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July 1978

New Zealand reinforced concrete design handbook

Ultimate strength design in accordance with NZS 3101 P Code of Practice for reinforced concrete design*

SI Units.

* Except where the provisions of the draft NZ Standard DZ 3101: Parts 1 and 2, "Code of practice for the design of concrete structures", are more applicable.

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A national non-profit organisation wholly financed by the cement industry in New Zealand comprising:
N.Z. Cement Holdings Ltd
The Golden Bay Cement Co. Ltd
Waitomo Portland Cement Ltd
Wilsons (N.Z.) Portland Cement Ltd.

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Otahuhu
Auckland.

The objects of the N.Z. Portland Cement Association are to improve and extend the uses of cement and concrete. In recent years, development in the use of these materials has been of a remarkable nature. It is the function of the Association to keep users abreast of these developments and at the same time, make its own contribution towards them.

Designed and published by Concrete Publications Ltd,
P.O. Box 3644, Wellington.

Foreword

This is the first publication of its type in New Zealand. Until comparatively recently it has been possible to attend to New Zealand requirements by reference to overseas design handbooks. With the advent of metrication and the particular steel grades used, the need for a publication directly related to New Zealand code requirements has increased. It is anticipated that users will find this handbook a worthwhile working document of design aids.

The material has been compiled by the N.Z. Portland Cement Association who gratefully acknowledge the assistance of the Cement and Concrete Association of Australia who facilitated the necessary data processing to be undertaken.

The co-operation of those currently carrying out revision of NZS 3101 "Reinforced Concrete — Design" is also acknowledged.

Publication has been made possible by the co-operation of N.Z. Steel Limited and Pacific Steel Limited who together with the N.Z. Portland Cement Association have underwritten the project.

It has been advantageous to publish material in separate self contained sections. For advice on additions and amendments users are invited to register with the N.Z. Portland Cement Association by means of the card provided.

Grateful acknowledgement is given to Morrison Cooper and Partners, Consulting Engineers, Wellington, for their advice as consultants to the publication committee.

Introduction

This handbook is not intended to serve as a text on ultimate strength design. A basic knowledge of the principles behind ultimate strength design philosophy is a pre-requisite for its use.

The purpose of this handbook is to assist the designer by setting out tables and charts to permit as far as possible direct evaluation of the effective strength of reinforced concrete cross-sections.

In the design process this allows for rapid assessment of the capacity of the chosen section geometry. If necessary, recycling then becomes a simple process of reading down a chart or table to a different set of conditions.

Calculation of the ultimate loads and analysis of the structure must be carried out separately by the designer. Ultimate loads should be determined in accordance with NZS 4203 Clause 1.3.

Effective strength and capacity reduction factors

The Code also stipulates that in the calculation of effective strength of a member or cross-section, its calculated or physically determined ultimate strength shall be multiplied by a capacity reduction factor ϕ. The capacity reduction factor allows for the possibility of unfavourable combinations or variations in material strengths, workmanship and dimensions, even though each may be separately within acceptable tolerances. Typical values of ϕ for various design situations are listed in the appropriate section.

In all the tables and charts of this handbook where capacity reduction factors are appropriate, their effects have been included; the user of the handbook should make no additional allowances.

Preferred concrete strengths

Standard grades of concrete, designated by their specified compressive strength at 28 days $f'c$ in MPa, are listed in NZS 3109 and are as follows:

17.5
20
25
30
35
40
45

The design aids in the handbook are based on these grades.

Steel grades

Reinforcing steel is produced in New Zealand to the requirements of NZS 3402P.

The mechanical properties of the two grades produced are shown below:

Mechanical properties	*Grade 275*	*Grade 380*
Minimum yield stress	275 MPa	380 MPa
Minimum tensile strength	380 MPa	570 MPa*
Maximum tensile strength	520 MPa	—
Minimum elongation (gauge length 5d)	20%	12%

* But not less than 1.2 times the actual yield stress.

Physical properties

Bar designation		Plain and deformed sections Nominal dimensions				Deformation requirements		
Plain bar	*Deformed bar*	*Dia.* *mm*	*Cross-sectional area* *mm²*	*Perimeter* *mm*	*Mass of 1 metre length of bar* *kg*	*Max. average spacing* *mm*	*Min. average height* *mm*	*Max. gap (Chord of 12.5% of nominal perimeter)* *mm*
R 6		6	28.29	18.86	0.222			
R 10	D 10	10	78.54	31.42	0.617	7.00	0.40	3.93
R 12	D 12	12	113.10	37.70	0.888	8.40	0.48	4.71
R 16	D 16	16	201.06	50.27	1.578	11.20	0.72	6.28
R 20	D 20	20	314.16	62.83	2.466	14.00	1.00	7.85
R 24	D 24	24	452.39	75.40	3.551	16.80	1.20	9.42
R 28	D 28	28	615.75	87.96	4.834	19.60	1.40	11.00
R 32	D 32	32	804.25	100.53	6.313	22.40	1.60	12.57
R 40	D 40	40	1256.64	125.66	9.865	28.00	2.00	15.71

NOTES —

(i) The nominal diameter of a deformed bar is equal to the diameter of a plain bar having the same mass per metre length as the deformed bar.

(ii) 6mm diameter bar mechanical properties are not subject to the requirements of NZS 3402P.

Preferred dimensions

Where appropriate, tabulations use preferred dimensions for widths and depth of members.

1st preference	100 mm multiples
2nd preference	50 mm multiples
3rd preference	25 mm multiples

Obviously these will not always apply as the structural member is frequently only part of an architectural unit, and is not expected to fill the entire controlling zone allocated.

Reinforcement notation

In any design examples showing reinforcement the standard notations used comply with NZS 5902 Building Drawing Practice Part 2.

Notation and units

The symbols used for notation in the tables and examples, are based upon NZS 3101P* supplemented where necessary with symbols from ACI 318-71. The notations are listed at the beginning of the appropriate section.

Metric units are used throughout. The tables have been developed on the basis of bending being calculated in kNm. This is generated from the spans being measured in m and total forces acting on the member being measured in kN.

Dimensions of the sections in the tables are in mm, section areas mm^2, section inertias mm^3.

Accordingly during the calculation of stresses or areas it is necessary to apply factors to obtain compatability of dimensions.

To facilitate a dimensional analysis check of final units the stress unit MPa, used to describe the concrete and steel stress levels, has also been shown in an alternative form, i.e. N/mm^2.

For example $A_s = \dfrac{M_u}{a_u d}$

M_u is in kNm = Nm x 10^3 = Nmm x 10^6

a_u is in MPa = N/mm^2

d is in mm

A_s is to be in mm^2

$$A_s = \frac{Nmm \times 10^6}{N/mm^2 \times mm} = mm^2 \times 10^6$$

References

NZS 3101 P Code of practice for reinforced concrete — design.

NZS 3109 Concrete construction — materials and workmanship. (Published as DZ 3109 late 1978)

NZS 3402 P Hot rolled steel bars for concrete reinforcement.

NZS 3421 Hard drawn mild steel for concrete reinforcement.

NZS 3422 Welded fabric of drawn steel wire for concrete reinforcement.

NZS 4203 Code of practice for general structural design and design loadings for buildings.

NZS 5902 Building drawing practice, Part 2 structural — concrete, steel, timber.

ACI 318-71 Building code requirements for reinforced concrete, American Concrete Institute.

DZ 3101 Parts 1 and 2 — Code of Practice for the Design of Concrete structures

*Except where the provisions of the draft NZ Standard DZ 3101: Parts 1 and 2, "Code of practice for the design of concrete structures", are more applicable.

Reinforcement data

Reinforcement data

Tables

R1 Cross-sectional areas of specific numbers of bars.

R2 Cross-sectional areas of bars at specific spacings.

R3 Masses of groups of bars.

R4 Mass in kg per square metre for various bar spacings.

R5 Dimensions of welded square mesh fabric.

TABLE R 1

Cross-sectional areas of specific numbers of bars (mm^2)

Bar Size mm	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	57	85	113	141	170	198	226	255	283
10	78.5	157	236	314	393	471	550	628	707	785
12	113.1	226	339	452	565	679	792	905	1018	1131
16	201.1	402	603	804	1005	1206	1407	1608	1810	2011
20	314.2	628	942	1257	1571	1885	2199	2513	2827	3142
24	452.4	905	1357	1810	2262	2714	3167	3619	4072	4524
28	615.8	1232	1847	2463	3079	3695	4310	4926	5542	6158
32	804.2	1608	2413	3217	4021	4825	5630	6434	7238	8042
40	1257	2513	3770	5026	6283	7540	8796	10053	11310	12566

TABLE R 2

Cross-sectional areas of bars at specific spacings (mm^2/m width)

Bar Size mm	Bar spacing mm												
	75	100	125	150	175	200	225	250	275	300	350	400	450
6	377	283	226	189	162	141	126	113	103	94	81	71	63
10	1047	785	628	524	449	393	349	314	286	262	224	196	174
12	1508	1131	905	754	646	565	503	452	411	377	323	283	251
16	2681	2011	1608	1340	1149	1005	894	804	731	670	575	503	447
20	4189	3142	2513	2094	1795	1571	1396	1257	1142	1047	898	783	698
24	6032	4524	3619	3016	2595	2262	2011	1810	1645	1508	1290	1130	1000
28	8210	6157	4926	4105	3519	3079	2737	2463	2239	2052	1760	1540	1370
32	–	8042	6434	5362	4596	4021	3574	3217	2925	2681	2300	2010	1790
40	–	–	10053	8378	7181	6283	5585	5027	4570	4189	3590	3140	2790

TABLE R 3

Weights of Groups of Bars (kg per metre run)

Bar Size mm	No. of Bars 1	2	3	4	5	6	7	8	9	10
6	0.222	0.444	0.666	0.888	1.110	1.332	1.554	1.776	1.998	2.220
8	0.395	0.790	1.185	1.580	1.975	2.370	2.765	3.160	3.555	3.950
10	0.616	1.232	1.848	2.464	3.080	3.696	4.312	4.928	5.544	6.160
12	0.888	1.776	2.664	3.552	4.440	5.328	6.216	7.104	7.992	8.880
16	1.579	3.158	4.737	6.316	7.895	9.474	11.053	12.632	14.211	15.790
20	2.466	4.932	7.398	9.864	12.330	14.796	17.262	19.728	22.194	24.660
24	3.551	7.102	10.653	14.204	17.755	21.306	24.857	28.408	31.959	35.510
28	4.834	9.668	14.502	19.336	24.170	29.004	33.838	38.672	43.506	48.340
32	6.313	12.626	18.939	25.252	31.565	37.878	44.191	50.504	56.817	63.130
40	9.864	19.728	29.592	39.456	49.320	59.184	69.048	78.912	88.776	98.640

TABLE R 4

Weight in kg per sq metre for various Bar Spacings

Bar Size mm	Spacing of Bars, (millimetres) 50	75	100	125	150	175	200	250	300
6	4.440	2.960	2.220	1.776	1.480	1.269	1.110	0.888	0.740
8	7.900	5.267	3.950	3.160	2.633	2.257	1.975	1.580	1.317
10	12.320	8.213	6.160	4.928	4.107	3.520	3.080	2.464	2.053
12	17.760	11.840	8.880	7.104	5.920	5.074	4.440	3.552	2.960
16	31.580	21.053	15.790	12.632	10.527	9.023	7.895	6.316	5.263
20	49.320	32.880	24.660	19.728	16.440	14.091	12.330	9.864	8.220
24	71.020	47.346	35.510	28.408	23.673	20.291	17.755	14.204	11.836
28	96.680	64.453	48.340	38.672	32.227	27.623	24.170	19.336	16.113
32	126.260	84.173	63.130	50.504	42.087	36.074	31.565	25.252	21.043
40	197.280	131.520	98.640	78.912	65.760	56.366	49.320	39.456	32.880

TABLE R 5

Dimensions of welded square mesh fabric

Mesh type	Nominal pitch	Main and Cross Wire: Diameter	Main and Cross Wire: Cross-sectional area	Welded Fabric (1): Cross-sectional area per metre width	Welded Fabric (1): Mass per square metre
	mm	mm	mm^2	mm^2	kg
333 M	75	6.30	31.17	409	6.422
334 M	75	6.00	28.27	371	5.825
335 M	75	5.30	22.06	290	4.545
338 M	75	4.00	12.57	165	2.589
661/0 M	150	8.00	50.27	330	5.178
661 M	150	7.50	44.18	290	4.551
662 M	150	7.10	39.59	260	4.079
663 M	150	6.30	31.17	205	3.211
664 M	150	6.00	28.27	186	2.913
665 M	150	5.30	22.06	145	2.273
666 M	150	5.00	19.64	129	2.203
668 M	150	4.00	12.57	82	1.294
6610 M	150	3.15	7.79	51	0.803

Note (1) Values based on exact pitches of 76.2 mm and 152.4 mm respectively.

Members in pure bending

Members in pure bending

Introduction

This part of the handbook deals with members in pure bending. The tables produced in this section have been based upon the design requirements of NZS 3101P*.

Acknowledgement

The calculation and translation of data into tabular form of many of the tables was produced by computer under the direction of F.D. Beresford, CSIRO Division of Building Research, Melbourne, Australia, to whom grateful acknowledgement is recorded.

Tables

B1.1 Coefficients for rectangular sections without compressive reinforcement. 20 MPa Concrete

B1.2 Coefficients for rectangular sections without compressive reinforcement. 25 MPa Concrete

B1.3 Coefficients for rectangular sections without compressive reinforcement. 30 MPa Concrete

B1.4 Coefficients for rectangular sections $M_u/\phi bd^2 f'_c$ without compressive reinforcement.

B2.1 Coefficients for rectangular sections with compressive reinforcement and for T sections. 20 MPa Concrete

B2.2 Coefficients for rectangular sections with compressive reinforcement and for T sections. 25 MPa Concrete

B2.3 Coefficients for rectangular sections with compressive reinforcement and for T sections. 30 MPa Concrete

B3 Coefficients a''_u for rectangular sections with compressive reinforcement and a'_{uf} for T sections.

B4 Value of M_{uc}/M_{uw} for design of compressive reinforcement.

B5 Coefficient F for resisting moments of rectangular or T sections. b = 100 to 400 mm.

B5 Coefficient F for resisting moments of rectangular or T sections. b = 450 to 1000 mm.

B6.1 Resisting moments for sections 1000 mm wide f_y = 275 MPa.

B6.2 Resisting moments for sections 1000 mm wide f_y = 380 MPa.

Notation

a = depth of rectangular stress block used in calculating the effective strengths of members under bending and compression. mm

a_u = tabulated quantity for rectangular sections without compressive reinforcement (Table B1)

$$a_u = \phi f_y\ (1 - 0.59\omega) = \frac{M_u}{A_s d}$$ MPa (N/mm²)

a'_u = tabulated quantity for rectangular sections with compressive reinforcement which yields. (Table B2)

$$a'_u = \phi f_y\ (1 - d'/d)$$ MPa (N/mm²)

a''_u = tabulated quantity for rectangular sections with compressive reinforcement where compression reinforcement does not yield when ϵ_c = 0.003 (Table B3)

$$a''_u = 600\phi\ (1 - d'/d)\left(1 - \frac{d'/d}{c/d}\right)$$ MPa (N/mm²)

a_{uf} = tabulated quantity for T beam sections (Tables B2)

$$a_{uf} = \phi f_y\ (1 - h_f/2d)$$ MPa (N/mm²)

*Except where the provisions of the draft NZ Standard DZ 3101: Parts 1 and 2, "Code of practice for the design of concrete structures", are more applicable.

a'_{uf}	=	tabulated quantity for T beam sections when compression reinforcement does not yield when ϵ_c = 0.003 (Table B3) $a'_{uf} = 600\phi\,(1 - h_f/2d)\left(1 - \dfrac{h_f/2d}{c/d}\right)$	MPa (N/mm^2)
A_s	=	area of non prestressed tension reinforcement	mm^2
A'_s	=	area of compression reinforcement	mm^2
A_{sf}	=	area of steel in tension zone required to balance the compression force in the overhanging portions of flanges in I or T or L sections	mm^2
b	=	width of compression face	mm
b_w	=	width of web of I or T or L sections	mm
c	=	distance from extreme compression fibre to the neutral axis	mm
C_c	=	compressive force in concrete	kN
C_f	=	compressive force in concrete flange areas of I, or T or L sections	kN
C_s	=	compressive force in steel	kN
d	=	distance from extreme compression fibre to centroid of tension reinforcement	mm
d'	=	distance from extreme compression fibre to centroid of compression reinforcement	mm
E_c	=	modulus of elasticity of concrete	MPa
E_s	=	modulus of elasticity of steel	MPa
E'_s	=	modulus of elasticity of steel in compression.	MPa
f_c	=	extreme fibre stress of concrete in compression	MPa
f'_c	=	specified compressive strength of concrete at 28 days.	MPa
f_s	=	tensile steel stress	MPa
f'_s	=	compressive steel stress	MPa
f_y	=	yield strength of reinforcement	MPa
F	=	tabulated coefficient for tabulation of resisting moments. $F = bd^2 \times 10^{-6}\ mm^3 = \dfrac{M_u}{K_u}$ (Table 5)	
h	=	overall thickness of member	mm
h_f	=	thickness of flange of I,T, or L section	mm
j_f	=	ratio between the distance from the centroid of the flange to the centroid of tension and the total depth of the section. $j_f = 1 - h_f/2d$	
j_u	=	ratio of the lever arm between the centroids of compression and tension to the depth d of the section $j_u = 1 - a/2d$	
K_u	=	strength coefficient of resistance $K_u = \dfrac{\phi M_u}{bd^2} = \phi f'_c\omega\,(1 - 0.59\omega)$ (Tables B1)	MPa (N/mm^2)

K_{uf} = coefficient for computing steel area A_{sf}

$K_{uf} = \phi 0.85 f'_c \left(\frac{b}{b_w} - 1\right)$

(Tables B2) MPa (N/mm²)

M_i = ideal moment strength kNm

M_u = applied design moment from ultimate loading kNm

M_{u1} = design moment strength of cross-section before compressive reinforcement and extra tension reinforcement are added.

$M_{u1} = M_u - M_{u2}$ kNm

M_{u2} = that portion of M_u assigned to compression steel or the flange regions of I,T, or L sections kNm

M_{uc} = moment capacity of section with compression and tension reinforcement kNm

M_{uw} = ultimate moment capcity of a rectangular beam or web of a T beam when reinforced in tension only kNm

T = tension force on reinforcement

β_1 = coefficient relating the depth of the equivalent rectangular stress block to the depth from the compression face to the neutral axis.

= 0.85 for $f'_c \leqslant 30$ MPa.

β_1 is reduced by 0.04 for every 5 MPa over 30 MPa i.e.

35 MPa $\beta_1 = 0.81$
40 MPa $\beta_1 = 0.77$
45 MPa $\beta_1 = 0.73$
50 MPa $\beta_1 = 0.69$

but not less than 0.65

ϵ = unit strain

ϵ_c = unit strain in concrete

ϵ_s = unit strain in tension steel

ϵ'_s = unit strain in compression steel

ϵ_u = ultimate strain

ϵ_y = nominal yield strain of reinforcement f_y/E_s

ρ = ratio of non prestressed tension reinforcement

$\rho = \frac{A_s}{bd}$

ρ' = ratio of non prestressed compression reinforcement

ρ_b = reinforcement ratio producing balanced conditions

ρ_f = reinforcement ratio $\frac{A_{sf}}{b_w d}$

ϕ = capacity reduction factor = 0.90 for bending in reinforced concrete.

ω = tabulated quantity (Tables B1)

$\omega = \frac{\rho f_y}{f'_c}$

Design notes

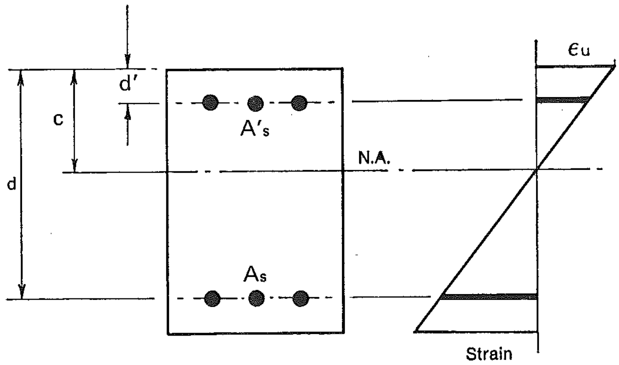
Tables B1 These are derived from code formula. Auxiliary expressions have been introduced for tabulation.

$$\omega = \frac{A_s}{bd}\,\frac{f_y}{f'_c} \qquad \text{dimensionless coefficient}$$

$$K_u = \phi f'_c \omega\,(1 - 0.59\omega) \qquad \text{MPa (N/mm}^2\text{)}$$
$$a_u = \phi f_y\,(1 - 0.59\omega) \qquad \text{MPa (N/mm}^2\text{)}$$

Tables B2 These Tables are used to obtain values for the additional couple from the compressive force in the flange when $a \geqslant h_f$ or from compressive reinforcement.

Table B3 This table is the result of general analysis when the compression steel does not yield.



$$f'_s = E'_s\,\epsilon'_s \qquad \frac{\epsilon'_s}{c - d'} = \frac{\epsilon_u}{c} \qquad \epsilon'_s = \epsilon_u\,(1 - d'/c)$$

$$f'_s = E'_s\,\epsilon_u\,(1 - d'/c)$$

$M_{u2} = \phi\,A'_s\,f'_s\,(d - d')$ Defining a''_u so that $A'_s = \dfrac{M_{u2}}{a''_u\,d}$

$$\text{then } a''_u = \frac{\phi\,A'_s f'_s\,(d - d')}{A'_s\,d} = \phi\,f'_s\,(1 - d'/d)$$
$$= \phi\,E'_s\,\epsilon_u\,(1 - d'/c)\;(1 - d'/d)$$

for $E'_s = 200 \times 10^3$ $\qquad \epsilon_u = 0.003$

$$a''_u = 600\,\phi\left(1 - \frac{d'/d}{c/d}\right)(1 - d'/d)$$

Similarly considering the overhanging portions of a T-beam flange to be replaceable by equivalent compressive steel.

$$a'_{uf} = 600\,\phi\left(1 - \frac{h_f}{2d}\right)\left(1 - \frac{h_f/2d}{c/d}\right)$$

These expressions apply when $f'_s \leqslant f_y$, i.e., when the compressive steel does not yield, the values of a'_u and a_{uf} in Tables B2 apply. By using the lesser value of a'_u or a''_u for rectangular sections and a_{uf} or a'_{uf} for T sections, the designer will automatically select the governing conditions.

Table B4 Values of M_{uc}/M_{uw} are shown for ρ greater than ρ_{max} for rectangular sections having tensile reinforcement only. With compressive reinforcement this limiting value of ρ may be exceeded to an extent depending upon the ratio ρ'/ρ.

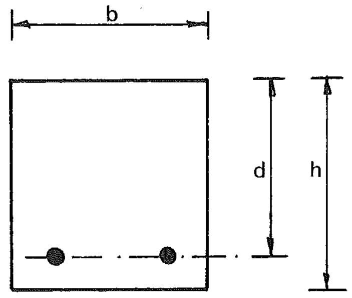
Table B5 Values of $F = bd^2$ are tabulated in 10^6 mm^3 units so that M in kNm = K in MPa x F.

Tables B6 Values of M_u are given for strips of unit width and varying d, ρ, f'_c and f_y. These tables are useful for slab analysis and, by entering with a given value of M_u for design, as in Example 4.

Examples in pure bending

Example 1. TABLES B1, B5,

Rectangular beam in pure bending, without compressive reinforcement. Find beam depth and reinforcement.



Given: M_u = 190 kNm
b = 200 mm
f'_c = 20 MPa
f_y = 380 MPa

1. Determine beam size by selecting a suitable steel percentage:

From **TABLE B1.1,** for f'_c = 20 MPa, f_y = 380 MPa, read ρ_{max} = 0.017

The value of ρ_{max} is used as a guide to selection of an economical steel percentage, which then defines the effective beam depth. An economical steel percentage will be some fraction of ρ_{max} usually between 0.4 and 0.6 for beams. A precise evaluation of the most economical steel percentage depends upon many factors, such as material costs, formwork costs, available clearances, deflection sensitivity, etc.

Select = 0.5 ρ_{max} = 0.5 x 0.017
= 0.0085 approximately as a reasonable steel content.

In **TABLE B1.1,** for ρ = 0.0085, read a_u = 310, K_u = 2.61. MPa (N/mm^2) j_u = 0.906

Calculate $F = \dfrac{M_u}{K_u} = \dfrac{190 \times 10^6}{2.61} = 73 \times 10^6 \text{ mm}^3$

From **TABLE B5,** for b = 200 mm, and F = 73, read d = 605 mm (minimum).

Allow 40 mm cover to centre of main bars: therefore = d + 40 = 605 + 40 = 645 mm.

Use nearest preferred dimension = 650 mm. Therefore d = 650 – 40 = 610 mm.

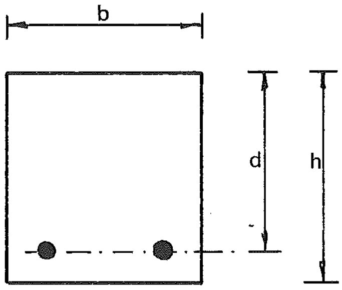
2. Determine reinforcement:

$$A_s = \frac{M_u}{a_u d} = \frac{190 \times 10^6}{310 \times 610} = 1005 \text{ mm}^2 \text{ or } A_s = \frac{M_u}{\phi\, j_u f_y d} = \frac{190 \times 10^6}{0.9 \times 0.906 \times 380 \times 610} = 1005 \text{ mm}^2$$

3. Check deflection

Example 2. TABLES B5, B1

Rectangular beam in pure bending, without compressive reinforcement. Find tensile reinforcement.



Given: M_u = 140 kNm
b = 250 mm
d = 450 mm
h = 500 mm
f'_c = 25 MPa
f_y = 380 MPa

1. From **TABLE B5,** for b = 250 mm and d = 450 mm, read F = 50.6×10^6 mm³

$$\therefore K_u = M_u/F = \frac{140 \times 10^6}{50.6 \times 10^6} = 2.77 \text{ N/mm}^2 \text{ (MPa)}$$

2. From **TABLE B1.2,** for f'_c = 25 MPa, f_y = 380 MPa, and K_u = 2.77, read ρ = 0.0088 and a_u = 315.

$$A_s = \rho bd = 0.0088 \times 250 \times 450 = 990 \text{ mm}^2, \text{ or } A_s = \frac{M_u}{a_u d} = \frac{140 \times 10^6}{315 \times 450} = 988 \text{ mm}^2$$

3. Check deflection.

Example 3 TABLES B1, B5,

Slab, pure bending, no compressive reinforcement. For a unit width of one metre, find h and A_s given M_u

Given: M_u = 250 kNm per metre width
f'_c = 25 MPa
f_y = 380 MPa

1. Determine depth of slab:

To determine a depth of slab, it is often convenient to select a suitable reinforcement percentage, using the value of ρ_{max} as a guide. An economical percentage will be some fraction of ρ_{max} usually between 0.3 and 0.5 for slabs. A precise evaluation of the most economical steel percentages depends upon many factors such as material costs, formwork costs, available clearances, deflection sensitivity, etc.

From **TABLE B1.2,** for f'_c = 25 MPa, f_y = 380 MPa, read ρ_{max} = 0.0218
select $\rho = 0.4\ \rho_{max}$
= 0.0087

From **TABLE B1.2,** for f'_c = 25 MPa, f_y = 380 MPa, and ρ = 0.0087 read a_u = 316 and K_u = 2.70

$F = M_u/K_u = 250/2.7 \times 10^6 = 92.59 \times 10^6$ mm³

From **TABLE B5,** for b = 1,000 mm, F = 92.6 read d = 300 (approx.)
h = d + ½ bar diameter + cover = d + 30 mm = 330

Use h = 325 mm as this is a preferred dimension; d = 295mm.

2. Determine reinforcement

$$A_s = \frac{M_u}{a_u d} = \frac{250 \times 10^6}{316 \times 295} = 2682 \text{ mm}^2/\text{m}$$

3. Check deflection

Example 4 TABLE B6,

Slab, pure bending, no compressive reinforcement. For a unit width of one metre given d and M_u, find A_s

Given: M_u = 140 kNm per metre width
f'_c = 25 MPa
f_y = 380 MPa
d = 245 mm

1. Determine reinforcement:

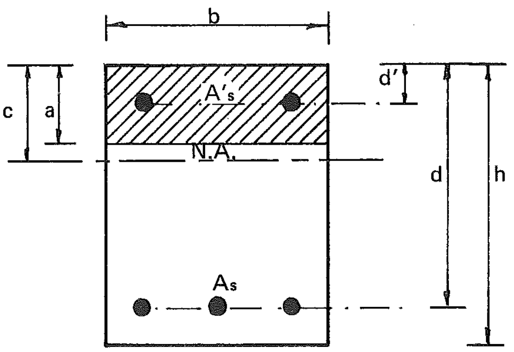
   From **TABLE B6.2,** for f_y = 380 MPa, f'_c = 25 MPa, d = 245 mm, M_u = 140 kNm/m, read $\rho = 0.0073$.

   $\therefore A_s = \rho\, b\, d = 0.0073 \times 1000 \times 245 = 1789\ mm^2/m$

2. Check deflection

Example 5 TABLES B1, B2, B3, B5

Rectangular beam, pure bending, with compressive reinforcement. Given beam dimensions and M_u, find A_s and A'_s.



Given: M_u = 260 kNm
b = 300 mm
d' = 60 mm
f'_c = 30 mm
f_y = 380 MPa

1. Proceed initially as if there was no compressive reinforcement.

   From **TABLE B1.3,** for f'_c = 30 MPa, f_y = 380 MPa, read maximum value of $\rho = 0.0262$

   $$\omega = \frac{\rho f_y}{f'_c} = 0.0262 \times \frac{380}{30} = 0.3318$$

   $$c/d = \frac{1.18\omega}{\beta_1} = 1.18 \times \frac{0.3318}{0.85} = 0.4606$$

   $K_u = \phi\, f'_c\, \omega\, (1 - 0.59\omega) = 7.18$ MPa (N/mm^2) from table B1.3

   $a_u = \phi\, f_y\, (1 - 0.59\omega) = 275$ MPa (N/mm^2) from table B1.3

2. From **TABLE B5,** for b = 300 mm, d = 300 mm, read $F = 27 \times 10^6\ mm^3$

3. Calculate the bending capacity of the beam without compressive reinforcement.

   $M_{u1} = K_u F = 7.18 \times 27 \times 10^6 \times 10^{-6} = 194$ kNm

   Since this is less than M_u, compressive reinforcement is required.

   The capacity of the compressive steel couple required,
   $M_{u2} = 260 - 194 = 66$ kNm

4. From **TABLE B2.3,** for f'_c = 30 MPa, f_y = 380 MPa, $d'/d = 60/300 = 0.20$, read a'_u = 274 MPa. (N/mm^2)

   From **TABLE B3,** for $d'/d = 0.20$, $c/d = 0.46$ read a''_u = 244 MPa (N/mm^2)

   Since $a''_u \leqslant a'_u$, the compressive steel has not yet reached yield, use a''_u = 244 the smaller value.

5. Calculate required reinforcement:

Section 10.3.2 of A.C.I. code 318-71 and associated commentary sets the net amount of tension reinforcement at 0.75 ρ_b

For the same reason when compression reinforcement is needed for strength, the cross sectional area of the compressive reinforcement actually provided shall be 4/3 times the theoretically required A'_s.

$$\therefore A'_s = \frac{4}{3} \times \frac{M_{u2}}{a''_u d} = \frac{4 \times 66 \times 10^6}{3 \times 244 \times 300} = 1202 \text{ mm}^2$$

$$A_s = \rho_{max}\, b\, d + \frac{M_{u2}}{f_y(d - d')}$$

$$= 0.0262 \times 300 \times 300 + \frac{66 \times 10^6}{380\ (300 - 60)} = 2358 + 724 = 3082 \text{ mm}^2$$

Check that net amount of tension reinforcement does not exceed $0.75\rho_b$

($0.75\rho_b$ is the value given at the bottom of the columns headed $\rho - \rho' = 0.0296$ max)

Net amount of reinforcement

$= \rho - 0.75\rho'$ (0.75 cuts back ρ' to the theoretical value)

$$= \frac{A_s - 0.75A_s'}{b\,d}$$

$$= \frac{3082 - 0.75 \times 1202}{300 \times 300}$$

$$= \frac{3082 - 902}{300 \times 300}$$

$= 0.0242 \leqslant 0.0296$ max ok

6. Check deflection.

Example 6 TABLES B1, B4, B5

Rectangular beam, pure bending, with compressive reinforcement. Given beam dimensions, M_u and A'_s find A_s.

Given: M_u = 250 kNm, b = 250 mm, d = 500 mm, d' = 50 mm, A'_s = 1240 mm², f'_c = 20 MPa, f_y = 275 MPa

1. Proceed initially as if there was no compressive reinforcement:

From **TABLE B5**, for b = 250 mm, d = 500 mm, read F = 62.5 x 10^6 mm³

$$K_u = \frac{M_u}{F} = \frac{250 \times 10^6}{62.5 \times 10^6} = 4.0 \quad \text{N/mm}^2 \text{ (MPa)}$$

2. From **TABLE B1.1**, for f'_c = 20 MPa, f_y = 275 MPa, and K_u = 4.0, read $\rho = 0.0191$

(**NOTE:** The Table does not give values of ρ greater than ρ_{max} although use of ρ in this range may still be valid).

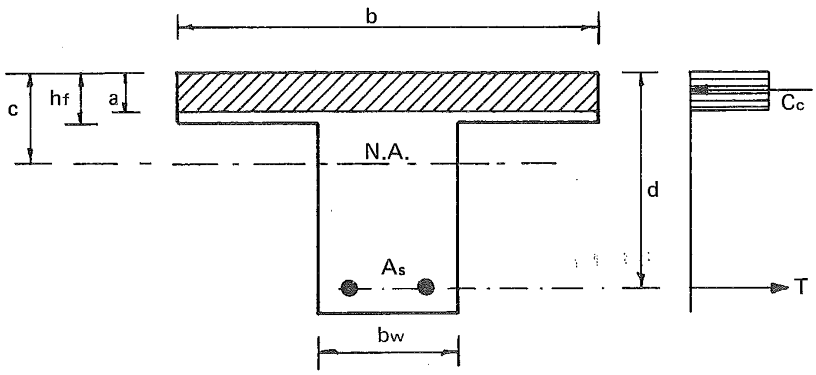
$$\rho' \text{ (act)} = \frac{A'_s}{b\,d} = \frac{1240}{250 \times 500} = 0.0099 \qquad \text{Calculate } \rho'/\rho = \frac{0.0099}{0.0191} = 0.52$$

3. From **TABLE B4,** for f'_c = 20 MPa, f_y = 275 MPa, d'/d = 50/500 = 0.10, ρ = 0.0191 and ρ'/ρ = 0.51, interpolate M_{uc}/M_{uw} = 1.07

$$\therefore \text{required } \rho = \frac{0.0191}{1.07} = 0.0179 \qquad A_s = \rho bd = 0.0179 \times 250 \times 500 = 2238\text{mm}^2$$

Example 7 TABLES B1, B5

T-Beam in pure bending, high neutral axis. Given beam dimensions and M_u, find A_s.



Given: M_u = 400 kNm
b = 750 mm
b_w = 250 mm
d = 475 mm
h_f = 62.5 mm
f'_c = 30 MPa
f_y = 380 MPa

1. Determine design method:

From **TABLE B5,** for b = 750 mm, and d = 475 mm, read F = 169 x 10^6 mm^3

$$K_u = \frac{M_u}{F} = \frac{400 \times 10^6}{169 \times 10^6} = 2.37 \quad N/mm^2 \quad (MPa)$$

From **TABLE B1.3,** for f'_c = 30 MPa, f_y = 380 MPa, and K_u = 2.37, read c/d = 0.129 and a/d = 0.110.

Calculate $h_f/d = \frac{62.5}{475} = 0.132$

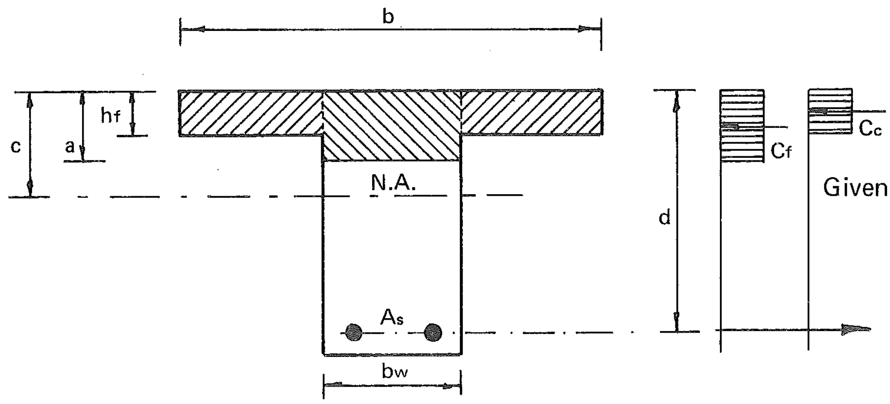
Since $a/d \leqslant h_f/d$, the whole of the compression block is within the flange depth. Use rectangular beam design with b = 750 mm. [If $a/d \geqslant h_f/d$, refer to Example 8]

2. From **TABLE B1.3,** again, read a_u = 323.4

$$A_s = \frac{M_u}{a_u d} = \frac{400 \times 10^6}{323.4 \times 475} = 2604 \text{ mm}^2$$

Example 8 TABLES B1, B2, B5

T-Beam in pure bending, low neutral axis. Given beam dimensions and M_u, find A_s.



Given: M_u = 545 kNm
b = 750 mm
b_w = 250 mm
d = 475 mm
h_f = 62.5 mm
f'_c = 30 MPa
f_y = 380 MPa

1. Determine design method:

From **TABLE B5,** for b = 750 mm, and d = 475 mm, read F = 169 x 10^6 mm^3

$$K_u = \frac{M_u}{F} = \frac{545 \times 10^6}{169 \times 10^6} = 3.22 \quad N/mm^2 \quad (MPa)$$

From **TABLE B1.3,** for f'_c = 30 MPa, f_y = 380 MPa, and K_u = 3.22, read c/d = 0.179 and a/d = 0.152.

Calculate $h_f/d = \frac{62.5}{475} = 0.132$

Since $a/d \geqslant h_f/d$, the compression block depth extends below the flange depth. Use T-Beam design. [If $a/d \leqslant h_f/d$, refer to Example 7]

2. Determine capacity of flange:

From **TABLE B2.3**, for $f'_c = 30$ MPa, $f_y = 380$ MPa, and $h_f/2d = 0.066$, read $a_{uf} = 319$ MPa (N/mm^2) $j_f = 0.933$.

From **TABLE B2.3**, for $b/b_w = \frac{750}{250} = 3.0$ read $K_{uf} = 45.9$ MPa (N/mm^2)

$\therefore M_{u2} = K_{uf}\, j_f\, b_w\, d\, h_f$
$= 45.9 \times 0.933 \times 250 \times 475 \times 62.5 \times 10^{-6}$
$= 318$ kNm

$A_{sf} = \frac{M_{u2}}{a_{uf} d} = \frac{318 \times 10^6}{319 \times 475} = 2099mm^2$

$\rho' = \frac{2099}{250 \times 475} = 0.0177$

or

$C_f = 0.85\, f'_c\, (b - b_w)\, h_f$
$= 0.85 \times 30\, (750 - 250) \times 62.5 \times 10^{-6}$
$= 797$ kN

Moment arm $= d - h_f/2 = 444mm$

$M_{u2} = \phi\, C_f\, (d - h_f/2)$
$= 0.90 \times 797 \times 0.444 = 318$ kNm

3. Determine capacity of web:

$M_{u1} = M_u - M_{u2} = 545 - 318 = 227$ kNm

From **TABLE B5,** for b = 250 mm and d = 475 mm, read $F = 56.4 \times 10^6\ mm^3$

$K_u = \frac{M_{u1}}{F} = \frac{227 \times 10^6}{56.4 \times 10^6} = 4.02 \quad N/mm^2 \quad (MPa)$

From **TABLE B1.3,** for $f'_c = 30$ MPa, $f_y = 380$ MPa, and $K_u = 4.02$, read $a_u = 309$ MPa (N/mm^2)

$A_s - A_{sf} = \frac{M_{u1}}{a_u d} = \frac{227 \times 10^6}{309 \times 475} = 1547\ mm^2$

4. $A_s = 1547 + A_{sf} = 1547 + 2099 = 3646mm^2$

Check $\rho - 0.75\, \rho'_{max} \quad \frac{A_s - 0.75\, A_{sf}}{b_w d} = \frac{3646 - 0.75 \times 2099}{250 \times 475} = 0.0174$

less than 0.0296 ok.

5. Check deflections.

TABLE B1.1 — 20 MPa CONCRETE

COEFFICIENTS FOR RECTANGULAR SECTIONS WITHOUT COMPRESSIVE REINFORCEMENT

$\rho = \dfrac{\omega f'_c}{f_y} = \dfrac{A_s}{bd}$

$c/d = 1.18 \dfrac{\omega}{\beta_1}$

$a/d = \beta_1 \dfrac{c}{d}$

$j_u = 1 - \dfrac{a}{2d}$

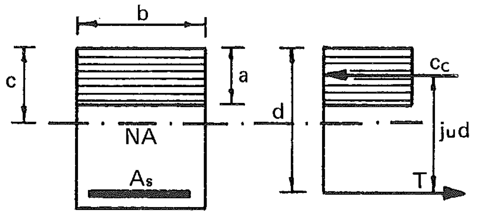
$K_u = \phi f'_c\, \omega\, (1 - 0.59\, \omega)$.

$a_u = \phi f_y\, (1 - 0.59\, \omega)$

$A_s = \dfrac{M_u}{a_u d} \times 10^6\ mm^2$

or $\dfrac{M_u}{\phi j_u f_y d} \times 10^6\ mm^2$

$F = \dfrac{M_u}{K_u} \times 10^6\ mm^3$



$\beta_1 = 0.85$ $\phi = 0.90$

UNITS A_s – mm², f'_c – MPa, M_u – kNm, f_y – MPa, d & b – mm

ω	(MPa) K_u	f'_c = 20 MPa, f_y = 275 MPa: ρ	f_y = 275 MPa: a_u (MPa)	f_y = 380 MPa: ρ	f_y = 380 MPa: a_u (MPa)	c/d	a/d	j_u
.02	.36	.0015	245	.0011	338	.028	.024	.988
.03	.53	.0022	243	.0016	336	.042	.035	.982
.04	.70	.0029	242	.0021	334	.056	.047	.976
.05	.87	.0036	240	.0026	330	.069	.059	.971
.06	1.04	.0044	239	.0032	332	.083	.071	.965
.07	1.21	.0051	237	.0037	328	.097	.083	.959
.08	1.37	.0058	236	.0042	326	.111	.094	.953
.09	1.53	.0065	234	.0047	324	.125	.106	.947
.10	1.69	.0073	233	.0053	322	.139	.118	.941
.11	1.85	.0080	231	.0058	320	.153	.130	.935
.12	2.01	.0087	230	.0063	318	.167	.142	.929
.13	2.16	.0095	229	.0068	316	.180	.153	.923
.14	2.31	.0102	227	.0074	314	.194	.165	.917
.15	2.46	.0109	226	.0079	312	.208	.177	.912
.16	2.61	.0116	224	.0084	310	.222	.189	.906
.17	2.75	.0124	223	.0089	308	.236	.201	.900
.18	2.90	.0131	221	.0095	306	.250	.212	.894
.19	3.04	.0138	220	.0100	304	.264	.224	.888
.20	3.18	.0145	218	.0105	302	.278	.236	.882
.21	3.31	.0153	217	.0111	300	.292	.248	.876
.22	3.45	.0160	215	.0116	298	.305	.260	.870
.23	3.58	.0167	214	.0121	296	.319	.271	.864
.24	3.71	.0175	212	.0126	294	.333	.283	.858
.25	3.84	.0182	211	.0132	292	.347	.295	.853
.26	3.96	.0189	210	.0137	290	.361	.307	.847
.27	4.09	.0196	208	.0142	288	.375	.319	.841
.28	4.21	.0204	207	.0147	286	.389	.330	.835
.29	4.33	.0211	205	.0153	283	.403	.342	.829
.30	4.44	.0218	204	0.158	281	.416	.354	.823
.31	4.56	.0225	202	.0163	279	.430	.366	.817
.32	4.67	.0233	201	.0168	277	.444	.378	.811
.33	4.78	.0240	199			.458	.389	.805
.34	4.89	.0247	198			.472	.401	.799
.35	5.00	.0255	196			.486	.413	.794
.36	5.10	.0262	195			.500	.425	.788
.37	5.21	.0269	193			.514	.437	.782
		ρ max = 0.027		ρ max = 0.017				

NOTES:

1. Values of ρ above upper solid line are below the minimum $^{1.4}/_{f_y}$
2. Check deflections.

TABLE B1.2

25 MPa CONCRETE

COEFFICIENTS FOR RECTANGULAR SECTIONS WITHOUT COMPRESSIVE REINFORCEMENT

$\rho = \frac{\omega f'_c}{f_y} = \frac{A_s}{bd}$

$c/d = 1.18 \frac{\omega}{\beta_1}$

$a/d = \beta_1 \frac{c}{d}$

$j_u = 1 - \frac{a}{2d}$

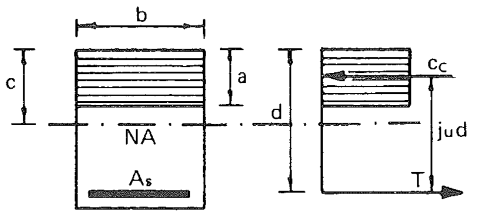
$K_u = \phi f'_c\, \omega\, (1 - 0.59\, \omega)$.

