250	*142	4.44	4.10	3.83	3.60	3.42	4.18	3.86	3.60	3.39	3.22	3.53	3.26	3.05	2.87	2.73	4.55	4.20	3.92	3.70	3.50
250	*193	4.81	4.43	4.14	3.90	3.70	4.56	4.21	3.93	3.70	3.51	3.96	3.66	3.41	3.22	3.05	5.15	4.75	4.44	4.18	3.96
250	252	5.19	4.79	4.47	4.21	3.99	4.95	4.56	4.26	4.01	3.80	4.39	4.05	3.78	3.56	3.38	5.74	5.30	4.94	4.65	4.41

LIGHTWEIGHT CONCRETE **MAXIMUM PERMISSIBLE SPAN (m)**

Slab Depth (mm)	Min Mesh Size	Fire rating: 1.0 hour(s) Total Applied Load (kN/m²) See note 6 (page 8)					Fire rating: 1.5 hour(s) Total Applied Load (kN/m²) See note 6 (page 8)					Fire rating: 2.0 hour(s) – end span Total Applied Load (kN/m²) See note 6 (page 8)					Fire rating: 2.0 hour(s) – internal span Total Applied Load (kN/m²) See note 6 (page 8)				
		4.00	6.00	8.00	10.00	12.00	4.00	6.00	8.00	10.00	12.00	4.00	6.00	8.00	10.00	12.00	4.00	6.00	8.00	10.00	12.00
120	142	3.60	3.43	3.11	2.87	2.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120	193	3.60	3.60	3.39	3.12	2.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120	252	3.60	3.60	3.60	3.37	3.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
130	142	3.90	3.63	3.30	3.04	2.84	3.63	3.22	2.92	2.70	2.52	-	-	-	-	-	-	-	-	-	-
130	193	3.90	3.90	3.60	3.32	3.10	3.90	3.54	3.22	2.97	2.77	-	-	-	-	-	-	-	-	-	-
130	252	3.90	3.90	3.89	3.59	3.35	3.90	3.87	3.52	3.25	3.03	-	-	-	-	-	-	-	-	-	-
140	142	4.20	3.77	3.43	3.17	2.97	3.83	3.40	3.10	2.86	2.68	3.39	3.01	2.74	2.54	2.38	4.09	3.63	3.31	3.06	2.86
140	193	4.20	4.12	3.75	3.46	3.24	4.20	3.75	3.42	3.16	2.96	3.80	3.38	3.07	2.84	2.66	4.20	4.08	3.72	3.43	3.21
140	252	4.20	4.20	4.07	3.76	3.51	4.20	4.11	3.74	3.46	3.23	4.20	3.73	3.40	3.14	2.94	4.20	4.20	4.11	3.80	3.55
150	142	4.31	3.84	3.50	3.24	3.04	3.93	3.50	3.19	2.96	2.77	3.56	3.17	2.90	2.68	2.51	4.35	3.87	3.53	3.27	3.06
150	193	4.50	4.19	3.82	3.54	3.31	4.35	3.88	3.53	3.27	3.06	4.00	3.56	3.25	3.01	2.82	4.50	4.37	3.98	3.68	3.45
150	252	4.50	4.50	4.14	3.83	3.59	4.50	4.25	3.88	3.59	3.36	4.43	3.95	3.60	3.34	3.12	4.50	4.50	4.42	4.09	3.82
160	142	4.37	3.91	3.57	3.31	3.10	3.97	3.56	3.25	3.01	2.82	3.63	3.25	2.97	2.76	2.58	4.48	4.01	3.66	3.39	3.18
160	193	4.76	4.26	3.89	3.60	3.38	4.40	3.93	3.59	3.33	3.12	4.09	3.66	3.34	3.10	2.90	4.80	4.53	4.14	3.83	3.59
160	252	4.80	4.62	4.22	3.91	3.66	4.80	4.31	3.94	3.65	3.42	4.53	40.5	3.70	3.43	3.21	4.80	4.80	4.59	4.25	3.96
175	*142	4.45	3.99	3.66	3.40	3.19	4.04	3.62	3.32	3.08	2.89	3.67	3.30	3.03	2.81	2.64	4.59	4.12	3.77	3.51	3.29
175	193	4.84	4.35	3.98	3.70	3.47	4.45	4.00	3.67	3.41	3.20	4.14	3.72	3.41	3.16	2.97	5.17	4.67	4.27	3.97	3.72
175	252	5.19	4.71	4.31	4.01	3.76	4.89	4.39	4.02	3.74	3.50	4.59	4.12	3.77	3.50	3.29	5.25	5.17	4.75	4.40	4.13
200	*142	4.57	4.13	3.80	3.54	3.33	4.13	3.73	3.44	3.20	3.01	3.74	3.39	3.12	2.91	2.73	4.76	4.30	3.96	3.68	3.46
200	193	4.97	4.49	4.13	3.85	3.61	4.56	4.12	3.79	3.53	3.32	4.21	3.81	3.50	3.27	3.07	5.40	4.87	4.48	4.17	3.92
200	252	5.38	4.86	4.47	4.16	3.91	5.00	4.52	4.15	3.87	3.64	4.67	4.22	3.88	3.62	3.40	5.00	5.43	4.99	4.64	4.36
250	*142	4.76	4.34	4.03	3.77	3.56	4.28	3.91	3.62	3.39	3.21	3.85	3.52	3.26	3.06	2.89	5.02	4.58	4.24	3.97	3.75
250	*193	5.16	4.71	4.37	4.09	3.86	4.72	4.31	3.99	3.74	3.53	4.33	3.95	3.66	3.43	3.24	5.70	5.21	4.82	4.51	4.26
250	252	5.58	5.10	4.72	4.42	4.17	5.17	4.72	4.37	4.09	3.86	4.80	4.38	4.06	3.80	3.59	6.37	5.81	5.38	5.04	4.75

Spans of 3.5m and over are based on 12mm deck only. For single span conditions use the Ward Multideck Software (see page 6) or contact Ward Technical Services.