$a_u = \phi f_y\, (1 - 0.59\, \omega)$

$A_s = \frac{M_u}{a_u d} \times 10^6\ \text{mm}^2$

or $\frac{M_u}{\phi j_u f_y d} \times 10^6\ \text{mm}^2$

$F = \frac{M_u}{K_u} \times 10^6\ \text{mm}^3$



$\beta_1 = 0.85$ $\phi = 0.90$

UNITS A_s – mm² f'_c – MPa
M_u – kNm f_y – MPa d & b – mm

ω	(MPa) Ku	f'c = 25 MPa						
		fy = 275 MPa		fy = 380 MPa		c/d	a/d	ju
		ρ	au (MPa)	ρ	au (MPa)			
.02	.44	.0018	245	.0013	338	.028	.024	.988
.03	.66	.0027	243	.0020	336	.042	.035	.982
.04	.88	.0036	242	.0026	334	.056	.047	.976
.05	1.09	.0045	240	.0033	332	.069	.059	.971
.06	1.30	.0055	239	.0039	330	.083	.071	.965
.07	1.51	.0064	237	.0046	328	.097	.083	.959
.08	1.72	.0073	236	.0053	326	.111	.094	.953
.09	1.92	.0082	234	.0059	324	.125	.106	.947
.10	2.12	.0091	233	.0066	322	.139	.118	.941
.11	2.31	.0100	231	.0072	320	.153	.130	.935
.12	2.51	.0109	230	.0079	318	.167	.142	.929
.13	2.70	.0118	229	.0086	316	.180	.153	.923
.14	2.89	.0127	227	.0092	314	.194	.165	.917
.15	3.08	.0136	226	.0099	312	.208	.177	.912
.16	3.26	.0145	224	.0105	310	.222	.189	.906
.17	3.44	.0155	223	.0112	308	.236	.201	.900
.18	3.62	.0164	221	.0118	306	.250	.212	.894
.19	3.80	.0173	220	.0125	304	.264	.224	.888
.20	3.97	.0182	218	.0132	302	.278	.236	.882
.21	4.14	.0191	217	.0138	300	.292	.248	.876
.22	4.31	.0200	215	.0145	298	.305	.260	.870
.23	4.47	.0209	214	.0151	296	.319	.271	.864
.24	4.64	.0218	212	.0158	294	.333	.283	.858
.25	4.80	.0227	211	.0164	292	.347	.295	.853
.26	4.95	.0236	210	.0171	290	.361	.307	.847
.27	5.11	.0245	208	.0178	288	.375	.319	.841
.28	5.26	.0255	207	.0184	286	.389	.330	.835
.29	5.41	.0264	205	.0191	283	.403	.342	.829
.30	5.56	.0273	204	.0197	281	.416	.354	.823
.31	5.70	.0282	202	.0204	279	.430	.366	.817
.32	5.84	.0291	201	.0211	277	.444	.378	.811
.33	5.98	.0300	199	.0217	275	.458	.389	.805
.34	6.12	.0309	198			.472	.401	.799
.35	6.25	.0318	196			.486	.413	.794
.36	6.38	.0327	195			.500	.425	.788
.37	6.51	.0336	193			.514	.437	.782
		ρ max = 0.0338		ρ max = 0.0218				

NOTES:

1. Values of ρ above upper solid line are below the minimum $^{1.4}/_{f_y}$
2. Check deflections.

TABLE B1.3

30 MPa CONCRETE

COEFFICIENTS FOR RECTANGULAR SECTIONS WITHOUT COMPRESSIVE REINFORCEMENT

$\rho = \frac{\omega f'_c}{f_y} = \frac{A_s}{bd}$

$c/d = 1.18 \frac{\omega}{\beta_1}$

$a/d = \beta_1 \frac{c}{d}$

$j_u = 1 - \frac{a}{2d}$

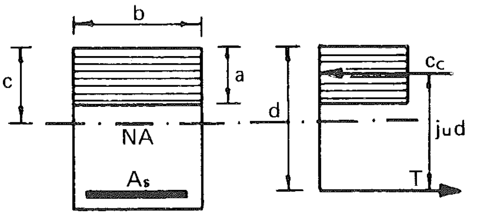
$K_u = \phi f'_c\, \omega\, (1 - 0.59\, \omega)$.

$a_u = \phi f_y\, (1 - 0.59\, \omega)$

$A_s = \frac{M_u}{a_u d} \times 10^6\ \text{mm}^2$

or $\frac{M_u}{\phi j_u f_y d} \times 10^6\ \text{mm}^2$

$F = \frac{M_u}{K_u} \times 10^6\ \text{mm}^3$



$\beta_1 = 0.85$ $\phi = 0.90$

UNITS A_s – mm² f'_c - MPa
M_u – kNm f_y – MPa d & b – mm

ω	(MPa) Ku	f'c = 30 MPa						
		fy = 275 MPa		fy = 380 MPa		c/d	a/d	ju
		ρ	au (MPa)	ρ	au (MPa)			
.02	.53	.0022	245	.0016	338	.028	.024	.988
.03	.80	.0033	243	.0024	336	.042	.035	.982
.04	1.05	.0044	242	.0032	334	.056	.047	.976
.05	1.31	.0055	240	.0039	332	.069	.059	.971
.06	1.56	.0065	239	.0047	330	.083	.071	.965
.07	1.81	.0076	237	.0055	328	.097	.083	.959
.08	2.06	.0087	236	.0063	326	.111	.094	.953
.09	2.30	.0098	234	.0071	324	.125	.106	.947
.10	2.54	.0109	233	.0079	322	.139	.118	.941
.11	2.7	.0120	231	.0087	320	.153	.130	.935
.12	3.01	.0131	230	.0095	318	.167	.142	.929
.13	3.24	.0142	229	.0103	316	.180	.153	.923
.14	3.4.	.0153	227	.0111	314	.194	.165	.917
.15	3.69	.0164	226	.0118	312	.208	.177	.912
.16	3.91	.0175	224	.0126	310	.222	.189	.906
.17	4.13	.0185	223	.0134	308	.236	.201	.900
.18	4.34	.0196	221	.0142	306	.250	.212	.894
.19	4.55	.0207	220	.0150	304	.264	.224	.888
.20	4.76	.0218	218	.0158	302	.278	.236	.882
.21	4.97	.0229	217	.0166	300	.292	.248	.876
.22	5.17	.0240	215	.0174	298	.305	.260	.870
.23	5.37	.0251	214	.0182	296	.319	.271	.864
.24	5.56	.0262	212	.0189	294	.333	.283	.858
.25	5.75	.0273	211	.0197	292	.347	.295	.853
.26	5.94	.0284	210	.0205	290	.361	.307	.847
.27	6.13	.0295	208	.0213	288	.375	.319	.841
.28	6.31	.0305	207	.0221	286	.389	.330	.835
.29	6.49	.0316	205	.0229	283	.403	.342	.829
.30	6.67	.0327	204	.0237	281	.416	.354	.823
.31	6.84	.0338	202	.0245	279	.430	.366	.817
.32	7.01	.0349	201	.0253	277	.444	.378	.811
.33	7.18	.0360	199	.0261	275	.458	.389	.805
.34	7.34	.0371	198			.472	.401	.799
.35	7.50	.0382	196			.486	.413	.794
.36	7.66	.0393	195			.500	.425	.788
.37	7.81	.0404	193			.514	.437	.782
		ρ max = 0.0406		ρ max = 0.0262				

NOTES:

1. Values of ρ above upper solid line are below the minimum $1.4/f_y$
2. Check deflections.

TABLE B1.4

COEFFICIENT FOR RECTANGULAR SECTIONS $M_u/\phi b d^2 f'_c$ WITHOUT COMPRESSIVE REINFORCEMENT

$$\rho = \frac{\omega f'_c}{f_y} \qquad \frac{A_s}{bd}$$

$$M_u = \phi b d^2 f'_c\, \omega\, (1 - 0.59\, \omega)$$

$$\frac{M_u}{\phi b d^2 f'_c} = \omega\, (1 - 0.59\, \omega)$$

a) With known M_u calculate $\dfrac{M_u}{\phi b d^2 f'_c}$

Find ω from table. Calculate ρ

b) With known ρ calculate ω from $\rho = \omega f'_c / f_y$

Find $\dfrac{M_u}{\phi b d^2 f'_c}$ from table. Calculate M_u

VALUES OF $M_u/\phi b d^2 f'_c$

ω	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
. 0	. 0	.0010	.0020	.0030	.0040	.0050	.0060	.0070	.0080	.0090
.01	.0099	.0109	.0119	.0129	.0139	.0149	.0159	.0168	.0178	.0188
.02	.0197	.0207	.0217	.0226	.0236	.0246	.0256	.0266	.0275	.0285
.03	.0295	.0304	.0314	.0324	.0333	.0343	.0352	.0362	.0372	.0381
.04	.0391	.0400	.0410	.0420	.0429	.0438	.0448	.0457	.0467	.0476
.05	.0485	.0495	.0504	.0513	.0523	.0532	.0541	.0551	.0560	.0569
.06	.0579	.0588	.0597	.0607	.0616	.0625	.0634	.0643	.0653	.0662
.07	.0671	.0680	.0689	.0699	.0708	.0717	.0726	.0735	.0744	.0753
.08	.0762	.0771	.0780	.0789	.0798	.0807	.0816	.0825	.0834	.0843
.09	.0852	.0861	.0870	.0879	.0888	.0897	.0906	.0915	.0923	.0932
.10	.0941	.0950	.0959	.0967	.0976	.0985	.0994	.1002	.1011	.1020
.11	.1029	.1037	.1046	.1055	.1063	.1072	.1081	.1089	.1098	.1106
.12	.1115	.1124	.1133	.1141	.1149	.1158	.1166	.1175	.1183	.1192
.13	.1200	.1209	.1217	.1226	.1234	.1243	.1251	.1259	.1268	.1276
.14	.1284	.1293	.1301	.1309	.1318	.1326	.1334	.1342	.1351	.1359
.15	.1367	.1375	.1384	.1392	.1400	.1408	.1416	.1425	.1433	.1441
.16	.1449	.1457	.1465	.1473	.1481	.1489	.1497	.1506	.1514	.1522
.17	.1529	.1537	.1545	.1553	.1561	.1569	.1577	.1585	.1593	.1601
.18	.1609	.1617	.1624	.1632	.1640	.1648	.1656	.1664	.1671	.1679
.19	.1687	.1695	.1703	.1710	.1718	.1726	.1733	.1741	.1749	.1756
.20	.1764	.1772	.1779	.1787	.1794	.1802	.1810	.1817	.1825	.1832
.21	.1840	.1847	.1855	.1862	.1870	.1877	.1885	.1892	.1900	.1907
.22	.1914	.1922	.1929	.1937	.1944	.1951	.1959	.1966	.1973	.1981
.23	.1988	.1995	.2002	.2010	.2017	.2024	.2031	.2039	.2046	.2053
.24	.2060	.2067	.2075	.2082	.2089	.2096	.2103	.2110	.2117	.2124
.25	.2131	.2138	.2145	.2152	.2159	.2166	.2173	.2180	.2187	.2194
.26	.2201	.2208	.2215	.2222	.2229	.2236	.2243	.2249	.2256	.2263
.27	.2270	.2277	.2284	.2290	.2297	.2304	.2311	.2317	.2324	.2331
.28	.2337	.2344	.2351	.2357	.2364	.2371	.2377	.2384	.2391	.2397
.29	.2404	.2410	.2417	.2423	.2430	.2437	.2443	.2450	.2456	.2463
.30	.2469	.2475	.2482	.2488	.2495	.2501	.2508	.2514	.2520	.2527
.31	.2533	.2539	.2546	.2552	.2558	.2565	.2571	.2577	.2583	.2590
.32	.2596	.2602	.2608	.2614	.2621	.2627	.2633	.2639	.2645	.2651
.33	.2657	.2664	.2670	.2676	.2682	.2688	.2694	.2700	.2706	.2712
.34	.2718	.2724	.2730	.2736	.2742	.2748	.2754	.2760	.2766	.2771
.35	.2777	.2783	.2789	.2795	.2801	.2807	.2812	.2818	.2824	.2830
.36	.2835	.2841	.2847	.2853	.2858	.2864	.2870	.2875	.2881	.2887
.37	.2892	.2898	.2904	.2909	.2915	.2920	.2926	.2931	.2937	.2943
.38	.2948	.2954	.2959	.2965	.2970	.2975	.2981	.2986	.2992	.2997
.39	.3003	.3008	.3013	.3019	.3024	.3029	.3035	.3040	.3045	.3051

TABLE B2.1 20 MPa CONCRETE

COEFFICIENTS FOR RECTANGULAR SECTIONS WITH COMPRESSIVE REINFORCEMENT AND FOR T-SECTIONS WITH $h_f/d < a/d$

$a'_u = \phi f_y (1 - d'/d)$

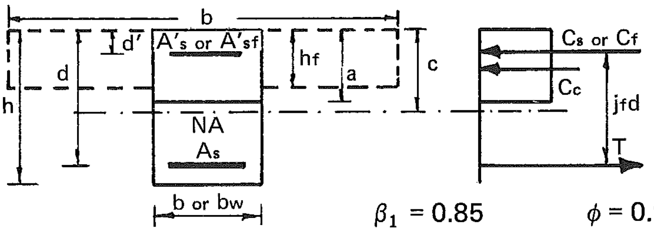
$a_{uf} = \phi f_y (1 - h_f/2d)$

$K_{uf} = \phi\, 0.85 f'_c \left(\frac{b}{b_w} - 1\right)$

$j_f = 1 - \frac{h_f}{2d}$

$\rho - \rho' = 0.85\beta_1 \frac{f'_c}{f_y} \frac{d'}{d} \frac{600}{600 - f_y}$

$\max(\rho - 0.75\rho_f) = 0.64\beta_1 \frac{f'_c}{f_y} \frac{600}{600 + f_y}$



$\beta_1 = 0.85$ $\phi = 0.90$

UNITS A'_s, A_{sf} — mm² f'_c — MPa
M_u — kNm f_y — MPa
d, b, b_w, h_f — mm

f'_c = 20 MPa							
	f_y = 275 MPa		f_y = 380 MPa				
d'/d or $h_f/2d$	$\rho - \rho'$	a'_u or a_{uf}	$\rho - \rho'$	a'_u or a_{uf}	j_f	b/b_w	K_{uf}
.01	.0010	245	.0010	339	.99	2.0	15.3
.02	.0019	243	.0021	335	.98	2.2	18.4
.03	.0029	240	.0031	332	.97	2.4	21.4
.04	.0039	238	.0041	328	.96	2.6	24.5
.05	.0049	235	.0052	325	.95	2.8	27.5
.06	.0058	233	.0062	321	.94	3.0	30.6
.07	.0068	230	.0073	318	.93	3.2	33.7
.08	.0078	228	.0083	315	.92	3.4	36.7
.09	.0087	225	.0093	311	.91	3.6	39.8
.10	.0097	223	.0104	308	.90	3.8	42.8
.11	.0107	220	.0114	304	.89	4.0	45.9
.12	.0116	218	.0124	301	.88	4.2	49.0
.13	.0126	215	.0135	298	.87	4.4	52.0
.14	.0136	213	.0145	294	.86	4.6	55.1
.15	.0146	210	.0156	291	.85	4.8	58.1
.16	.0155	208	.0166	287	.84	5.0	61.2
.17	.0165	205	.0176	284	.83	5.2	64.3
.18	.0175	203	.0187	280	.82	5.4	67.3
.19	.0184	200	.0197	277	.81	5.6	70.4
.20	.0194	198		274	.80	5.8	73.4
.21	.0204	196		270	.79	6.0	76.5
.22	.0213	193		267	.78	6.2	79.6
.23	.0223	191		263	.77	6.4	82.6
.24	.0233	188		260	.76	6.6	85.7
.25	.0243	186		257	.75	6.8	88.7
.26	.0252	183		253	.74	7.0	91.8
.27	.0262	181		250	.73	7.2	94.9
.28	.0272	178		246	.72	7.4	97.9
.29	.0281	176		243	.71	7.6	101.0
.30	.0291	173		239	.70	7.8	104.0
						8.0	107.1
						8.2	110.2
						8.4	113.2
						8.6	116.3
						8.8	119.3
						9.0	122.4
						9.2	125.5
						9.4	128.5
						9.6	131.6
						9.8	134.6
						10.0	137.7
	max $\rho - \rho'$ = 0.0305		max $\rho - \rho'$ = 0.0197				

NOTES:

1. If $\rho - \rho'$ is less than value tabulated, compression steel does not yield. Flexure table B3 should be used to determine M_u.
2. Check deflections.

TABLE B2.2

25 MPa CONCRETE

COEFFICIENTS FOR RECTANGULAR SECTIONS WITH COMPRESSIVE REINFORCEMENT AND FOR T-SECTIONS WITH $h_f/d < a/d$

$a'_u = \phi f_y (1 - d'/d)$

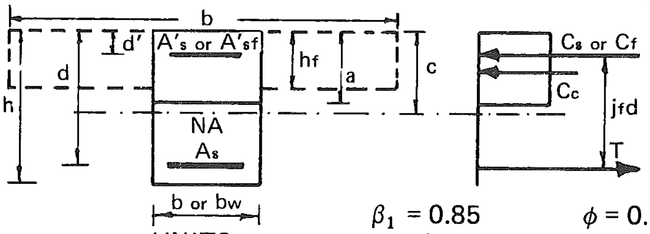
$a_{uf} = \phi f_y (1 - h_f/2d)$

$K_{uf} = \phi\, 0.85 f'_c \left(\frac{b}{b_w} - 1\right)$

$j_f = 1 - \frac{h_f}{2d}$

$\rho - \rho' = 0.85\beta_1 \frac{f'_c}{f_y} \frac{d'}{d} \frac{600}{600 - f_y}$

$\max(\rho - 0.75\rho_f) = 0.64\beta_1 \frac{f'_c}{f_y} \frac{600}{600 + f_y}$



$\beta_1 = 0.85$ $\phi = 0.90$

UNITS A'_s, A_{sf} — mm² f'_c — MPa
M_u — kNm f_y — MPa
d, b, b_w, h_f — mm

$f'_c = 25$ MPa

d'/d or $h_f/2d$	$f_y = 275$ MPa: $\rho - \rho'$	$f_y = 275$ MPa: a'_u or a_{uf}	$f_y = 380$ MPa: $\rho - \rho'$	$f_y = 380$ MPa: a'_u or a_{uf}	j_f	b/b_w	K_{uf}
.01	.0012	245	.0013	339	.99	2.0	19.1
.02	.0024	243	.0026	335	.98	2.2	23.0
.03	.0036	240	.0039	332	.97	2.4	26.8
.04	.0049	238	.0052	328	.96	2.6	30.6
.05	.0061	235	.0065	325	.95	2.8	34.4
.06	.0073	233	.0078	321	.94	3.0	38.3
.07	.0085	230	.0091	318	.93	3.2	42.1
.08	.0097	228	.0104	315	.92	3.4	45.9
.09	.0109	225	.0117	311	.91	3.6	49.7
.10	.0121	223	.0130	308	.90	3.8	53.6
.11	.0133	220	.0143	304	.89	4.0	57.4
.12	.0146	218	.0156	301	.88	4.2	61.2
.13	.0158	215	.0169	298	.87	4.4	65.0
.14	.0170	213	.0181	294	.86	4.6	68.9
.15	.0182	210	.0194	291	.85	4.8	72.7
.16	.0194	208	.0207	287	.84	5.0	76.5
.17	.0206	205	.0220	284	.83	5.2	80.3
.18	.0218	203	.0233	280	.82	5.4	84.1
.19	.0230	200	.0246	277	.81	5.6	88.0
.20	.0243	198		274	.80	5.8	91.8
.21	.0255	196		270	.79	6.0	95.6
.22	.0267	193		267	.78	6.2	99.5
.23	.0279	191		263	.77	6.4	103.3
.24	.0291	188		260	.76	6.6	107.1
.25	.0303	186		257	.75	6.8	110.9
.26	.0315	183		253	.74	7.0	114.8
.27	.0327	181		250	.73	7.2	118.6
.28	.0340	178		246	.72	7.4	122.4
.29	.0352	176		243	.71	7.6	126.2
.30	.0364	173		239	.70	7.8	130.1
						8.0	133.9
						8.2	137.7
						8.4	141.5
						8.6	145.4
						8.8	149.2
						9.0	153.0
						9.2	156.8
						9.4	160.7
						9.6	164.5
						9.8	168.3
						10.0	172.1
	max $\rho - \rho' = 0.0382$		max $\rho - \rho' = 0.0247$				

NOTES:

1. If $\rho - \rho'$ is less than value tabulated, compression steel does not yield. Flexure table B3 should be used to determine M_u.
2. Check deflections.

TABLE B2.3

30 MPa CONCRETE

COEFFICIENTS FOR RECTANGULAR SECTIONS WITH COMPRESSIVE REINFORCEMENT AND FOR T-SECTIONS WITH $h_f/d < a/d$

$a'_u = \phi f_y (1 - d'/d)$

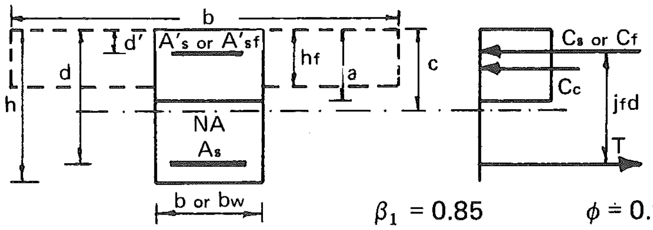
$a_{uf} = \phi f_y (1 - h_f/2d)$

$K_{uf} = \phi\, 0.85 f'_c \left(\frac{b}{b_w} - 1\right)$

$j_f = 1 - \frac{h_f}{2d}$

$\rho - \rho' = 0.85\beta_1 \frac{f'_c}{f_y} \frac{d'}{d} \frac{600}{600 - f_y}$

$\max(\rho - 0.75\rho_f) = 0.64\beta_1 \frac{f'_c}{f_y} \frac{600}{600 + f_y}$



$\beta_1 = 0.85$ $\phi \doteq 0.90$

UNITS A'_s, A_{sf} -- mm² f'_c -- MPa
M_u — kNm f_y — MPa
d, b, b_w, h_f — mm

$f'_c = 30$ MPa

d'/d or $h_f/2d$	$f_y = 275$ MPa		$f_y = 380$ MPa		j_f	b/b_w	K_{uf}
	$\rho - \rho'$	a'_u or a_{uf}	$\rho - \rho'$	a'_u or a_{uf}			
.01	.0015	245	.0016	339	.99	2.0	23.0
.02	.0029	243	.0031	335	.98	2.2	27.5
.03	.0044	240	.0047	332	.97	2.4	32.1
.04	.0058	238	.0062	328	.96	2.6	36.7
.05	.0073	235	.0078	325	.95	2.8	41.3
.06	.0087	233	.0093	321	.94	3.0	45.9
.07	.0102	230	.0109	218	.93	3.2	50.5
.08	.0116	228	.0124	315	.92	3.4	55.0
.09	.0131	225	.0140	311	.91	3.6	59.7
.10	.0146	223	.0156	308	.90	3.8	64.3
.11	.0160	220	.0171	304	.89	4.0	68.9
.12	.0175	218	.0187	301	.88	4.2	73.4
.13	.0189	215	.0202	298	.87	4.4	78.0
.14	.0204	213	.0218	294	.86	4.6	82.6
.15	.0218	210	.0233	291	.85	4.8	87.2
.16	.0233	208	.0249	287	.84	5.0	91.8
.17	.0247	205	.0264	284	.83	5.2	96.4
.18	.0262	203	.0280	280	.82	5.4	101.0
.19	.0276	200	.0296	277	.81	5.6	105.6
.20	.0291	198		274	.80	5.8	110.2
.21	.0306	196		270	.79	6.0	114.8
.22	.0320	193		267	.78	6.2	119.3
.23	.0335	191		263	.77	6.4	123.9
.24	.0349	188		260	.76	6.6	128.5
.25	.0364	186		257	.75	6.8	133.1
.26	.0378	183		253	.74	7.0	137.7
.27	.0393	181		250	.73	7.2	142.3
.28	.0407	178		246	.72	7.4	146.9
.29	.0422	176		243	.71	7.6	151.5
.30	.0437	173		239	.70	7.8	156.1
						8.0	160.7
						8.2	165.2
						8.4	169.8
						8.6	174.4
						8.8	179.0
						9.0	183.6
						9.2	188.2
						9.4	192.8
						9.6	197.4
						9.8	202.0
						10.0	206.6
	max $\rho - \rho' = 0.0458$		max $\rho - \rho' = 0.0296$				

NOTES:

1. If $\rho - \rho'$ is less than value tabulated, compression steel does not yield. Flexure table B3 should be used to determine M_u.
2. Check deflections.

TABLE B3

COEFFICIENTS a''_u FOR RECTANGULAR SECTIONS WITH COMPRESSIVE REINFORCEMENT, and a'_{uf} FOR T-SECTIONS (where compression reinforcement does not yield when $\epsilon_c = 0.003$)

$$a''_u = 600\,\phi\,(1 - d'/d)\left(1 - \frac{d'/d}{c/d}\right) \leqslant a'_u \qquad \phi = 0.90$$

$$a'_{uf} = 600\,\phi\,(1 - h_f/2d)\left(1 - \frac{h_f/2d}{c/d}\right) \geqslant a_{uf}$$

c/d	d'/d or hf/2d												c/d
	0.025	0.050	0.075	0.100	0.125	0.150	0.175	0.200	0.225	0.250	0.275	0.300	
.04	197												.04
.06	307	86											.06
.08	362	192	31										.08
.10		257	125										.10
.12		299	187	81									.12
.14		330	232	139	51								.14
.16		353	265	182	103	29							.16
.18		371	291	216	144	76	12						.18
.20			312	243	177	115	56						.20
.22			329	265	204	146	91	39					.22
.24			343	284	226	172	121	72	26				.24
.26			355	299	245	194	146	100	56	16			.26
.28			366	312	262	213	167	123	82	43	7		.28
.30				324	276	229	186	144	105	67	33		.30
.31				329	282	237	194	153	115	78	44	12	.31
.32				334	288	244	202	162	124	89	55	24	.32
.33				339	294	250	209	170	133	98	65	34	.33
.34				343	299	257	216	178	142	107	75	44	.34
.35				347	304	262	223	185	149	116	84	54	.35
.36				351	308	268	229	192	157	124	92	63	.36
.37				355	313	273	235	198	164	131	101	72	.37
.38					317	278	240	205	171	139	108	80	.38
.39					321	282	246	210	177	145	115	87	.39
.40					325	287	251	216	183	152	122	94	.40
.41					328	291	255	221	189	158	129	101	.41
.42					332	295	260	226	194	164	135	108	.42
.43					335	299	264	231	200	170	141	114	.43
.44					338	303	268	236	204	175	147	120	.44
.45					341	306	272	240	209	180	152	126	.45
.46					344	309	276	244	214	185	157	131	.46
.47						313	280	248	218	190	162	137	.47
.48						316	283	252	222	194	167	142	.48
.49						318	286	256	226	198	172	147	.49
.50						321	290	259	230	203	176	151	.50
.51						324	293	263	234	206	180	156	.51
.52						327	296	266	237	210	184	160	.52
.53						329	298	269	241	214	188	164	.53
.54						332	301	272	244	218	192	168	.54
.55						334	304	275	247	221	196	172	.55
.56						336	306	278	250	224	199	175	.56
.57							309	280	253	227	203	179	.57
.58							311	283	256	230	206	182	.58
.59							313	285	258	232	208	185	.59

Notes:

1) This table is used with Tables B2; for rectangular sections with compression reinforcement use the lesser value of a''_u or a'_u; for T beam sections use the lesser value of a'_{uf} or a_{uf} but use a_{uf} for development of overhanging flanges.

2) Values of a''_u or a'_{uf} not provided where a'_u and a_{uf} definitely control.

TABLE B4

VALUES OF M_{uc}/M_{uw} FOR DESIGN OF COMPRESSIVE REINFORCEMENT

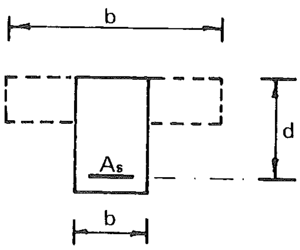
$$M_{uc}/M_{uw} = \frac{\left[\rho'(f'_s - 0.85\,f'_c)(1 - d'/d) + 0.85\,\beta_1 f'_c\,c/d\,\left(1 - \frac{\beta_1 c}{2d}\right)\right]}{\rho\,f_y\,(1 - \rho\,f_y/1.7\,f'_c)}$$

f'_c	f_y	ρ'/ρ ; ρ	d'/d = .05			d'/d = .10			d'/d = .15			d'/d = .20		
			0.2	0.6	1.0	0.2	0.6	1.0	0.2	0.6	1.0	0.2	0.6	1.0
20	275	.005	1.00	1.01	1.01	1.01	1.04	1.00	1.02	1.05	1.08	1.04	1.08	1.11
		.010	1.02	1.04	1.04	1.01	1.01	1.01	1.00	1.00	1.00	1.01	1.03	1.00
		.015	1.04	1.08	1.09	1.03	1.04	1.05	1.01	1.02	1.02	1.00	1.00	1.00
		.020	1.05	1.12	1.14	1.04	1.09	1.09	1.03	1.05	1.05	1.02	1.03	1.03
		.025	1.07	1.17	1.19	1.06	1.13	1.14	1.05	1.09	1.10	1.04	1.06	1.06
		.030	1.10	1.22	1.26	1.08	1.18	1.20	1.07	1.15	1.15	1.06	1.10	1.11
		.035												
		.040												
	380	.005	1.01	1.02	1.02	1.00	1.00	1.00	1.01	1.03	1.04	1.02	1.04	1.06
		.010	1.03	1.07	1.07	1.02	1.03	1.04	1.01	1.01	1.01	1.00	1.00	1.00
		.015	1.06	1.13	1.14	1.05	1.09	1.10	1.03	1.05	1.06	1.02	1.03	1.03
		.020												
		.025												
		.030												
		.035												
		.040												
25	275	.005	1.00	1.00	1.00	1.02	1.05	1.08	1.03	1.08	1.11	1.06	1.12	1.16
		.010	1.01	1.02	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.05	1.08
		.015	1.03	1.06	1.06	1.02	1.02	1.02	1.00	1.01	1.01	1.00	1.00	1.00
		.020	1.04	1.09	1.10	1.03	1.05	1.06	1.02	1.02	1.03	1.01	1.01	1.01
		.025	1.05	1.12	1.14	1.04	1.09	1.09	1.03	1.05	1.05	1.02	1.03	1.03
		.030	1.07	1.16	1.18	1.06	1.12	1.13	1.05	1.09	1.09	1.03	1.05	1.06
		.035	1.09	1.20	1.23	1.07	1.16	1.18	1.06	1.12	1.13	1.05	1.09	1.09
		.040												
	380	.005	1.00	1.01	1.01	1.00	1.00	1.00	1.02	1.04	1.06	1.03	1.07	1.09
		.010	1.02	1.05	1.05	1.01	1.02	1.02	1.00	1.00	1.00	1.00	1.00	1.00
		.015	1.04	1.09	1.10	1.03	1.05	1.06	1.02	1.03	1.03	1.01	1.01	1.01
		.020	1.06	1.14	1.16	1.05	1.10	1.11	1.04	1.06	1.07	1.02	1.04	1.04
		.025												
		.030												
		.035												
		.040												
30	275	.005	1.00	1.00	1.00	1.02	1.06	1.10	1.05	1.10	1.14	1.08	1.16	1.21
		.010	1.01	1.02	1.02	1.00	1.00	1.00	1.02	1.05	1.09	1.03	1.07	1.11
		.015	1.02	1.04	1.04	1.01	1.01	1.01	1.00	1.00	1.00	1.02	1.00	1.00
		.020	1.03	1.07	1.07	1.02	1.03	1.03	1.01	1.01	1.01	1.00	1.00	1.00
		.025	1.04	1.09	1.10	1.03	1.06	1.06	1.02	1.03	1.03	1.01	1.01	1.01
		.030	1.05	1.12	1.14	1.04	1.09	1.09	1.03	1.05	1.05	1.02	1.03	1.03
		.035	1.07	1.15	1.17	1.05	1.12	1.12	1.04	1.08	1.08	1.03	1.05	1.05
		.040	1.08	1.18	1.21	1.07	1.15	1.16	1.06	1.11	1.12	1.04	1.07	1.08
	380	.005	1.00	1.00	1.00	1.01	1.04	1.07	1.02	1.06	1.08	1.04	1.09	1.12
		.010	1.02	1.03	1.03	1.00	1.01	1.01	1.00	1.00	1.00	1.01	1.04	1.06
		.015	1.03	1.07	1.07	1.02	1.03	1.04	1.01	1.01	1.01	1.00	1.00	1.00
		.020	1.05	1.11	1.12	1.04	1.07	1.07	1.02	1.04	1.04	1.01	1.02	1.02
		.025	1.07	1.15	1.17	1.05	1.11	1.12	1.04	1.07	1.08	1.02	1.04	1.05
		.030												
		.035												
		.040												

NOTE: M_{uc} is the capacity of the section with compressive reinforcement
M_{uw} is capacity of same section without compressive reinforcement

TABLE B.5 100 – 400 mm width
COEFFICIENT F FOR RESISTING MOMENTS OF RECTANGULAR OR T-SECTIONS

$F = bd^2$ mm^3
Note: F = tabulated value x 10^6



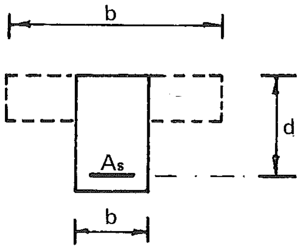
d	b = width of compression face 100 – 400 mm						
	100	150	200	250	300	350	400
150	2.3	3.4	4.5	5.6	6.8	7.9	9.0
175	3.1	4.6	6.1	7.7	9.2	10.7	12.3
200	4.0	6.0	8.0	10.0	12.0	14.0	16.0
225	5.1	7.6	10.1	12.7	15.2	17.7	20.3
250	6.3	9.4	12.5	15.6	18.8	21.9	25.0
275	7.6	11.3	15.1	18.9	22.7	26.5	30.3
300	9.0	13.5	18.0	22.5	27.0	31.5	36.0
325	10.6	15.8	21.1	26.4	31.7	37.0	42.3
350	12.3	18.4	24.5	30.6	36.8	42.9	49.0
375	14.1	21.1	28.1	35.2	42.2	49.2	56.3
400	16.0	24.0	32.0	40.0	48.0	56.0	64.0
425	18.1	27.1	36.1	45.2	54.2	63.2	72.3
450	20.3	30.4	40.5	50.6	60.8	70.9	81.0
475	22.6	33.8	45.1	56.4	67.7	79.0	90.3
500	25.0	37.5	50.0	62.5	75.0	87.5	100.0
525	27.6	41.3	55.1	68.9	82.7	96.5	110.3
550	30.3	45.4	60.5	75.6	90.8	105.9	121.0
575	33.1	49.6	66.1	82.7	99.2	115.7	132.3
600	36.0	54.0	72.0	90.0	108.0	126.0	144.0
625	39.1	58.6	78.1	97.7	117.2	136.7	156.3
650	42.3	63.4	84.5	105.6	126.8	147.9	169.0
675	45.6	68.3	91.1	113.9	136.7	159.5	182.3
700	49.0	73.5	98.0	122.5	147.0	171.5	196.0
725	52.6	78.8	105.1	131.4	157.7	184.0	210.3
750	56.3	84.4	112.5	140.6	168.8	196.9	225.0
775	60.1	90.1	120.1	150.2	180.2	210.2	240.3
800	64.0	96.0	128.0	160.0	192.0	224.0	256.0
825	68.1	102.1	136.1	170.2	204.2	238.2	272.3
850	72.3	108.4	144.5	180.6	216.8	252.9	289.0
875	76.6	114.8	153.1	191.4	229.7	268.0	306.3
900	81.0	121.5	162.0	202.5	243.0	283.5	324.0
925	85.6	128.3	171.1	213.9	256.7	299.5	342.3
950	90.3	135.4	180.5	225.6	270.8	315.9	361.0
975	95.1	142.6	190.1	237.7	285.2	332.7	380.3
1 000	100.0	150.0	200.0	250.0	300.0	350.0	400.0
1 025	105.1	157.6	210.1	262.7	315.2	367.7	420.3
1 050	110.3	165.4	220.5	275.6	330.8	385.9	441.0
1 075	115.6	173.3	231.1	288.9	346.7	404.5	462.3
1 100	121.0	181.5	242.0	302.5	363.0	423.5	484.0
1 125	126.6	189.8	253.1	316.4	379.7	443.0	506.3
1 150	132.3	198.4	264.5	330.6	396.8	462.9	529.0
1 175	138.1	207.1	276.1	345.2	414.2	483.2	552.3
1 200	144.0	216.0	288.0	360.0	432.0	504.0	576.0
1 225	150.1	255.1	300.1	375.2	450.2	525.2	600.3
1 250	156.3	234.4	312.5	390.6	468.8	546.9	625.0
1 275	162.6	243.8	325.1	406.4	487.7	569.0	650.3
1 300	169.0	253.5	338.0	422.5	507.0	591.5	676.0
1 325	175.6	263.3	351.1	438.9	526.7	614.5	702.3
1 350	182.3	273.4	364.5	455.6	546.8	637.9	729.0
1 375	189.1	283.6	378.1	472.7	567.2	661.7	756.3
1 400	196.0	294.0	392.0	490.0	588.0	686.0	784.0
1 425	203.1	304.6	406.1	507.7	609.2	710.7	812.3
1 450	210.3	315.4	420.5	525.6	630.8	735.9	841.0
1 475	217.6	326.3	435.1	543.9	652.7	761.5	870.3
1 500	225.0	337.5	450.0	562.5	675.0	787.5	900.0

continued ...

TABLE B.5 Cont. 450 — 1000 mm width

COEFFICIENT F FOR RESISTING MOMENTS OF RECTANGULAR ORIT-SECTIONS

$F = bd^2$ mm^3
Note: F = tabulated value x 10^6



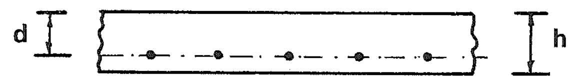
d	b = width of compression face 450 — 1000 mm						
	450	500	600	700	800	900	1000
150	10.1	11.3	13.5	15.8	18.0	20.3	22.5
175	13.8	15.3	18.4	21.4	24.5	27.6	30.6
200	18.0	20.0	24.0	28.0	32.0	36.0	40.0
225	22.8	25.3	30.4	35.4	40.5	45.6	50.6
250	28.1	31.3	37.5	43.8	50.0	56.3	62.5
275	34.0	37.8	45.4	52.9	60.5	68.1	75.6
300	40.5	45.0	54.0	63.0	72.0	81.0	90.0
325	47.5	52.8	63.4	73.9	84.5	95.1	105.6
350	55.1	61.3	73.5	85.8	98.0	110.3	122.5
375	63.3	70.3	84.4	98.4	112.5	126.6	140.6
400	72.0	80.0	96.0	112.0	128.0	144.0	160.0
425	81.3	90.3	108.4	126.4	144.5	162.6	180.6
450	91.1	101.3	121.5	141.8	162.0	182.3	202.5
475	101.5	112.8	135.4	157.9	180.5	203.1	225.6
500	112.5	125.0	150.0	175.0	200.0	225.0	250.0
525	124.0	137.8	165.4	192.9	220.5	248.1	275.6
550	136.1	151.3	181.5	211.8	242.0	272.3	302.5
575	148.8	165.3	198.4	231.4	264.5	297.6	330.6
600	162.0	180.0	216.0	252.0	288.0	324.0	360.0
625	175.8	195.3	234.4	273.4	312.5	351.6	390.6
650	190.1	211.3	253.5	295.8	338.0	380.3	422.5
675	205.0	227.8	273.4	318.9	364.5	410.1	455.6
700	220.5	245.0	294.0	343.0	392.0	441.0	490.0
725	236.5	262.8	315.4	367.9	420.5	473.1	525.6
750	253.1	281.3	337.5	393.8	450.0	506.3	562.5
775	270.3	300.3	360.4	420.4	480.5	540.6	600.6
800	288.0	320.0	384.0	448.0	512.0	576.0	640.0
825	306.3	340.3	408.4	476.4	544.5	612.6	680.6
850	325.1	361.3	433.5	505.8	578.0	650.3	722.5
875	344.5	382.8	459.4	535.9	612.5	689.1	765.6
900	364.5	405.0	486.0	567.0	648.0	729.0	810.0
925	385.0	427.8	513.4	598.9	684.5	770.1	855.6
950	406.1	451.3	541.5	631.8	722.0	812.3	902.5
975	427.8	475.3	570.4	665.4	760.5	855.6	950.6
1 000	450.0	500.0	600.0	700.0	800.0	900.0	1 000.0
1 025	472.8	525.3	630.4	735.4	840.5	945.6	1 050.6
1 050	496.1	551.3	661.5	771.8	882.0	992.3	1 102.5
1 075	520.0	577.8	693.4	808.9	924.5	1 040.1	1 155.6
1 100	544.5	605.0	726.0	847.0	968.0	1 089.0	1 210.0
1 125	569.5	632.8	759.4	885.9	1 012.5	1 139.1	1 265.6
1 150	595.1	661.3	793.5	925.8	1 058.0	1 190.3	1 322.5
1 175	621.3	690.3	828.4	966.4	1 104.5	1 242.6	1 380.6
1 200	648.0	720.0	864.0	1 008.0	1 152.0	1 296.0	1 440.0
1 225	675.3	750.3	900.4	1 050.4	1.200.5	1 350.6	1 500.6
1 250	703.1	781.3	937.5	1 093.8	1 250.0	1 406.3	1 562.5
1 275	731.5	812.8	975.4	1 137.9	1 300.5	1 463.1	1 625.6
1 300	760.5	845.0	1 014.0	1 183.0	1 352.0	1 521.0	1 690.0
1 325	790.0	877.8	1 053.4	1 228.9	1 404.5	1 580.1	1 755.6
1 350	820.1	911.3	1 093.5	1 275.8	1 458.0	1 640.3	1 822.5
1 375	850.8	945.3	1 134.4	1 323.4	1 512.5	1 701.6	1 890.6
1 400	882.0	980.0	1 176.0	1 372.0	1 568.0	1 764.0	1 960.0
1 425	913.8	1 015.3	1 218.4	1 421.4	1 624.5	1 827.6	2 030.6
1 450	946.1	1 051.3	1 261.5	1 471.8	1 682.0	1 892.3	2 102.5
1 475	979.0	1 087.8	1 305.4	1 522.9	1 740.5	1 958.1	2 175.6
1 500	1 012.5	1 125.0	1 350.0	1 575.0	1 800.0	2 025.0	2 250.0

TABLE B6.1 RESISTING MOMENTS M kNm FOR SECTIONS 1000 mm WIDE

$f_y = 275$ MPa

$M = \phi\, b\, d^2\, f'_c\, \omega\, (1 - 0.59\, \omega)$

NOTE: for h – d = 30 mm, listed d values lead to preferred h dimensions



f'c	ρ	Effective depth d (mm) 45	58	70	83	95	108	120	145	170	195	220	245	270	295	320
20 MPa	.002	1.0	1.6	2.4	3.3	4.4	5.6	7.0	10.2	14.1	18.5	23.6	29.2	35.5	42.4	49.9
	.003	1.5	2.4	3.5	4.9	6.5	8.4	10.4	15.2	20.9	27.5	35.1	43.5	52.8	63.0	74.2
	.004	1.9	3.2	4.7	6.5	8.6	11.1	13.8	20.1	27.7	36.4	46.4	57.5	69.8	83.4	98.1
	.005	2.4	3.9	5.8	8.1	10.7	13.7	17.1	25.0	34.3	45.1	57.5	71.3	86.6	103.3	121.6
	.006	2.9	4.7	6.9	9.6	12.7	16.3	20.3	29.7	40.8	53.7	68.4	84.8	103.0	122.9	144.7
	.007	3.3	5.4	8.0	11.1	14.7	18.9	23.5	34.4	47.2	62.1	79.1	98.1	119.1	142.2	167.3
	.008	3.7	6.1	9.1	12.6	16.7	21.4	26.7	38.9	53.5	70.4	89.6	111.1	135.0	161.1	189.6
	.009	4.2	6.8	10.1	14.1	18.6	23.9	29.7	43.4	59.7	78.5	99.9	123.9	150.5	179.7	211.4
	.010	4.6	7.5	11.1	15.5	20.5	26.3	32.7	47.8	65.7	86.5	110.1	136.5	165.8	197.9	232.9
	.011	5.0	8.2	12.1	16.9	22.4	28.7	35.7	52.1	71.7	94.3	120.0	148.8	180.8	215.8	253.9
	.012	5.4	8.9	13.1	18.2	24.2	31.0	38.6	56.4	77.5	101.9	129.8	160.9	195.4	233.3	274.5
	.013	5.8	9.5	14.1	19.6	26.0	33.3	41.4	60.5	83.2	109.4	139.3	172.8	209.8	250.5	294.7
	.014	6.2	10.2	15.1	20.9	27.7	35.5	44.2	64.6	88.8	116.8	148.7	184.4	223.9	267.3	314.5
	.015	6.6	10.8	16.0	22.2	29.4	37.7	47.0	68.6	94.2	124.0	157.8	195.7	237.7	283.8	333.9
	.016	7.0	11.4	16.9	23.5	31.1	39.8	49.6	72.5	99.6	131.0	166.8	206.8	251.2	299.9	352.9
	.017	7.3	12.0	17.8	24.7	32.7	41.9	52.2	76.3	104.8	137.9	175.6	217.7	264.4	315.7	371.4
	.018	7.7	12.6	18.6	25.9	34.3	44.0	54.8	80.0	109.9	144.7	184.1	228.4	277.3	331.1	389.6
	.019	8.1	13.2	19.5	27.1	35.9	46.0	57.3	83.6	115.0	151.3	192.5	238.8	290.0	346.2	407.3
	.020	8.4	13.7	20.3	28.2	37.4	47.9	59.7	87.2	119.8	157.7	200.7	248.9	302.3	360.9	424.6
	.021	8.7	14.3	21.1	29.3	38.9	49.8	62.1	90.7	124.6	164.0	208.7	258.8	314.3	375.3	441.6
	.022	9.1	14.8	21.9	30.4	40.4	51.7	64.4	94.0	129.3	170.1	216.5	268.5	326.1	389.3	458.1
	.023	9.4	15.3	22.7	31.5	41.8	53.5	66.7	97.4	133.8	176.1	224.1	277.9	337.6	403.0	474.1
	.024	9.7	15.8	23.4	32.6	43.2	55.3	68.9	100.6	138.2	181.9	231.5	287.1	348.7	416.3	489.8
	.025	10.0	16.3	24.2	33.6	44.5	57.0	71.0	103.7	142.6	187.6	238.7	296.1	359.6	429.3	505.1
	.026	10.3	16.8	24.9	34.6	45.8	58.7	73.1	106.8	146.7	193.1	245.8	304.8	370.2	441.9	520.0
	.027	10.6	17.3	25.6	35.5	47.1	60.3	75.2	109.7	150.8	198.4	252.6	313.3	380.4	454.2	534.4

TABLE B6.1 Cont.

f_y = 275 MPa

f'c	ρ	Effective depth d (mm)														
		45	58	70	83	95	108	120	145	170	195	220	245	270	295	320
25 MPa	.002	1.0	1.6	2.4	3.3	4.4	5.6	7.0	10.3	14.1	18.6	23.6	29.3	35.6	42.5	50.0
	.003	1.5	2.4	3.6	5.0	6.6	8.4	10.5	15.3	21.0	27.7	35.2	43.7	53.1	63.4	74.6
	.004	2.0	3.2	4.7	6.6	8.7	11.1	13.9	20.3	27.9	36.7	46.7	57.9	70.3	83.9	98.7
	.005	2.4	4.0	5.9	8.1	10.8	13.8	17.2	25.2	34.6	45.5	58.0	71.9	87.3	104.2	122.6
	.006	2.9	4.7	7.0	9.7	12.9	16.5	20.6	30.0	41.2	54.3	69.1	85.7	104.0	124.2	146.1
	.007	3.3	5.5	8.1	11.3	14.9	19.1	23.8	34.8	47.8	62.9	80.0	99.3	120.6	143.9	169.3
	.008	3.8	6.2	9.2	12.8	16.9	21.7	27.0	39.5	54.3	71.4	90.9	112.7	136.8	163.4	192.2
	.009	4.2	6.9	10.3	14.3	18.9	24.2	30.2	44.1	60.6	79.8	101.5	125.9	152.9	182.5	214.8
	.010	4.7	7.7	11.3	15.8	20.9	26.7	33.3	48.7	66.9	88.0	112.0	138.9	168.7	201.4	237.0
	.011	5.1	8.4	12.4	17.2	22.8	29.2	36.4	53.2	73.1	96.1	122.4	151.8	184.3	220.0	258.9
	.012	5.5	9.1	13.4	18.6	24.7	31.6	39.4	57.6	79.1	104.1	132.6	164.4	199.7	238.3	280.4
	.013	6.0	9.7	14.4	20.1	26.6	34.0	42.4	61.9	85.1	112.0	142.6	176.8	214.8	256.4	301.7
	.014	6.4	10.4	15.4	21.4	28.4	36.4	45.4	66.2	91.0	119.8	152.5	189.1	229.6	274.1	322.6
	.015	6.8	11.1	16.4	22.8	30.2	38.7	48.3	70.5	96.8	127.4	162.2	201.1	244.3	291.6	343.2
	.016	7.2	11.7	17.4	24.2	32.0	41.0	51.1	74.6	102.6	134.9	171.8	213.0	258.7	308.8	363.4
	.017	7.6	12.4	18.3	25.5	33.8	43.3	53.9	78.7	108.2	142.3	181.2	224.7	272.9	325.8	383.3
	.018	8.0	13.0	19.3	26.8	35.5	45.5	56.7	82.7	113.7	149.6	190.4	236.2	286.8	342.4	402.9
	.019	8.3	13.6	20.2	28.1	37.2	47.6	59.4	86.7	119.1	156.8	199.5	247.5	300.5	358.8	422.2
	.020	8.7	14.2	21.1	29.3	38.9	49.8	62.0	90.6	124.5	163.8	208.5	258.6	314.0	374.9	441.1
	.021	9.1	14.8	22.0	30.6	40.5	51.9	64.6	94.4	129.7	170.7	217.3	269.5	327.3	390.7	459.7
	.022	9.5	15.4	22.9	31.8	42.1	53.9	67.2	98.1	134.9	177.5	225.9	280.2	340.3	406.2	478.0
	.023	9.8	16.0	23.7	33.0	43.7	56.0	69.7	101.8	140.0	184.1	234.4	290.7	353.0	421.4	495.9
	.024	10.2	16.6	24.6	34.1	45.3	58.0	72.2	105.4	144.9	190.7	242.7	301.0	365.6	436.4	513.5
	.025	10.5	17.1	25.4	35.3	46.8	59.9	74.6	109.0	149.8	197.1	250.9	311.1	377.9	451.1	530.8
	.026	10.8	17.7	26.2	36.4	48.3	61.8	77.0	112.5	154.6	203.4	258.9	321.1	390.0	465.5	547.8
	.027	11.2	18.2	27.0	37.5	49.7	63.7	79.4	115.9	159.3	209.6	266.8	330.8	401.8	479.6	564.4
	.028	11.5	18.7	27.8	38.6	51.2	65.5	81.7	119.2	163.9	215.6	274.5	340.4	413.4	493.5	580.7
	.029	11.8	19.3	28.6	39.7	52.6	67.3	83.9	122.5	168.4	221.6	282.0	349.7	424.8	507.1	596.6
	.030	12.1	19.8	29.3	40.7	54.0	69.1	86.1	125.7	172.8	227.4	289.4	358.9	435.9	520.4	612.3
	.031	12.4	20.3	30.0	41.7	55.3	70.8	88.3	128.9	177.1	233.1	296.6	367.9	446.8	533.4	627.6
	.032	12.7	20.7	30.7	42.7	56.6	72.5	90.4	131.9	181.4	238.6	303.7	376.7	457.5	546.1	642.6
	.033	13.0	21.2	31.4	43.7	57.9	74.2	92.4	134.9	185.5	244.1	310.6	385.3	467.9	558.5	657.2
	.034	13.3	21.7	32.1	44.6	59.2	75.8	94.4	137.9	189.5	249.4	317.4	393.7	478.1	570.7	671.6

TABLE B6.1 Cont.

f_y = 275 MPa

f'c	ρ	45	58	70	83	95	108	120	145	170	195	220	245	270	295	320
		Effective depth d (mm)														
30 MPa	.002	1.0	1.6	2.4	3.3	4.4	5.7	7.1	10.3	14.2	18.6	23.7	29.4	35.7	42.6	50.1
	.003	1.5	2.4	3.6	5.0	6.6	8.4	10.5	15.4	21.1	27.8	35.4	43.8	53.3	63.6	74.8
	.004	2.0	3.2	4.7	6.6	8.7	11.2	13.9	20.4	28.0	36.8	46.9	58.1	76.6	84.3	99.2
	.005	2.4	4.0	5.9	8.2	10.9	13.9	17.3	25.3	34.8	45.8	58.3	72.3	87.8	104.8	123.3
	.006	2.9	4.8	7.0	9.8	13.0	16.6	20.7	30.2	41.5	54.6	69.5	86.2	104.7	125.0	147.1
	.007	3.4	5.5	8.2	11.3	15.0	19.3	24.0	35.0	48.2	63.4	80.7	100.1	121.5	145.1	170.7
	.008	3.8	6.3	9.3	12.9	17.1	21.9	27.3	39.8	54.7	72.0	91.7	113.7	138.1	164.9	194.0
	.009	4.3	7.0	10.4	14.4	19.1	24.5	30.5	44.6	61.2	80.6	102.6	127.2	154.5	184.4	217.0
	.010	4.7	7.7	11.5	15.9	21.1	27.1	33.7	49.2	67.7	89.0	113.3	140.5	176.7	203.7	239.7
	.011	5.2	8.5	12.5	17.4	23.1	29.6	36.9	53.8	74.0	97.4	123.9	153.7	186.7	222.8	262.2
	.012	5.6	9.2	13.6	18.9	25.1	32.1	40.0	58.4	80.3	105.6	134.4	166.7	202.5	241.7	284.4
	.013	6.1	9.9	14.7	20.4	27.0	34.6	43.1	62.9	86.4	113.7	144.8	179.6	218.1	260.3	306.3
	.014	6.5	10.6	15.7	21.8	28.9	37.0	46.1	67.3	92.6	121.8	155.0	192.2	233.5	278.7	328.0
	.015	6.9	11.3	16.7	23.2	30.8	39.4	49.1	71.7	98.6	129.7	165.1	204.8	248.7	296.9	349.3
	.016	7.3	12.0	17.7	24.6	32.6	41.8	52.1	76.1	104.5	137.5	175.1	217.1	263.7	314.8	370.4
	.017	7.7	12.6	18.7	26.0	34.5	44.2	55.0	80.3	110.4	145.3	184.9	229.3	278.5	332.5	391.2
	.018	8.1	13.3	19.7	27.4	36.3	46.5	57.9	84.5	116.2	152.9	194.6	241.4	293.2	350.0	411.8
	.019	8.5	13.9	20.7	28.7	38.1	48.8	60.8	88.7	121.9	160.4	204.2	253.3	307.6	367.2	432.1
	.020	8.9	14.6	21.6	30.0	39.8	51.0	63.6	92.8	127.6	167.9	213.7	265.0	321.8	384.2	452.1
	.021	9.3	15.2	22.6	31.4	41.6	53.2	66.3	96.9	133.1	175.2	223.0	276.5	335.9	400.9	471.8
	.022	9.7	15.9	23.5	32.7	43.3	55.4	69.1	100.9	138.6	182.4	232.2	287.9	349.7	417.5	491.2
	.023	10.1	16.5	24.4	33.9	45.0	57.6	71.8	104.8	144.0	189.5	241.2	299.2	363.4	433.8	510.4
	.024	10.5	17.1	25.3	35.2	46.7	59.7	74.4	108.7	149.4	196.6	250.2	310.3	376.8	449.8	529.3
	.025	10.8	17.7	26.2	36.4	48.3	61.8	77.1	112.5	154.6	203.5	259.0	321.2	396.1	465.7	547.9
	.026	11.2	18.3	27.1	37.6	49.9	63.9	79.6	116.3	159.8	210.3	267.7	331.9	403.1	481.3	566.3
	.027	11.6	18.9	28.0	38.8	51.5	65.9	82.2	120.0	164.9	217.0	276.2	342.5	416.0	496.6	584.4
	.028	11.9	19.4	28.8	40.0	53.1	68.0	84.7	123.6	169.9	223.6	284.6	353.0	428.7	511.8	602.2
	.029	12.3	20.0	29.7	41.2	54.6	69.9	87.1	127.2	174.9	230.1	292.9	363.3	441.2	526.7	619.7
	.030	12.6	20.6	30.5	42.3	56.1	71.9	89.6	130.8	179.8	236.5	301.1	373.4	453.5	541.3	637.0
	.031	12.9	21.1	31.3	43.5	57.6	73.8	92.0	134.3	184.6	242.8	309.1	383.3	465.5	555.8	653.9
	.032	13.3	21.7	32.1	44.6	59.1	75.7	94.3	137.7	189.3	249.0	317.0	393.1	477.4	570.0	670.6
	.033	13.6	22.2	32.9	45.7	60.6	77.5	96.6	141.1	193.9	255.1	324.8	402.8	489.1	583.9	687.1
	.034	13.9	22.7	33.7	46.7	62.0	79.4	98.9	144.4	198.5	261.1	332.4	412.2	500.6	597.7	703.2
	.035	14.2	23.2	34.4	47.8	63.4	81.2	101.1	147.7	203.0	267.0	339.9	421.5	512.0	611.2	719.1
	.036	14.5	23.7	35.2	48.8	64.8	82.9	103.3	150.9	207.4	272.8	347.3	430.7	523.1	624.4	734.7
	.037	14.8	24.2	35.9	49.9	66.1	84.6	105.5	154.0	211.7	278.5	354.5	439.7	534.0	637.5	750.1
	.038	15.1	24.7	36.6	50.9	67.4	86.3	107.6	157.1	215.9	284.1	361.7	448.5	544.7	650.3	765.1
	.039	15.4	25.2	37.3	51.8	68.7	88.0	109.7	160.1	220.1	289.6	368.6	457.2	555.2	662.8	779.9
	.040	15.7	25.7	38.0	52.8	70.0	89.7	111.7	163.1	224.2	295.0	375.5	465.7	565.6	675.2	794.4
	.041	16.0	26.1	38.7	53.8	71.3	91.3	113.7	166.0	228.2	300.3	382.2	474.0	575.7	687.3	808.7

TABLE B6.2 RESISTING MOMENTS M kNm FOR SECTIONS 1000 mm WIDE

f_y = 380 MPa

$M = \phi b d^2 f'_c \omega (1 - 0.59 \omega)$

NOTE: for h – d = 30 mm, listed d values lead to preferred h dimensions

f'c	ρ	45	58	70	83	95	108	120	145	170	195	220	245	270	295	320
		Effective depth d (mm)														
20 MPa	.002	1.4	2.2	3.3	4.6	6.0	7.7	9.6	14.1	19.3	25.4	32.4	40.1	48.7	58.2	68.5
	.003	2.0	3.3	4.9	6.7	8.9	11.5	14.3	20.8	28.7	37.7	48.0	59.5	72.3	86.3	101.5
	.004	2.6	4.3	6.4	8.9	11.8	15.1	18.8	27.5	37.8	49.7	63.2	78.4	95.3	113.7	133.8
	.005	3.3	5.3	7.9	11.0	14.6	18.7	23.2	33.9	46.6	61.4	78.1	96.9	117.7	140.5	165.3
	.006	3.9	6.3	9.4	13.0	17.3	22.1	27.6	40.2	55.3	72.8	92.6	114.9	139.5	166.6	196.0
	.007	4.5	7.3	10.8	15.0	19.9	25.5	31.8	46.4	63.8	83.9	106.8	132.4	160.8	192.0	225.9
	.008	5.0	8.2	12.2	17.0	22.5	28.8	35.9	52.4	72.0	94.7	120.5	149.5	181.6	216.7	255.0
	.009	5.6	9.1	13.6	18.8	25.0	32.0	39.9	58.2	80.0	105.2	133.9	166.1	201.7	240.8	283.4
	.010	6.1	10.0	14.9	20.7	27.4	35.1	43.7	63.8	87.8	115.5	147.0	182.3	221.4	264.3	310.9
	.011	6.7	10.9	16.2	22.4	29.8	38.1	47.5	69.3	95.3	125.4	159.6	198.0	240.4	287.0	337.7
	.012	7.2	11.7	17.4	24.2	32.1	41.0	51.1	74.7	102.7	135.1	171.9	213.2	258.9	309.1	363.7
	.013	7.7	12.6	18.6	25.9	34.3	43.9	54.7	79.9	109.8	144.4	183.8	228.0	276.9	330.5	388.9
	.014	8.2	13.3	19.8	27.5	36.4	46.6	58.1	84.9	116.7	153.5	195.4	242.3	294.3	351.3	413.3
	.015	8.6	14.1	20.9	29.0	38.5	49.3	61.5	89.7	123.3	162.3	206.5	256.2	311.1	371.4	437.0
	.016	9.1	14.8	22.0	30.6	40.5	51.9	64.7	94.4	129.8	170.8	217.3	269.5	327.4	390.8	459.8
	.017	9.5	15.6	23.1	32.0	42.5	54.4	67.8	98.9	136.0	178.9	227.8	282.5	343.1	409.5	481.9
25 MPa	.002	1.4	2.2	3.3	4.6	6.1	7.8	9.7	14.1	19.4	25.5	32.5	40.3	49.0	58.5	68.8
	.003	2.0	3.3	4.9	6.8	9.0	11.5	14.4	21.0	28.9	38.0	48.3	59.9	72.8	86.9	102.2
	.004	2.7	4.4	6.5	9.0	11.9	15.2	19.0	27.7	38.1	50.2	63.8	79.2	96.1	114.8	135.1
	.005	3.3	5.4	8.0	11.1	14.7	18.9	23.5	34.3	47.2	62.1	79.1	98.0	119.1	142.1	167.3
	.006	3.9	6.4	9.5	13.2	17.5	22.4	28.0	40.8	56.1	73.8	94.0	116.5	141.5	169.0	198.8
	.007	4.5	7.4	11.0	15.3	20.2	25.9	32.3	47.2	64.8	85.3	108.6	134.7	163.6	195.3	229.8
	.008	5.1	8.4	12.4	17.3	22.9	29.3	36.6	53.4	73.4	96.6	122.9	152.4	185.1	221.0	260.1
	.009	5.7	9.4	13.9	19.3	25.5	32.7	40.7	59.5	81.8	107.6	137.0	169.8	206.3	246.2	289.7
	.010	6.3	10.3	15.3	21.2	28.1	36.0	44.8	65.5	90.0	118.4	150.7	186.9	227.0	270.9	318.0
	.011	6.9	11.2	16.6	23.1	30.6	39.2	48.8	71.3	98.0	128.9	164.1	203.5	247.2	295.1	347.2
	.012	7.4	12.1	17.9	24.9	33.1	42.3	52.7	77.0	105.8	139.3	177.3	219.8	267.0	318.7	375.0

continued ...

ENG.CCANZ.0002.36

TABLE B6.2 Cont.

f_y = 380 MPa

		Effective depth d (mm)														
f′c	ρ	45	58	70	83	95	108	120	145	170	195	220	245	270	295	320
Cont.	.013	8.0	13.0	19.2	26.7	35.4	45.4	56.6	82.6	113.5	149.3	190.1	235.8	286.3	341.8	402.2
	.014	8.5	13.8	20.5	28.5	37.8	48.4	60.3	88.0	121.0	159.2	202.6	251.3	305.2	364.4	428.7
	.015	9.0	14.7	21.8	30.2	40.1	51.3	63.9	93.3	128.3	168.8	214.9	266.5	323.7	386.4	454.6
25 MPa	.016	9.5	15.5	23.0	31.9	42.3	54.2	67.5	98.5	135.4	178.2	226.8	281.3	341.7	407.9	479.9
	.017	10.0	16.3	24.1	33.5	44.5	56.9	71.0	103.6	142.4	187.4	238.5	295.8	359.2	428.8	504.6
	.018	10.5	17.1	25.3	35.1	46.6	59.7	74.3	108.5	149.2	196.3	249.9	309.9	376.3	449.2	528.6
	.019	10.9	17.8	26.4	36.7	48.7	62.3	77.6	113.3	155.8	205.0	260.9	323.6	393.0	469.1	552.0
	.020	11.4	18.6	27.5	38.2	50.7	64.9	80.8	118.0	162.2	213.4	271.7	336.9	409.2	488.5	574.8
	.021	11.8	19.3	28.6	39.7	52.6	67.4	83.9	122.6	168.5	221.7	282.1	349.9	425.0	507.3	596.9
	.022	12.2	20.0	29.6	41.1	54.5	69.8	87.0	127.0	174.5	229.7	292.3	362.5	446.3	525.6	618.4
	.002	1.4	2.2	3.3	4.6	6.1	7.8	9.7	14.2	19.5	25.6	32.6	40.4	49.1	58.6	69.0
	.003	2.0	3.3	4.9	6.8	9.1	11.6	14.4	21.1	29.0	38.1	48.5	60.2	73.1	87.3	102.7
	.004	2.7	4.4	6.5	9.0	12.0	15.3	19.1	27.9	38.4	50.5	64.2	79.7	96.7	115.5	135.9
	.005	3.3	5.4	8.1	11.2	14.9	19.0	23.7	34.6	47.6	62.6	79.7	98.8	120.0	143.3	168.6
	.006	4.0	6.5	9.6	13.3	17.7	22.7	28.2	41.2	56.6	74.5	94.9	117.6	142.9	170.6	200.7
	.007	4.6	7.5	11.1	15.4	20.5	26.2	32.7	47.7	65.6	86.3	109.8	136.2	165.4	197.4	232.3
	.008	5.2	8.5	12.6	17.5	23.2	29.7	37.0	54.1	74.3	97.8	124.5	154.4	187.5	223.9	263.4
	.009	5.8	9.5	14.1	19.5	25.9	33.2	41.3	60.4	83.0	109.2	139.0	172.3	209.3	249.8	294.0
	.010	6.4	10.5	15.5	21.5	28.6	36.6	45.6	66.5	91.5	120.3	153.2	189.9	230.7	275.4	324.0
	.011	7.0	11.4	16.9	23.5	31.2	39.9	49.7	72.6	99.8	131.3	167.1	207.3	251.7	300.5	353.6
	.012	7.6	12.4	18.3	25.4	33.7	43.2	53.8	78.5	108.0	142.1	180.8	224.3	272.4	325.1	382.6
30 MPa	.013	8.1	13.3	19.7	27.3	36.2	46.4	57.8	84.4	116.0	152.6	194.3	240.9	292.6	349.3	411.0
	.014	8.7	14.2	21.0	29.2	38.7	49.5	61.7	90.1	123.9	163.0	207.5	257.3	312.5	373.1	439.0
	.015	9.2	15.1	22.3	31.0	41.1	52.6	65.6	95.8	131.6	173.2	220.5	273.4	332.1	396.4	466.4
	.016	9.8	15.9	23.6	32.8	43.5	55.7	69.4	101.3	139.2	183.2	233.2	289.2	351.2	419.3	493.3
	.017	10.3	16.8	24.9	34.5	45.8	58.7	73.1	106.7	146.7	193.0	245.6	304.6	370.0	441.7	519.7
	.018	10.8	17.6	26.1	36.3	48.1	61.6	76.7	112.0	154.0	202.6	257.9	319.8	388.4	463.7	545.6
	.019	11.3	18.4	27.3	37.9	50.3	64.4	80.3	117.2	161.1	212.0	269.8	334.7	406.4	485.2	570.9
	.020	11.8	19.2	28.5	39.6	52.5	67.2	83.8	122.3	168.1	221.2	281.6	349.2	424.1	506.3	595.7
	.021	12.3	20.0	29.7	41.2	54.6	70.0	87.2	127.3	175.0	230.2	293.1	363.4	441.4	526.9	620.0
	.022	12.7	20.8	30.8	42.8	56.7	72.7	90.5	132.2	181.7	239.1	304.3	377.4	458.3	547.1	643.8
	.023	13.2	21.5	31.9	44.3	58.8	75.3	93.8	137.0	188.3	247.7	315.3	391.0	474.9	566.9	667.0
	.024	13.6	22.3	33.0	45.8	60.8	77.8	97.0	141.6	194.7	256.1	326.0	404.3	491.0	586.2	689.7
	.025	14.1	23.0	34.1	47.3	62.7	80.3	100.1	146.2	200.9	264.4	336.5	417.3	506.8	605.0	711.9
	.026	14.5	23.7	35.1	48.8	64.7	82.8	103.2	150.6	207.0	272.4	346.7	430.0	522.3	623.5	733.6

Members in combined bending and axial load

Members in combined bending and axial load

Introduction

This part of the handbook deals with members subjected to combined bending and axial loads in an uniaxial state. The tables produced in this section have been based upon the design requirements of NZS 3101P*.

After considerable discussion on the relative merits of including ϕ factors, two complete sets of tables are published. The white set continues the overall policy of the handbook by including the relevant ϕ factors. The buff set has been produced for those designers wishing to work with P_i in the calculation method and these charts do not include capacity reduction factors. In effect therefore they represent the $\phi = 1$ condition.

Acknowledgement

In the preparation of this part of the handbook the assistance of the following is gratefully recorded:

Beca Carter Hollings and Ferner, Auckland.

Cement and Concrete Association of Australia, Sydney.

Civil Engineering Division, Ministry of Works and Development, Wellington.

Control Data Australia Pty. Ltd, Sydney.

Department of Civil Engineering, University of Canterbury, Christchurch.

Computer services were provided by the University of Canterbury and the Ministry of Works and Development.

The continued advice of Morrison Cooper and Partners as consultants to the publication committee is acknowledged.

Tables and charts

*Except where the provisions of the draft NZ Standard DZ 3101: Parts 1 and 2, "Code of practice for the design of concrete structures", are more applicable.

Notation

Notations are in addition to those contained in Members in Pure Bending.

A_c	=	area of core of spirally reinforced compression member measured to outside diameter of spiral,	mm
A_g	=	gross area of section,	mm^2
A_{st}	=	total area of longitudinal reinforcement	mm^2
A_{sh}	=	total effective area of hoop bars and supplementary ties in direction under consideration	mm^2
a	=	depth of equivalent rectangular stress block	mm
a_b	=	depth of equivalent rectangular stress block at balanced strain conditions	mm
C_m	=	a factor relating actual moment diagram to an equivalent uniform moment diagram	
d_b	=	diameter of reinforcing bar	mm
d_c	=	thickness of concrete cover measured from extreme tension fibre to centre of bar or wire located closest thereto	mm
d_s	=	distance from extreme tension fibre to centroid of tension reinforcement	mm
D	=	overall diameter of circular member	mm
EI	=	flexural stiffness of compression member	
e	=	eccentricity of load parallel to axis of member measured from centroid of gross section	mm
f_{yh}	=	specified yield strength of spiral reinforcement	MPa
g	=	factor where distance between centreline of reinforcement in opposite faces of a member is gh or gD	
h''	=	dimension of concrete core measured perpendicular to direction of hoop bars	mm^2
I_g	=	moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement	m^4 or mm^4
I_{se}	=	moment of inertia of reinforcement about centroidal axis of member cross section	m^4 or mm^4

k	=	effective length factor for compression members	
l	=	span length of member	m
l_c	=	height of column, centre-to-centre of floors or roof	m
l_u	=	unsupported length of compression member	m
m	=	factor $\frac{f_y}{0.85\, f'_c}$	
M_b	=	ideal moment strength at balanced strain condition	kNm
M_c	=	factored moment to be used for design of compression member	kNm
M_1	=	value of smaller factored end moment on compression member calculated by conventional elastic frame analysis, positive if member is bent in single curvature, negative if bent in double curvature.	kNm
M_2	=	value of larger factored end moment on compression member calculated by conventional elastic frame analysis, always positive	kNm
P_b	=	ideal axial load strength at balanced strain conditions	kN
P_c	=	critical load	kN
P_{cx}	=	load carried by concrete in critical loading conditions where $P_c = P_{cx} + P_{cy}$	
P_{cy}	=	load carried by steel in critical loading condition where $P_c = P_{cx} + P_{cy}$	
P_i	=	ideal axial load strength at given eccentricity	kN
P_o	=	ideal axial load strength at zero eccentricity	kN
P_u	=	axial design load at given eccentricity ϕP_i	kN
r	=	radius of gyration of cross section of a compression member	
s_h	=	centre to centre spacing of hoop sets	mm
β_d	=	ratio of maximum factored dead load moment to maximum factored total load moment, always positive	
δ	=	moment magnification factor	
ρ_t	=	ratio of non prestressed longitudinal reinforcement $= \frac{A_{st}}{bh}$ or $\frac{A_{st}}{\pi/4\ D^2}$	
ρ_s	=	ratio of volume of core (out-to-out of spirals) of spiral reinforcement to total volume of a spirally reinforced compression member	
ϕ	=	strength reduction factor. Varies 0.75 to 0.90 columns steel confined with spirals, or 0.70 to 0.90 columns steel confined with ties.	
ψ	=	stiffness ratio Ratio of $\Sigma EI/l_c$ of compression members to $\Sigma EI/l_b$ of flexural members in a plane at one end of compression members.	

Note ψ_A & ψ_B indicate opposite ends of the compression member

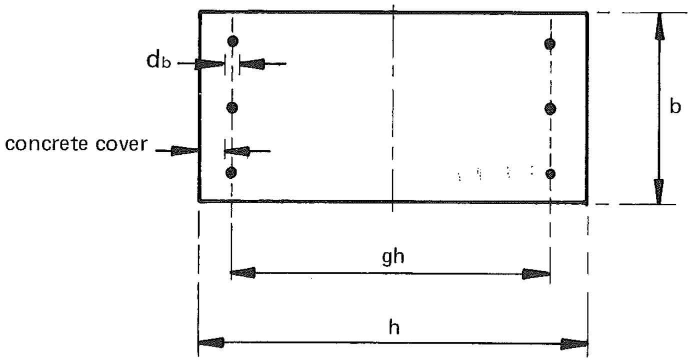
ψ_{min} is the smaller ratio of ψ_A or ψ_B

ψ_m is the average of ψ_A or ψ_B

Design notes

TABLES C1.1 and C1.2

Two tables have been prepared using the two principal cover requirements of 40 mm and 50 mm to main steel for columns.



$$g = \frac{h - d_b - 2 \times \text{Concrete cover}}{h}$$

CHARTS C2.1, C2.2 & C2.3

Chart C2.1 has been produced by plotting values of the two equations

$$k = 0.7 + 0.05\,(\psi_A + \psi_B)$$
$$k = 0.85 + 0.05\,\psi_{min}$$

Chart C2.2 has been produced by plotting values of the two equations

$$k = \frac{20 - \psi_m}{20}\sqrt{1 + \psi_m}$$
$$k = 0.9\sqrt{1 + \psi_m}$$

Chart C2.3 has been produced by plotting values of the equation

$$k = 2.0 + 0.3\,\psi$$

CHARTS C3.1 & C3.2

Chart C3.1 is produced by considering formulae in Chapter 6, DZ 3101, viz:

$$P_c = \frac{\pi^2 EI}{(k\,l_u)^2}$$

where EI can be

either $\frac{(E_c I_g)/5 + E_s I_{se}}{1 + \beta_d}$ giving **A** below

or $\frac{(E_c I_g)/2.5}{1 + \beta_d}$ giving **B** below

$$\text{A:}\ P_c = \frac{\pi^2}{(kl_u)^2(1+\beta_d)}\frac{E_c\,I_g}{5} + \frac{\pi^2}{(kl_u)^2(1+\beta_d)}E_s\,I_{se}$$

$$= P_{cx} + P_{cy}$$

where $P_{cx} = \frac{\pi^2}{(kl_u)^2(1+\beta_d)}\frac{E_c\,I_g}{5}$

and $P_{cy} = \frac{\pi^2}{(kl_u)^2(1+\beta_d)}E_s\,I_{se}$

Curves for $\dfrac{P_{cy}}{E_s I_{se}} = \dfrac{\pi^2}{(kl_u)^2(1+\beta_d)}$ are produced

Note that $P_{cx} = \dfrac{P_c}{2}$ produced by the alternative **B** below

B: $P_c = \dfrac{\pi^2}{(kl_u)^2(1+\beta_d)} \quad \dfrac{E_c I_g}{2.5}$

Curves of $\dfrac{P_c}{E_c I_g} = \dfrac{\pi^2}{2.5\,(1+\beta_d)\,(kl_u)^2}$ are plotted to produce $\dfrac{P_c}{I_g}$ the value of E_c being based on $4700 \sqrt{f'_c}$ MPa

Chart C3.2 is produced by plotting values of the equation

$$\delta/C_m = \frac{1}{1 - P_u/\phi P_c}$$

Chart C4.1 Gross moments of inertia are calculated from $\dfrac{bh^3}{12}$

Values are quoted in mm^4 and m^4

Chart C4.2 Gross moments of inertia are calculated from $\dfrac{\pi D^4}{64}$

Values are quoted in mm^4 and m^4

CHARTS C5.1 — 5.6 and C6.1 — 6.6

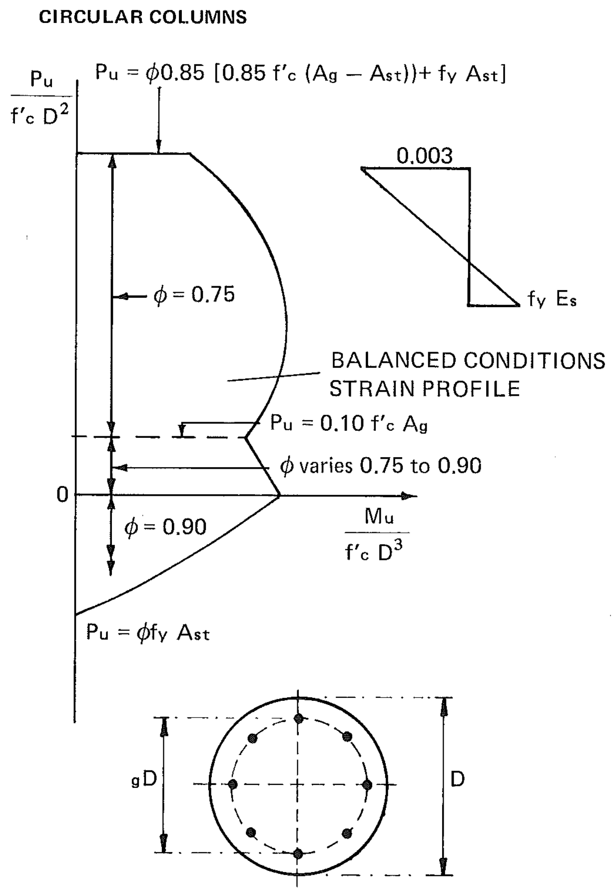
Charts are dimensionless but are based upon f'_c = 30 MPa with two levels of steel stress, i.e. 275 and 380 MPa.

ϕ Factors have been included in all white charts consistent with DZ 3101. Buff charts are plotted for P_i and M_i conditions, to which the appropriate reduction factors must be applied by the designer.

The charts have been based on the provisions of DZ 3101 and derived using the following:

1. The strain in the concrete and steel is assumed proportional to the distance from the neutral axis.
2. The ultimate compression strain is assumed to be 0.003 and at ultimate strength the concrete compressive stress distribution is assumed to be rectangular with intensity 0.85 f'_c. The concrete compressive block is assumed bounded by the edges of the cross section and a line parallel to the neutral axis at a distance $\beta_1 c$ from the extreme compression fibres. The parameter β_1 equals 0.85 (for f'_c = 30 MPa).
3. The tensile strength of the concrete is neglected in the calculations.
4. The steel is assumed to have a modulus of elasticity of 200 GPa at stresses below the yield stress f_y. For steel strains greater than those corresponding to f_y, the steel stress is assumed equal to in both tension and compression.
5. The reinforcement in the circular columns is assumed to be uniformly distributed in a thin annulus of area equal to the total steel area. For rectangular columns two steel configurations are considered, i.e. steel equal in two faces and four faces respectively.
6. The total concrete area in compression is reduced in the calculations to take account of the concrete area displaced by the steel.
7. The capacity reduction factor, ϕ for circular columns is assumed to be 0.75 for ϕ P_i greater than 0.10 f'_c A_g in compression and 0.90 for tensile axial loads. For ϕ P_i greater than zero but less than 0.10 f'_c A_g, ϕ is assumed to vary linearly between 0.90 and 0.75. See Figure 2.

   The capacity reduction factor, ϕ for rectangular columns is assumed to be 0.70 for ϕ Pi greater than 0.10 f'_c A_g in compression and 0.90 for tensile axial loads. For ϕ Pi greater than zero but less than 0.10 f'_c A_g, ϕ is assumed to vary linearly between 0.90 and 0.70. See Figure 2.



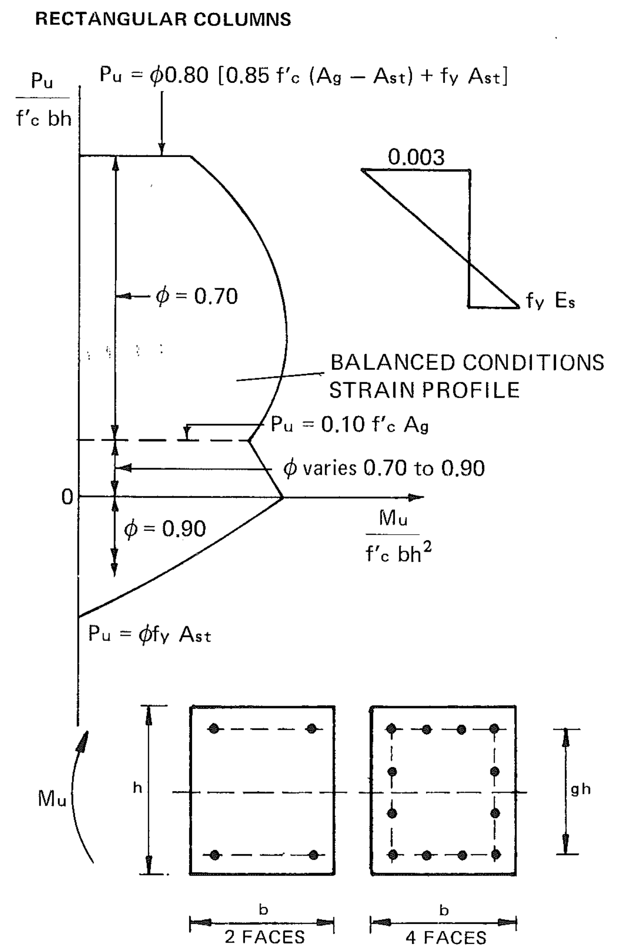


FIGURE 2

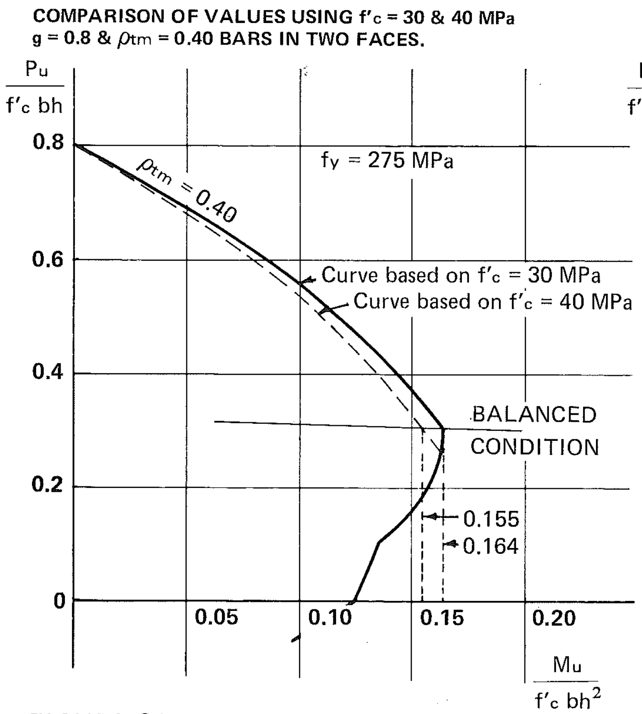


FIGURE 3A

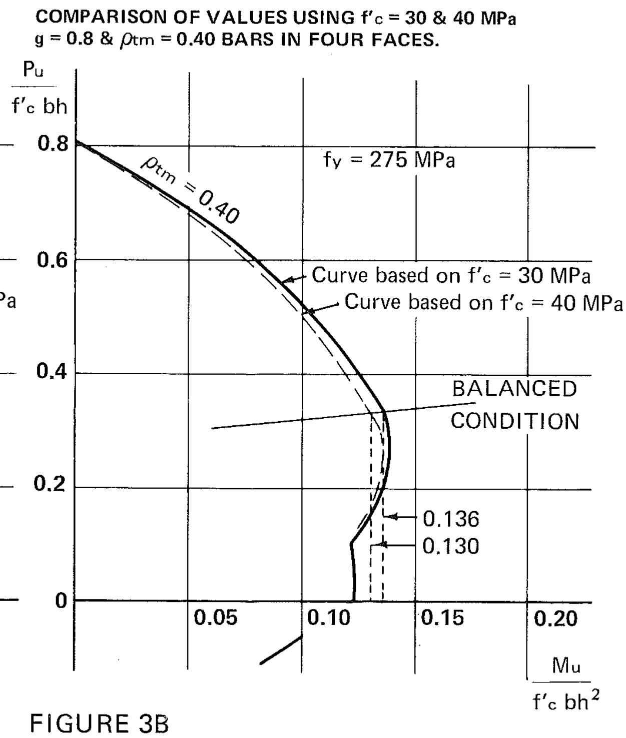


FIGURE 3B

The relative accuracy of using dimensionless charts for concrete strengths other than 30 MPa has been checked. The different curve shapes are shown in Figure 3 for $\rho_t m = 0.4$, $f'_c = 30$ and $f'_c = 40$ MPa. The use of the dimensionless chart based on 30 MPa for 40 MPa concrete results in an over-estimate of moment capacity of approximately 5% at or near balance point conditions.

The circular charts show an overestimate of moment capacity of approximately 4% when comparing 30 & 45 MPa concretes each with $\rho_t m = 0.65$. A check using 20 MPa concrete disclosed an under-estimate of approximately 3%.

Examples in combined bending and axial load

Example 1. — Charts & Tables C2, C3, & C4

Charts C2, C3, & C4 have been developed to follow the formulae recommended in DZ 3101 for the approximate evaluation of slenderness effects and moment magnification. The following procedure for using the charts is envisaged.

1. Assessment of k

   Calculate ψ_A & ψ_B stiffness ratios at either end of compression member and for a braced member determine k from Chart C2.1 using ψ_A & ψ_B and the minimum value ψ_{min}.
   (Use charts C2.2 & C2.3 for unbraced and unbraced/hinged one end conditions respectively, not normally applicable for New Zealand conditions.)

2. Evaluate slenderness

   Determine kl_u, r and M_1/M_2

   Calculate $\frac{kl_u}{r}$ and check against following: slenderness effects may be neglected if:

   (a) $\frac{kl_u}{r} < 34 - 12\frac{M_1}{M_2}$ for members braced against sidesway

   (b) $\frac{kl_u}{r} < 22$ for members not braced against sidesway

   (c) If $\frac{kl_u}{r} > 100$ the special design consideration must be used and it is not appropriate to use the approximate methods

3. Moment magnification

   (a) Calculate β_d from factored loading information

   (b) Proceed to Chart C3.1
   Using kl_u and β_d read $\frac{P_c}{E_c I_g}$ Using f'_c value read $\frac{P_c}{I_g}$ MNm^{-4}

   (c) Determine I_g in m^4 from Table C4
   Hence determine P_c

   (d) Depending upon accuracy requirement decide whether to recalculate P_c based on considering steel content. If not proceed to (h) otherwise return to Chart C3.1
   using kl_u and β_d read $\frac{P_{cy}}{E_s I_{se}}$

   (e) Calculate $E_s I_{se}$ Hence P_{cy}

   (f) Determine P_{cx} from (c) since $P_{cx} = \frac{P_c}{2}$

   (g) Determine $P_c = P_{cx} + P_{cy}$

   (h) Decide ϕ, determine ϕP_c hence $P_u/\phi P_c$

   (i) Proceed to Chart C3.2
   Using $P_u/\phi P_c$ read δ/C_m

   (j) Calculate C_m from

   $C_m = 0.6 + 0.4\frac{M_1}{M_2}$ for members braced against sidesway

   C_m cannot be less than 0.4.

   For all other cases take $C_m = 1$.

(k) From j and i

Determine the magnification factor δ.

Example 2. — Tables C1, C5 & C6

Design of reinforced, circular column where compression controls.

Given: P_u = 2990 kN

M_u = 366 kNm

f'_c = 20 MPa

f_y = 380 MPa

Assume 600 mm diameter column:
Slenderness effects are considered using DZ 3101 Chapter 6.

If the approximate evaluation of slenderness method is used, then tables C2.1, C2.2, C2.3, and C3.2 greatly simplify the calculations. See moment magnification procedure Example 1.

$$e = \frac{M_u}{P_u} = \frac{366 \times 10^3}{2990} \text{ kN.mm}$$

$$= 123 \text{ mm}$$

$$\therefore \frac{e}{D} = \frac{123}{600}$$

$$= 0.204$$

Assume 20 mm bars, 40 mm cover

From Table C1.1

$$g = 0.83$$

$$\therefore \frac{P_u}{f'_c D^2} = \frac{2990 \times 10^3}{20 \times 600^2} = 0.415$$

(Use actual value of f'_c even though charts are all for f'_c = 30 MPa)

$$\therefore \frac{M_u}{f'_c D^3} = \frac{P_u}{f'_c D^2} \times \frac{e}{D}$$

$$= 0.415 \times 0.204$$

$$= 0.0847$$

From Charts C5.6 380/0.9 & C5.6 380/0.8 read

$\rho_t m$ = 0.445 for g = 0.9

$\rho_t m$ = 0.501 for g = 0.8

Interpolate for g = 0.83

$$\rho_t m = 0.484$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{380}{0.85 \times 20} = 22.35$$

This value can be found on the table in the lower RH corner of the above charts.

$$\therefore \rho_t = \frac{0.484}{22.35} = 0.0217$$

$$\therefore A_{st} = 0.0217 \times \frac{\pi \times 600^2}{4}$$

$$= 6122 \text{ mm}^2$$

Try 20 No. 20 mm diameter bars with $A_{st} = 6284\ mm^2$.

Check that required lap conditions are OK for 20 No. 20 mm bars.

Over strength calculation:

Actual $\rho_t = \dfrac{6284}{\pi/4 \times 600^2} = 0.0222$

$\therefore \quad \rho_t m = 0.022 \times 22.35 = 0.497$

$P_i \text{ (ideal)} = \dfrac{P_u}{\phi} = \dfrac{2990}{0.75} = 3987 \text{ kN}$

$\therefore \quad \dfrac{P_i}{f'_c D^2} = \dfrac{3987 \times 10^3}{20 \times 600^2} = 0.554$

From charts C6.6 380/0.9 C6.6 380/0.8

for $\dfrac{P_i}{f'_c D^2} = 0.554 \ \& \ \rho_t m = 0.497$

$\dfrac{M_i}{f'_c D^3} = 0.121 \text{ for } g = 0.9$

& $\dfrac{M_i}{f'_c D^3} = 0.112 \text{ for } g = 0.8$

Interpolate for g = 0.83

$\dfrac{M_i}{f'_c D^3} = 0.115$

$\therefore \quad M_i = 0.115 \times 20 \times 600^3 \text{ N.mm}$

$= 497 \text{ kN.m}$

Check overstrength condition.