D.3 **Purlin Systems - Zed purlin sleeved system [Metsec]**

Loading	**Factor**
Dead load	1.40
Dead load restraining uplift or overturning	1.00
Dead load acting with wind and imposed loads combined	1.20
Imposed load	1.60
Imposed load acting with wind load	1.20
Wind load	1.40
Wind load acting with imposed load	1.20
Forces due to temperature effects	1.20
Drifting Snow	1.05

Wind Assessment
With reference to BS 5950 : Part 5 : 1987 'Code of Practice for design of cold formed sections' please note the following:- (Clause 2.2.2). "In the case of purlins an sheeting rails, local wind pressure and suction need to be considered".

The load tables contained in this technical catalogue are based on the criteria shown below and are the results of a extensive design and testing programme completed by using the facilities and skills of the Department of Mechanic's of Materials at Strathclyde University.

Performance
The performance of the systems shown in the Technical Design Manual has been derived by calculation in accordance with BS 5950 Part 5, calibrated and proven by full scale tests. Purlin load tables are valid up to and including 25º roof slopes. For slopes greater than 25º use the Metspec Pulin computer design program.

SECTION REFERENCE	**WEIGHT kg/m**	**WORKING LOAD**									**ULTIMATE U.D.L. IN kN/SPAN**			
		TOTAL U.D.L kN	**ALLOWABLE LOADNG in kN/m² PURLIN CENTRES in millimetres**						**DEFLECTION**		**DOWN LOAD**	**Uplift – Metal Cladding**		
									SPAN **180**	SPAN **360**		**Number of Anti Sags**		
			1000	**1200**	**1500**	**1800**	**2000**	**2400**				**0**	**1**	**2**
SPAN 6.0m														
142.Z.16	3.60	6.14	1.02	0.85	0.68	0.57	0.51	0.43	6.35	3.18	13.09	8.31	13.09	13.09
172.Z.14	3.60	8.29	1.38	1.15	0.92	0.77	0.69	0.58	8.98	4.49	13.56	8.10	13.56	13.56
172.Z.15	3.85	9.29	1.55	1.29	1.03	0.86	0.77	0.64	9.60	4.80	15.17	8.80	16.17	15.17
172.Z.16	4.11	9.97	1.66	1.39	1.11	0.92	0.83	0.69	10.22	5.11	16.73	9.45	16.73	16.73
202.Z.15	4.21	11.02	1.84	1.53	1.22	1.02	0.92	0.76	13.72	6.86	17.97	8.78	17.97	17.97
202.Z.16	4.49	12.20	2.03	1.69	1.36	1.13	1.02	0.85	14.60	7.30	19.89	9.46	19.89	19.89
202.Z.18	5.03	14.47	2.41	2.01	1.61	1.34	1.21	1.00	16.35	8.17	23.57	10.74	23.57	23.57
202.Z.20	5.57	16.62	2.77	2.31	1.85	1.54	1.38	1.15	18.08	9.04	27.04	11.92	27.04	27.04
232.Z.16	5.11	14.68	2.45	2.04	1.63	1.36	1.22	1.02	21.61	10.81	23.92	13.66	23.92	23.92
SPAN 6.5m														
172.Z.15	3.85	8.01	1.23	1.03	0.82	0.68	0.62	0.51	8.25	4.13	14.01	7.91	14.01	14.01
172.Z.16	4.11	8.52	1.31	1.09	0.87	0.73	0.66	0.55	8.78	4.39	15.44	8.51	15.44	15.44
202.Z.15	4.21	10.13	1.56	1.30	1.04	0.87	0.78	0.65	11.80	5.90	16.59	7.85	16.59	16.59
202.Z.16	4.49	11.23	1.73	1.44	1.15	0.96	0.86	0.72	12.56	6.28	18.36	8.47	18.36	18.36
202.Z.18	5.03	13.32	2.05	1.71	1.37	1.14	1.02	0.85	14.06	7.03	21.75	9.62	21.75	21.75
202.Z.20	5.57	15.20	2.34	1.95	1.56	1.30	1.17	0.97	15.55	7.78	24.96	10.68	24.96	24.96
232.Z.16	5.11	13.51	2.08	1.73	1.39	1.15	1.04	0.87	18.61	9.30	22.08	12.19	22.08	22.08
232.Z.18	5.37	16.39	2.52	2.10	1.68	1.40	1.26	1.05	20.85	10.42	26.74	14.38	26.74	26.74
SPAN 7.0m														
202.Z.15	4.21	9.37	1.34	1.12	0.89	0.74	0.67	0.56	10.27	5.13	15.40	7.11	15.40	15.40
202.Z.16	4.49	10.39	1.48	1.24	0.99	0.82	0.74	0.62	10.92	5.46	17.05	7.67	17.05	17.05
202.Z.18	5.03	11.89	1.70	1.41	1.13	0.94	0.85	0.71	12.23	6.12	20.20	8.71	20.20	20.20
232.Z.16	5.11	12.51	1.79	1.49	1.19	0.99	0.89	0.74	16.19	8.10	20.50	11.02	20.50	20.50
232.Z.18	5.73	15.17	2.17	1.81	1.45	1.20	1.08	0.90	18.14	9.07	24.83	13.02	24.83	24.83
232.Z.20	6.34	17.75	2.54	2.11	1.69	1.41	1.27	1.06	20.07	10.04	29.01	15.00	29.01	29.01
262.Z.18	6.25	17.45	2.49	2.08	1.66	1.39	1.25	1.04	24.43	12.22	28.53	13.90	28.53	28.53
SPAN 7.5m														
202.Z.16	4.49	9.26	1.23	1.03	0.82	0.69	0.62	0.51	5.59	4..79	15.92	-	15.92	15.92
202.Z.18	5.03	10.37	1.38	1.15	0.92	0.77	0.69	0.58	10.74	5.37	18.85	-	18.85	18.85
232.Z.16	5.11	11.63	1.55	1.29	1.03	0.86	0.78	0.65	14.22	7.11	19.13	-	19.13	19.13
232.Z.18	5.73	14.12	1.88	1.57	1.25	1.05	0.94	0.78	15.94	7.97	23.17	-	23.17	23.17
232.Z.20	6.34	16.51	2.20	1.83	1.47	1.22	1.10	0.92	17.63	8.82	27.08	-	27.08	27.08
232.Z.23	7.26	19.62	2.62	2.18	1.74	1.45	1.31	1.09	20.15	10.08	32.58	-	32.58	32.58
262.Z.18	6.25	16.24	2.17	1.80	1.44	1.20	1.08	0.90	21.47	10.74	26.62	12.65	26.62	26.62
262.Z.20	6.92	19.18	2.56	2.13	1.70	1.42	1.28	1.07	23.77	11.88	31.40	14.64	31.40	31.40
SPAN 8.0m														
202.Z.20	5.57	10.07	1.26	1.05	0.84	0.70	0.63	0.52	10.51	5.25	20.28	-	20.28	20.28
202.Z.23	6.35	11.50	1.44	1.20	0.96	0.80	0.72	0.60	12.00	6.00	24.00	-	24.00	24.00
232.Z.16	5.11	10.68	1.36	1.13	0.91	0.75	0.68	0.57	12.60	6.30	17.94	-	17.94	17.94
232.Z.18	5.73	13.19	1.65	1.37	1.10	0.92	0.82	0.69	14.11	7.06	21.73	-	21.73	21.73
262.Z.18	6.25	15.17	1.90	1.58	1.26	1.05	0.95	0.79	19.03	9.51	24.96	-	24.96	24.96
262.Z.20	6.92	17.92	2.24	1.87	1.49	1.24	1.12	0.93	21.06	10.53	29.43	-	29.43	29.43
262.Z.23	7.92	21.83	2.73	2.27	1.82	1.52	1.36	1.14	24.08	12.04	35.80	-	35.80	35.08
262.Z.25	8.59	24.32	3.04	2.53	2.03	1.69	1.52	1.27	26.07	13.03	39.85	-	39.85	39.85
SPAN 8.5m														
232.Z.18	5.73	12.11	1.42	1.19	0.95	0.79	0.71	0.59	12.59	6.29	20.45	-	20.45	20.45
232.Z.20	6.34	13.40	1.58	1.31	1.05	0.88	0.79	0.66	13.93	6.96	23.89	-	23.89	23.89
262.Z.18	6.25	14.23	1.67	1.39	1.12	0.93	0.84	0.70	16.98	8.49	23.49	-	23.49	23.49
262.Z.20	6.92	16.81	1.98	1.65	1.32	1.10	0.99	0.82	1879	9.39	27.70	-	27.70	27.70
262.Z.23	7.92	20.48	2.41	2.01	1.61	1.34	1.20	1.00	21.48	10.74	33.70	-	33.70	33.70
262.Z.25	8.59	22.55	2.65	2.21	1.77	1.47	1.33	1.11	23.26	11.63	37.51	-	37.51	37.51
SPAN 9.0m														
232.Z.18	5.73	10.79	1.20	1.00	0.80	0.67	0.60	0.50	11.30	5.65	19.31	-	-	19.31
232.Z.20	6.34	11.94	1.33	1.11	0.88	0.74	0.66	0.55	12.50	6.25	22.56	-	-	22.56
262.Z.18	6.25	13.38	1.49	1.24	0.99	0.83	0.74	0.62	15.24	7.62	22.19	-	-	22.19
262.Z.20	6.92	1582	1.76	1.46	1.17	0.98	0.88	0.73	16.87	8.44	26.16	-	-	26.16
262.Z.23	7.92	18.59	2.07	1.72	1.38	1.15	1.03	0.86	19.29	9.64	31.82	-	-	31.82
262.Z.25	8.59	20.13	2.24	1.86	1.49	1.24	1.12	0.93	20.89	10.44	35.42	-	--	35.42
302.Z.23	9.04	23.84	2.65	2.21	1.77	1.47	1.32	1.10	28.63	14.31	39.26	-	39.26	39.26
302.Z.25	9.80	26.86	2.98	2.49	1.99	1.66	1.49	1.24	31.01	15.51	44.18	-	44.18	44.18
SPAN 9.5m														
262.Z.18	6.25	12.63	1.33	1.11	0.89	0.74	0.66	0.55	13.76	6.88	21.02	-	-	21.02
262.Z.20	6.92	14.59	1.54	1.28	1.02	0.85	0.77	0.64	15.23	7.62	24.79	-	-	24.79
262.Z.23	7.92	16.68	1.76	1.46	1.17	0.98	0.88	0.73	17.42	8.71	30.15	-	-	30.15
262.Z.25	8.59	18.06	1.90	1.58	1.27	1.06	0.95	0.79	18.86	9.43	33.56	-	-	33.56
302.Z.23	9.04	22.51	2.37	1.97	1.58	1.32	1.18	0.99	25.86	12.93	37.19	-	37.19	37.19
302.Z.25	9.80	25.36	2.67	2.22	1.78	1.48	1.33	1.11	28.02	14.01	41.85	-	41.85	41.85
SPAN 10.0m														
262.Z.18	6.25	11.88	1.19	0.99	0.79	0.66	0.59	0.49	12.49	6.25	19.97	-	-	19.97
262.Z.20	6.92	13.15	1.31	1.10	0.88	0.73	0.66	0.55	13.83	6.91	23.55	-	-	23.55
262.Z.23	7.92	15.03	1.50	1.25	1.00	0.84	0.75	0.63	15.81	7.90	28.64	-	-	28.64
262.Z.25	8.59	16.27	1.63	1.36	1.08	0.90	0.81	0.68	17.12	8.56	31.88	-	-	31.88
302.Z.23	9.04	21.31	2.13	1.78	1.42	1.18	1.07	0.89	23.48	11.74	35.33	-	35.33	35.33
302.Z.25	9.80	24.01	2.40	2.00	1.60	1.33	1.20	1.00	25.44	12.72	39.76	-	39.76	39.76
SPAN 10.5m														
262.Z.23	7.92	13.60	1.29	1.08	0.86	0.72	0.65	0.54	14.41	7.21	27.28	-	-	27.28
262.Z.25	8.59	14.72	1.40	1.17	0.93	0.78	0.70	0.58	15.61	7.80	30.36	-	-	30.36
302.Z.23	9.04	20.22	1.93	1.60	1.28	1.07	0.96	0.80	21.42	10.71	33.65	-	33.65	33.65
302.Z.25	9.80	22.20	2.11	1.76	1.41	1.17	1.06	0.88	23.21	11.60	37.87	-	37.87	37.87
342.Z.25	10.98	27.24	2.59	2.16	1.73	1.44	1.30	1.08	32.69	16.35	45.16	-	45.16	45.16
SPAN 11.0m														
262.Z.25	8.59	13.36	1.21	1.01	0.81	0.67	0.61	0.51	14.29	7.14	28.98	-	-	28.98
302.Z.23	9.04	18.64	1.69	1.41	1.13	0.94	0.85	0.71	19.62	9.81	32.12	-	32.12	32.12
302.Z.25	9.80	20.20	1.84	1.53	1.22	1.02	0.92	0.77	21.25	10.63	36.15	-	36.15	36.15
342.Z.25	10.98	25.91	2.36	1.96	1.57	1.31	1.18	0.98	29.65	14.98	43.11	-	43.11	43.11
342.Z.29	12.68	32.02	2.91	2.43	1.94	1.62	1.46	1.21	34.54	17.27	53.15	-	5315	53.15