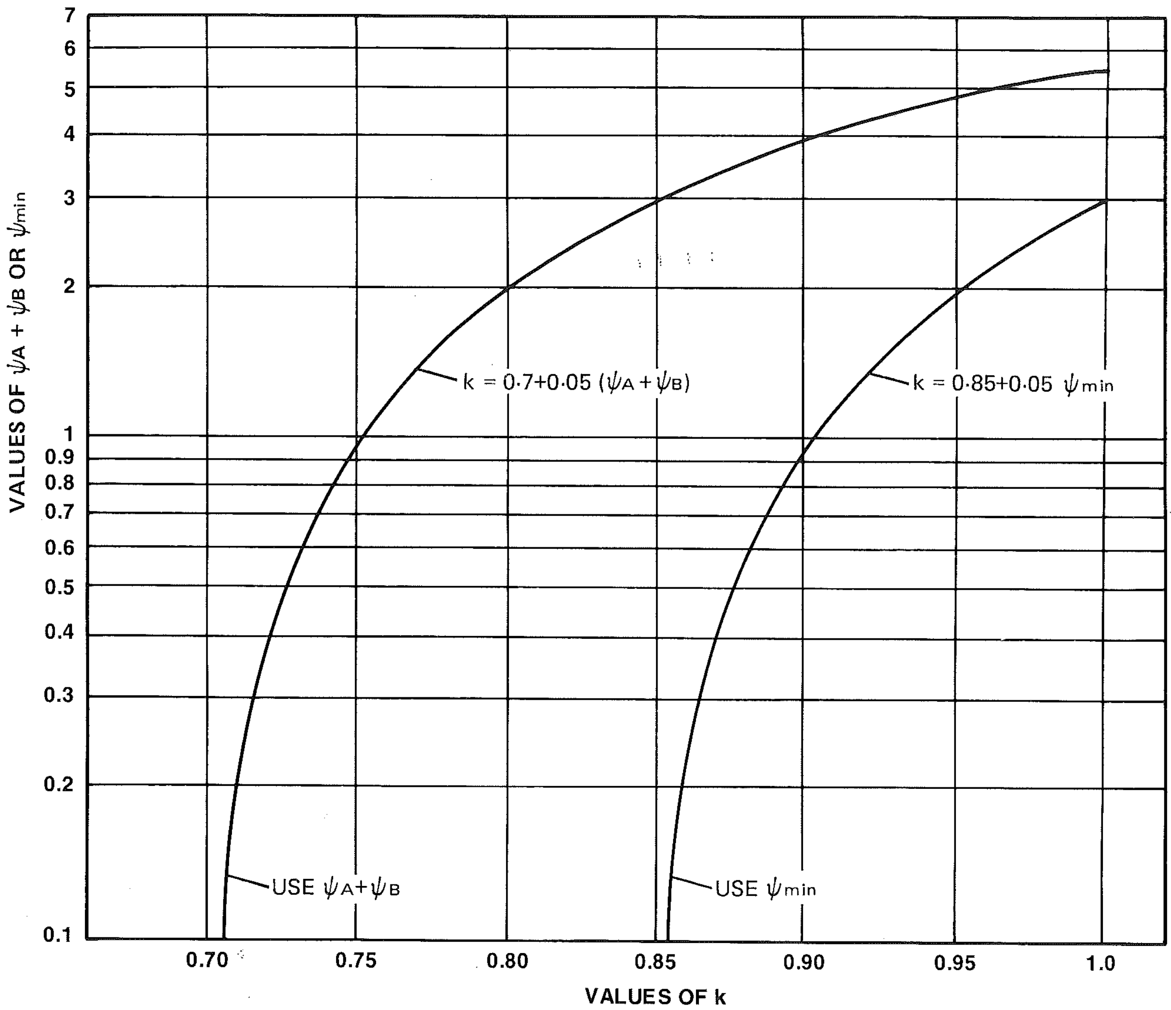
TABLE C 1.1 Values of "g" Steel cover 40 mm

Column Size h or D mm	Values of g Cover to main steel = 40 mm						
	Bar Diameter main steel						
	12	16	20	24	28	32	40
200	0.54	0.52	0.50	0.48			
250	0.63	0.62	0.60	0.58	0.57	0.55	0.52
300	0.69	0.68	0.67	0.65	0.64	0.63	0.60
350	0.74	0.73	0.71	0.70	0.69	0.68	0.66
400	0.77	0.76	0.75	0.74	0.73	0.72	0.70
450	0.80	0.79	0.78	0.77	0.76	0.75	0.73
500	0.82	0.81	0.80	0.79	0.78	0.78	0.76
550	0.83	0.83	0.82	0.81	0.80	0.80	0.78
600	0.85	0.84	0.83	0.83	0.82	0.81	0.81
650	0.86	0.85	0.85	0.84	0.83	0.83	0.82
700	0.87	0.86	0.86	0.85	0.85	0.84	0.83
800	0.89	0.88	0.88	0.87	0.87	0.86	0.85
900	0.90	0.89	0.89	0.88	0.88	0.88	0.87
1000	0.91	0.90	0.90	0.90	0.89	0.89	0.88
1100	0.92	0.91	0.91	0.91	0.90	0.90	0.89
1200	0.92	0.92	0.92	0.91	0.91	0.91	0.90

TABLE C 1.2 Values of "g" Steel cover 50mm

Column Size h or D mm	Values of g Cover to main steel = 50 mm						
	Bar Diameter main steel						
	12	16	20	24	28	32	40
200	0.44						
250	0.55	0.54	0.52	0.50	0.49	0.47	0.44
300	0.63	0.61	0.60	0.59	0.57	0.56	0.53
350	0.68	0.67	0.66	0.65	0.63	0.62	0.60
400	0.72	0.71	0.70	0.69	0.68	0.67	0.65
450	0.75	0.74	0.73	0.72	0.72	0.71	0.69
500	0.78	0.77	0.76	0.75	0.74	0.74	0.72
550	0.80	0.79	0.78	0.77	0.77	0.76	0.75
600	0.81	0.81	0.80	0.79	0.79	0.78	0.77
650	0.83	0.82	0.82	0.81	0.80	0.80	0.78
700	0.84	0.83	0.83	0.82	0.82	0.81	0.80
800	0.86	0.86	0.85	0.85	0.84	0.84	0.82
900	0.88	0.87	0.87	0.86	0.86	0.85	0.84
1000	0.89	0.89	0.88	0.88	0.87	0.87	0.86
1100	0.90	0.89	0.89	0.89	0.88	0.88	0.87
1200	0.91	0.90	0.90	0.90	0.89	0.89	0.88

C2.1 VALUES OF k FOR BRACED FRAMES

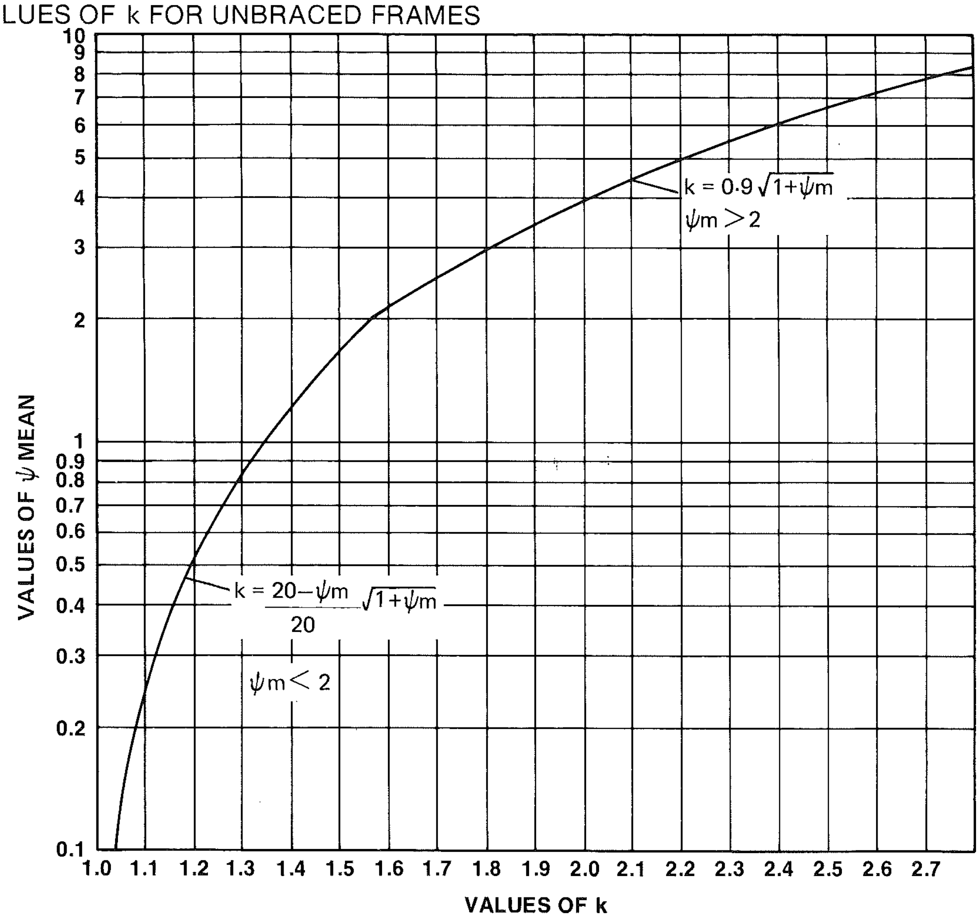


Calculate ψ_A and ψ_B stiffness ratios at either end of compression member and determine k from chart using either $\psi_A + \psi_B$ or ψ_{min}

Note:

Charts 2.2 and 2.3 which relate to unbraced conditions are not generally applicable to New Zealand conditions.

C2.2 VALUES OF k FOR UNBRACED FRAMES



C2.3 VALUES OF k FOR UNBRACED, HINGED AT ONE END MEMBER

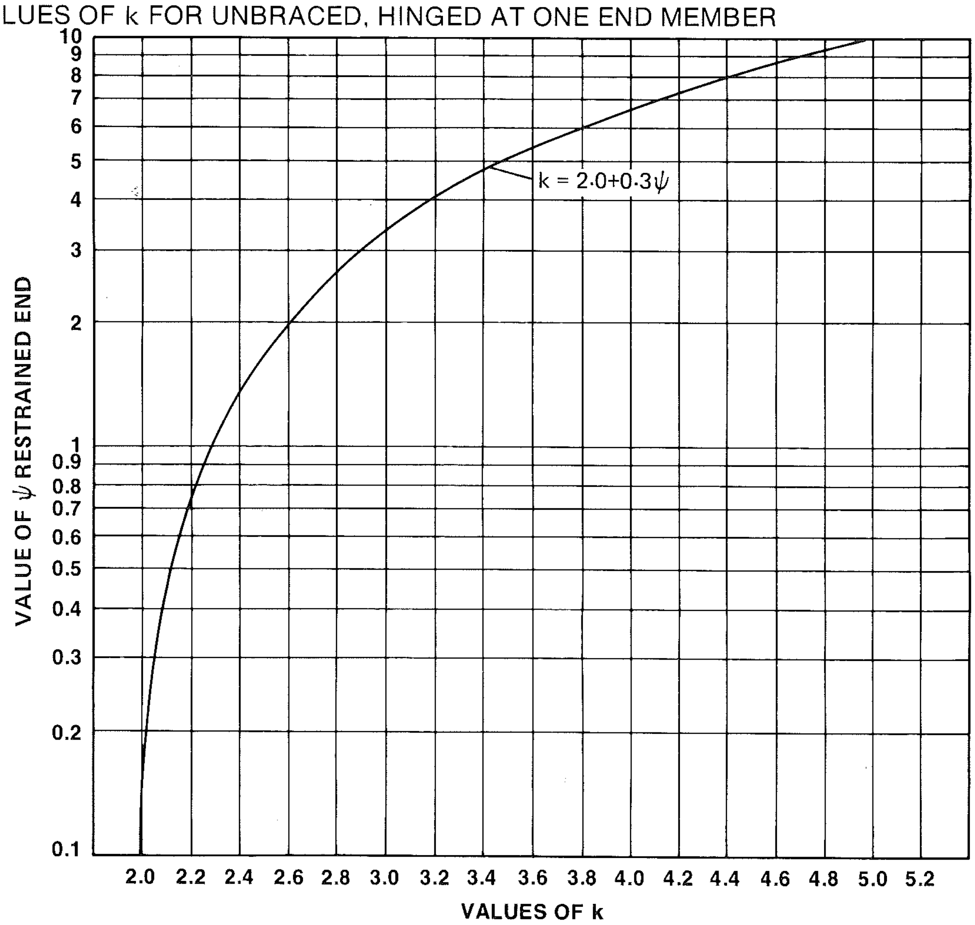


CHART 3.1 DETERMINATION OF P_c/E_cI_g, P_c/I_g & P_{cy}/E_sI_{se}

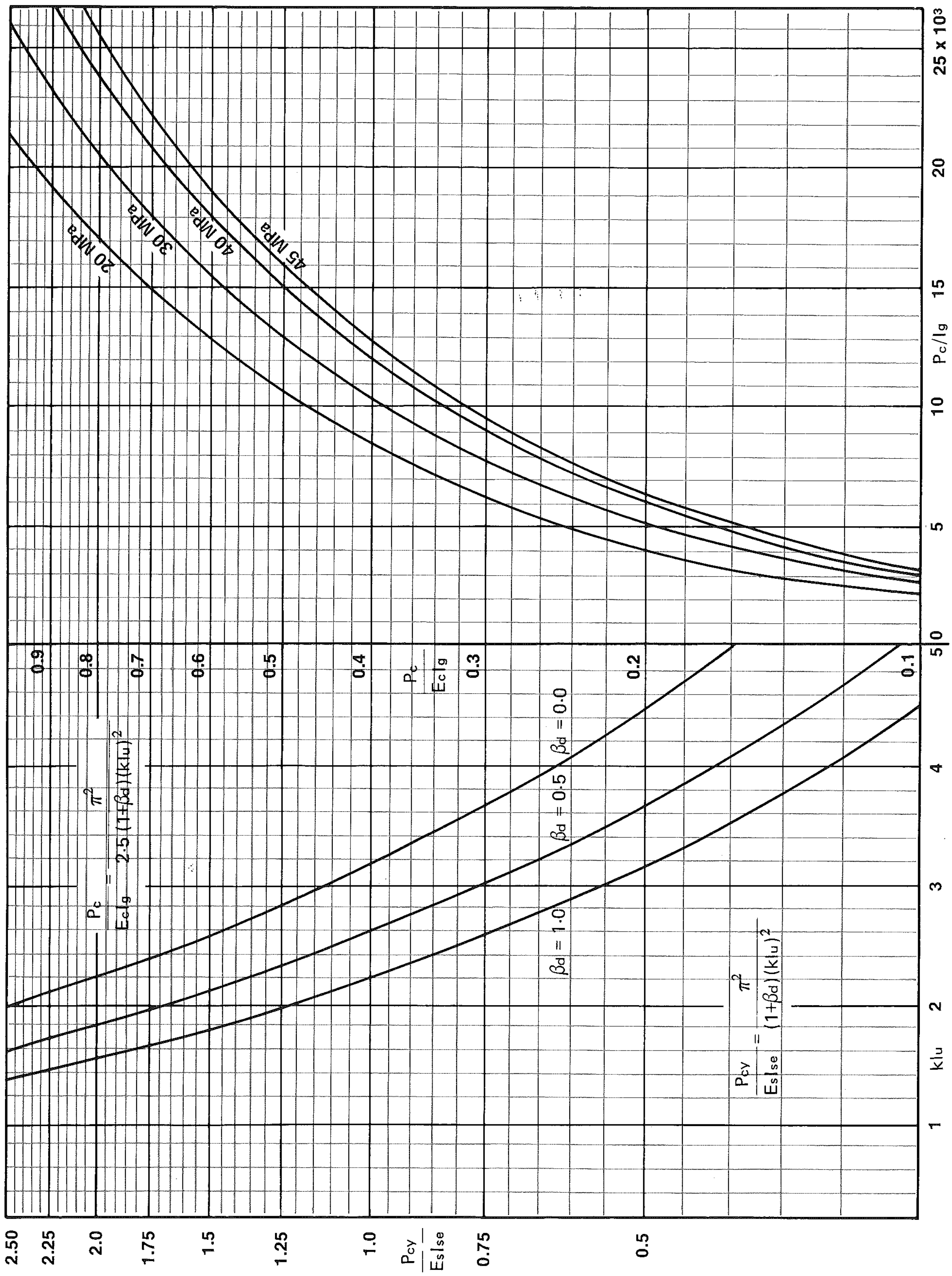


CHART 3.2 DETERMINATION OF δ/C_m

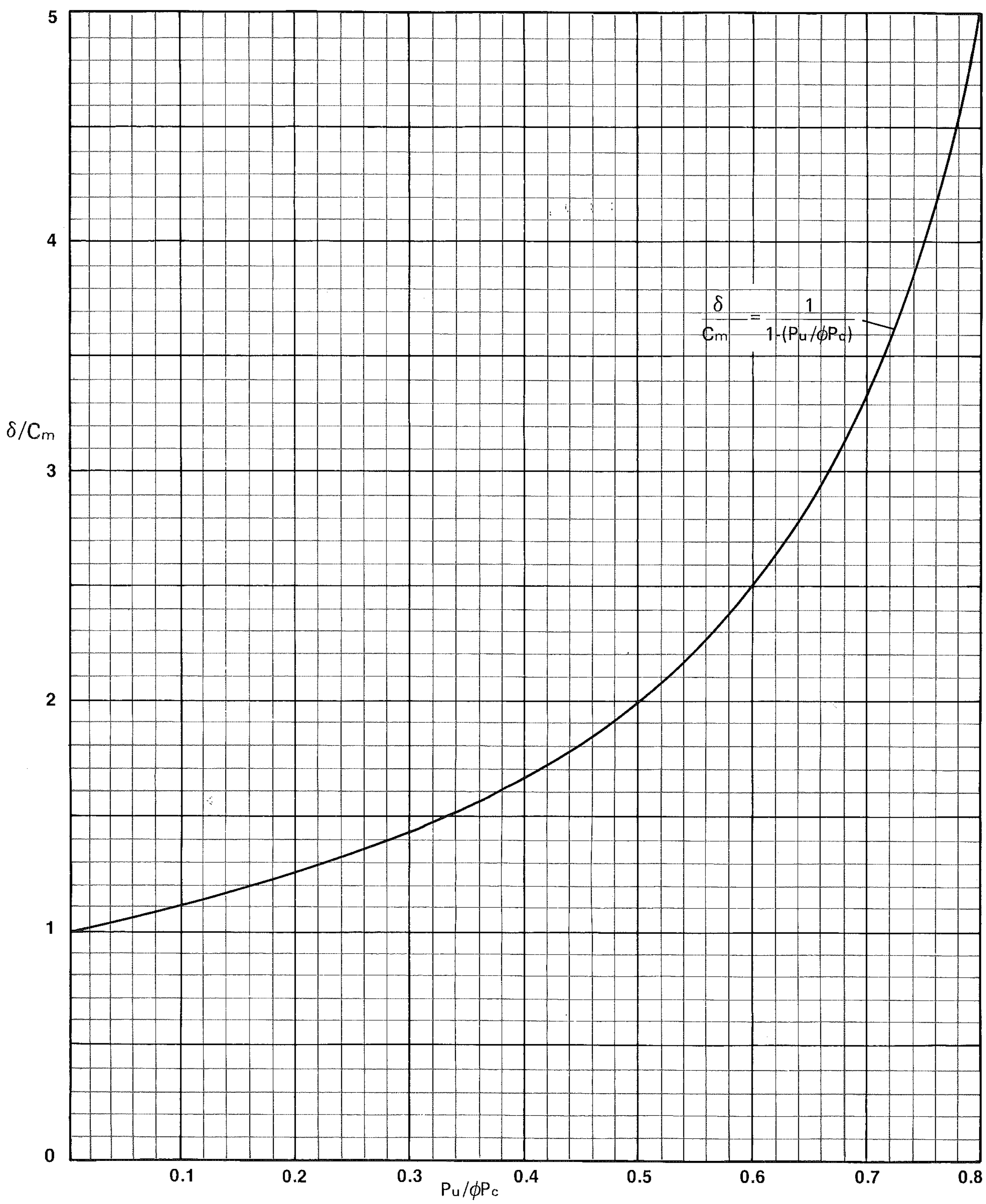
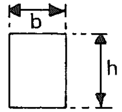


TABLE C4.1 GROSS MOMENTS OF INERTIA OF RECTANGULAR SECTIONS



I_g = Tabulated value x 10^6 mm^4
I_g = Tabulated value x 10^{-6} m^4

h mm	b = width mm 100	150	200	250	300	350	400	450	500	600	700	800	900	1000
150.0	28	42	56	70	84	98	113	127	141	169	197	225	253	281
175.0	45	67	89	112	134	156	179	201	223	268	313	357	402	447
200.0	67	100	133	167	200	233	267	300	333	400	467	533	600	667
225.0	95	142	190	237	285	332	380	427	475	570	664	759	854	949
250.0	130	195	260	326	391	456	521	586	651	781	911	1042	1172	1302
275.0	173	260	347	433	520	607	693	780	867	1040	1213	1386	1560	1733
300.0	225	338	450	563	675	788	900	1013	1125	1350	1575	1800	2025	2250
325.0	286	429	572	715	858	1001	1144	1287	1430	1716	2002	2289	2575	2861
350.0	357	536	715	893	1072	1251	1429	1608	1786	2144	2501	2858	3216	3573
375.0	439	659	879	1099	1318	1538	1758	1978	2197	2637	3076	3516	3955	4395
400.0	533	800	1067	1333	1600	1867	2133	2400	2667	3200	3733	4267	4800	5333
425.0	640	960	1279	1599	1919	2239	2559	2879	3199	3838	4478	5118	5757	6397
450.0	759	1139	1519	1898	2278	2658	3038	3417	3797	4556	5316	6075	6834	7594
475.0	893	1340	1786	2233	2679	3126	3572	4019	4465	5359	6252	7145	8038	8931
500.0		1563	2083	2604	3125	3646	4167	4688	5208	6250	7292	8333	9375	10417
525.0		1809	2412	3015	3618	4221	4823	5426	6029	7235	8441	9647	10853	12059
550.0		2080	2773	3466	4159	4853	5546	6239	6932	8319	9705	11092	12478	13865
575.0		2376	3168	3961	4753	5545	6337	7129	7921	9505	11090	12674	14258	15842
600.0		2700	3600	4500	5400	6300	7200	8100	9000	10800	12600	14400	16200	18000
625.0		3052	4069	5086	6104	7121	8138	9155	10173	12207	14242	16276	18311	20345
650.0		3433	4577	5721	6866	8010	9154	10298	11443	13731	16020	18308	20597	22885
675.0		3844	5126	6407	7689	8970	10252	11533	12814	15377	17940	20503	23066	25629
700.0		4288	5717	7146	8575	10004	11433	12863	14292	17150	20008	22867	25725	28583
725.0		4763	6351	7939	9257	11115	12703	14290	15878	19054	22230	25405	28581	31757
750.0			7031	8789	10547	12305	14063	15820	17578	21094	24609	28125	31641	35158
775.0			7758	9698	11637	13577	15516	17456	19395	23274	27153	31032	34911	38790
800.0			8533	10667	12800	14933	17067	19200	21333	25600	29867	34133	38400	42667
825.0			9359	11698	14038	16378	18717	21057	23396	28076	32755	37434	42114	46793
850.0			10235	12794	15353	17912	20471	23030	25589	30706	35824	40942	46059	51177
875.0			11165	13957	16748	19539	22331	25122	27913	33496	39079	44661	50244	55827
900.0			12150	15188	18225	21263	24300	27338	30375	36450	42525	48600	54675	60750
925.0			13191	16489	19786	23084	26382	29679	32977	39573	46168	52764	59359	65954
950.0			14290	17862	21434	25007	28579	32152	35724	42869	50014	57158	64303	71448
975.0			15448	19310	23171	27033	30895	34757	38619	46343	54067	61791	69514	77238
1000.0				20833	25000	29167	33333	37500	41667	50000	58333	66667	75000	83333

TABLE C4.1 GROSS MOMENTS OF INERTIA OF RECTANGULAR SECTIONS Cont.

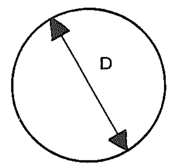
I_g = Tabulated value x 10^{-6} m^4 I_g = Tabulated value x 10^{6} mm^4

h	b = width mm												
	100	150	200	250	300	350	400	450	500	600	700	800	900	1000
1025.0				22435	26922	31409	35896	40383	44870	53845	62819	71793	80767	89741
1050.0				24117	28941	33764	38588	43411	48234	57881	67528	77175	86822	95469
1075.0				25881	31057	36234	41410	46586	51762	62115	72467	82820	93172	103525
1100.0				27729	33275	38821	44367	49913	55458	66550	77642	88733	99825	110917
1125.0				29663	35596	41528	47461	53394	59326	71191	83057	94922	106787	118652
1150.0				31685	38022	44359	50696	57033	63370	76044	88718	101392	114066	126740
1175.0				33797	40556	47315	54074	60834	67593	81112	94630	108149	121668	135186
1200.0				36000	43200	50400	57600	64800	72000	86400	100800	115200	129600	144000
1225.0				38297	45957	53616	61276	68935	76594	91913	107232	122551	137870	153189
1250.0					48828	56966	65104	73242	81380	97656	113932	130208	146484	162760
1275.0					51817	60453	69089	77725	86361	103634	120906	138178	155450	172723
1300.0					54925	60479	73233	82388	91542	109850	128158	146467	164775	183083
1325.0					58155	67848	77540	87233	96925	116310	135695	155080	174465	193850
1350.0					61509	71761	82013	92264	102516	123019	143522	164025	184528	205031
1375.0					64990	75822	86654	97485	108317	129980	151644	173307	194971	216634
1400.0					68600	80033	91467	102900	114333	137200	160067	182933	205800	228667
1425.0					72341	84398	96455	108512	120568	144682	168796	192909	217023	241137
1450.0					76216	88918	101621	114323	127026	152431	117836	203242	228647	254052
1475.0					80226	93597	106968	120339	133710	160452	187194	213936	240679	267421
1500.0						98438	112500	126563	140625	168750	196875	225000	253125	281250
1525.0						103442	118219	132997	147774	177329	206884	236439	265993	295548
1550.0						108613	124129	139645	155161	186194	217226	248258	279291	310323
1575.0						113954	130233	146512	162791	195349	227907	260466	293024	325582
1600.0						119467	136533	153600	170667	204800	238933	273067	307200	341333
1625.0						125155	130304	160913	178792	214551	250309	286068	321826	357585
1650.0						131020	149738	168455	187172	222606	262041	299475	336909	374344
1675.0						137066	156647	176228	195809	234971	274133	313295	352457	391618
1700.0						143296	163767	184238	204708	245650	286592	327533	368475	409417

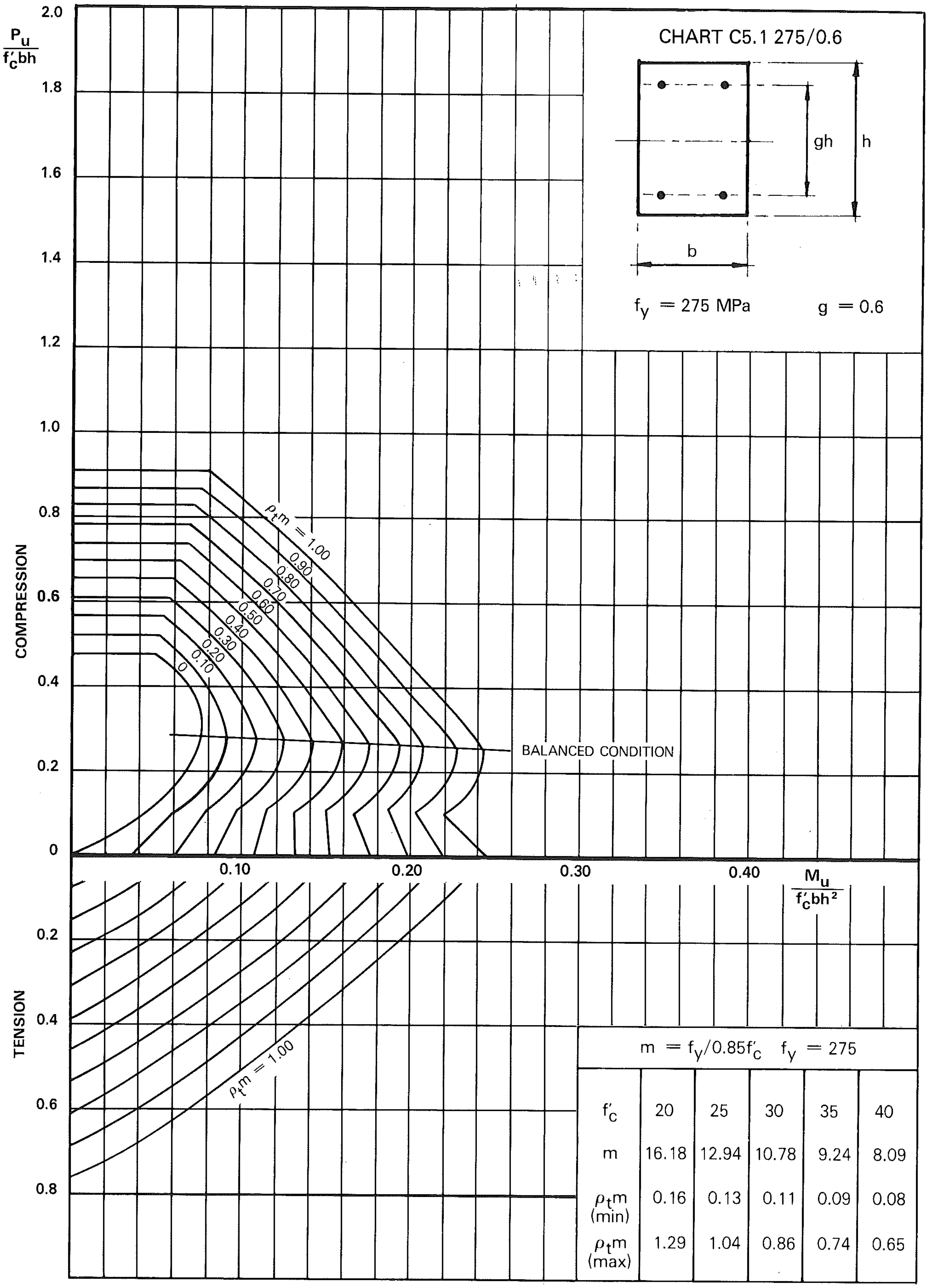
TABLE C 4.2 GROSS MOMENTS OF INERTIA OF CIRCULAR SECTIONS

I_g = Tabulated value x 10^{-6} m^4 I_g = Tabulated value x 10^{6} mm^4

Dmm	200	300	400	500	550	600	650	700	750	800	850	900	950	1000
I_g	79	398	1257	3063	4492	6362	8762	11785	15531	20106	25623	32206	39981	49087



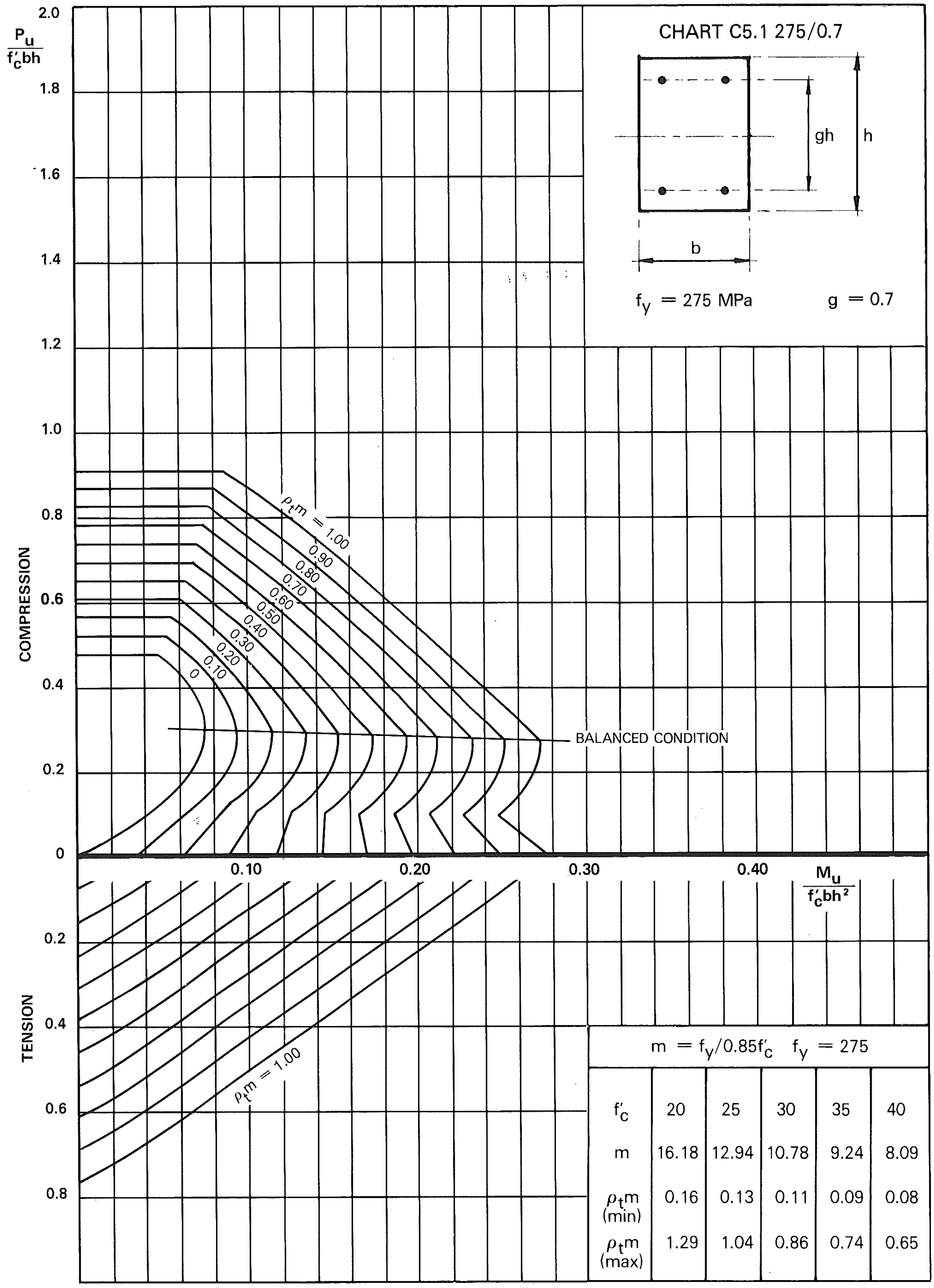
C5.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

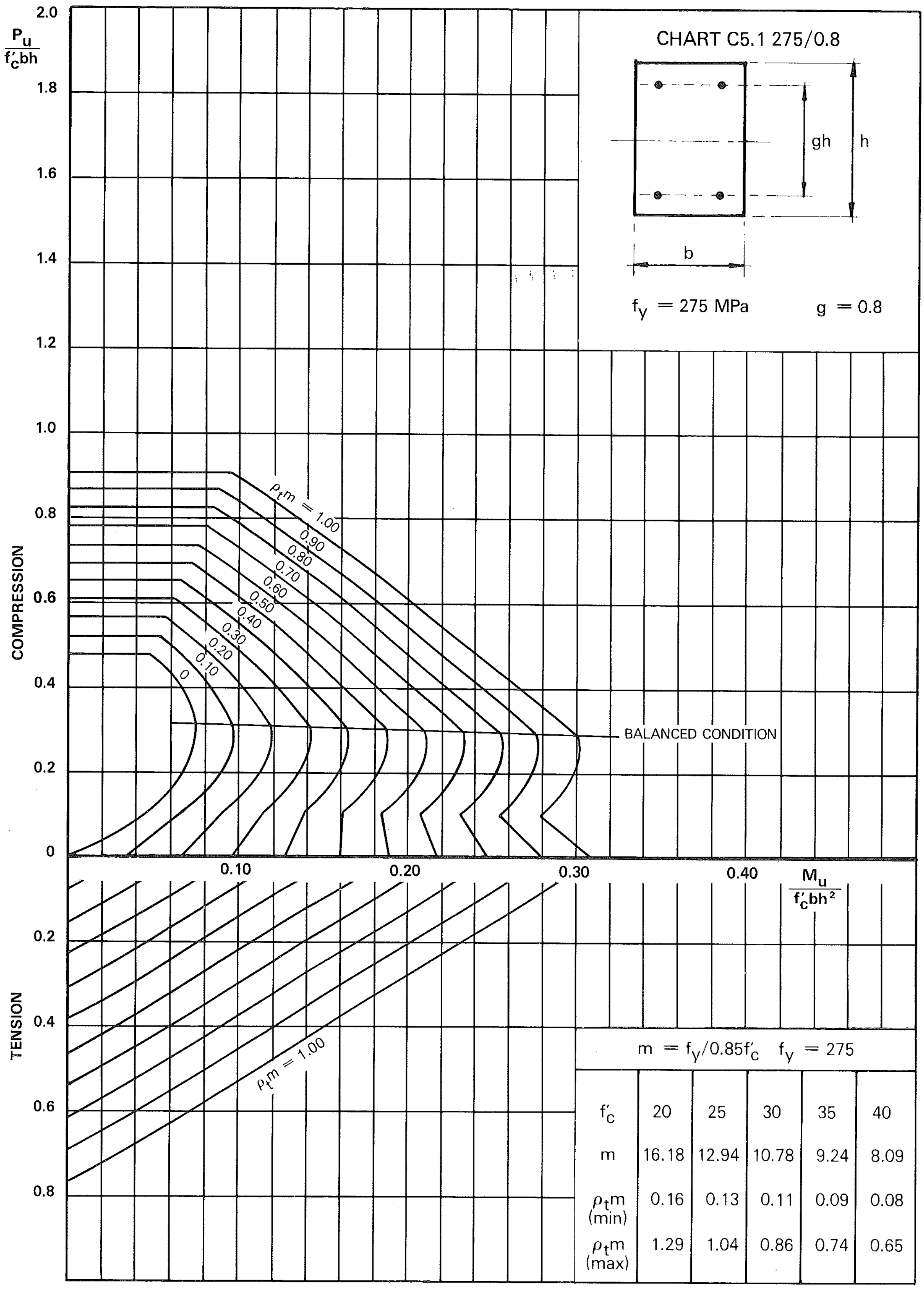
C5.1 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

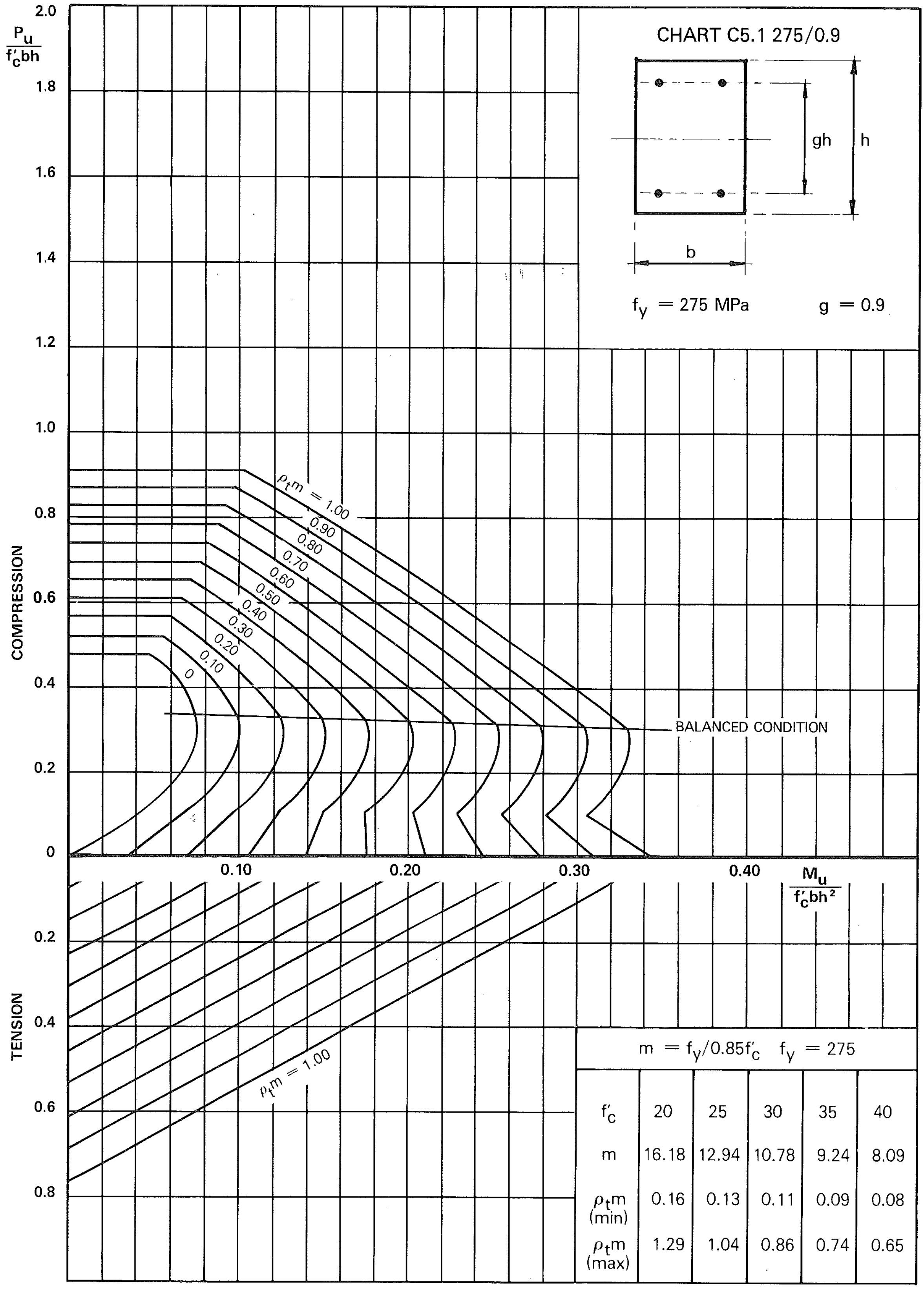
C5.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

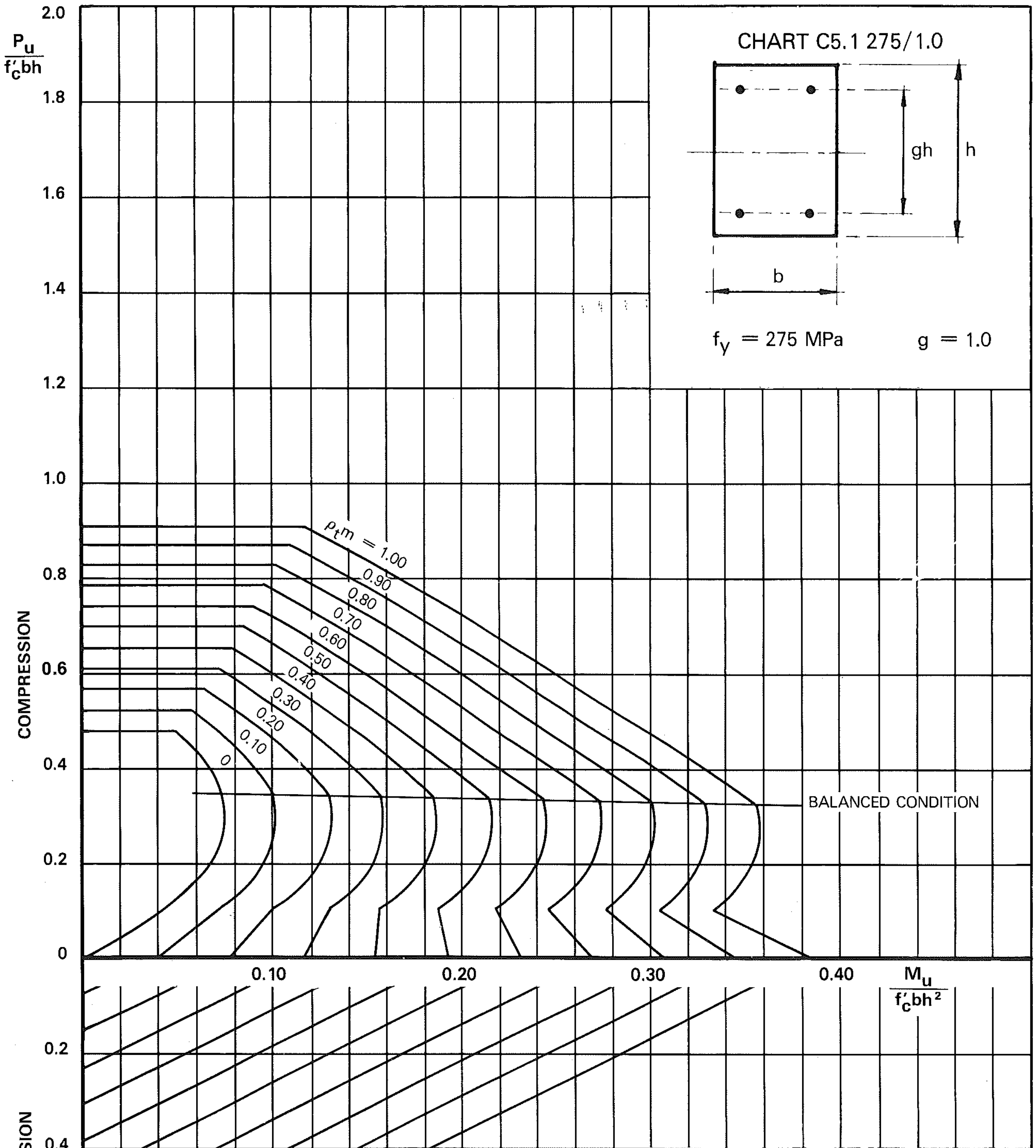
C5.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 275

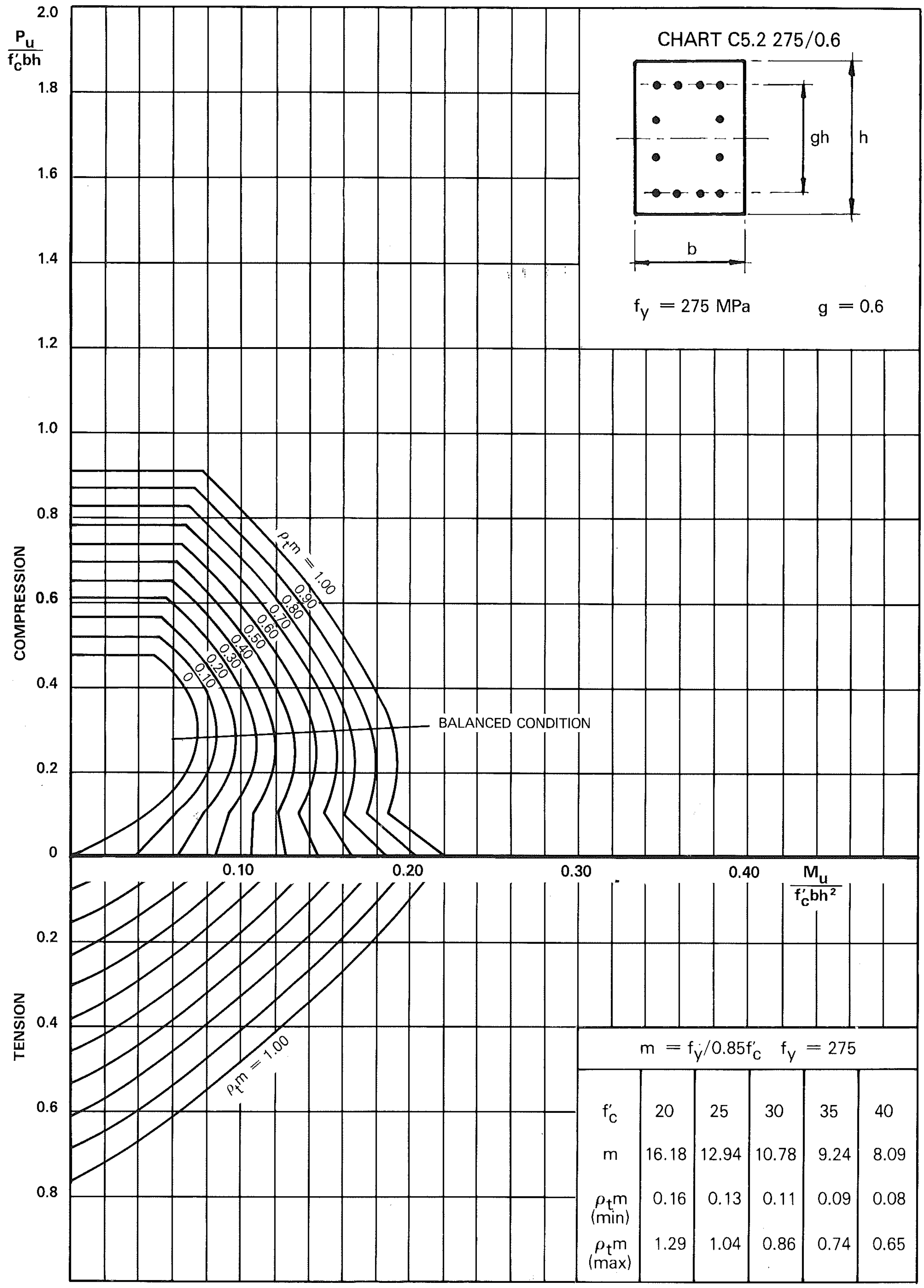
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

C5.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$					
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

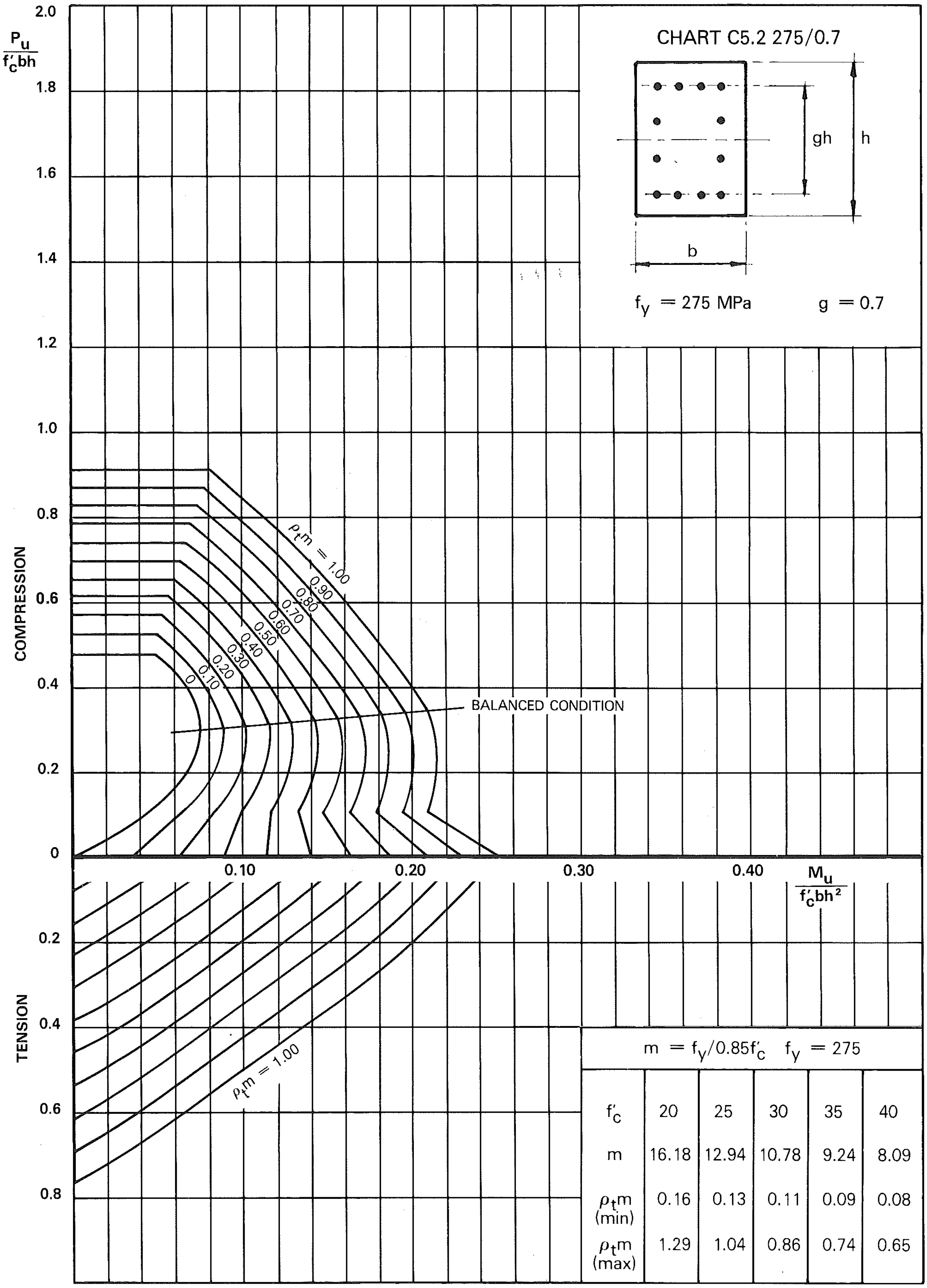
C5.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 275

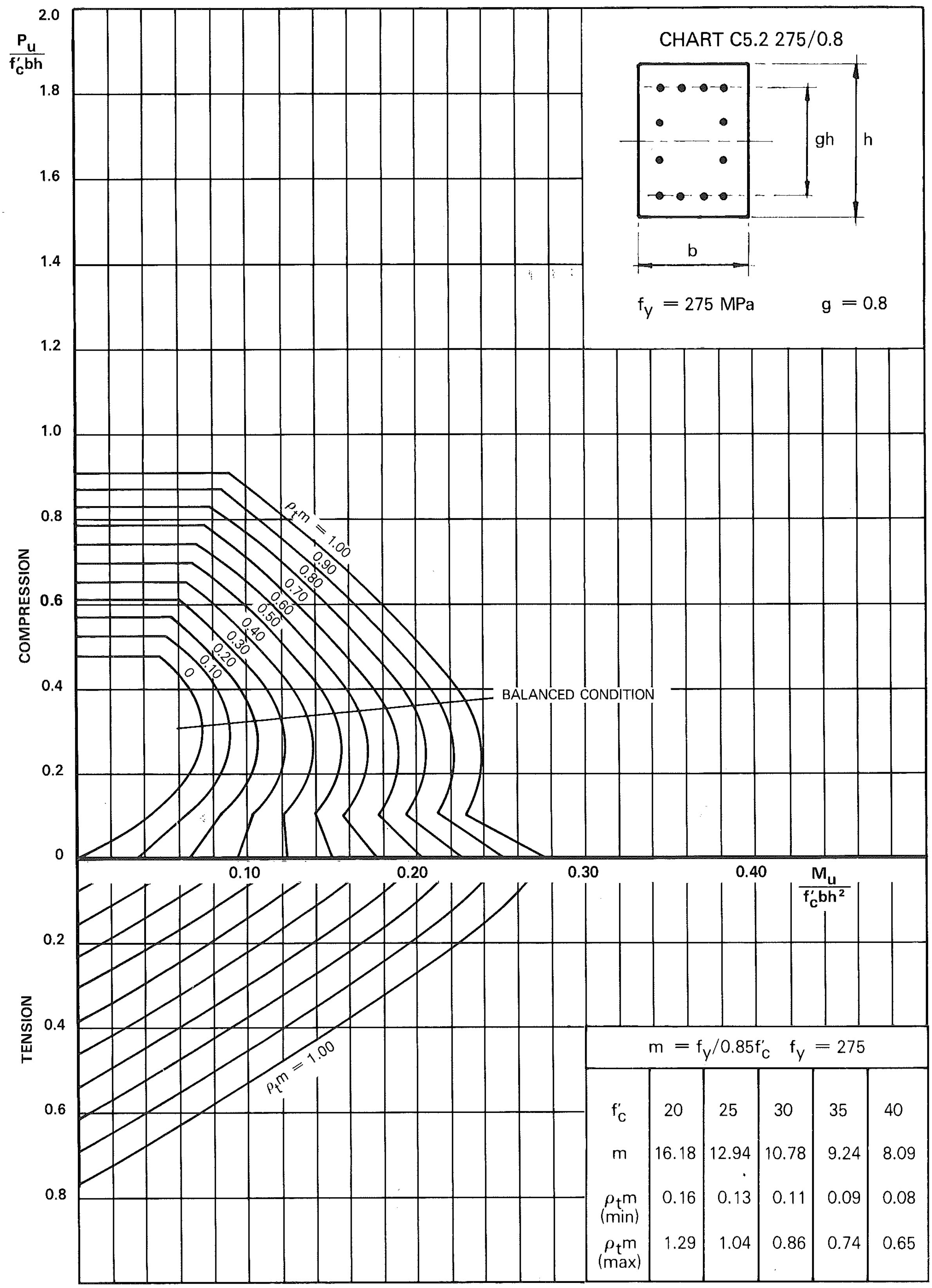
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

C5.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$					
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

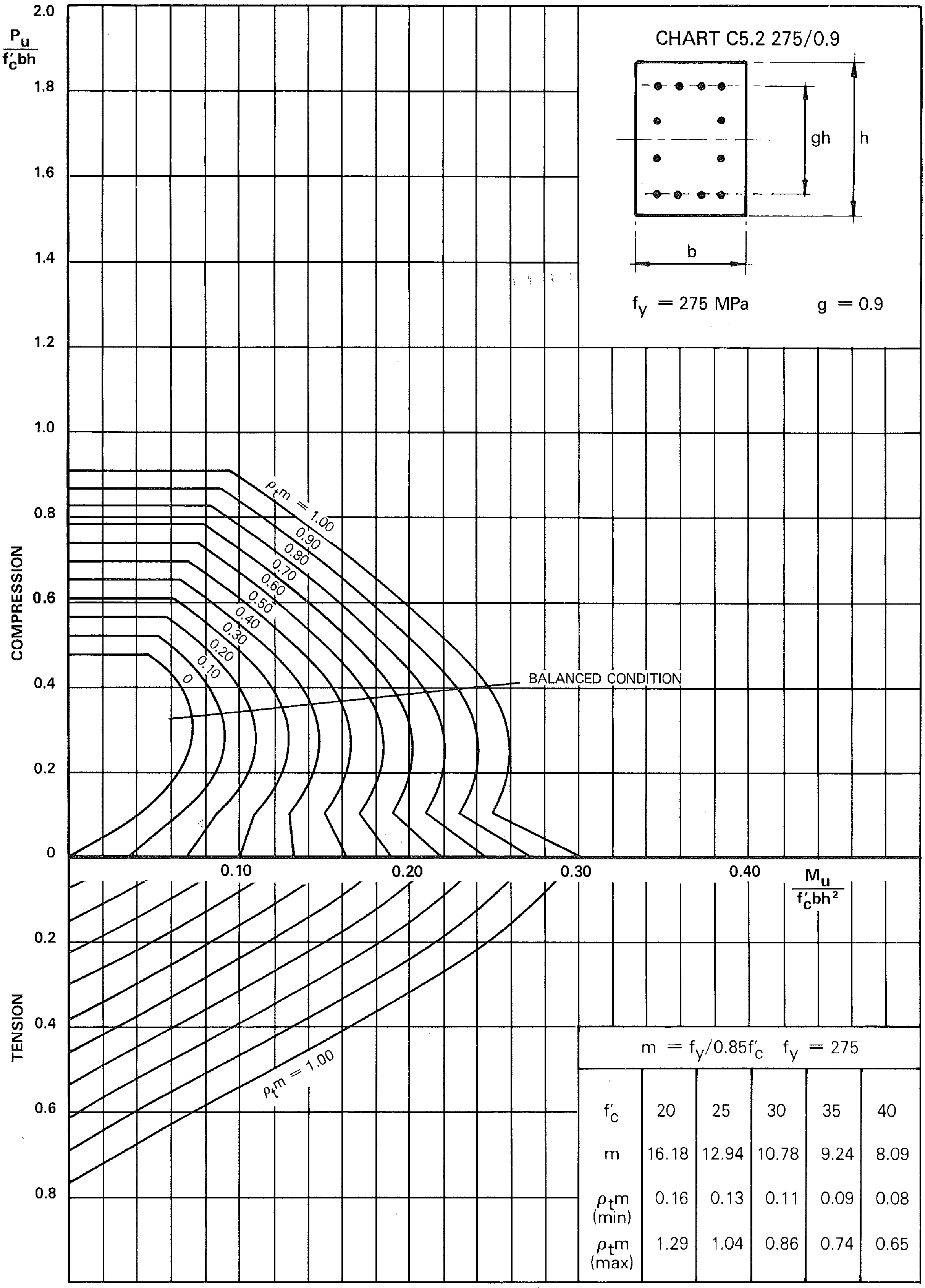
C5.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

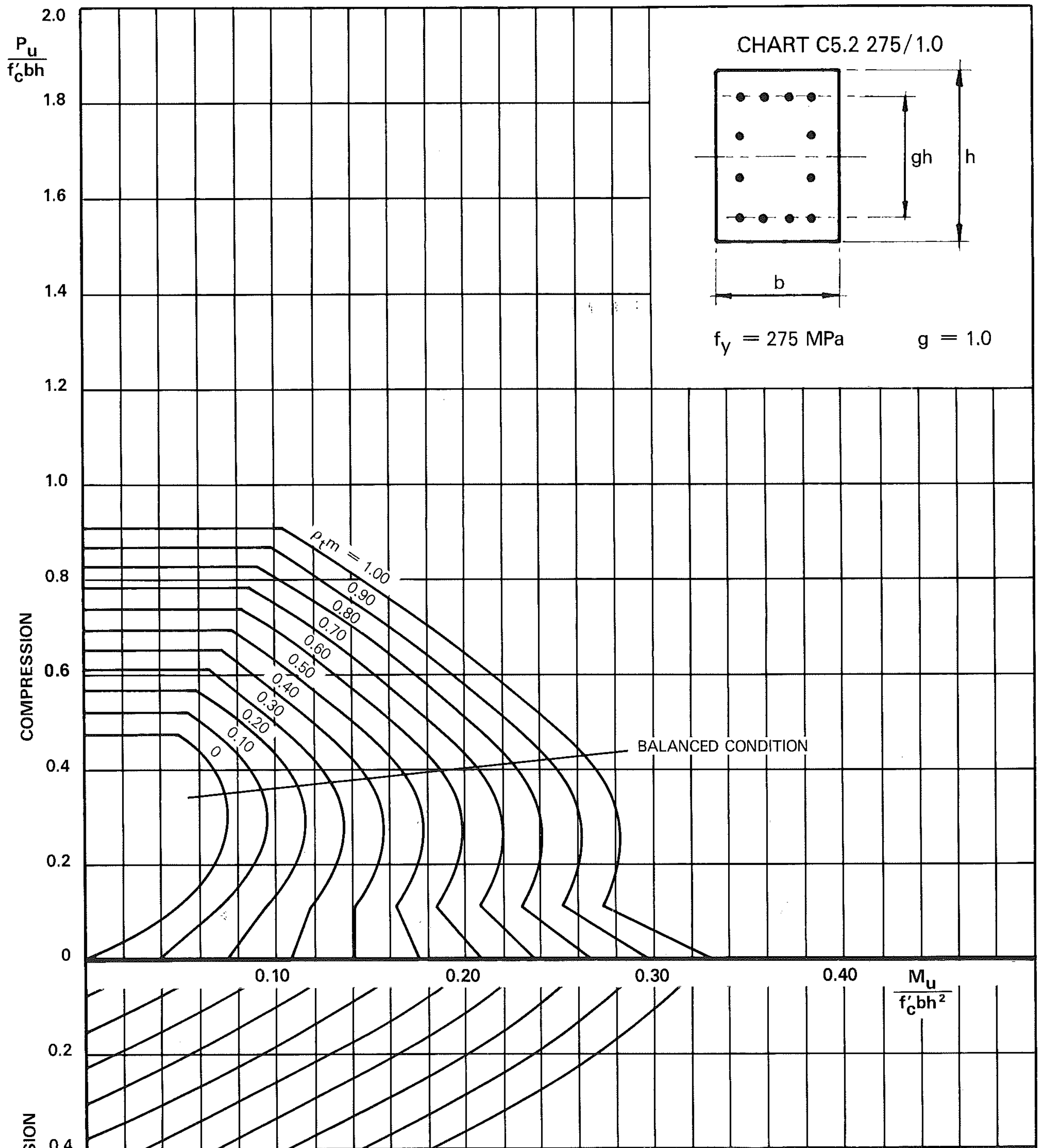
C5.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

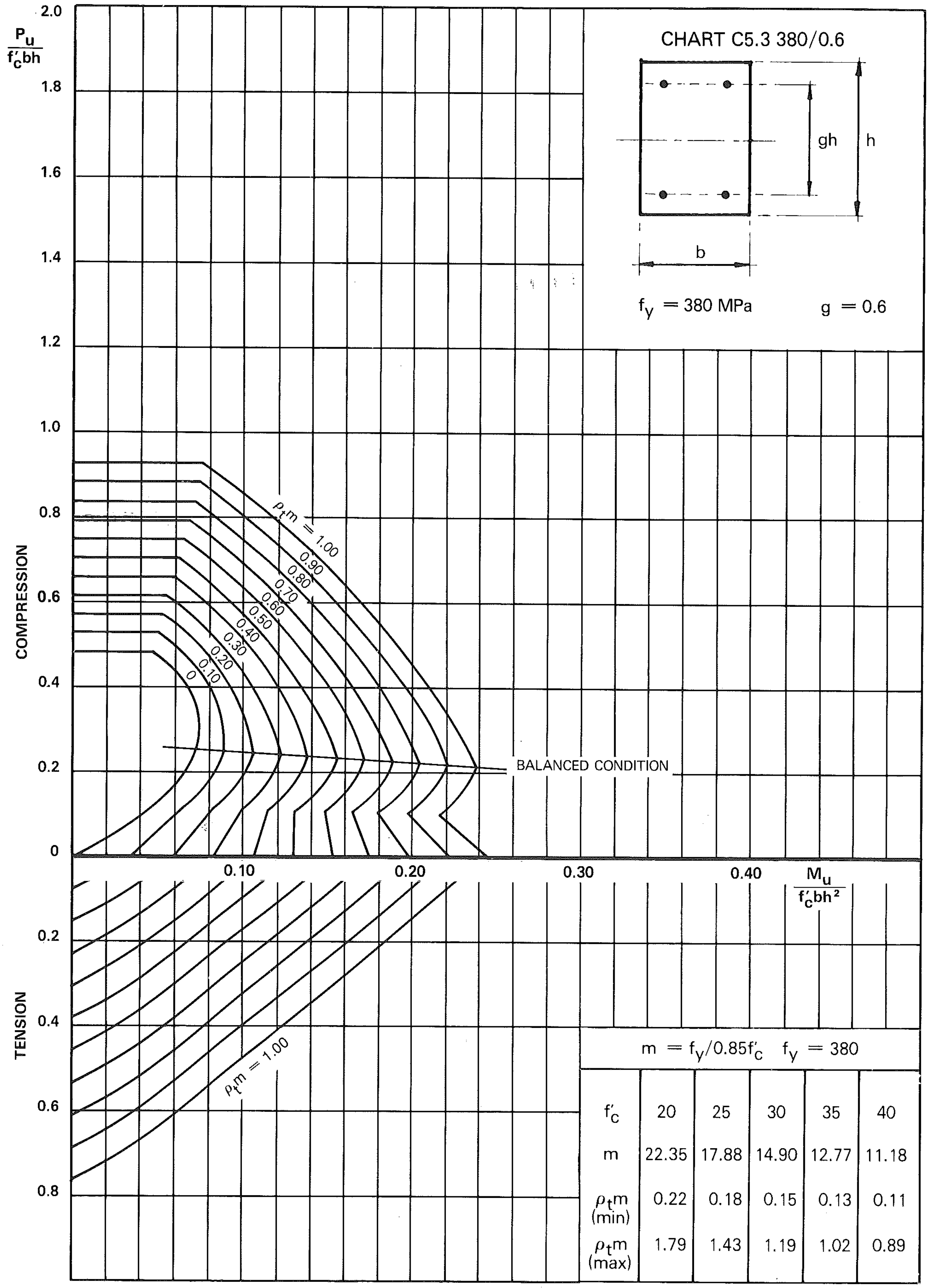
C5.2 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

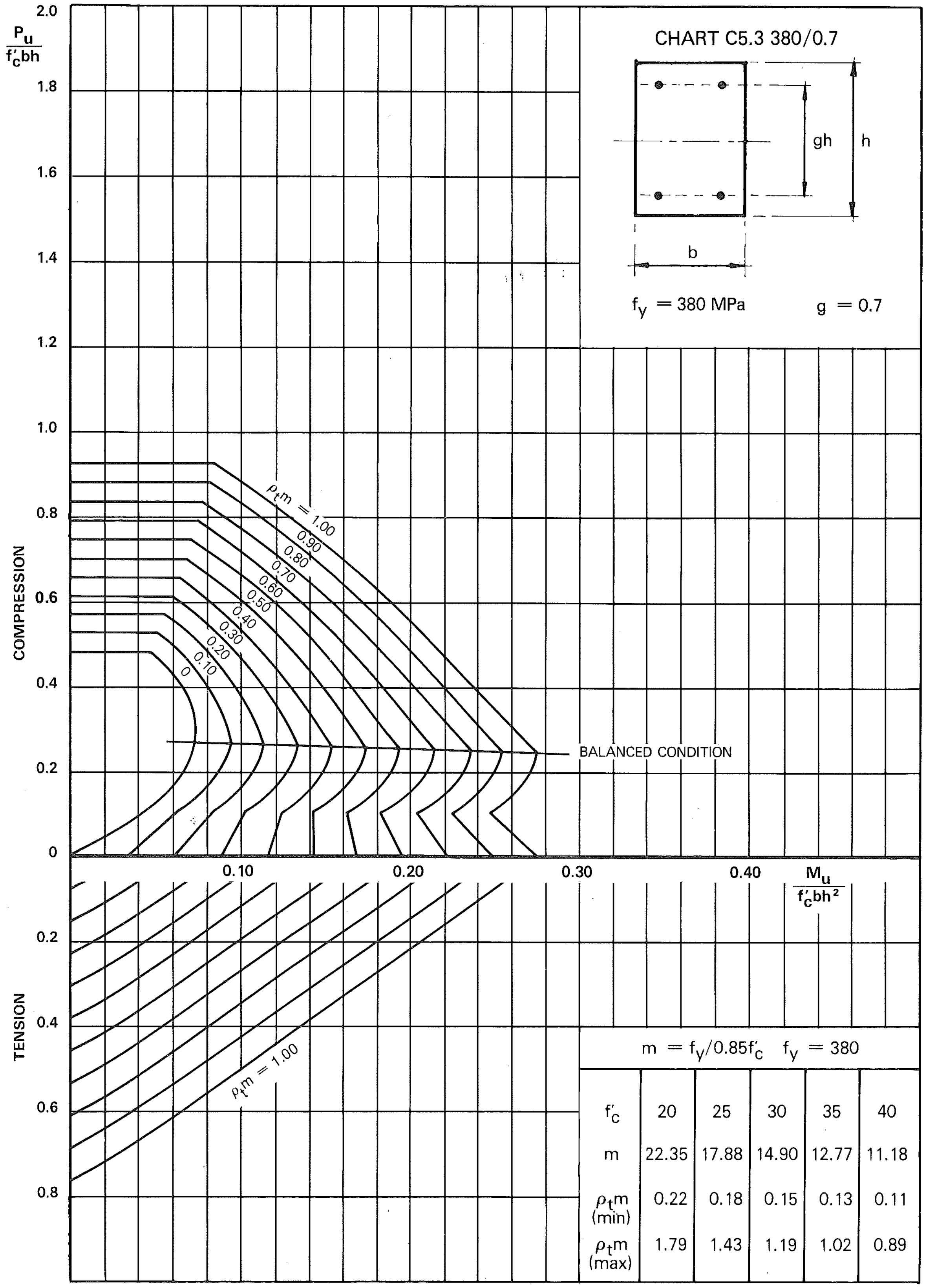
C5.3 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

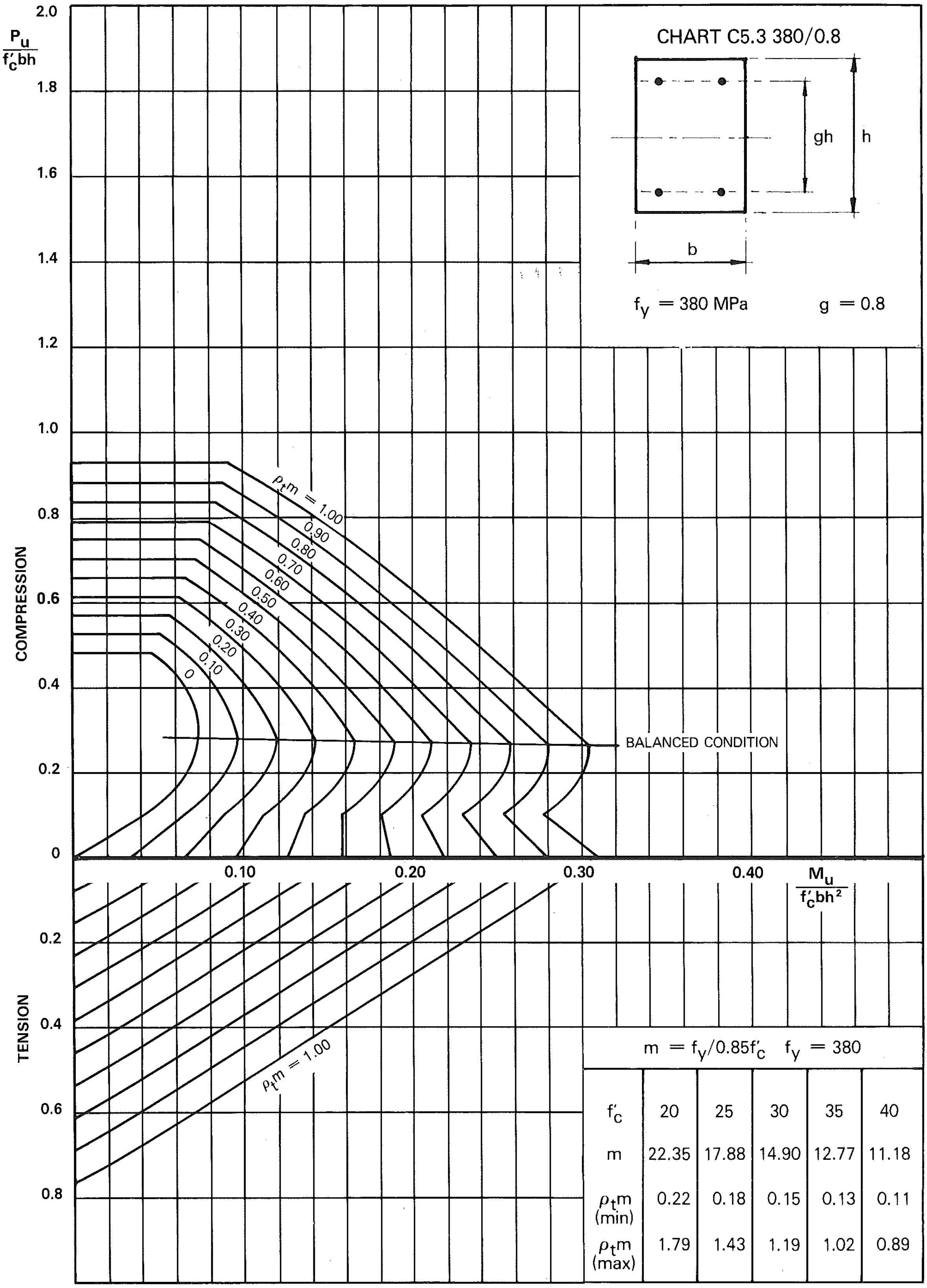
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C5.3 COLUMN DESIGN CHART



f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

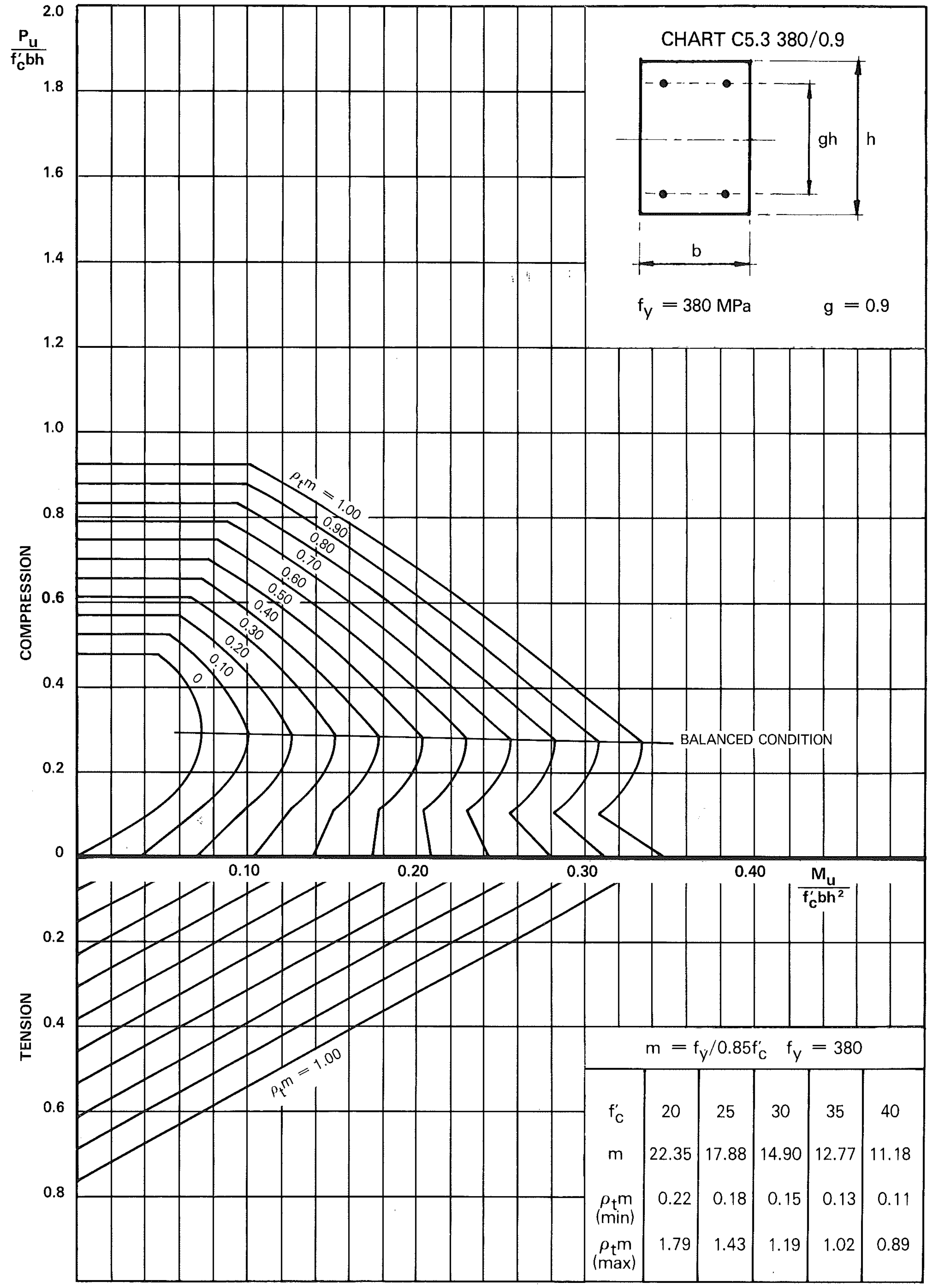
C5.3 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $\quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

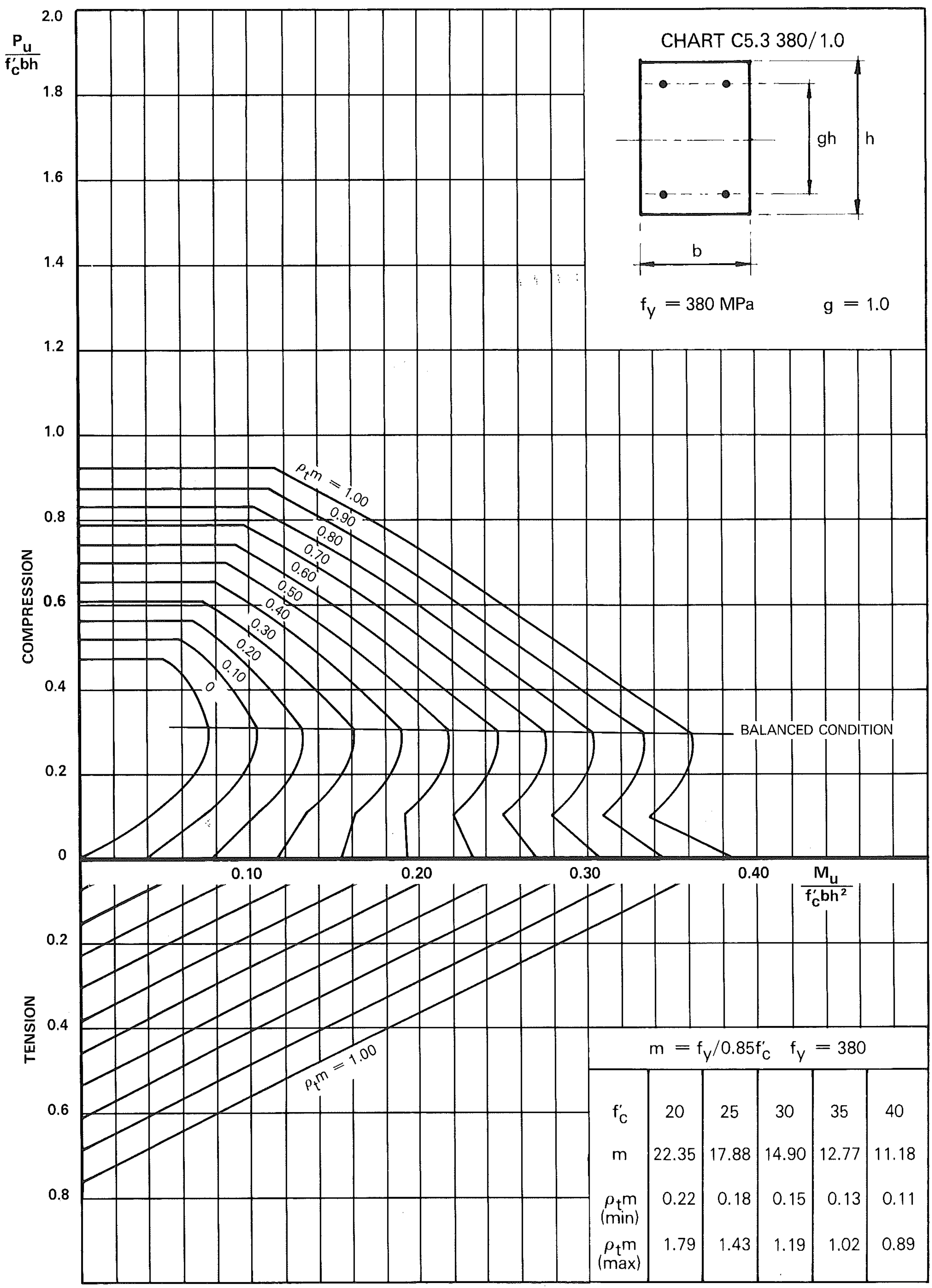
C5.3 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

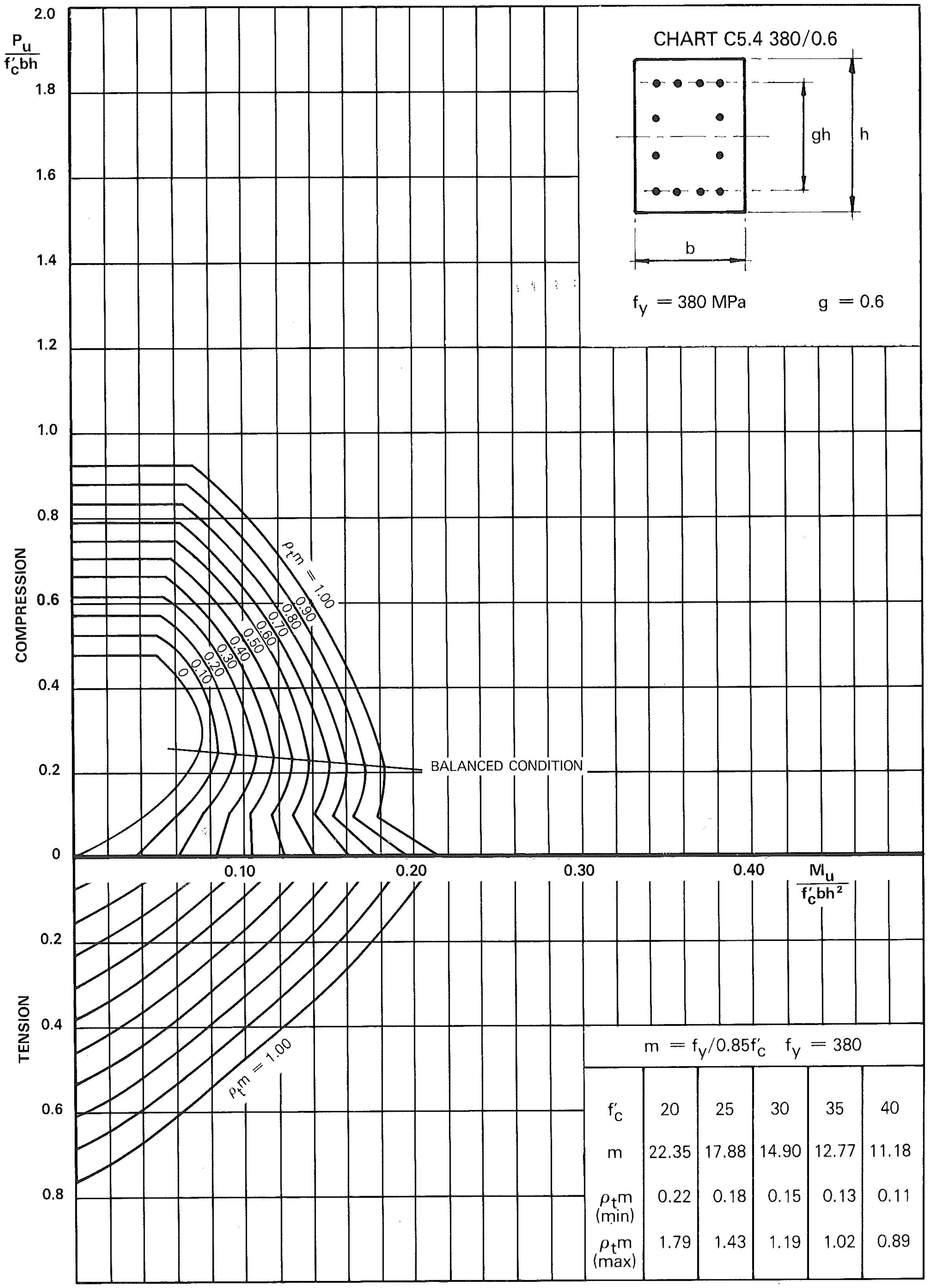
C5.3 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

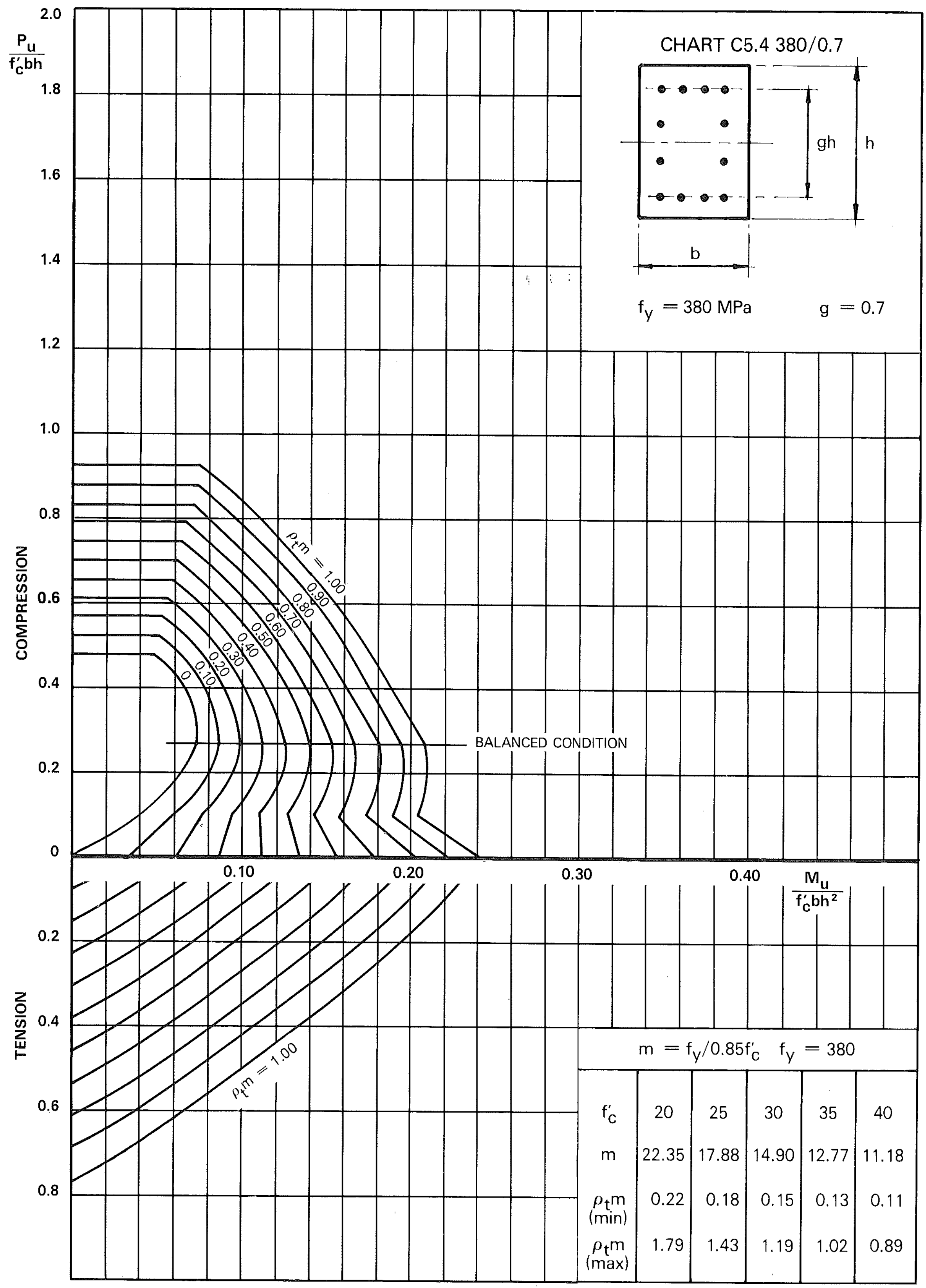
C5.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

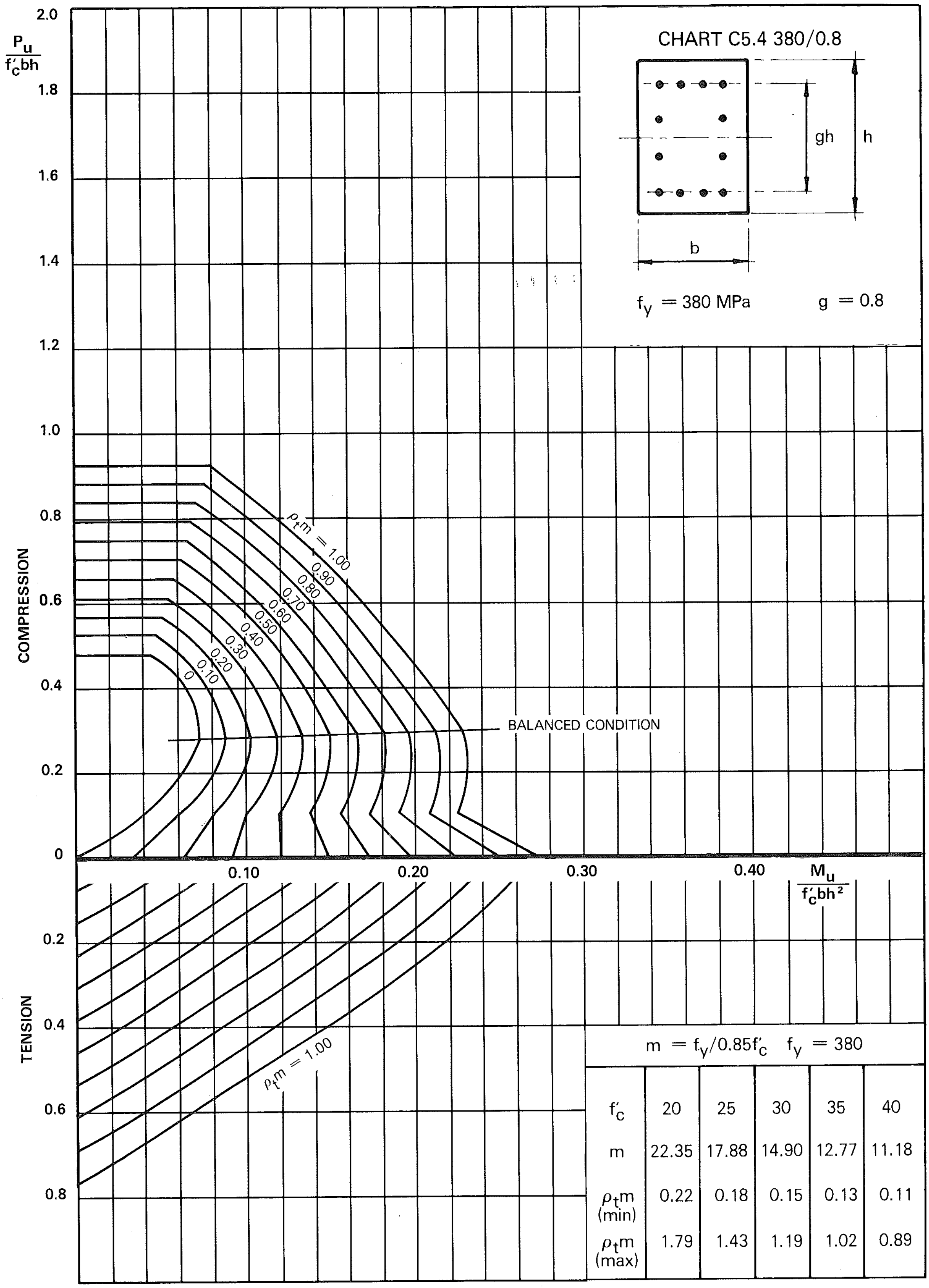
C5.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

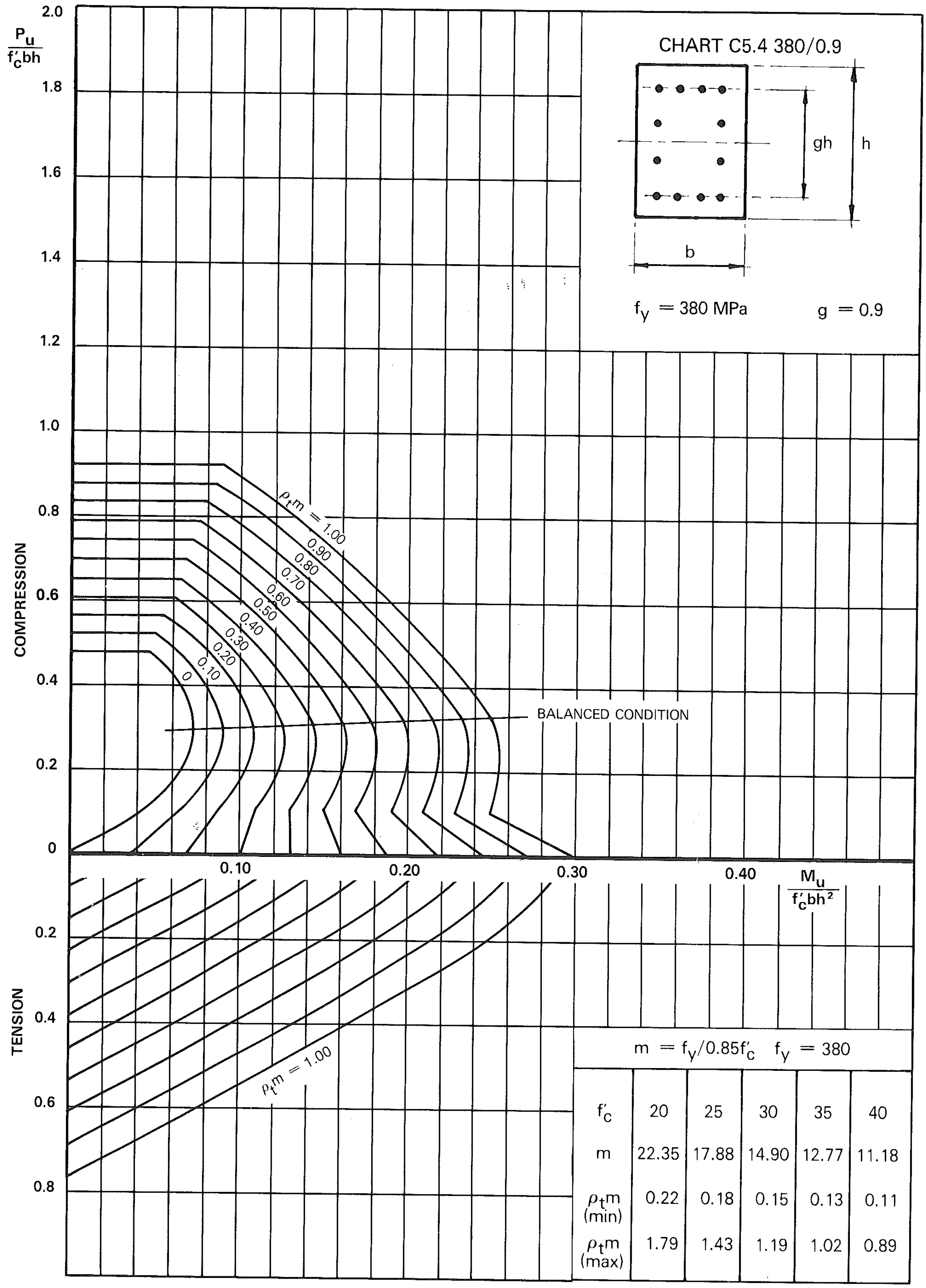
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C5.4 COLUMN DESIGN CHART