Zed purlin butt system [Metsec]

Loading	Factor
Dead load	1.40
Dead load restraining uplift or overturning	1.00
Dead load acting with wind and imposed loads combined	1.20
Imposed load	1.60
Imposed load acting with wind load	1.20
Wind load	1.40
Wind load acting with imposed load	1.20
Forces due to temperature effects	1.20
Drifting Snow	1.05

Wind Assessment
With reference to BS 5950 : Part 5 : 1987 'Code of Practice for design of cold formed sections' please note the following:- (Clause 2.2.2). "In the case of purlins an sheeting rails, local wind pressure and suction need to be considered".

The load tables contained in this technical catalogue are based on the criteria shown below and are the results of a extensive design and testing programme completed by using the facilities and skills of the Department of Mechanic's of Materials at Strathclyde University.

Performance
The performance of the systems shown in the Technical Design Manual has been derived by calculation in accordance with BS 5950 Part 5, calibrated and proven by full scale tests. Purlin load tables are valid up to and including 25º roof slopes. For slopes greater than 25º use the Metspec Pulin computer design program.

SECTION REFERENCE	WEIGHT kg/m	WORKING LOAD									ULTIMATE U.D.L. IN kN/SPAN			
		TOTAL U.D.L kN	ALLOWABLE LOADNG in kN/m² PURLIN CENTRES in millimetres						DEFLECTION		DOWN LOAD	Uplift – Metal Cladding Number of Anti Sags		
			1000	1200	1500	1800	2000	2400	SPAN 180	SPAN 360		0	1	2
SPAN 3.5m														
142.Z.14	3.16	8.63	2.46	2.05	1.64	137	1.23	1.03	9.29	4.64	13.95	8.19	13.95	13.95
142.Z.15	3.38	9.58	2.74	2.28	1.82	1.52	1.37	1.14	9.86	4.93	15.49	9.11	15.49	15.49
SPAN 4.0m														
142.Z.14	3.16	6.99	1.75	1.46	1.16	0.97	0.87	0.73	7.11	3.56	12.21	7.25	12.21	12.21
142.Z.15	3.38	7.42	1.85	1.55	1.24	1.03	0.93	0.77	7.55	3.77	13.55	8.07	13.55	13.55
142.Z.16	3.60	7.94	1.98	1.65	1.32	1.10	0.99	0.83	8.08	4.04	14.83	8.84	14.83	14.83
142.Z.18	4.03	8.87	2.22	1.85	1.48	1.23	1.11	0.92	9.03	4.52	17.25	10.24	16.98	16.98
SPAN 4.5m														
142.Z.15	3.38	5.82	1.29	1.08	0.86	0.72	0.65	0.54	5.97	2.98	12.05	7.20	12.05	12.05
172.Z.14	3.60	8.39	1.86	1.55	1.24	1.04	0.93	0.78	9.22	4.61	13.65	7.40	13.65	13.65
172.Z.15	3.85	9.40	2.09	1.74	1.39	1.16	1.04	0.87	9.85	4.93	15.27	8.32	15.27	15.27
172.Z.16	4.11	10.30	2.29	1.91	1.53	1.27	1.14	0.95	10.48	5.24	16.84	9.20	16.84	16.84
SPAN 5.0m														
172.Z.14	3.60	7.29	1.46	1.21	0.97	0.81	0.73	0.61	7.47	3.73	12.28	6.65	12.28	12.28
172.Z.15	3.85	7.79	1.56	1.30	1.04	0.87	0.78	0.65	7.98	3.99	13.75	7.49	13.75	13.75
172.Z.16	4.11	8.29	1.66	1.38	1.11	0.92	0.83	0.69	8.49	4.25	15.15	8.28	15.15	15.15
202.Z.15	4.21	9.99	2.00	1.67	1.33	1.11	1.00	0.83	11.62	5.81	16.28	7.94	16.28	16.28
202.Z.16	4.49	11.07	2.21	1.85	1.48	1.23	1.11	0.92	12.37	6.18	18.02	8.83	18.02	18.02
202.Z.18	5.03	13.13	2.63	2.19	1.75	1.46	1.31	1.09	13.85	6.92	21.35	10.49	21.35	21.35
SPAN 5.5m														
172.Z.14	3.60	5.98	1.09	0.91	0.72	0.60	0.54	0.45	6.17	3.09	11.17	6.02	11.17	11.17
172.Z.15	3.85	6.39	1.16	0.97	0.77	0.65	0.58	0.48	6.60	3.30	12.50	6.77	12.50	12.50
172.Z.16	4.11	6.80	1.24	1.03	0.82	0.69	0.62	0.51	7.02	3.51	13.78	7.49	13.78	13.78
202.Z.15	4.21	9.05	1.65	1.37	1.10	0.91	0.82	0.69	9.61	4.80	14.80	7.18	14.80	14.80
202.Z.16	4.49	9.98	1.81	1.51	1.21	1.01	0.91	0.76	10.22	5.11	16.38	7.98	16.38	16.38
202.Z.18	5.03	11.17	2.03	1.69	1.35	1.13	1.02	0.85	11.44	5.72	19.41	9.48	19.21	19.41
SPAN 6.0m														
202.Z.15	4.21	7.82	1.30	1.09	0.87	0.72	0.65	0.54	8.07	4.04	13.57	6.52	13.32	13.57
202.Z.16	4.49	8.32	1.39	1.16	0.92	0.77	0.69	0.58	8.59	4.29	15.02	7.25	14.12	15.02
202.Z.18	5.03	9.32	1.55	1.29	1.04	0.86	0.78	0.65	9.62	4.81	17.19	8.62	15.78	17.43
232.Z.16	5.11	11.02	1.84	1.53	1.22	1.02	0.92	0.77	12.94	6.47	18.05	8.39	18.05	18.05
232.Z.18	5.73	13.37	2.23	1.86	1.49	1.24	1.11	0.93	14.50	7.25	21.87	10.22	21.87	21.87
232.Z.20	6.34	15.64	2.61	2.17	1.74	1.45	1.30	1.09	16.04	8.02	25.55	11.92	25.55	25.55
SPAN 6.5m														
202.Z.18	5.03	7.78	1.21	1.01	0.81	0.67	0.61	0.50	8.19	4.10	16.42	7.87	12.89	14.91
202.Z.20	5.57	8.71	1.34	1.12	0.89	0.74	0.67	0.56	9.06	4.53	18.85	9.00	14.24	16.45
232.Z.16	5.11	10.13	1.56	1.30	1.04	0.87	0.78	0.65	11.03	5.51	16.67	7.69	16.67	16.67