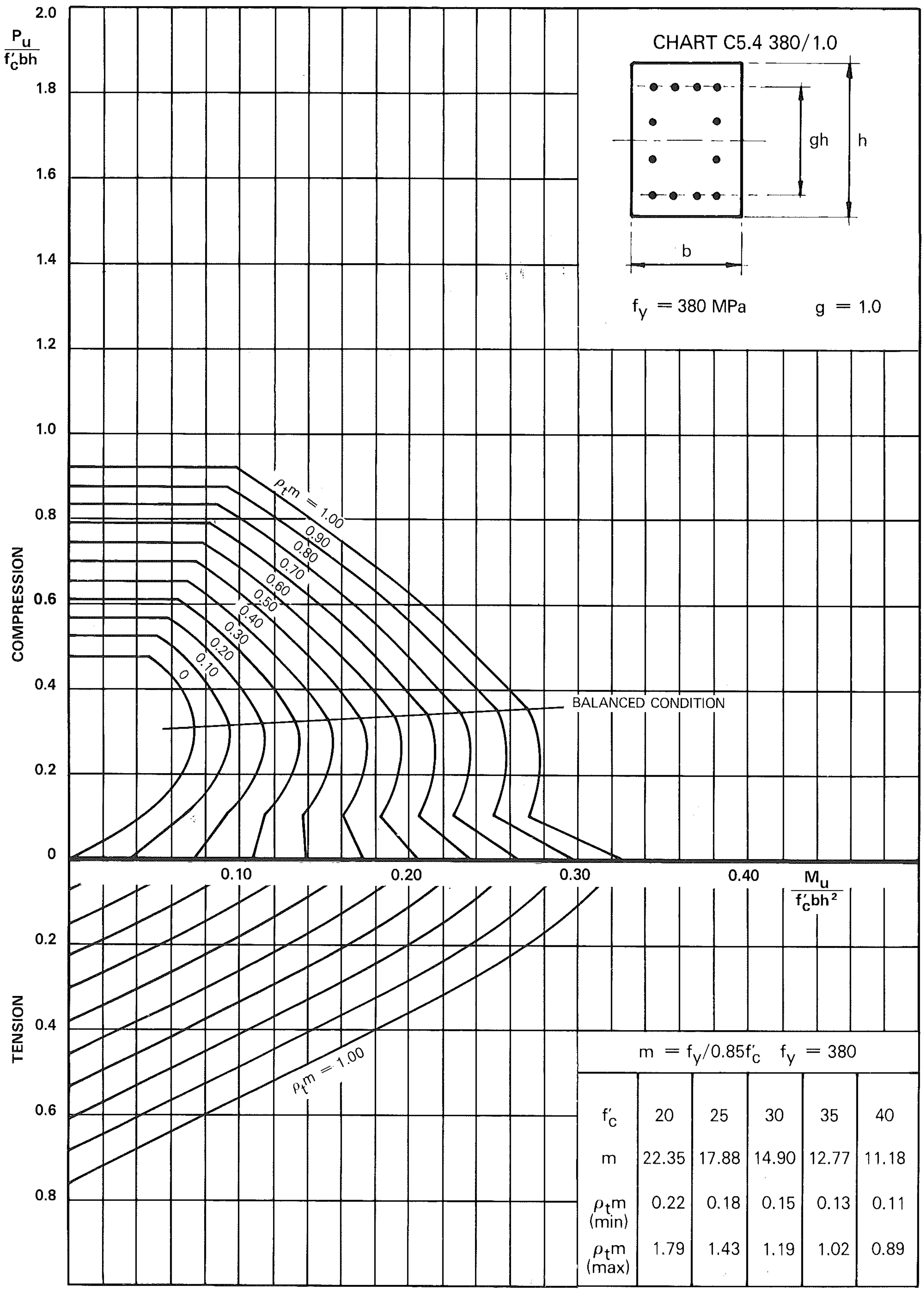
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C5.4 COLUMN DESIGN CHART



f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

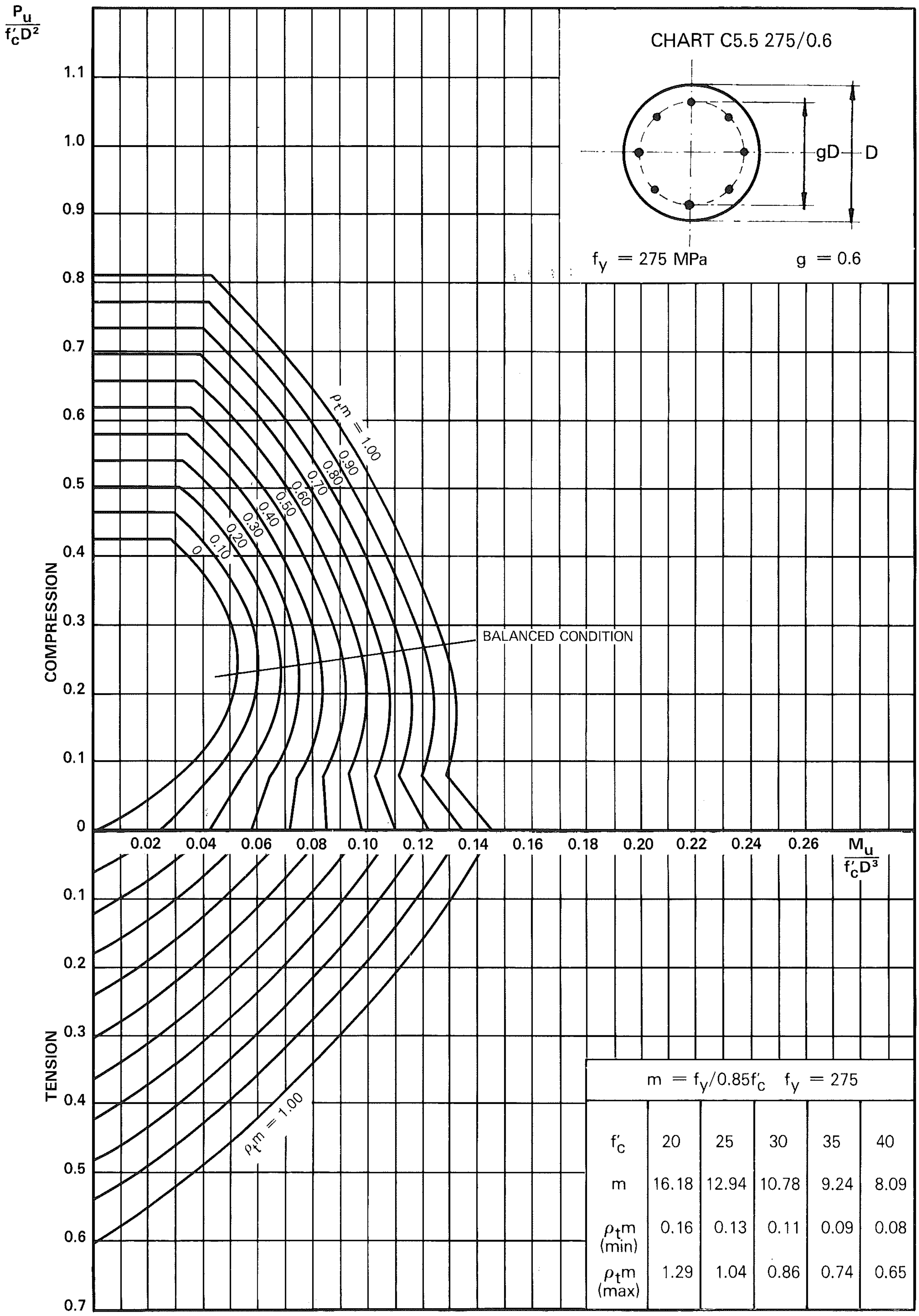
C5.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

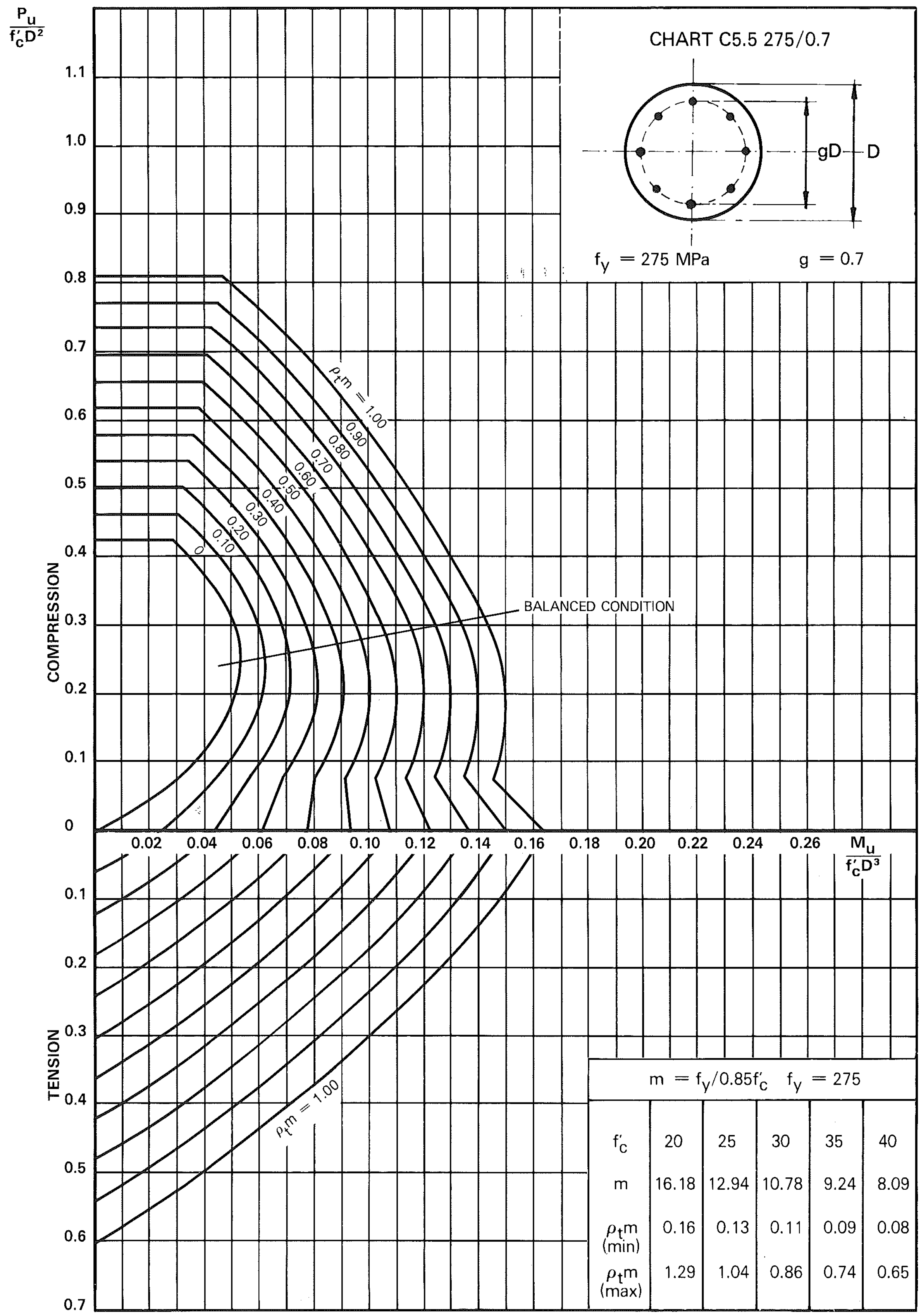
C5.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

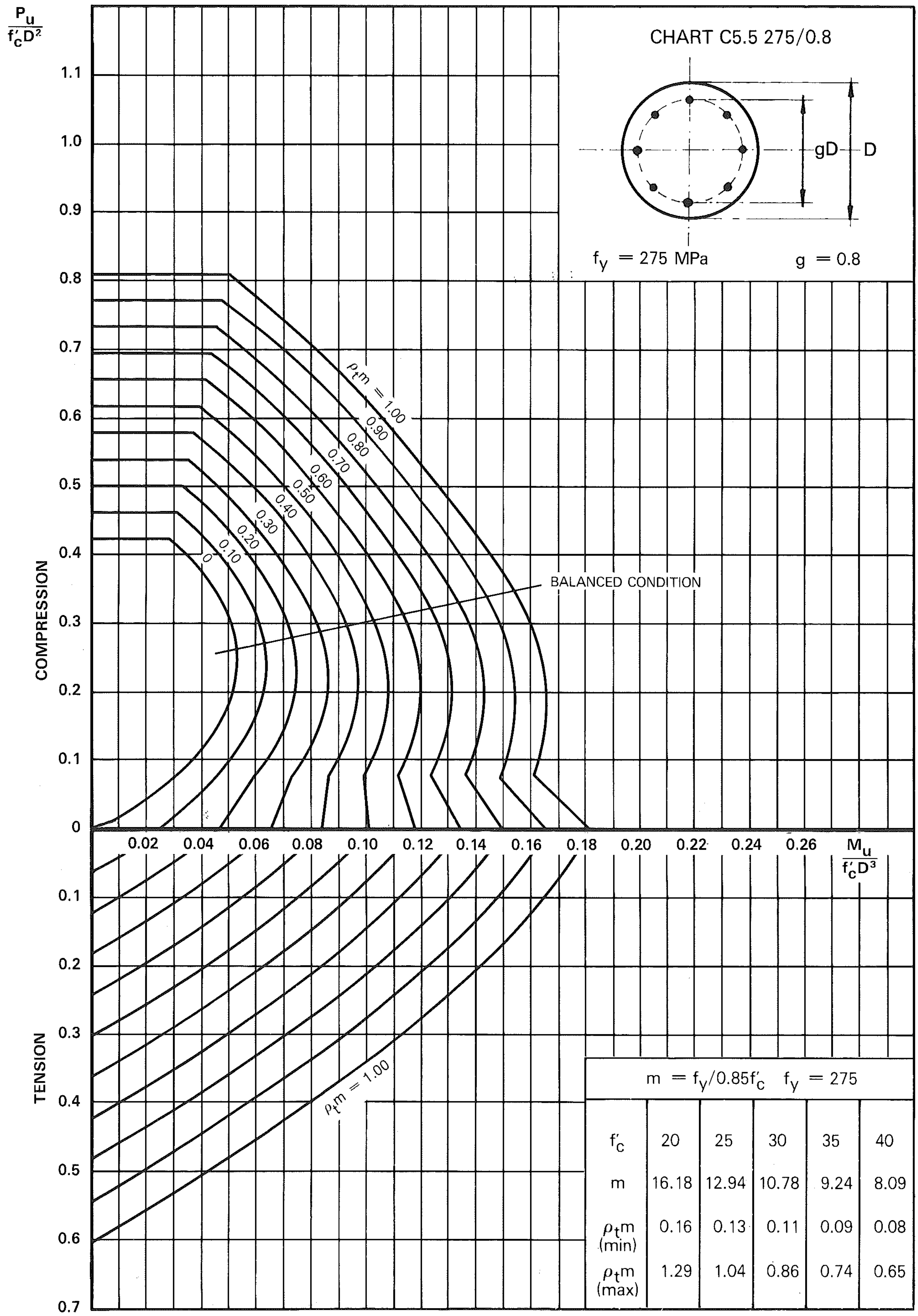
C5.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

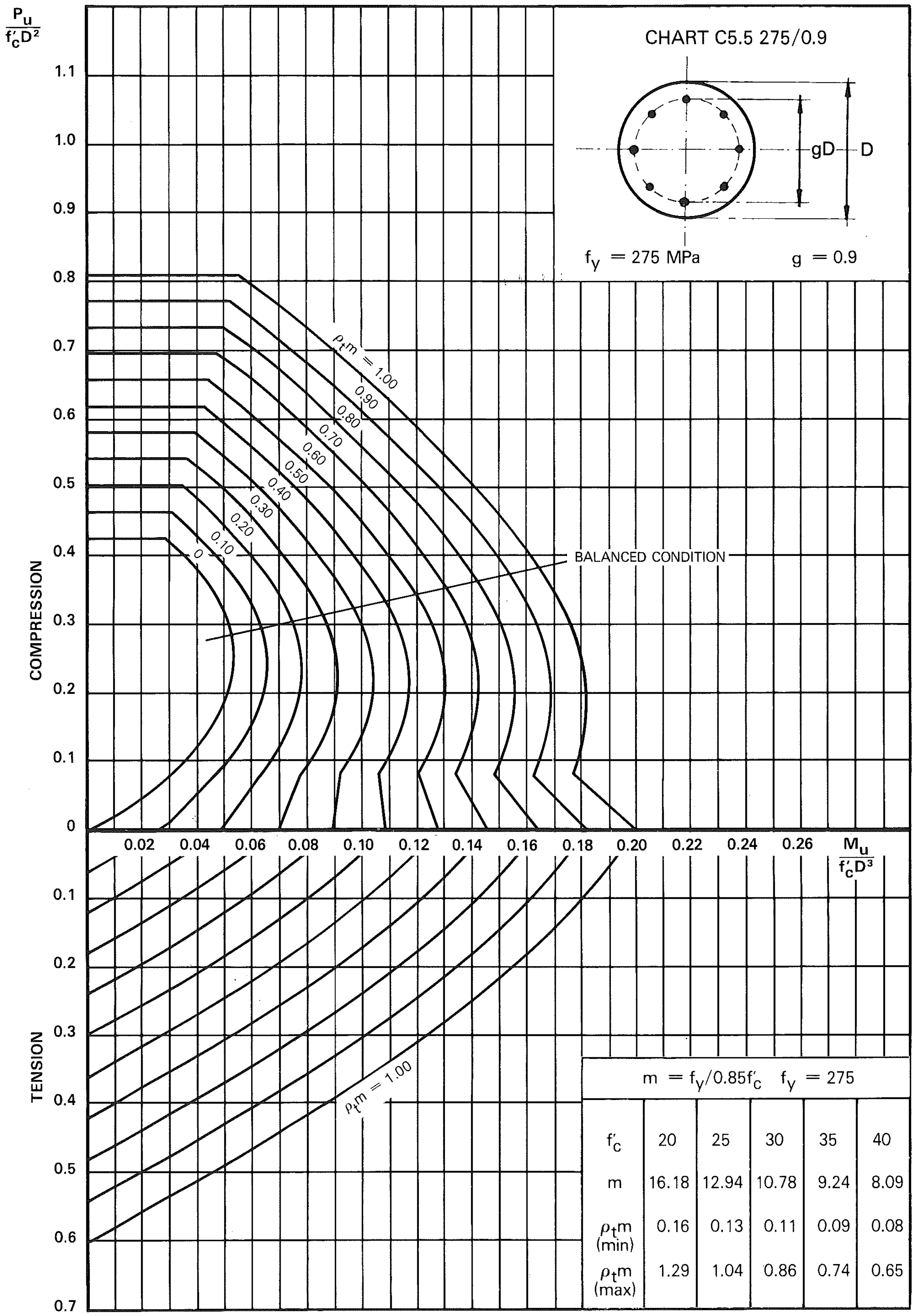
C5.5 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

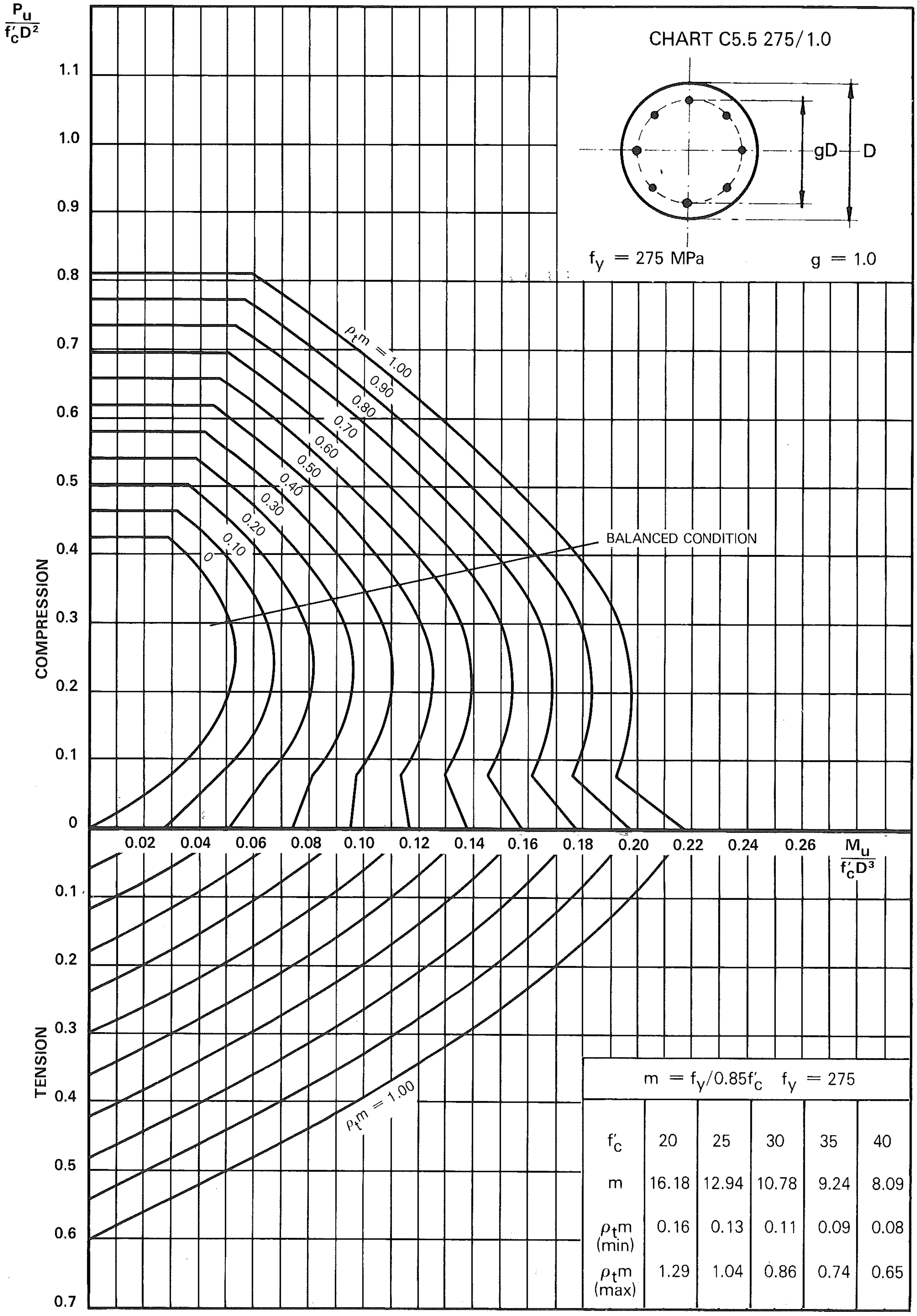
C5.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

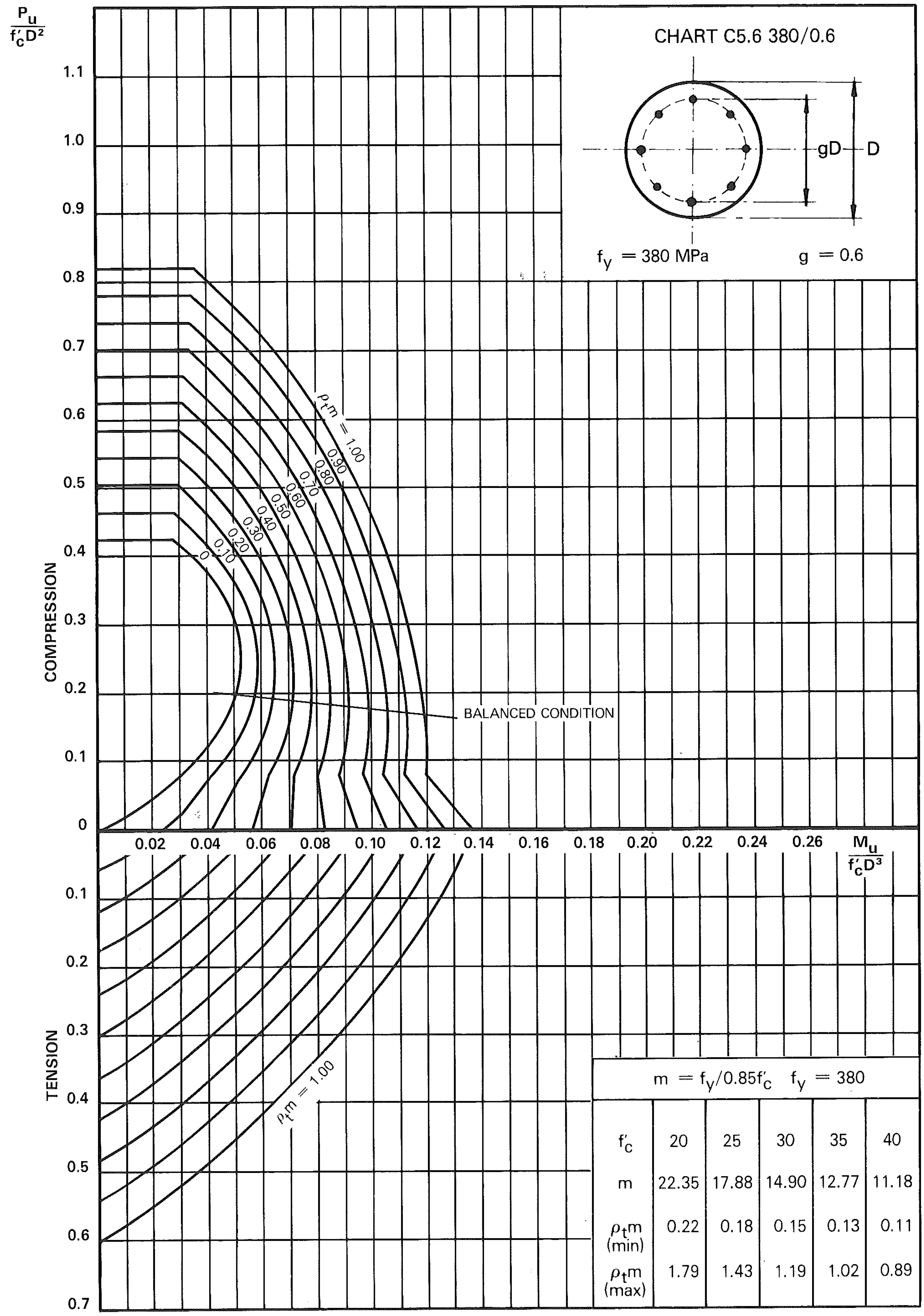
C5.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

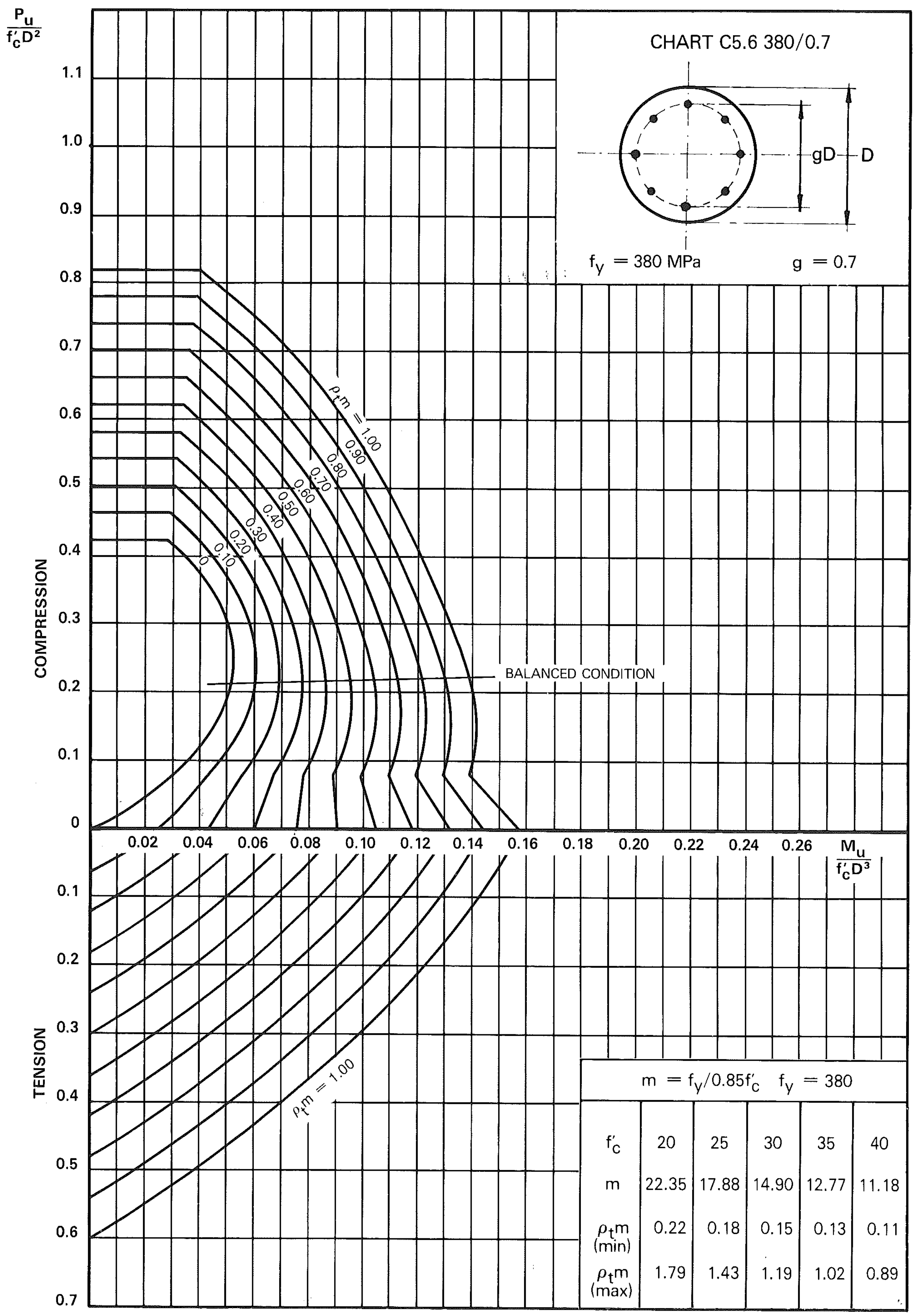
C5.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

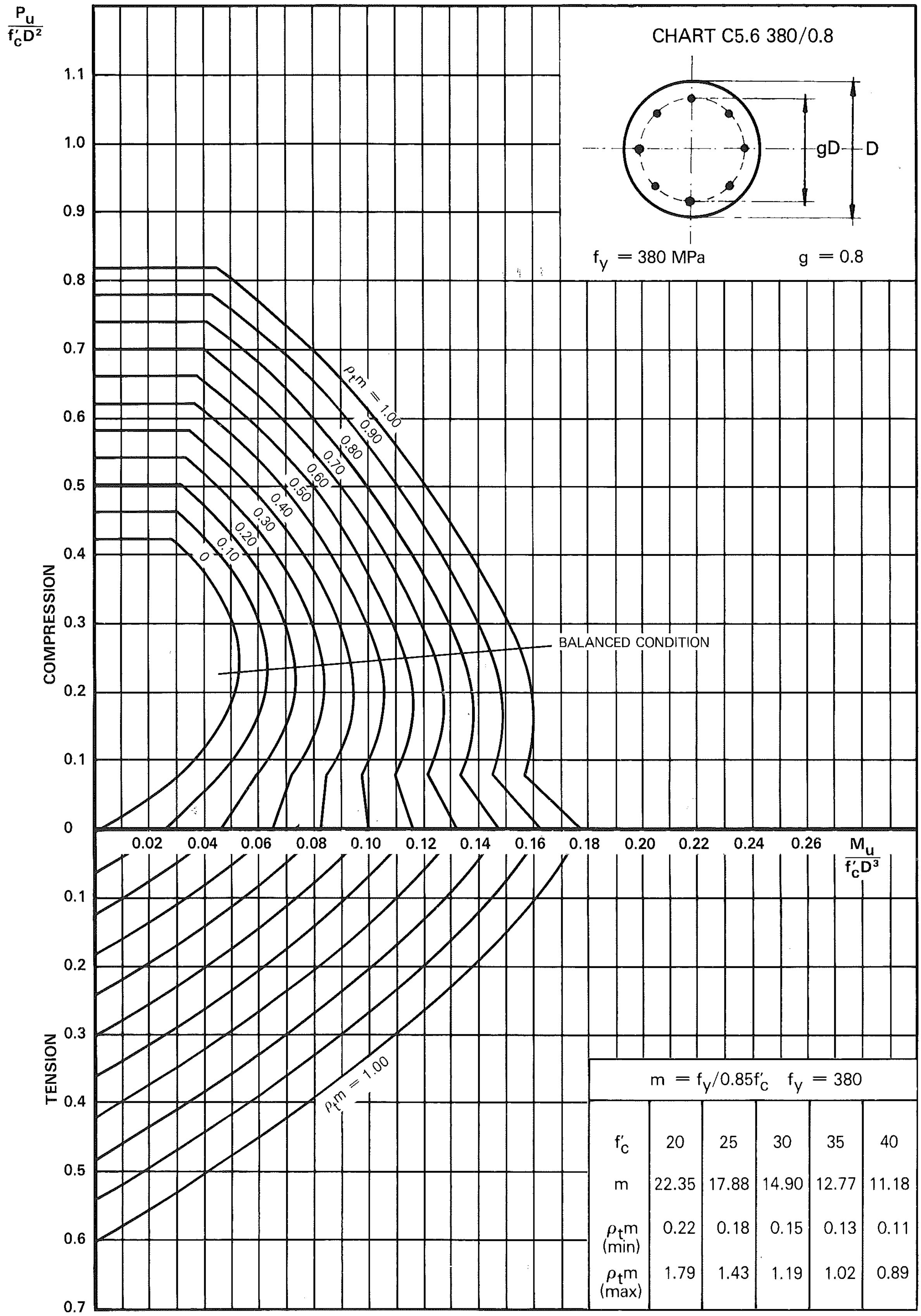
C5.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

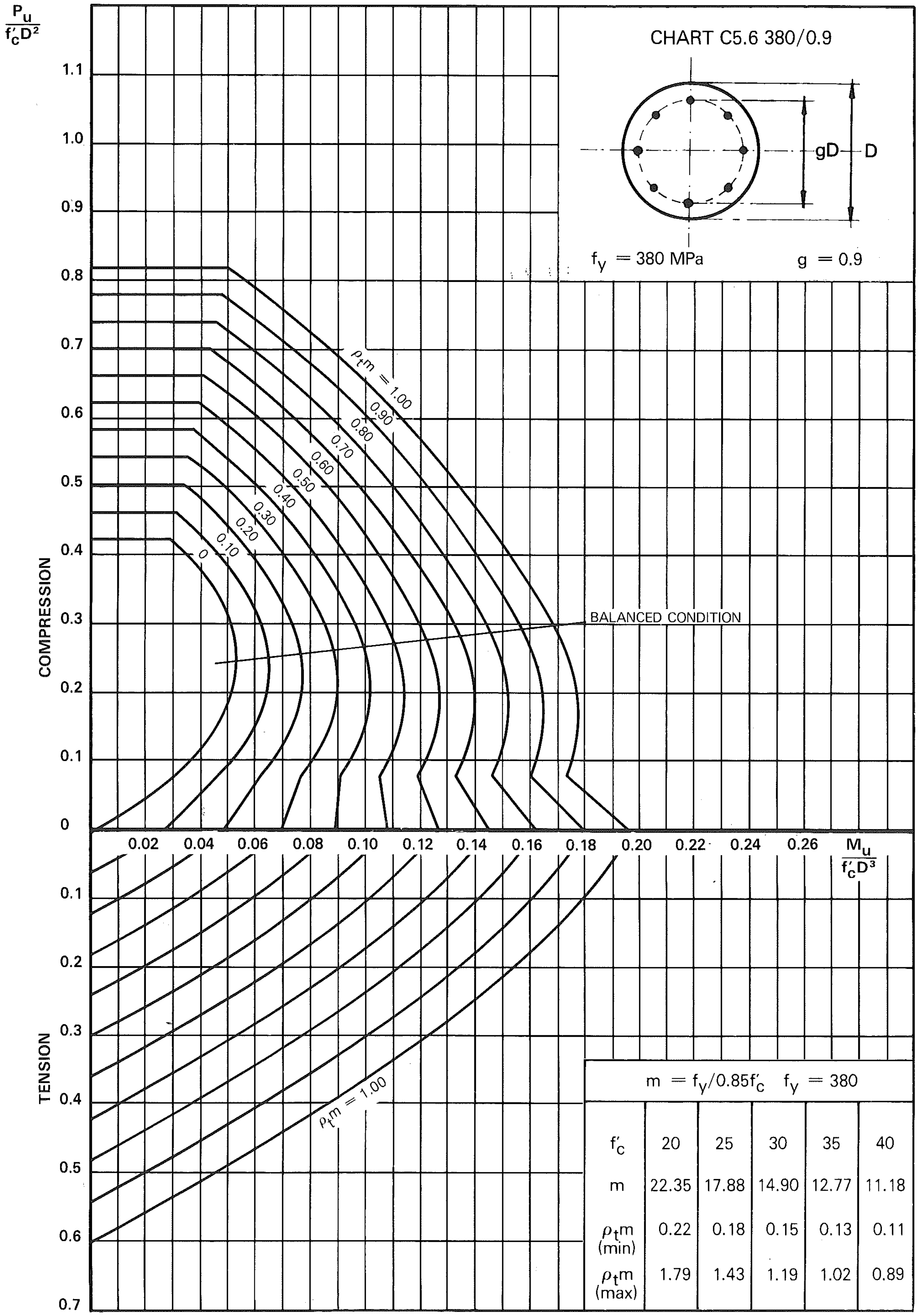
C5.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

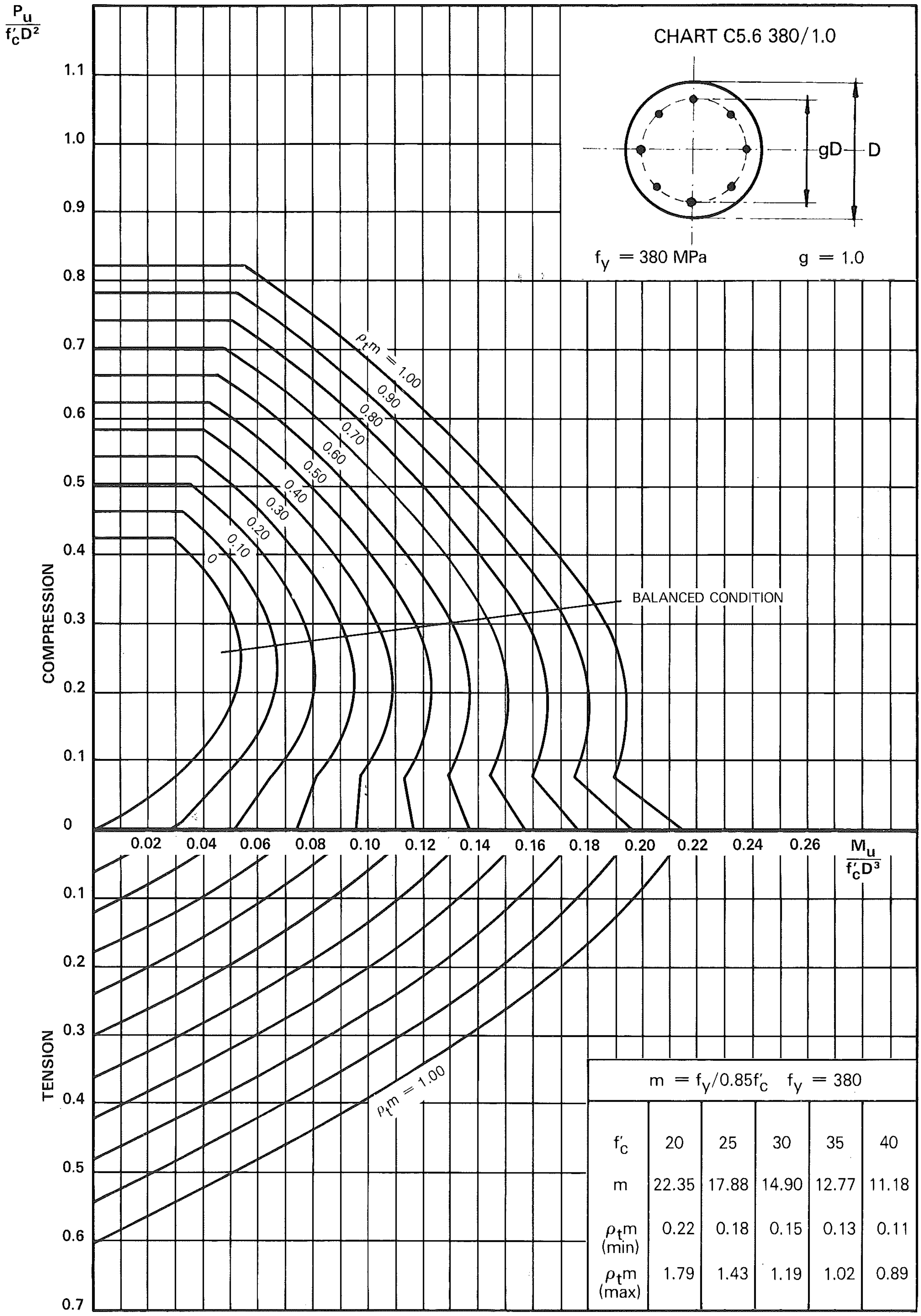
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C5.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 380					
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C5.6 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 380

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

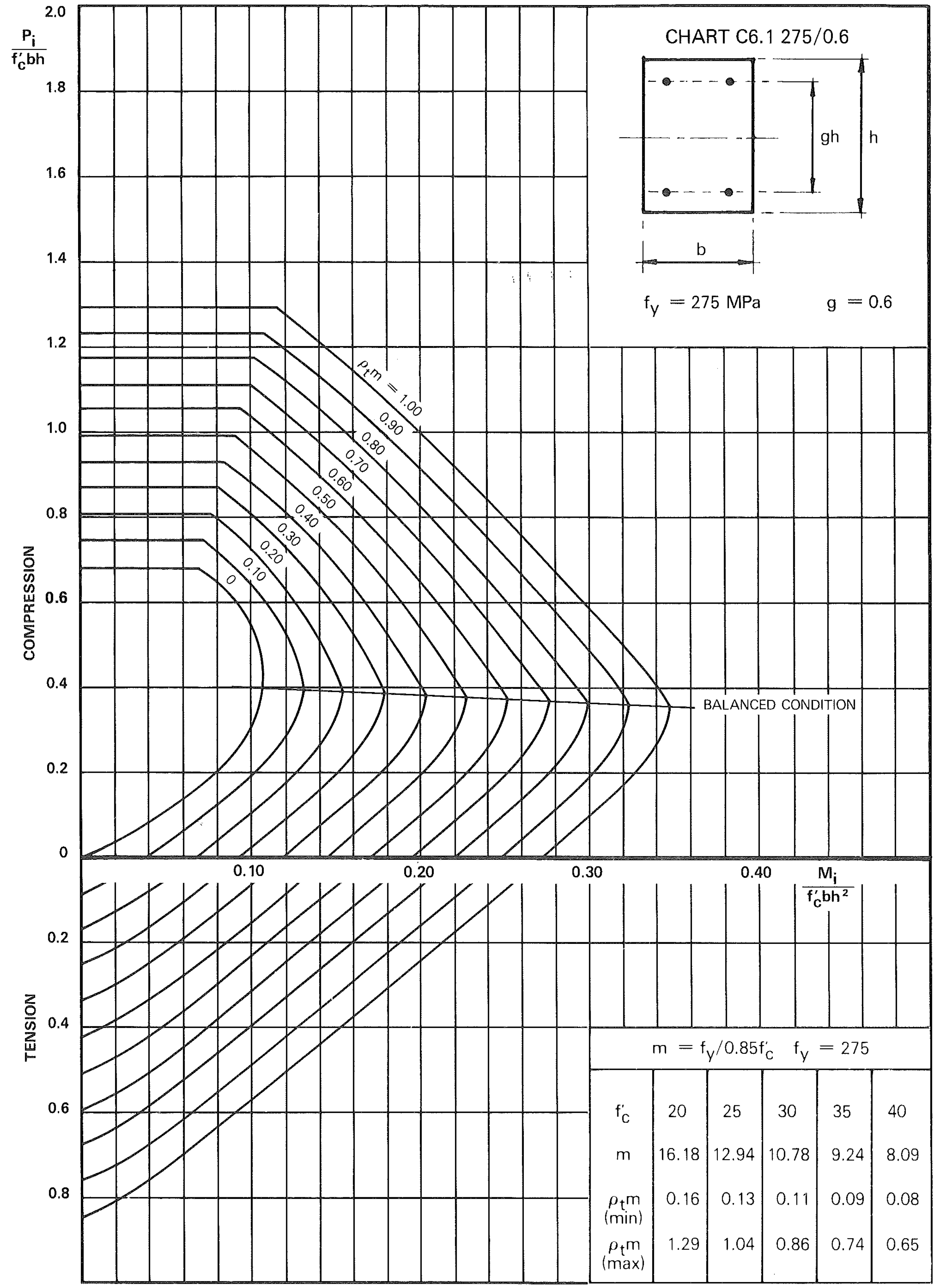
Note

Buff charts C6.1 to C6.6.