232.Z.18	5.73	11.99	1.84	1.54	1.23	1.02	0.92	0.77	12.36	6.18	20.19	9.37	20.19	20.19
262.Z.18	6.25	14.15	2.18	1.81	1.45	1.21	1.09	0.91	16.90	8.45	23.19	10.03	23.19	23.19
262.Z.20	6.92	16.71	2.57	2.14	1.71	1.43	1.29	1.07	18.70	9.35	27.35	11.83	27.35	27.35
SPAN 7.0m														
232.Z.16	5.11	9.16	1.31	1.09	0.87	0.73	0.65	0.55	9.51	4.75	15.48	7.07	15.25	15.48
232.Z.18	5.73	10.26	1.47	1.22	0.98	0.81	0.73	0.61	10.65	5.33	18.74	8.63	17.06	18.74
262.Z.18	6.25	13.08	1.87	1.56	1.25	1.04	0.93	0.78	14.57	7.28	21.53	9.24	21.40	21.53
262.Z.20	6.92	15.46	2.21	1.84	1.47	1.23	1.10	0.92	16.13	8.06	25.39	10.90	23.64	25.39
262.Z.23	7.92	17.89	2.56	2.13	1.70	1.42	1.28	1.07	18.44	9.22	30.89	13.14	26.90	29.92
SPAN 7.5m														
232.Z.18	5.73	8.86	1.18	0.98	0.79	0.66	0.59	0.49	9.28	4.64	17.49	-	14.26	16.67
262.Z.18	6.25	12.16	1.62	1.35	1.08	0.90	0.81	0.68	12.69	6.35	20.10	8.54	17.97	20.10
262.Z.20	6.92	13.54	1.81	1.50	1.20	1.00	0.90	0.75	14.05	7.02	23.70	10.08	19.85	22.94
262.Z.23	7.92	15.48	2.06	1.72	1.38	1.15	1.03	0.86	16.06	8.03	28.83	12.15	22.59	26.11
262.Z.25	8.59	16.76	2.23	1.86	1.49	1.24	1.12	0.93	17.39	8.70	32.09	13.39	24.43	28.22
SPAN 8.0m														
262.Z.18	6.25	10.66	1.33	1.11	0.89	0.74	0.67	0.56	11.15	5.58	18.84	-	15.12	18.01
262.Z.20	6.92	11.80	1.48	1.23	0.98	0.82	0.74	0.61	12.35	6.17	22.22	-	16.72	19.89
262.Z.23	7.92	13.49	1.69	1.41	1.12	0.94	0.84	0.70	14.12	7.06	27.03	-	190.3	22.62
262.Z.25	8.59	14.61	1.83	1.52	1.22	1.01	0.91	0.76	15.28	7.64	30.09	-	20.59	24.45
302.Z.23	9.04	20.22	2.53	2.11	1.68	1.40	1.26	1.05	21.31	10.65	33.34	13.31	29.73	33.34
SPAN 8.5m														
262.Z.20	6.92	10.36	1.22	1.02	0.81	0.68	0.61	0.51	10.94	5.47	20.91	-	14.16	17.18
262.Z.23	7.92	11.84	1.39	1.16	0.93	0.77	0.70	0.58	12.50	6.25	25.44	-	16.13	19.54
262.Z.25	8.59	12.82	1.51	1.26	1.01	0.84	0.75	0.63	13.54	6.77	28.32	-	17.46	21.11
302.Z.23	9.04	18.12	2.13	1.78	1.42	1.18	1.07	0.89	18.87	9.44	31.38	-	25.43	29.64
302.Z.25	9.80	19.63	2.31	1.92	1.54	1.28	1.15	0.96	20.45	10.22	35.31	-	27.38	31.95
SPAN 9.0m														
262.Z.25	8.59	11.32	1.26	1.05	0.84	0.70	0.63	0.52	12.08	6.04	26.74	-	-	18.24
262.Z.29	9.90	13.03	1.45	1.21	0.97	0.80	0.72	0.60	13.90	6.95	31.96	-	-	20.83
302.Z.23	9.04	16.04	1.78	1.48	1.19	0.99	0.89	0.74	16.84	8.42	29.64	-	21.82	26.05
302.Z.25	9.80	17.37	1.93	1.61	1.29	1.07	0.97	0.80	18.24	9.12	33.35	-	23.50	28.06
SPAN 9.5m														
302.Z.23	9.04	14.27	1.50	1.25	1.00	0.83	0.75	0.63	15.11	7.56	28.08	-	18.81	22.84
302.Z.25	9.80	15.46	1.63	1.36	1.08	0.90	0.81	0.68	16.37	8.18	31.60	-	20.27	24.60
342.Z.25	10.98	22.38	2.36	1.96	1.57	1.31	1.18	0.98	23.40	11.70	37.68	-	29.95	35.28
342.Z.29	12.68	25.80	2.72	2.26	1.81	1.51	1.36	1.13	26.98	13.49	46.45	-	34.29	40.40
SPAN 10.0m														
302.Z.23	9.04	12.75	1.28	1.06	0.85	0.71	0.64	0.53	13.64	6.82	26.67	-	16.31	20.04
302.Z.25	9.80	13.81	1.38	1.15	0.92	0.77	0.69	0.58	14.77	7.39	30.02	-	17.58	21.57
342.Z.25	10.98	20.04	2.00	1.67	1.34	1.11	1.00	0.84	21.12	10.56	35.80	-	26.07	31.32
342.Z.29	12.68	23.11	2.31	1.93	1.54	1.28	1.16	0.96	24.35	12.17	44.13	-	29.87	35.85
342.Z.32	13.94	25.38	2.54	2.11	1.69	1.41	1.27	1.06	26.74	13.37	50.07	-	32.84	39.34
SPAN 10.5m														
302.Z.25	9.80	12.39	1.18	0.98	0.79	0.66	0.59	0.49	13.40	6.70	28.59	-	15.34	18.96
342.Z.25	10.98	18.02	1.72	1.43	1.14	0.95	0.86	0.72	19.16	9.58	34.09	-	22.80	27.77
342.Z.29	12.68	20.78	1.98	1.65	1.32	1.10	0.99	0.82	22.09	11.04	42.03	-	26.13	31.77
342.Z.32	13.94	22.82	2.17	1.81	1.45	1.21	1.09	0.91	24.26	12.13	47.69	-	28.74	34.88
SPAN 11.0m														
342.Z.25	10.98	16.27	1.48	1.23	0.99	0.82	0.74	0.62	17.45	8.73	32.54	-	20.03	24.64
342.Z.29	12.68	18.76	1.71	1.42	1.14	0.95	0.85	0.71	20.12	10.06	40.12	-	22.96	28.19
342.Z.32	13.94	20.60	1.87	1.56	1.25	1.04	0.94	0.78	22.10	11.05	45.52	-	25.28	30.95
SPAN 11.5m														
342.Z.25	10.98	14.73	1.28	1.07	0.85	0.71	0.64	0.53	15.97	7.98	31.13	-	17.68	21.90
342.Z.29	12.68	16.98	1.48	1.23	0.98	0.82	0.74	0.62	18.41	9.21	38.38	-	20.28	25.06
342.Z.32	13.94	18.65	1.62	1.35	1.08	0.90	0.81	0.68	20.22	10.11	43.54	-	22.34	27.52
SPAN 12.0m														
342.Z.29	12.68	15.42	1.28	1.07	0.86	0.71	0.64	0.54	16.91	8.45	36.78	-	18.00	22.33
342.Z.32	13.94	16.93	1.41	1.18	0.94	0.78	0.71	0.59	18.57	9.29	41.73	-	19.83	24.53

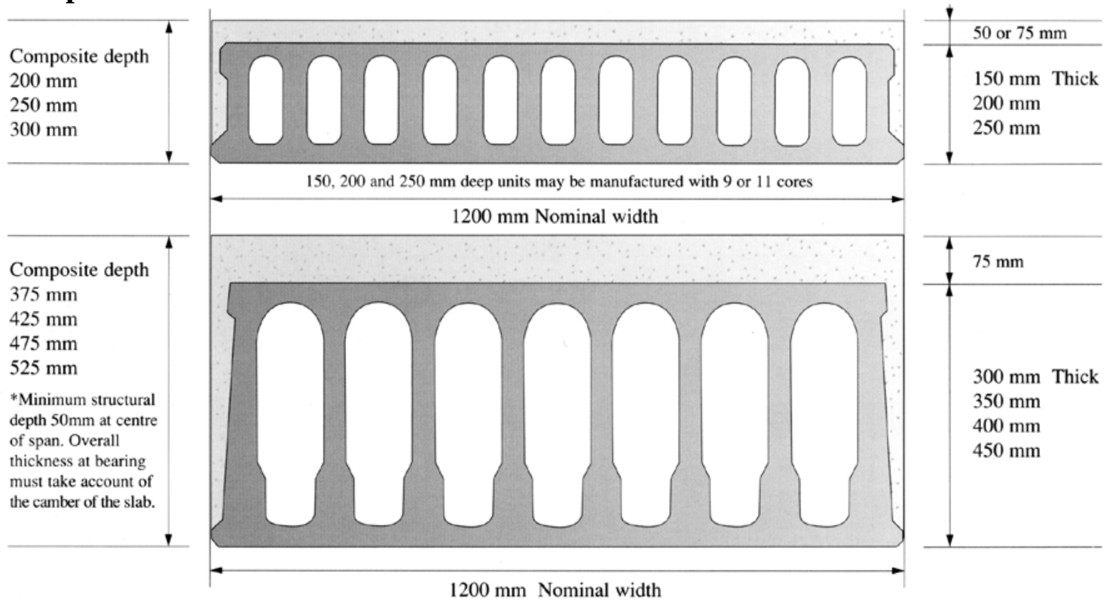
D.4 **Precast hollow composite concrete floors [Bison]**