These charts do not incorporate ϕ factors and are plotted in terms of P_i and M_i,

The designer must include the appropriate capacity reduction factor for the design condition being analysed

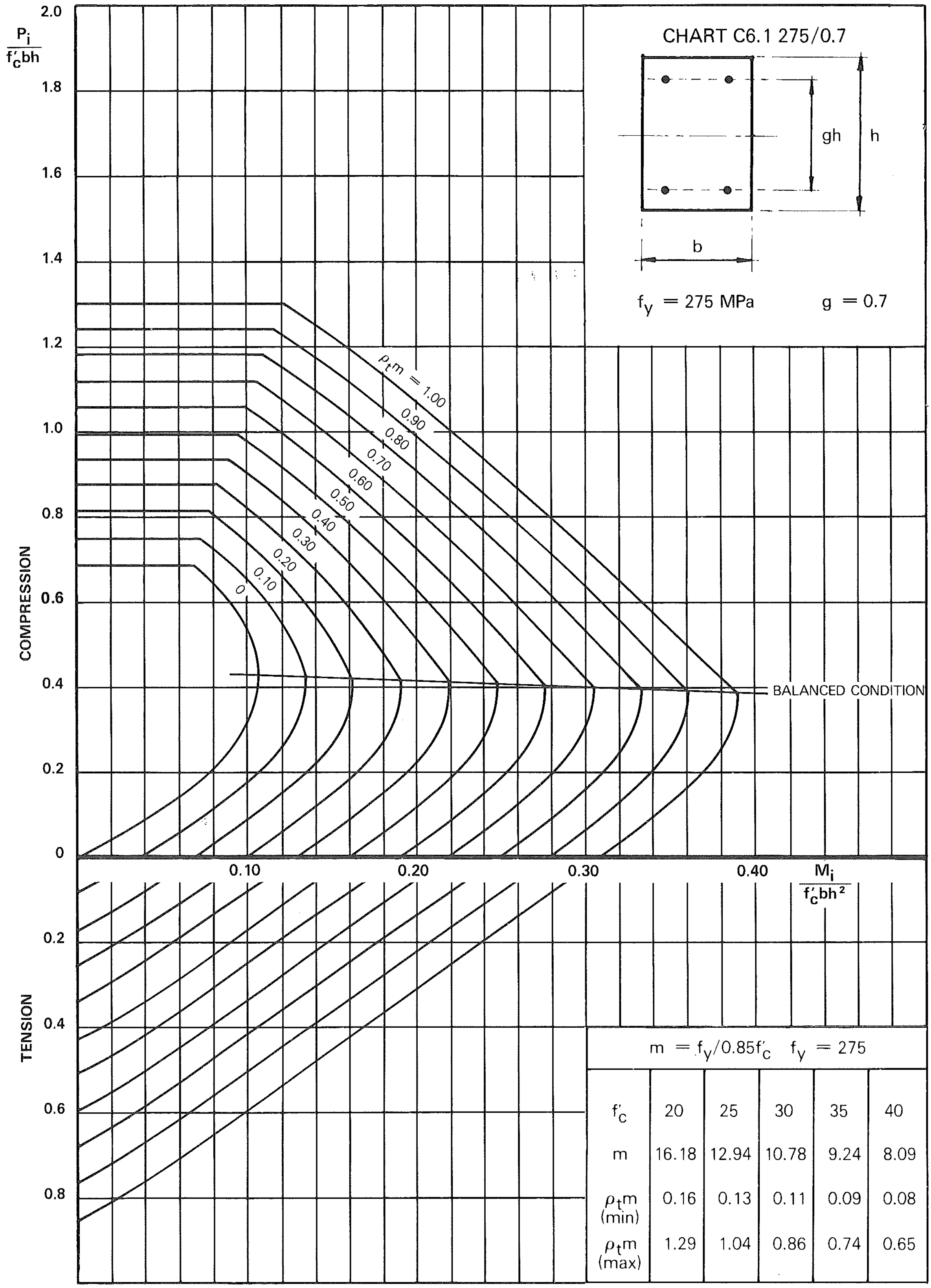
C6.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

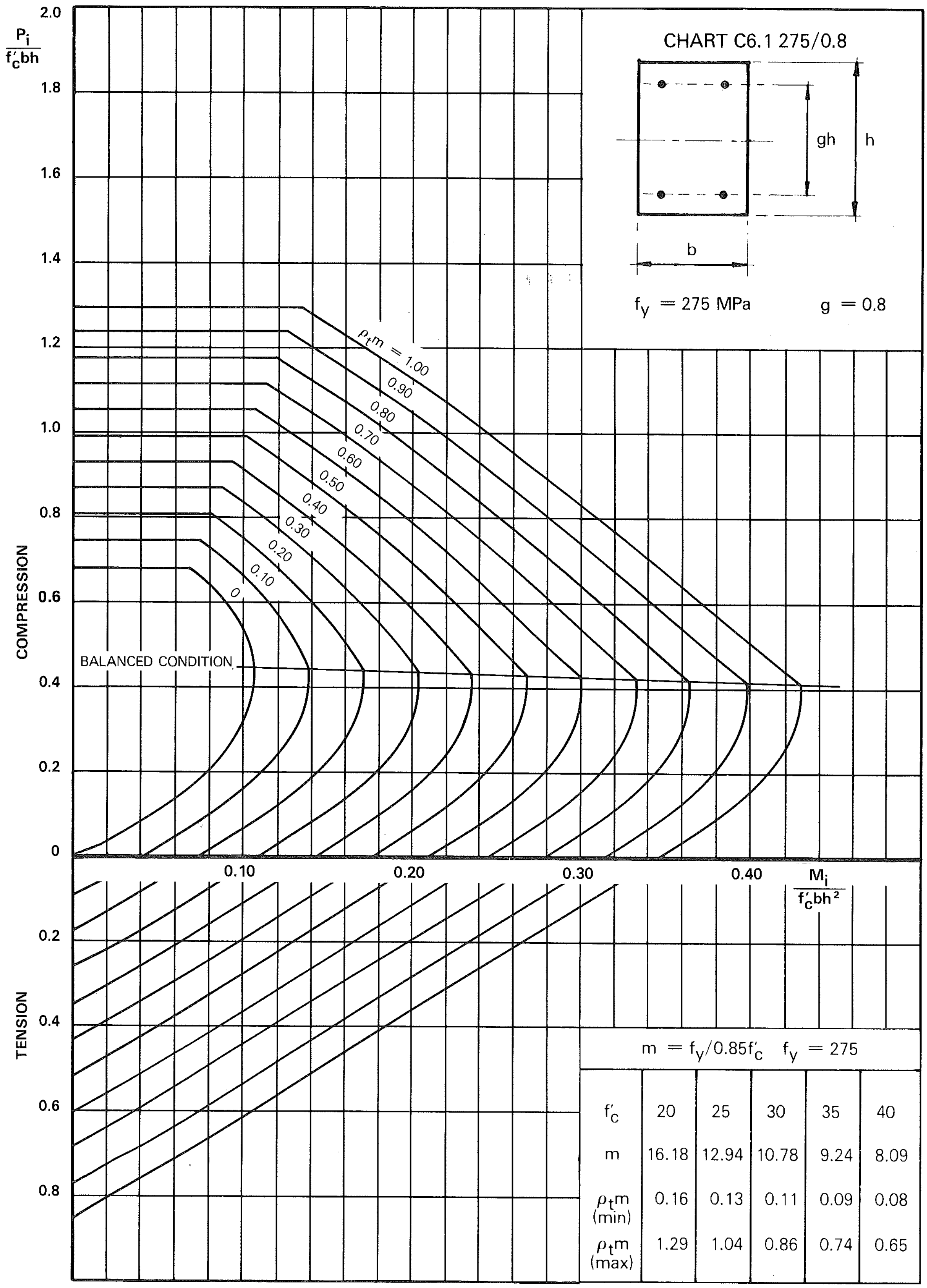
C6.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

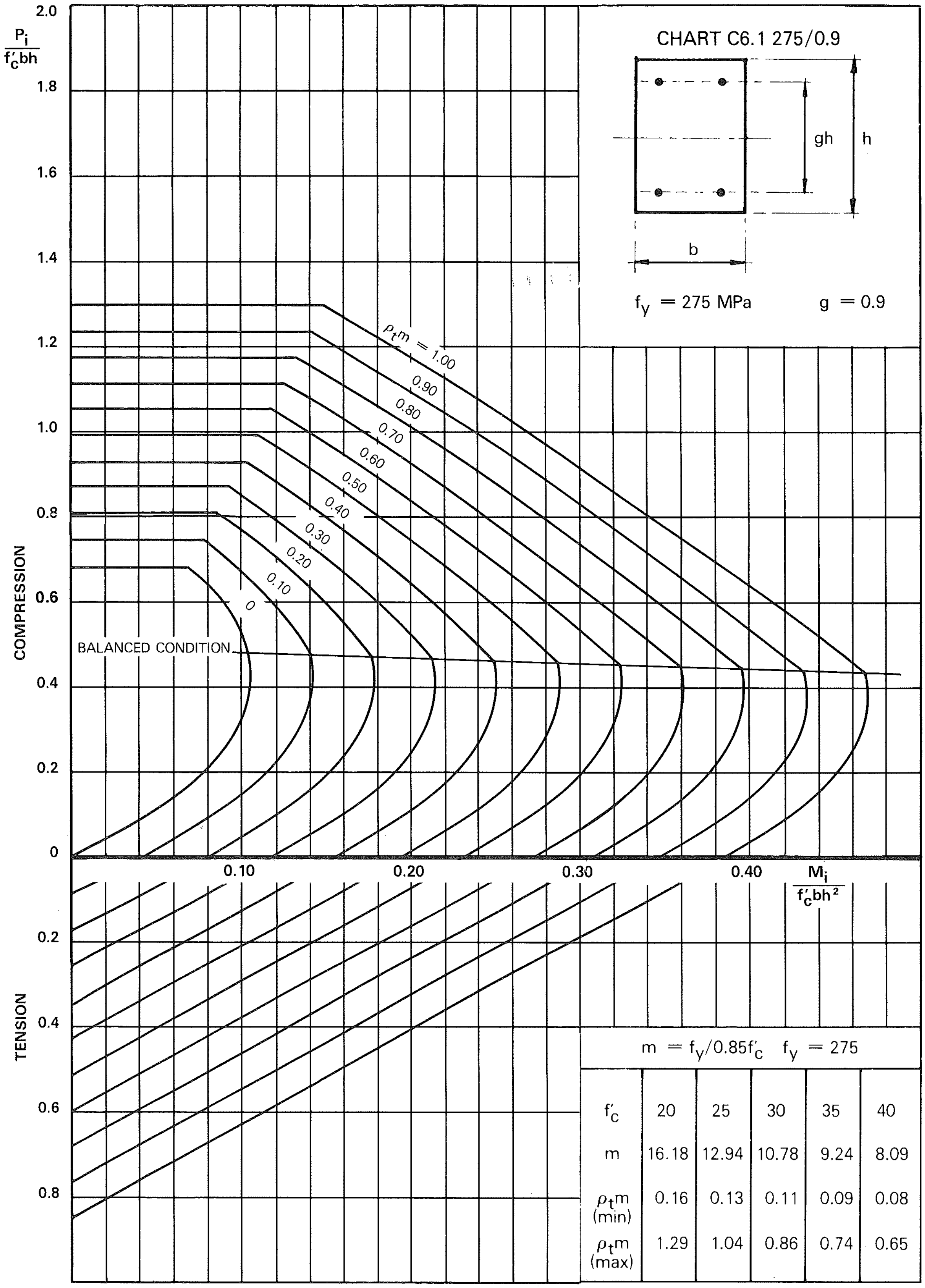
C6.1 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

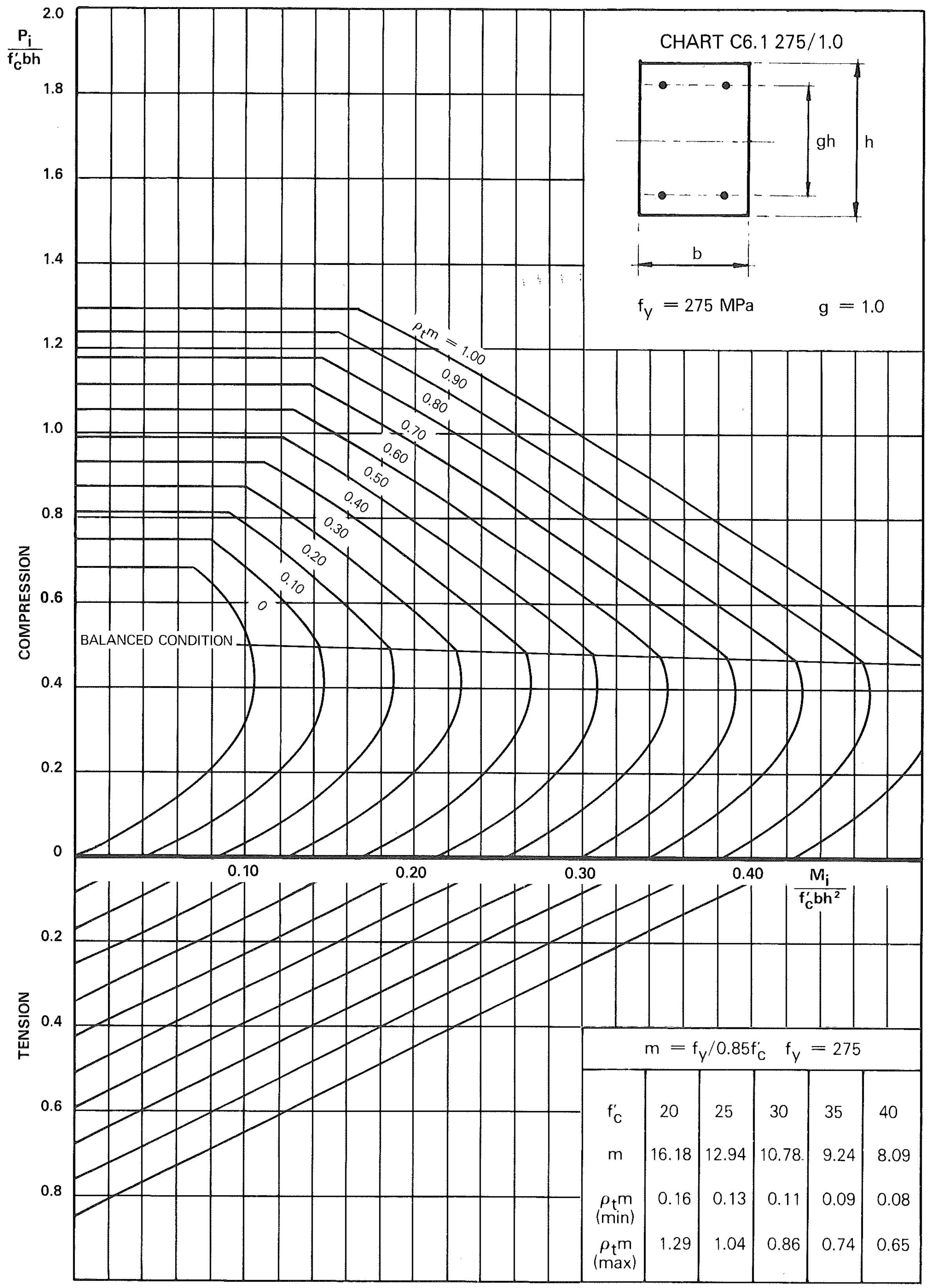
C6.1 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

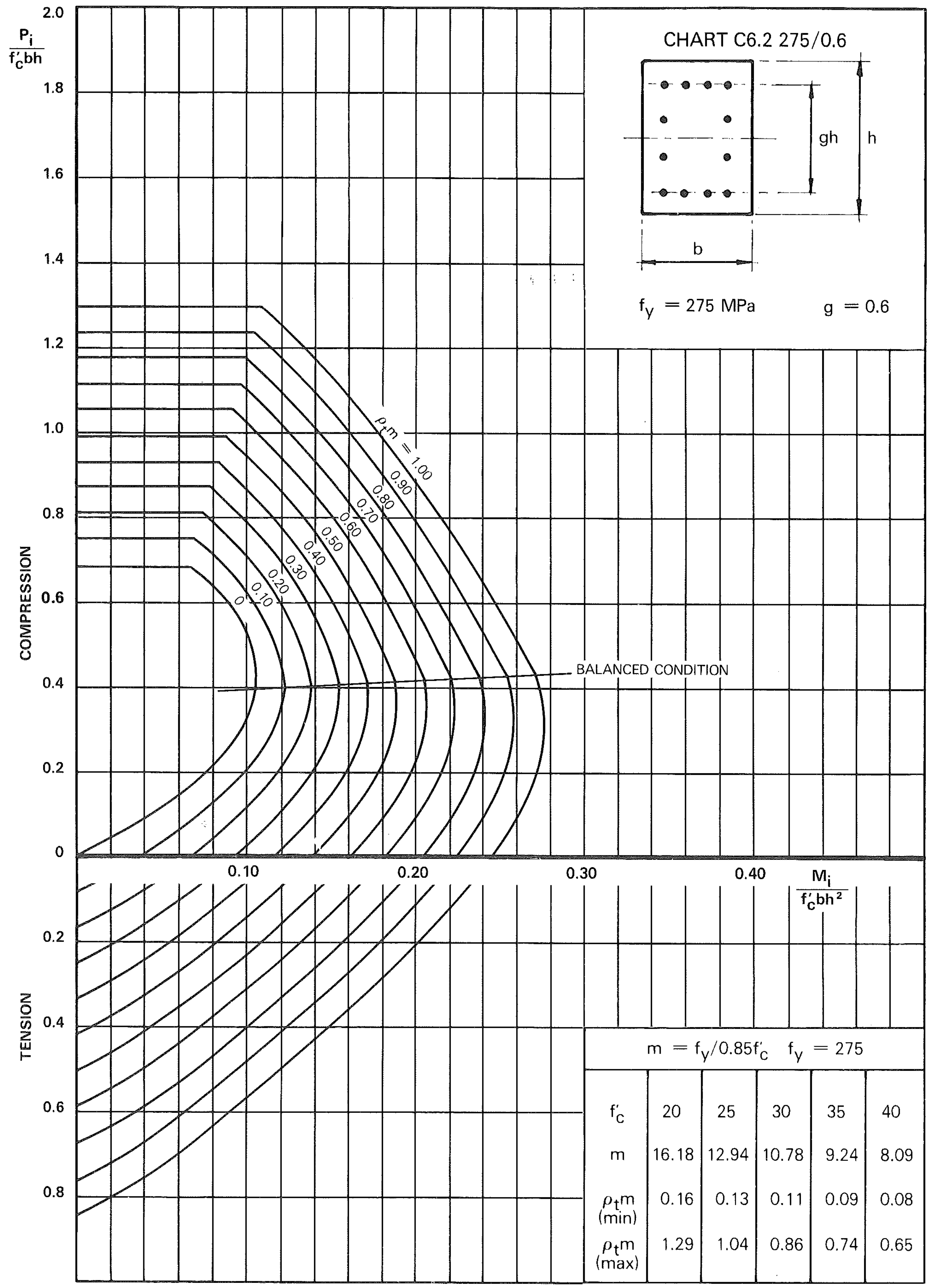
C6.1 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

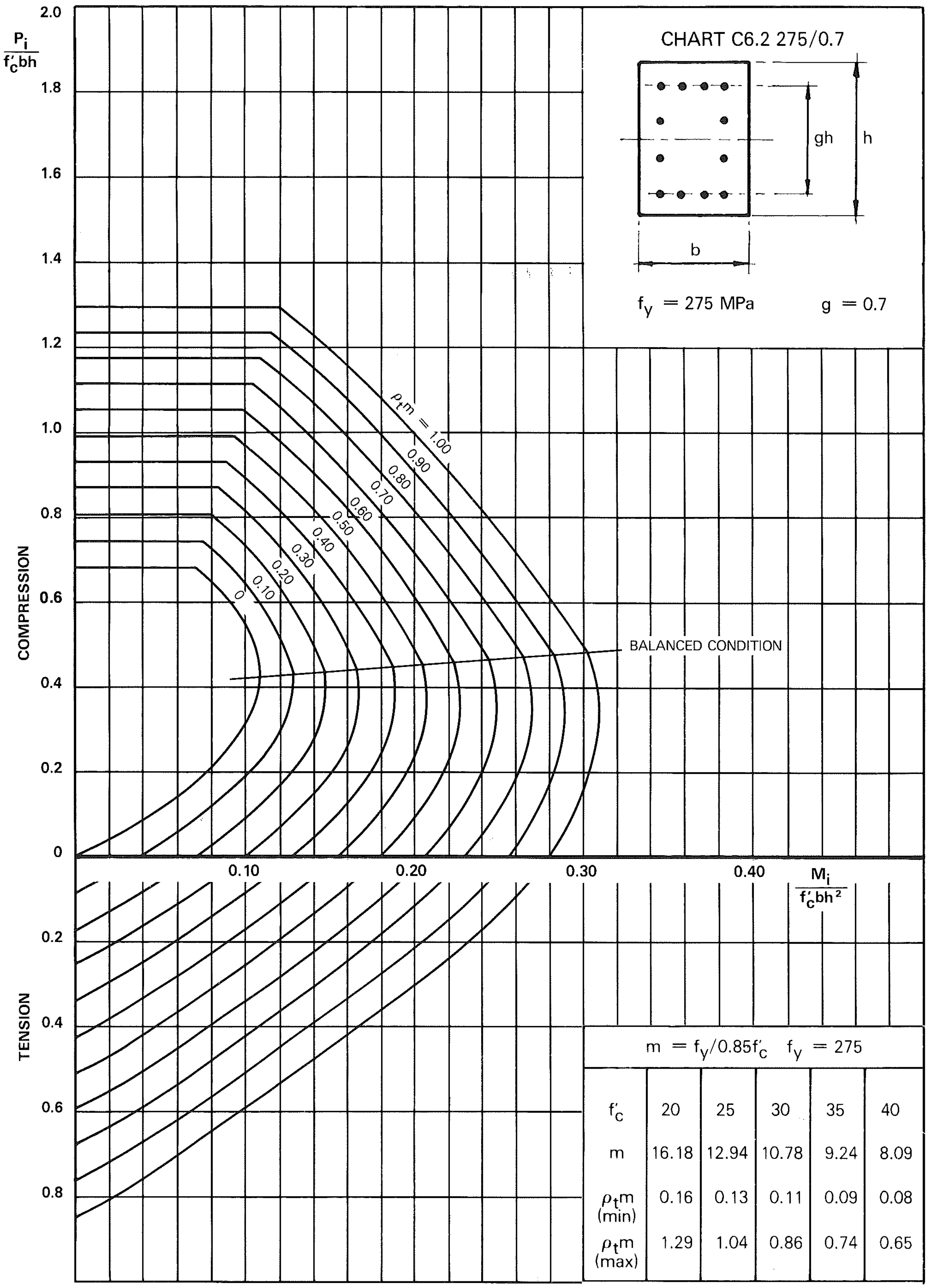
C6.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 275

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

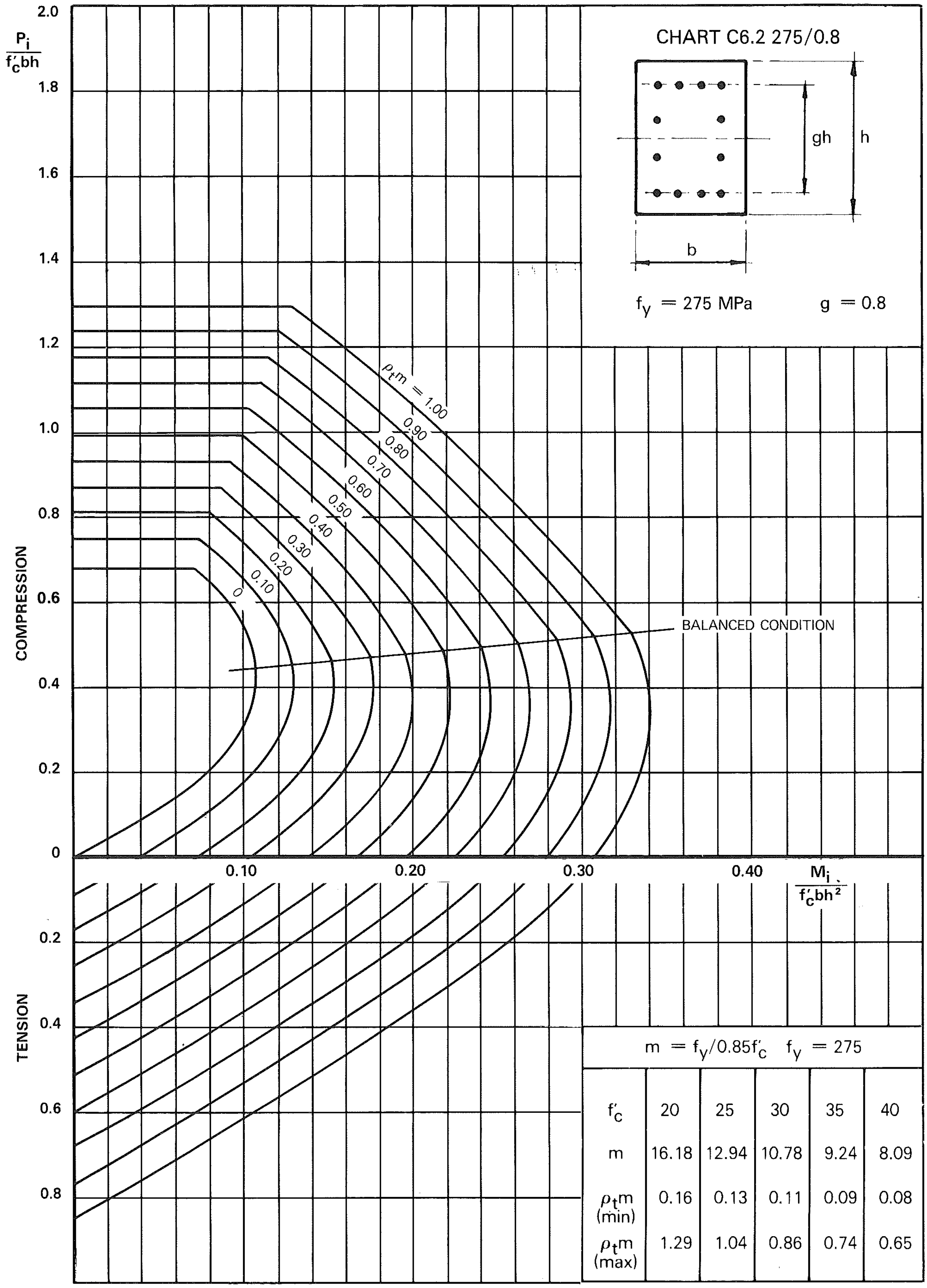
C6.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

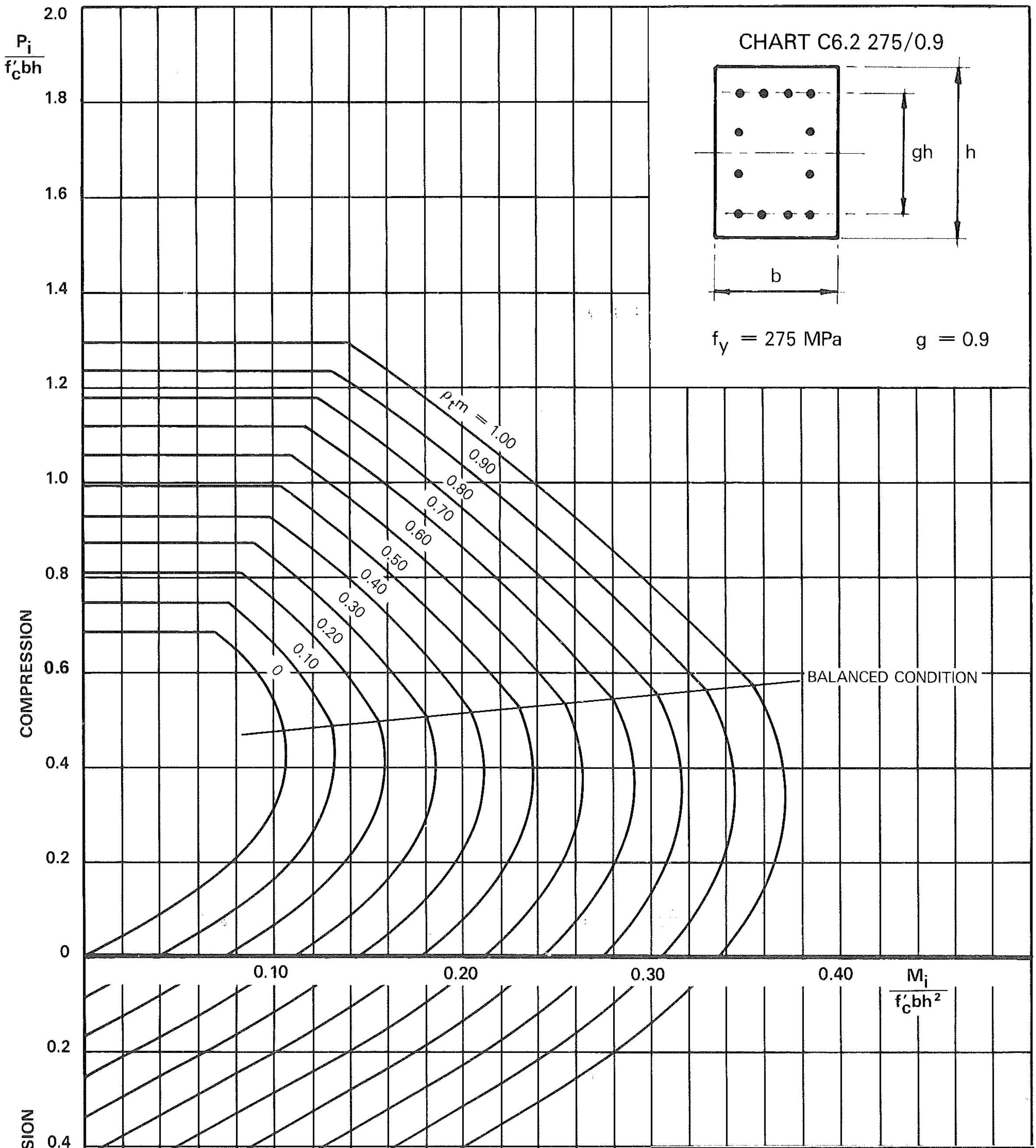
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

C6.2 COLUMN DESIGN CHART



f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

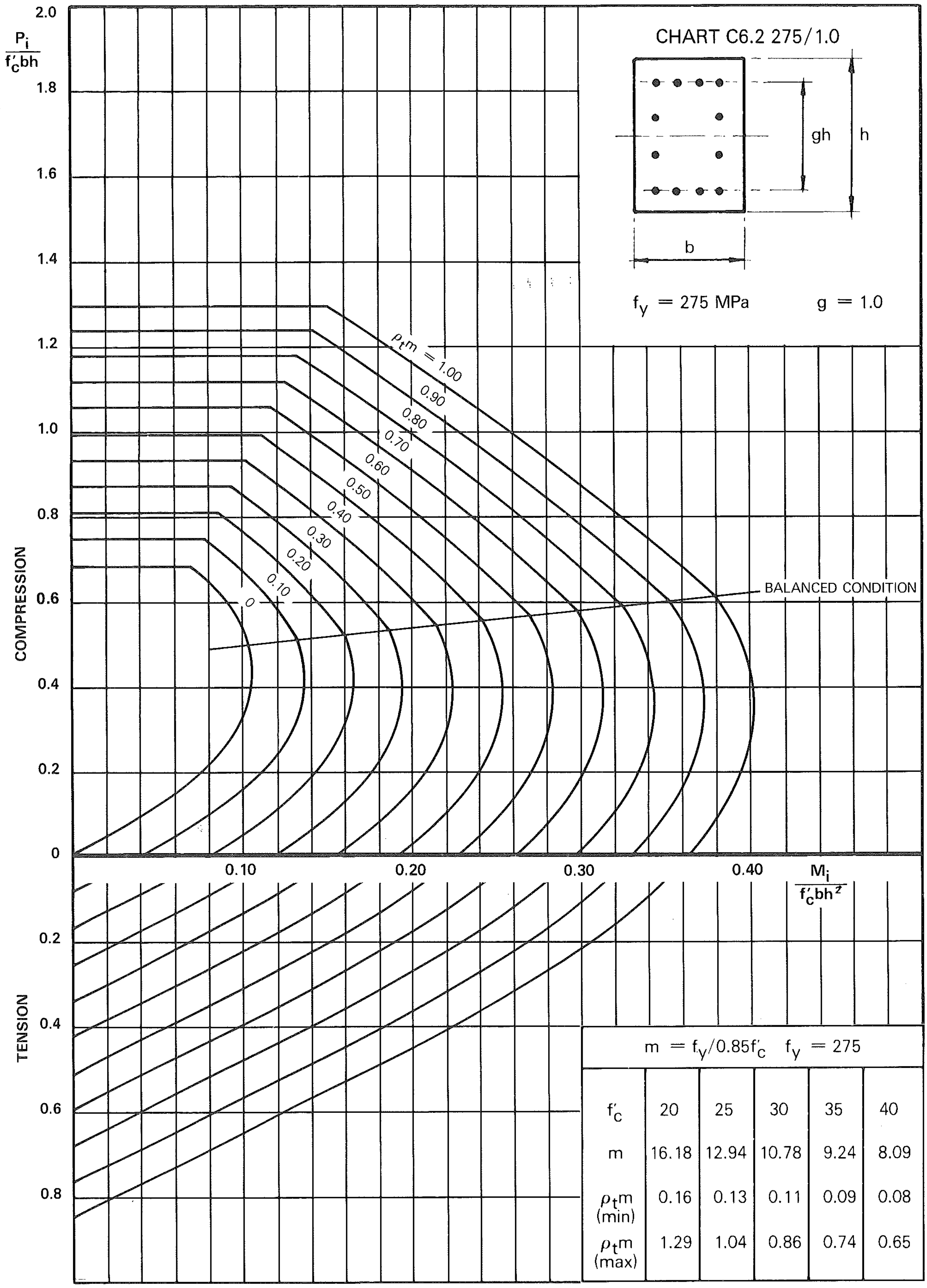
C6.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$

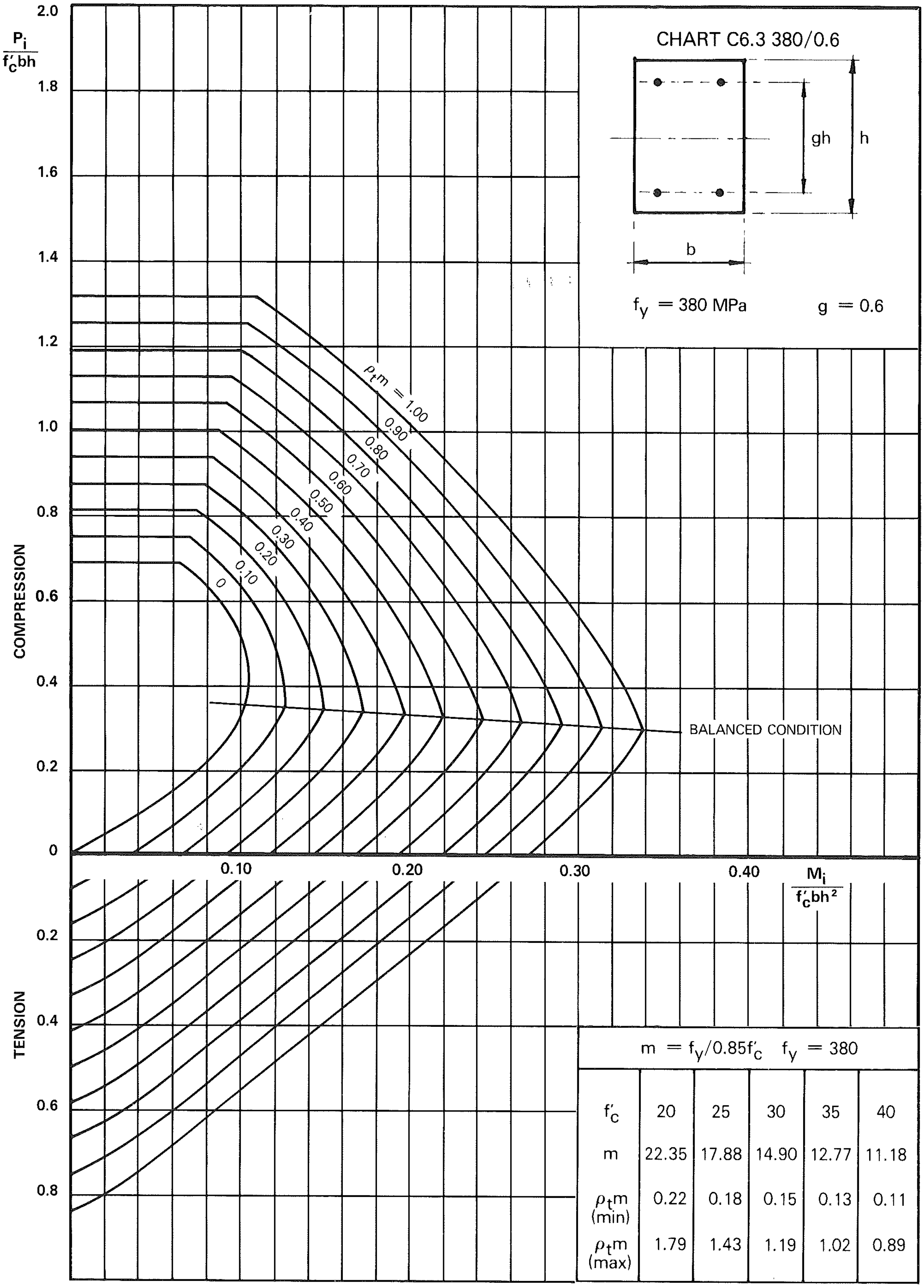
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

C6.2 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 275					
f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

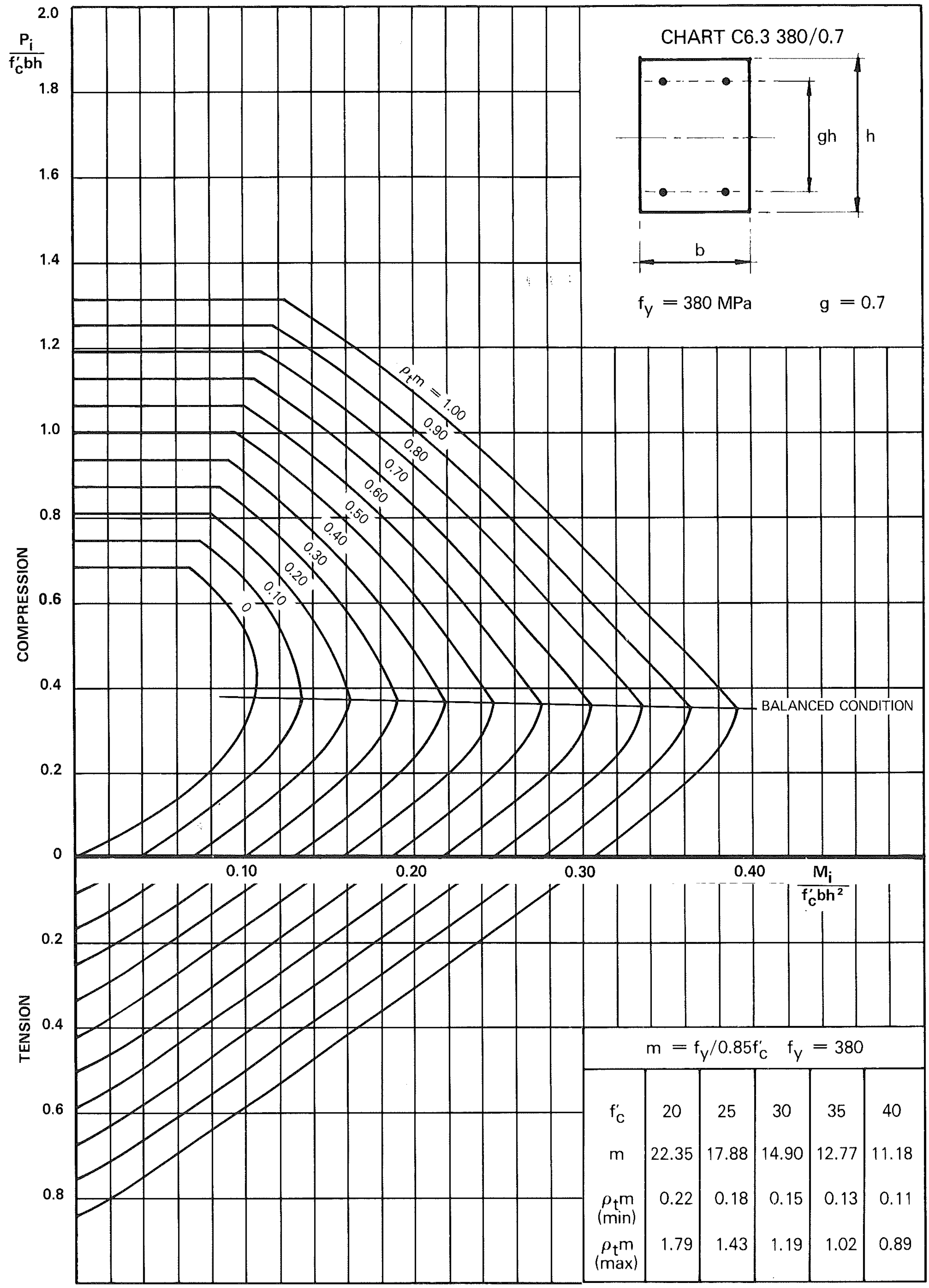
C6.3 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 380

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

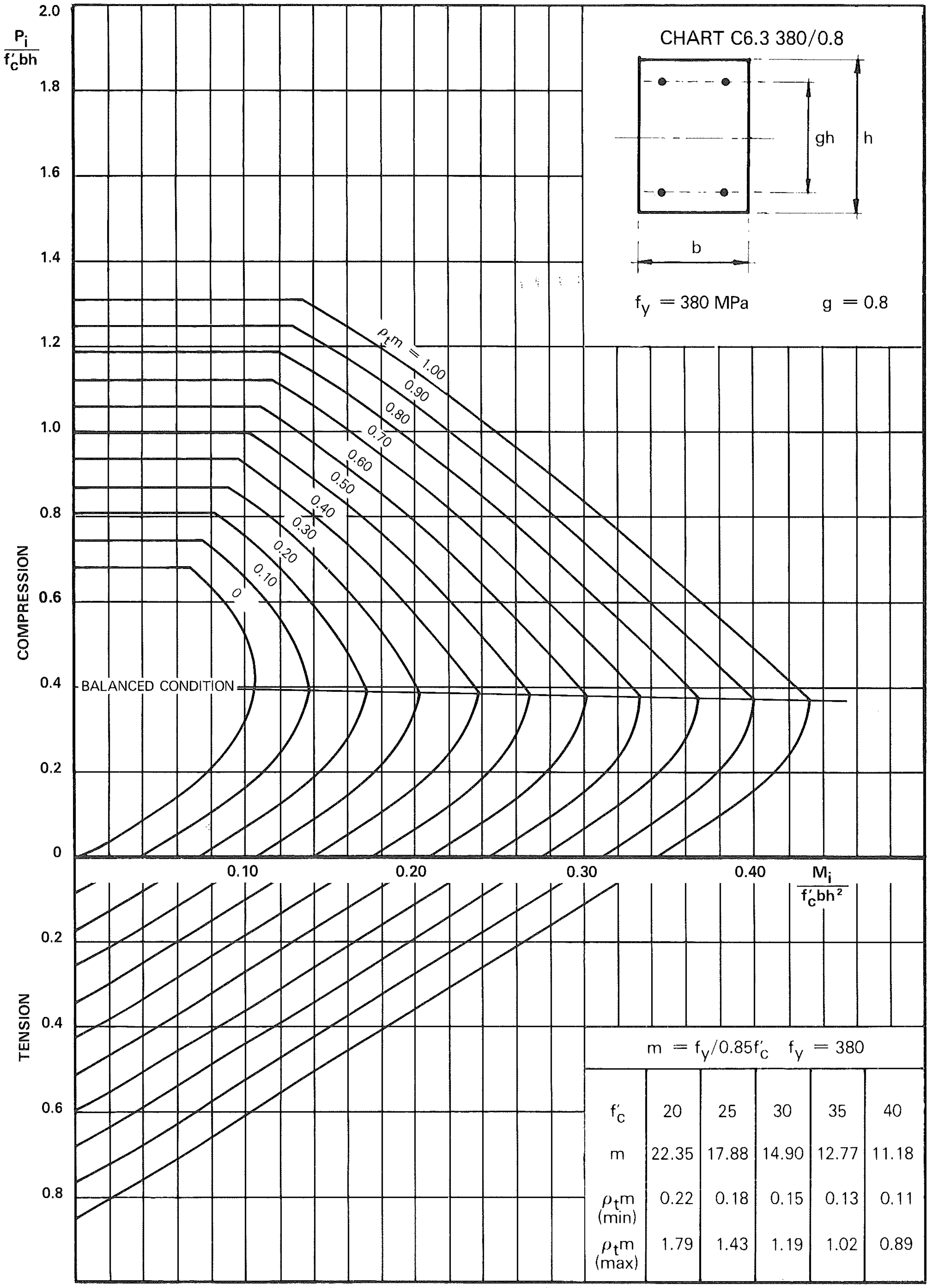
C6.3 COLUMN DESIGN CHART



m = $f_y/0.85f'_c$ f_y = 380

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

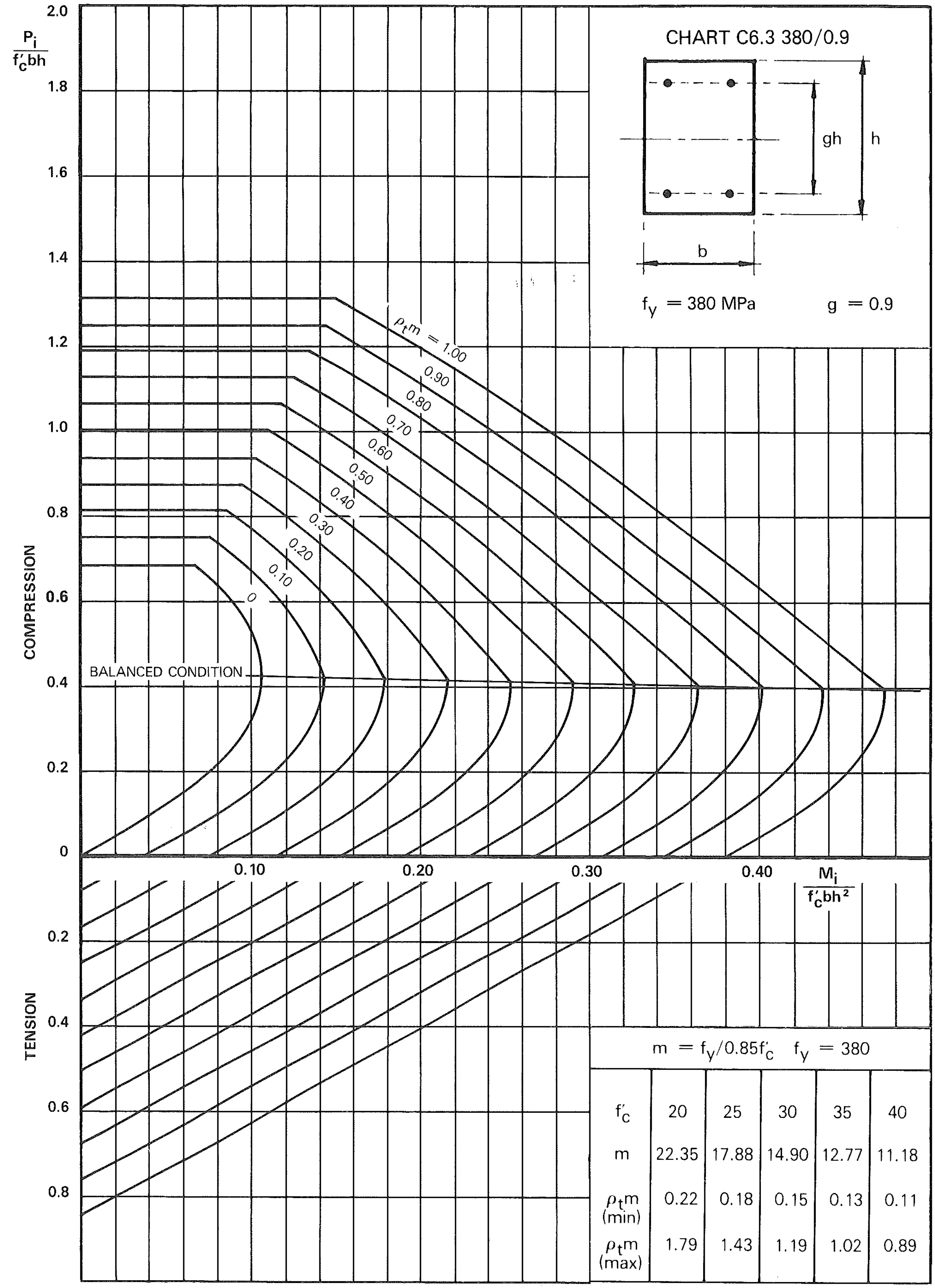
C6.3 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