LOAD / SPAN TABLE

Overall structural depth mm	Unit depth	Available fire period	Self Wt KN/m²	Spans indicated below allow for characteristic service load (live load) Plus self weight plus 1.5 kN/m² for finishes Characteristic service loads kN/m²								
				0.75	1.5	2.0	2.5	3.0	4.0	5.0	10.0	15.0
				Effective span in metres								
200	150	1 Hour or 2 Hours	3.6	8.2	8.2	8.2	8.1	7.9	7.5	7.1	5.8	5.0
250	200	2 Hours or 4 Hours	4.1	10.5	10.1	9.8	9.6	9.3	8.9	8.5	6.9	6.0
300	250	2 Hours	4.5	12.0	11.6	11.3	11.0	10.7	10.1	9.6	7.9	6.8
375	300	2 Hours	5.7	14.2	13.7	13.4	13.2	12.9	12.4	12.0	10.3	9.2
425	350	2 Hours	6.2	15.7	15.2	14.9	14.6	14.3	13.7	13.3	11.5	10.3
475	400	2 Hours	6.6	16.7	16.2	15.9	15.6	15.3	14.7	14.2	12.4	11.1
525	450	2 Hours	7.1	18.0	17.4	17.1	16.8	16.5	15.9	15.4	13.4	12.1

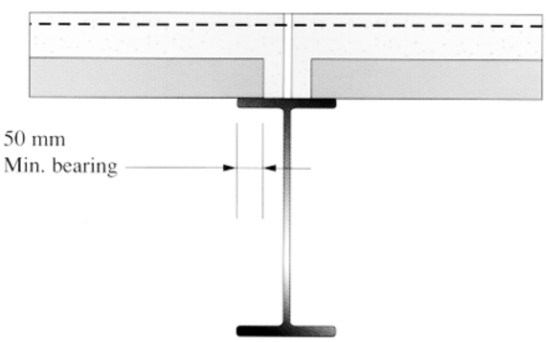
The above data is based upon 50 or 75mm structural topping of C30 concrete which should be regarded as a minimum. Other topping depths may be recommended in some circumstances. Design data for alternative combinations are available from Bison Design Offices. Topping reinforcement, daywork and movement joints should be considered in relation to the overall structural concept of the building.

Composite Profiles



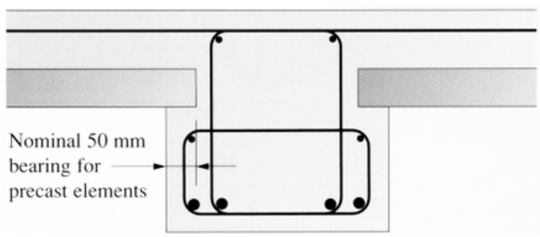
Simple bearing on top flange of steelwork

Nominal support reinforcement and/or daywork joints
Determined by general layout and site operation



Insitu construction

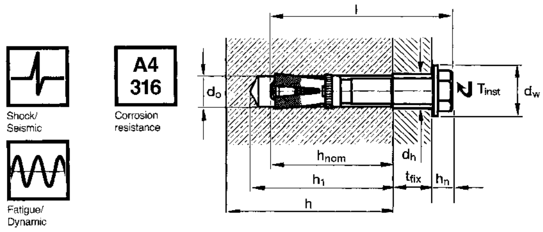
Solid composite floors may be placed on insitu beam downstands or supported on shutters before pouring site concrete



D.5 **Heavy duty anchors (Hilti HSL) [Hilti - feb 1994]**

Features: high loading capacity
force controlled expansion
reliable pull-down of part fastened
suitable for dynamic loading
no rotation when tightening bolt

Bolt material: 8.8, ISO 898 T1
Galvanised to min 5 µm



Versions:
Hilti HSLB heavy-duty anchor with inspection control
Features: - Automatic torque control
Hilti HSLG heavy-duty anchor with threaded rod
Feature: - Various threaded rod lengths

Bolt/rod material
HSLG 8.8, ISO 898 T1, galvanised to min 5 µm
HSLG-R: X5CrNi Mo1810, 1,4401, A4-70 DIN 267 T11
(stainless steel)

Setting Details

Setting details	Anchor	M 8/20	M 8/40	M 10/20	M 10/40	M 12/25	M 12/50	M 16/25	M 16/50	M 20/30	M 20/60	M 24/30	M 24/60
d_o (mm) Drill bit diameter		12		15		18		24		28		32	
h_1 (mm) Hole depth		80		90		100		125		155		180	
h_{nom} (mm) Min. depth of embedment		65		75		80		105		130		155	
t_{fix} (mm) Max. thickness fastened		20	40	20	40	25	50	25	50	30	60	30	60
I (mm) Anchor length		95	115	107	127	120	145	148	173	183	213	205	235
h_n (mm) Head weight + washer		7.5		10		11		14		17		19	
T_{inst} (Nm) Tightening torque	HSL	25		50		80		200		380		500	
	HGSGL-R							120		200		-	
Max. gap (mm)		4		5		8		9		12		16	
S_w (mm) Width across flats	HSL	13		17		19		24		30		36	
	HSLB	-		-		24		30		36		41	
d_h (mm) Max. clearance hole		14		17		20		26		31		35	
d_w (mm) Washer diameter		20		25		30		40		45		50	
h (mm) Min. base material thickness		120		140		160		180		220		270	
Drill bit		TE-C-12/20 TE-Y-12/34		TE-C-15/25 TE-Y-15/34		TE-C-18/20 TE-Y-18/34		TE-C-24/25 TE-Y-24/32		TE-Y-28/37		TE-Y-32/37	
Drilling system		TE10, TE14, TE18-M TE24, TE54		TE14, TE18-M, TE24 TE54				TE24, TE54, TE74		TE54, TE74		TE54, TE74	

Recommended load F_{30}, in kN, non-cracked
Concrete f_{cc} = N/mm², *V* = 3.0

Anchor size		M8	M10	M12	M16	M20	M24
Tensile N	0	6.9	10.4	15.0	25.7	34.6	45.5
Combined Load	30	7.9	12.5	18.2	31.3	42.6	55.9
	45	8.4	13.6	19.8	34.2	46.6	61.1
	60	8.8	14.6	21.3	37.0	50.6	66.2
Shear V	90	9.8	16.7	24.5	42.6	58.6	76.6

Recommended load for specific application:
$F_{rec} = F_{30}\ f_B\ f_T\ f_A\ f_R$
Influence of concrete strength f_B
$F_B = 1 + 0.02\ (1 - \alpha/90)\ (f_{cc,act} - 30)$
For $(20 \leq f_{cc,act} \leq 55)$
Influence of depth embedment f_T
$f_T = \frac{h_{act}}{h_{nom}}$
Limiting depth of embedment
$h_{lim} = 1.5\ h_{nom}$
h_{act} actual embedment depth

Influence of anchor spacing and edge distance f_A, f_R

Reduction Factors (Anchor Spacing) f_A							Reduction Factors (Edge Distance) f_R												
Tensile/Shear							Tensile f_{RN}							Shear f_{RV}					
Spacing S (mm)	Anchor size						Edge Distance C (mm)	Anchor size						Anchor size					
	M8	M10	M12	M16	M20	M24		M8	M10	M12	M16	M20	M24	M8	M10	M12	M16	M20	M24
65	0.70	0					65	0.70	0					0.30	0				
75	0.72	0.70	0				75	0.73	0.70	0				0.37	0.30	0			
80	0.73	0.71	0.70	0			80	0.75	0.71	0.70	0			0.40	0.33	0.30	0		
105	0.79	0.76	0.74	0.70	0		105	0.82	0.78	0.76	0.70	0		0.59	0.49	0.44	0.30	0	
130	0.85	0.81	0.79	0.73	0.70	0	130	0.90	0.85	0.83	0.74	0		0.77	0.64	0.59	0.41	0.30	0
155	0.90	0.86	0.84	0.77	0.73	0.70	155	0.97	0.91	0.88	0.79	0.73	0.70	0.95	0.80	0.74	0.52	0.39	0.30
175	0.95	0.90	0.87	0.80	0.77	0.71	162	1.0	0.93	0.90	0.80	0.75	0.71	1.0	0.84	0.78	0.55	0.41	0.32
195	1.0	0.94	0.91	0.82	0.80	0.73	187		1.0	0.96	0.85	0.78	0.74		1.0	0.92	0.66	0.50	0.39
225		1.0	0.97	0.87	0.82	0.76	200			1.0	0.88	0.80	0.75			1.0	0.72	0.55	0.43
240			1.0	0.89	0.87	0.78	225			1.0	0.92	0.84	0.79			1.0	0.83	0.64	0.51
275			1.0	0.94	0.89	0.81	265				1.0	0.91	0.84				1.0	0.79	0.63
315				1.0	0.94	0.85	275				1.0	0.92	0.85				1.0	0.82	0.66
350					1.0	0.88	300				1.0	0.96	0.88				1.0	0.91	0.73
395						0.92	325					1.0	0.92					1.0	0.81
430						0.96	350					1.0	0.95					1.0	0.89
470						1.0	390						1.0						1.0

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