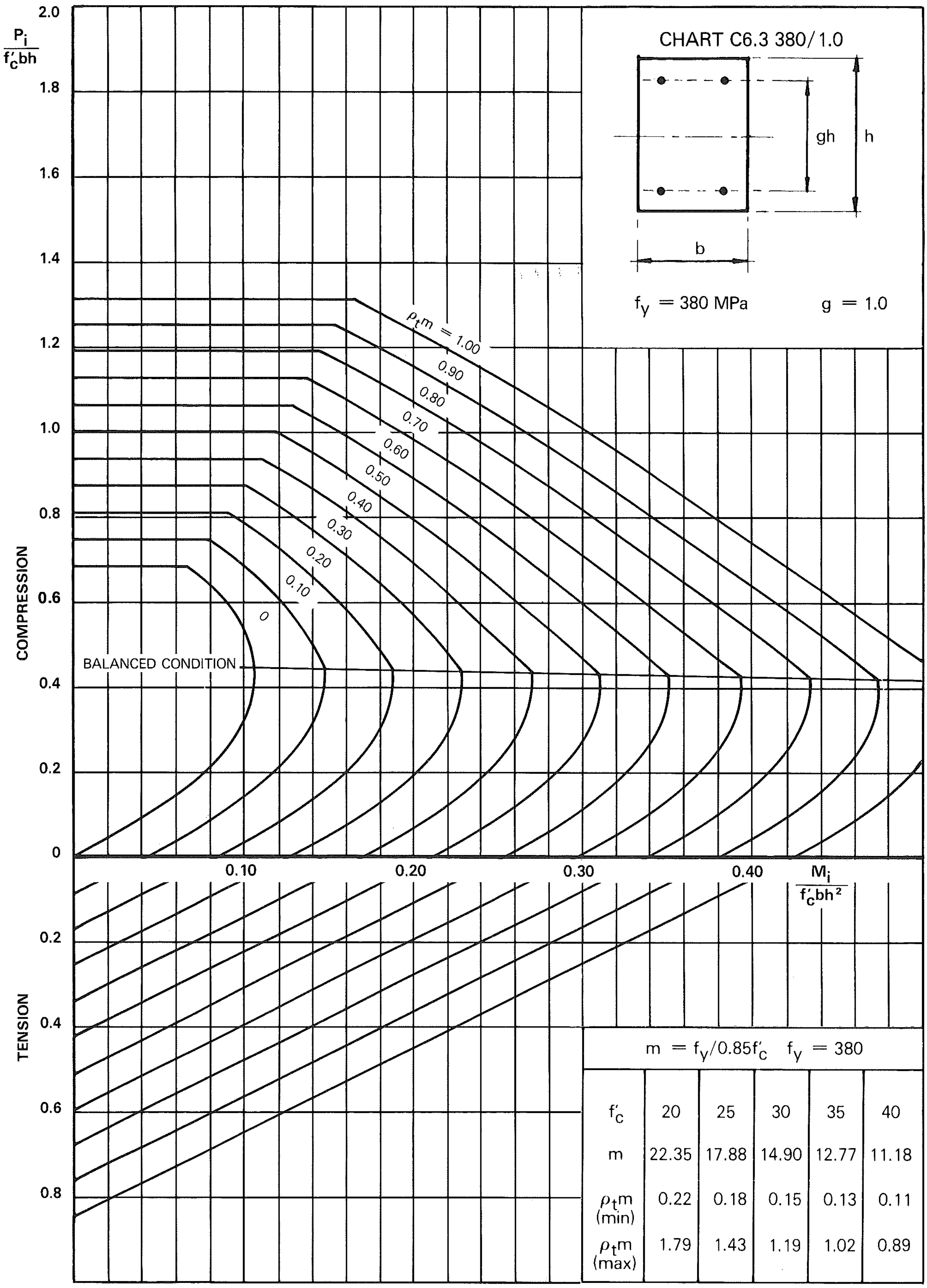
C6.3 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

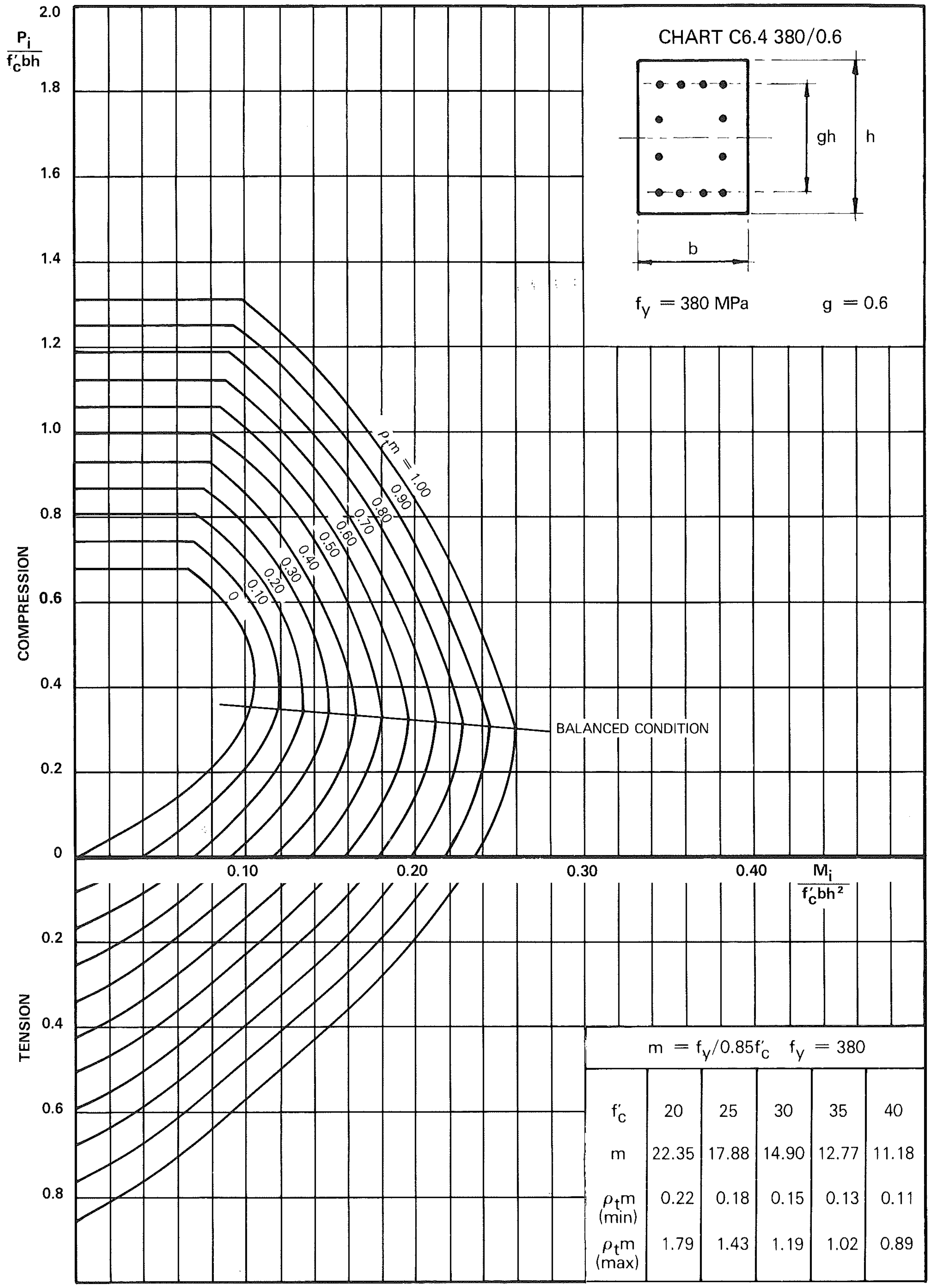
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C6.3 COLUMN DESIGN CHART



f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

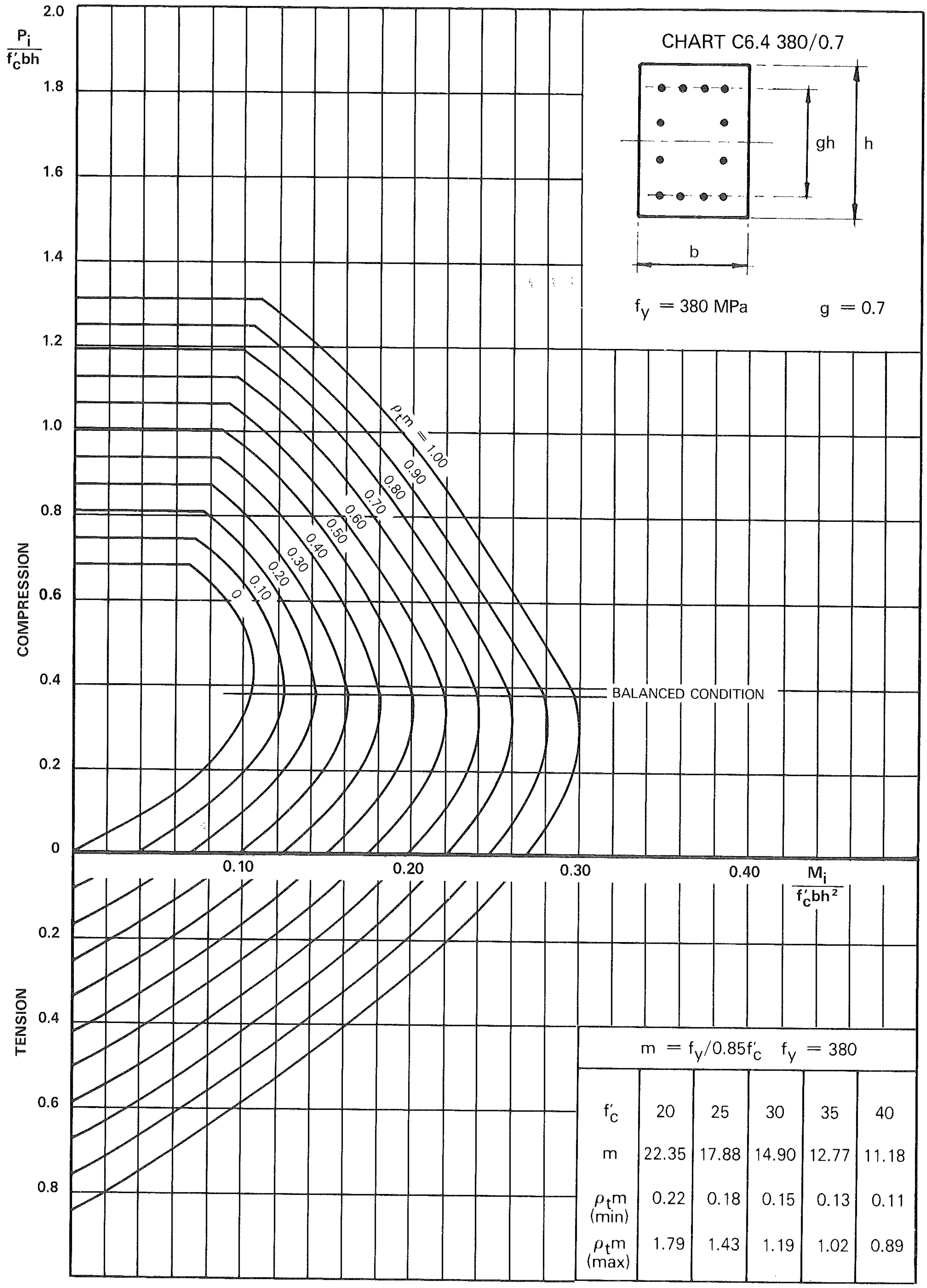
C6.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

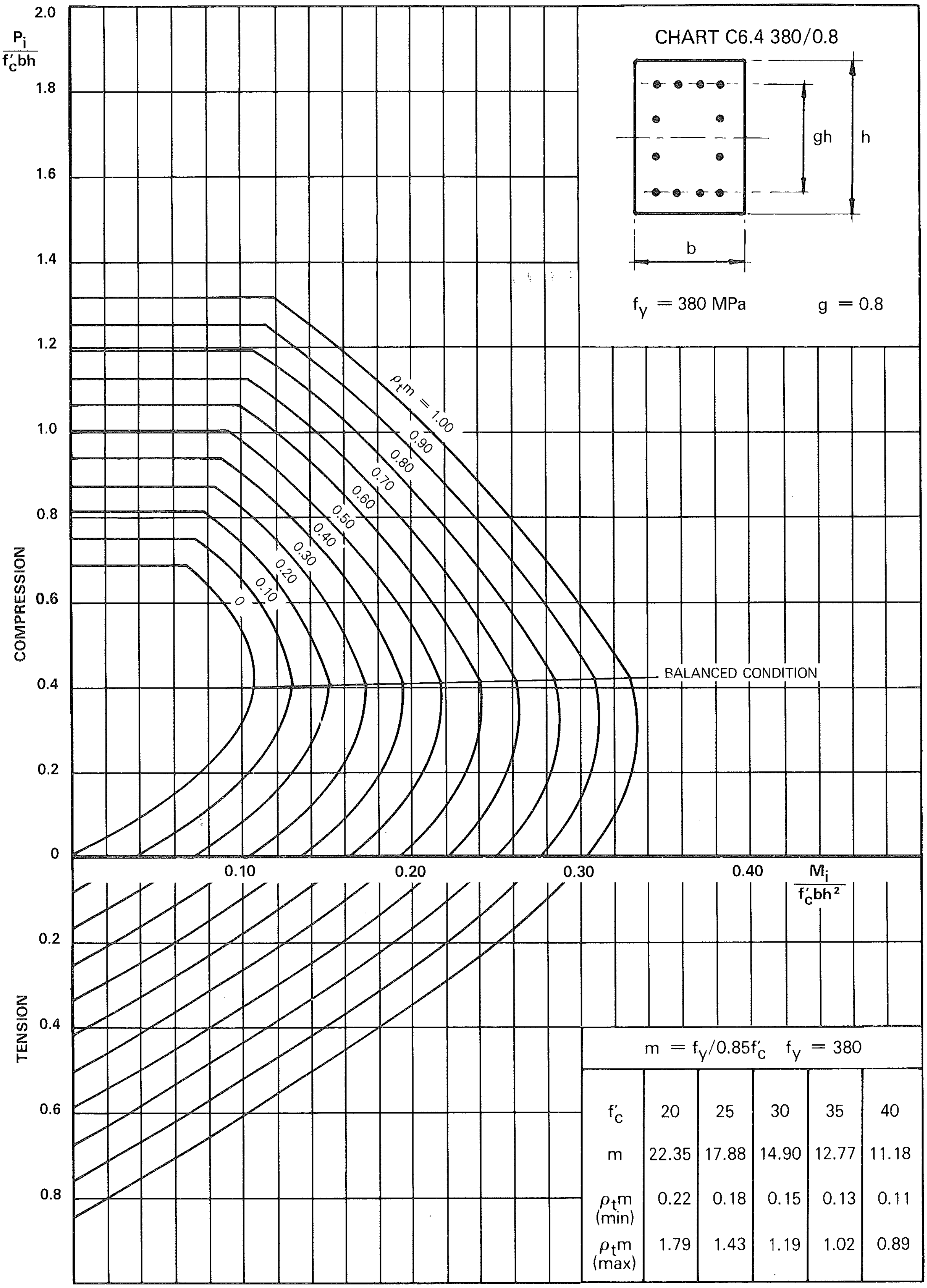
C6.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

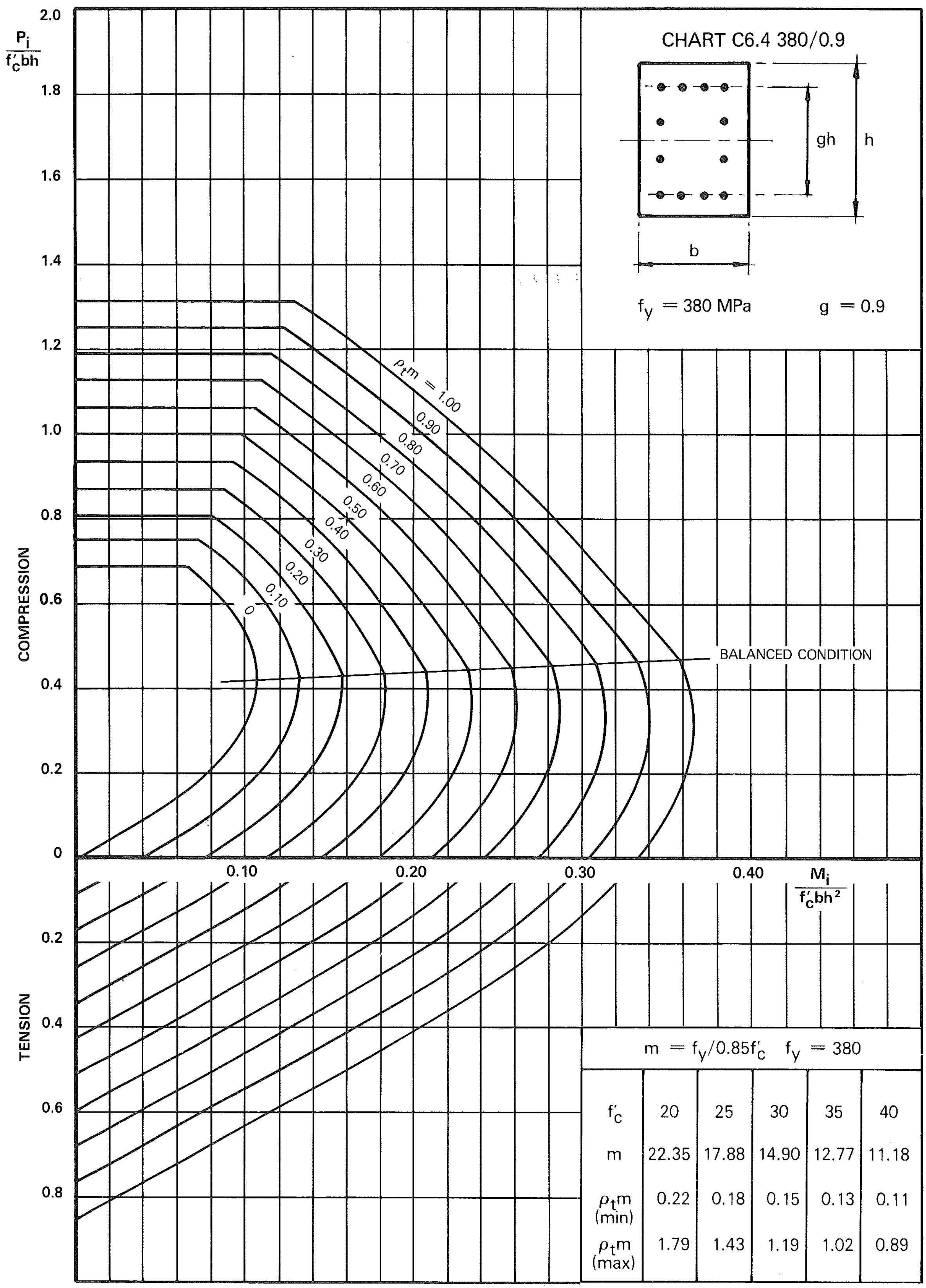
C6.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

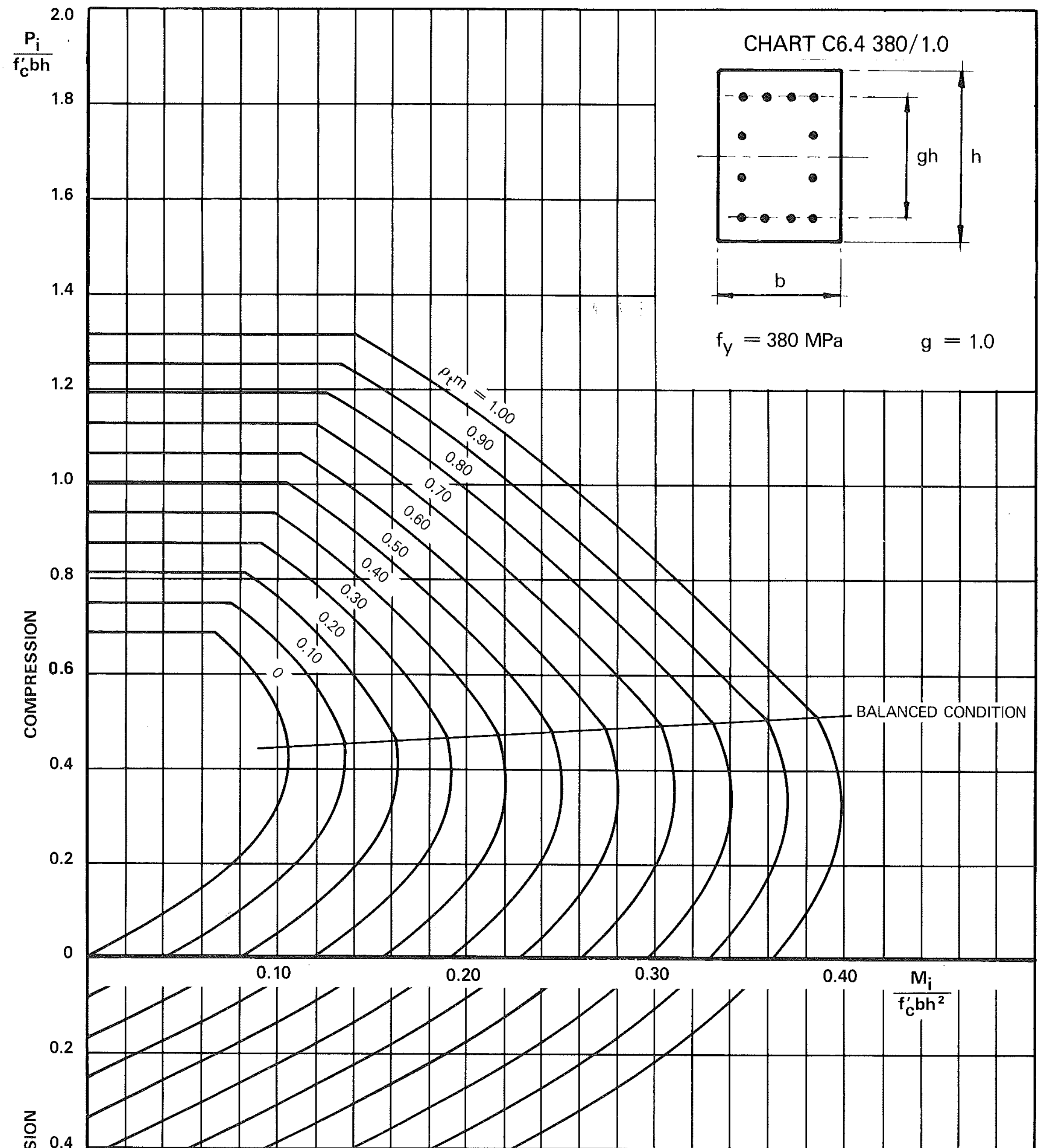
C6.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

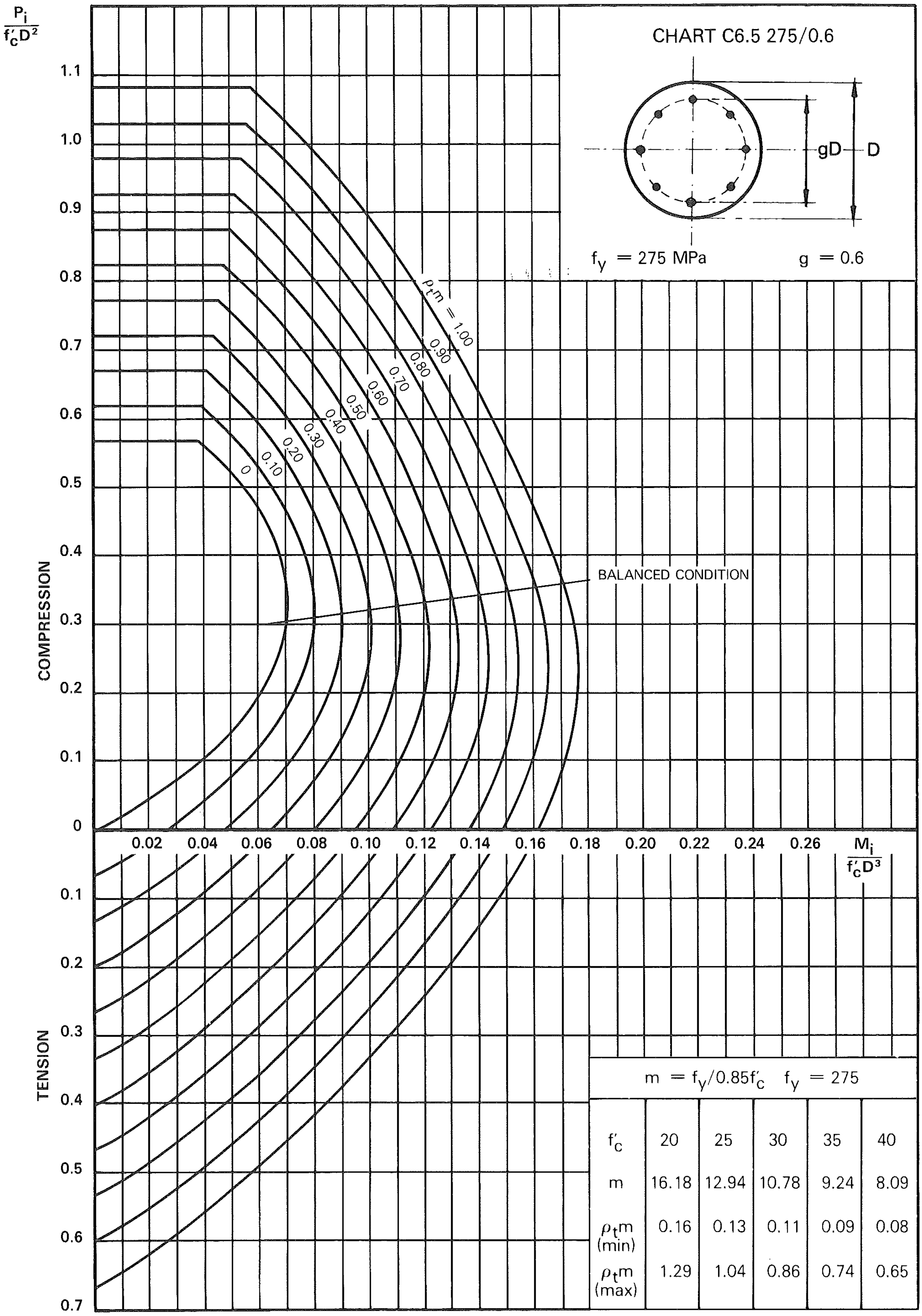
C6.4 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

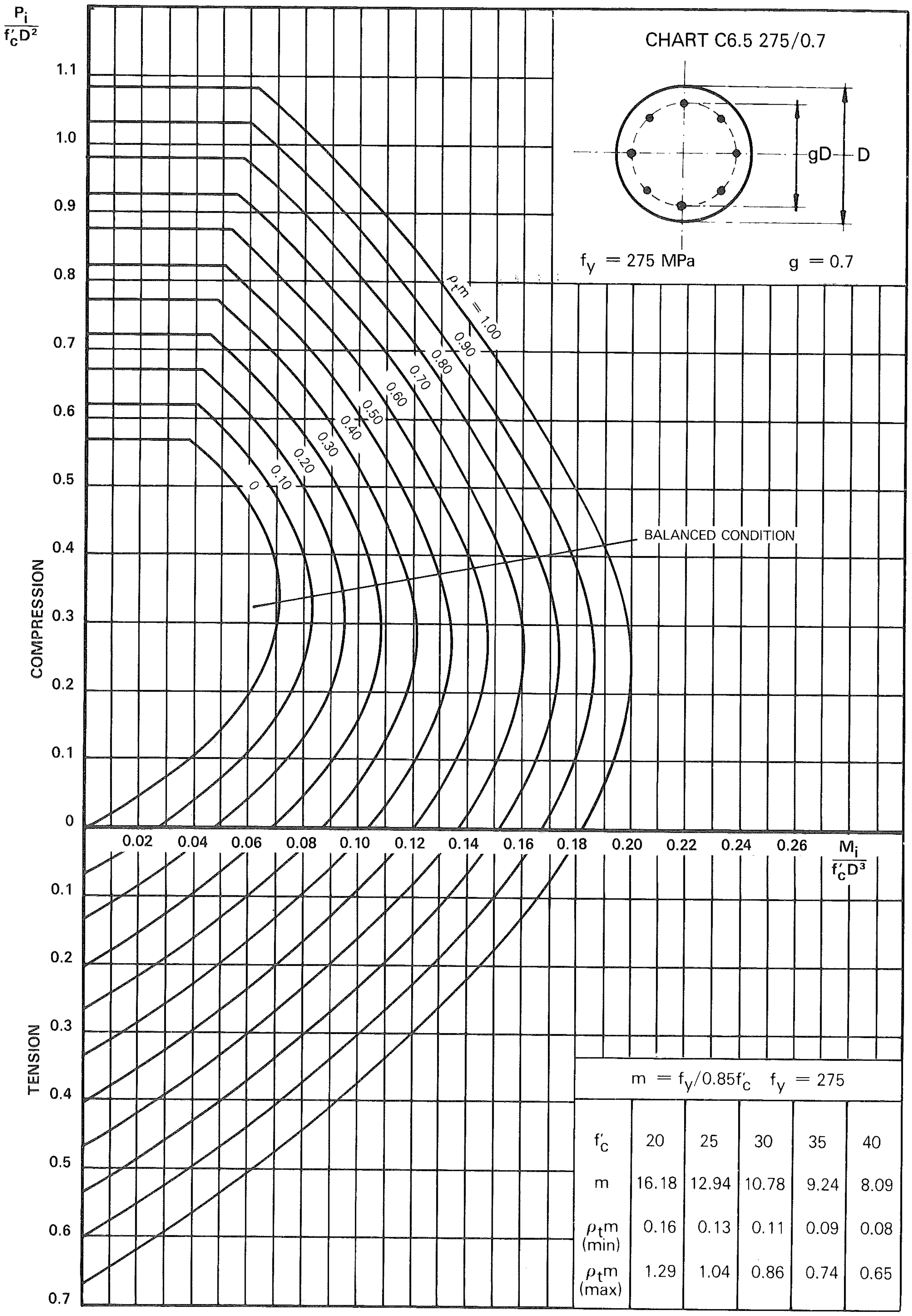
C6.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

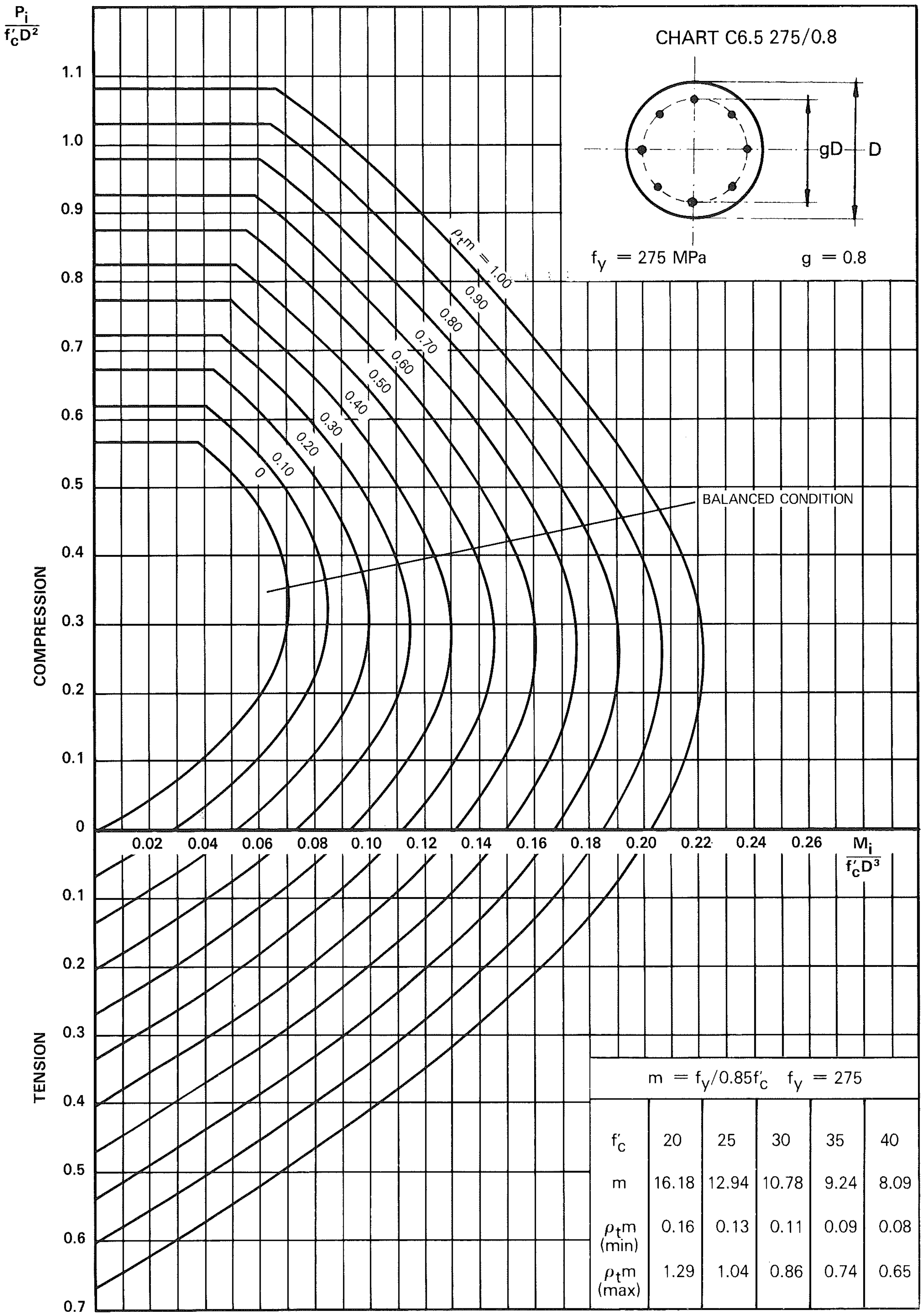
C6.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

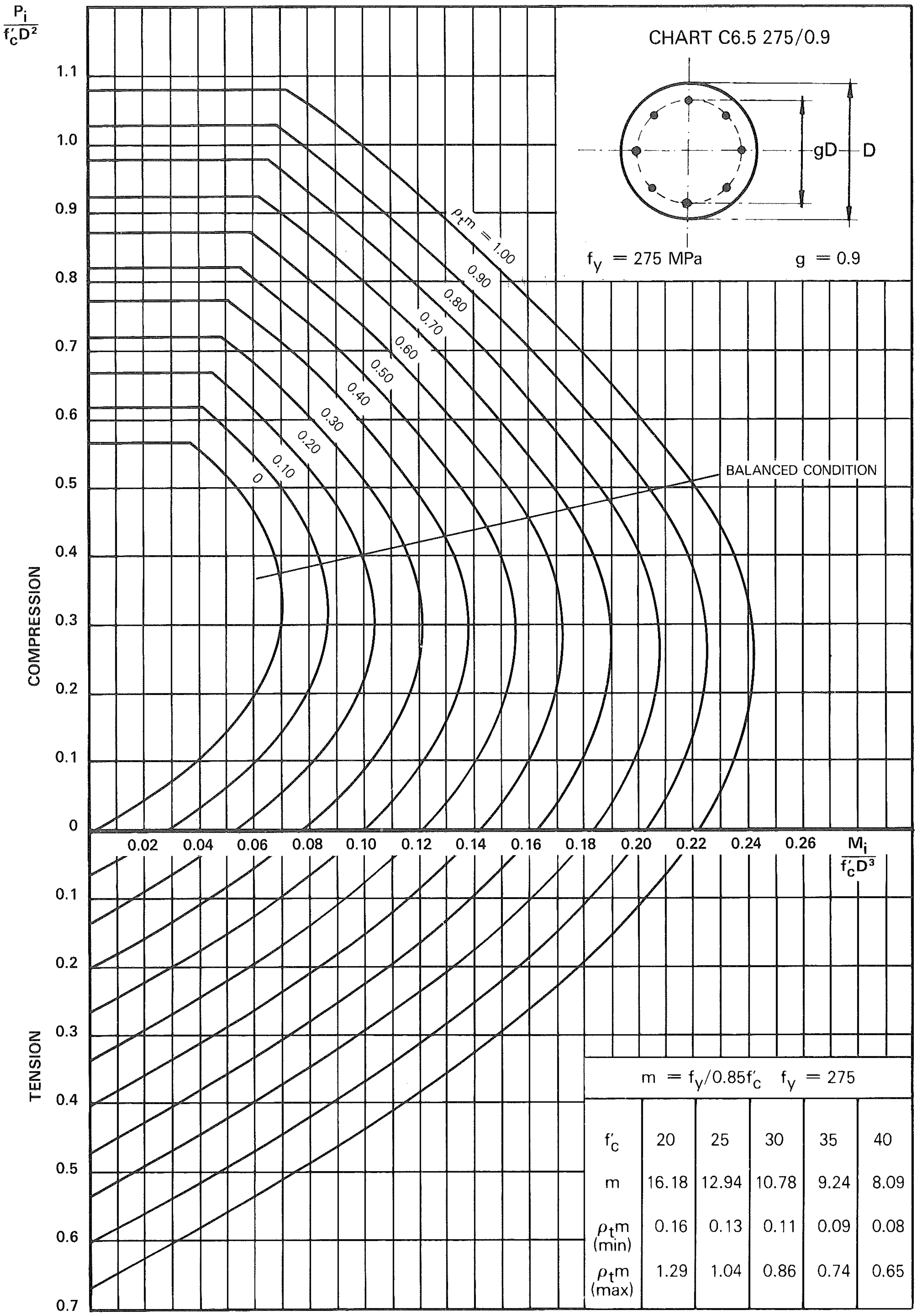
C6.5 COLUMN DESIGN CHART



$m = f_y / 0.85 f'_c$ $f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

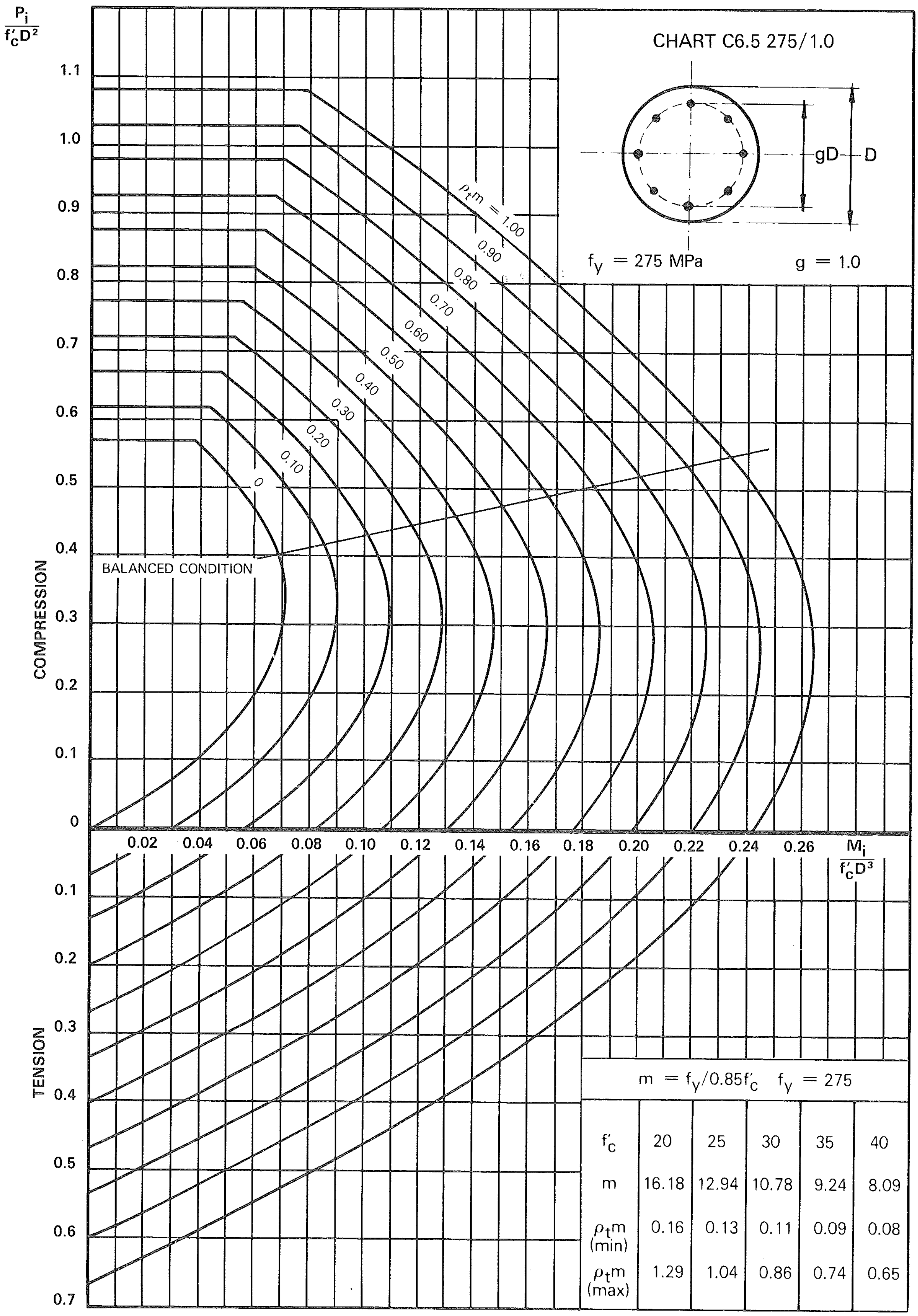
C6.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

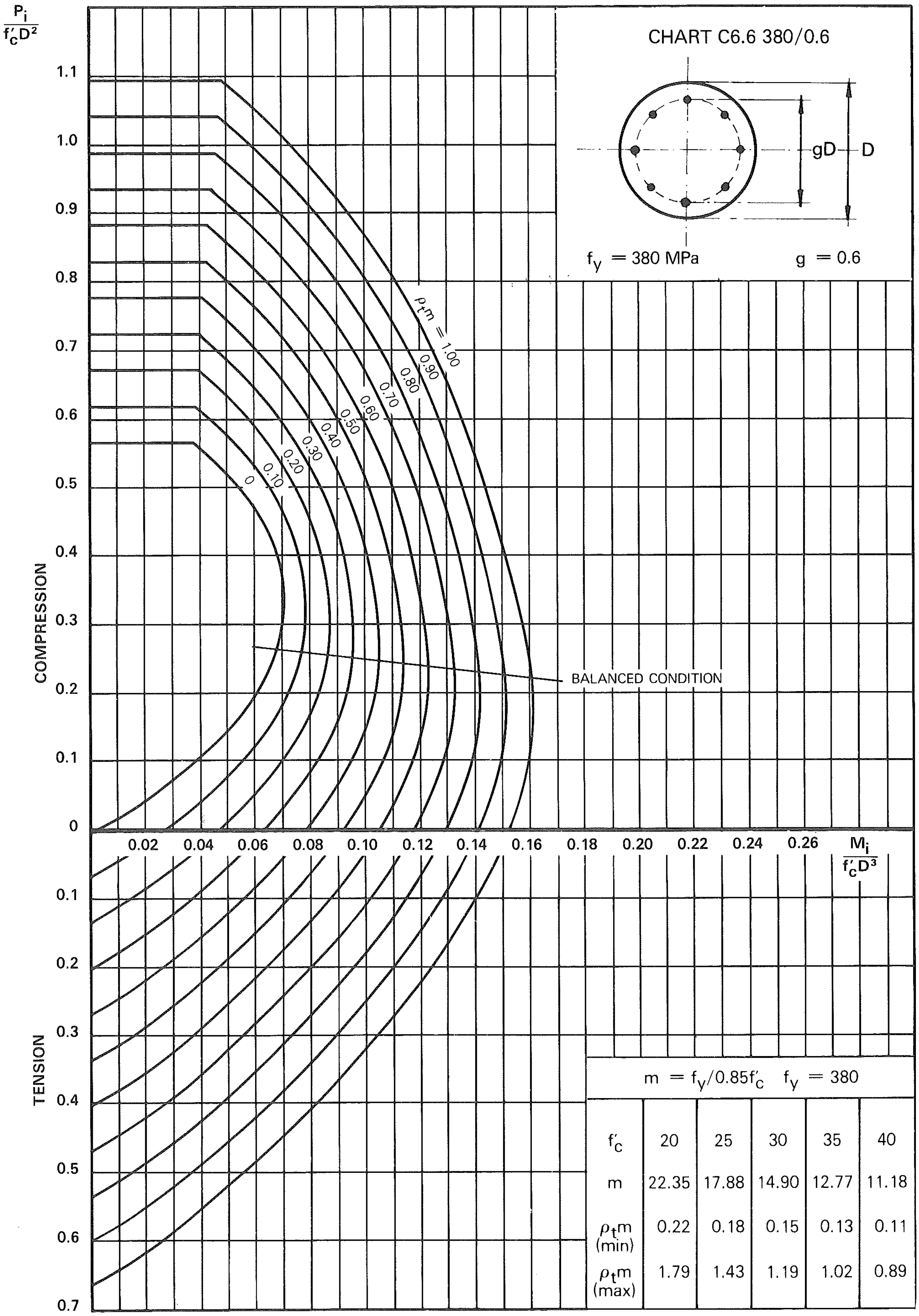
C6.5 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ $f_y = 275$

f'_c	20	25	30	35	40
m	16.18	12.94	10.78	9.24	8.09
$\rho_t m$ (min)	0.16	0.13	0.11	0.09	0.08
$\rho_t m$ (max)	1.29	1.04	0.86	0.74	0.65

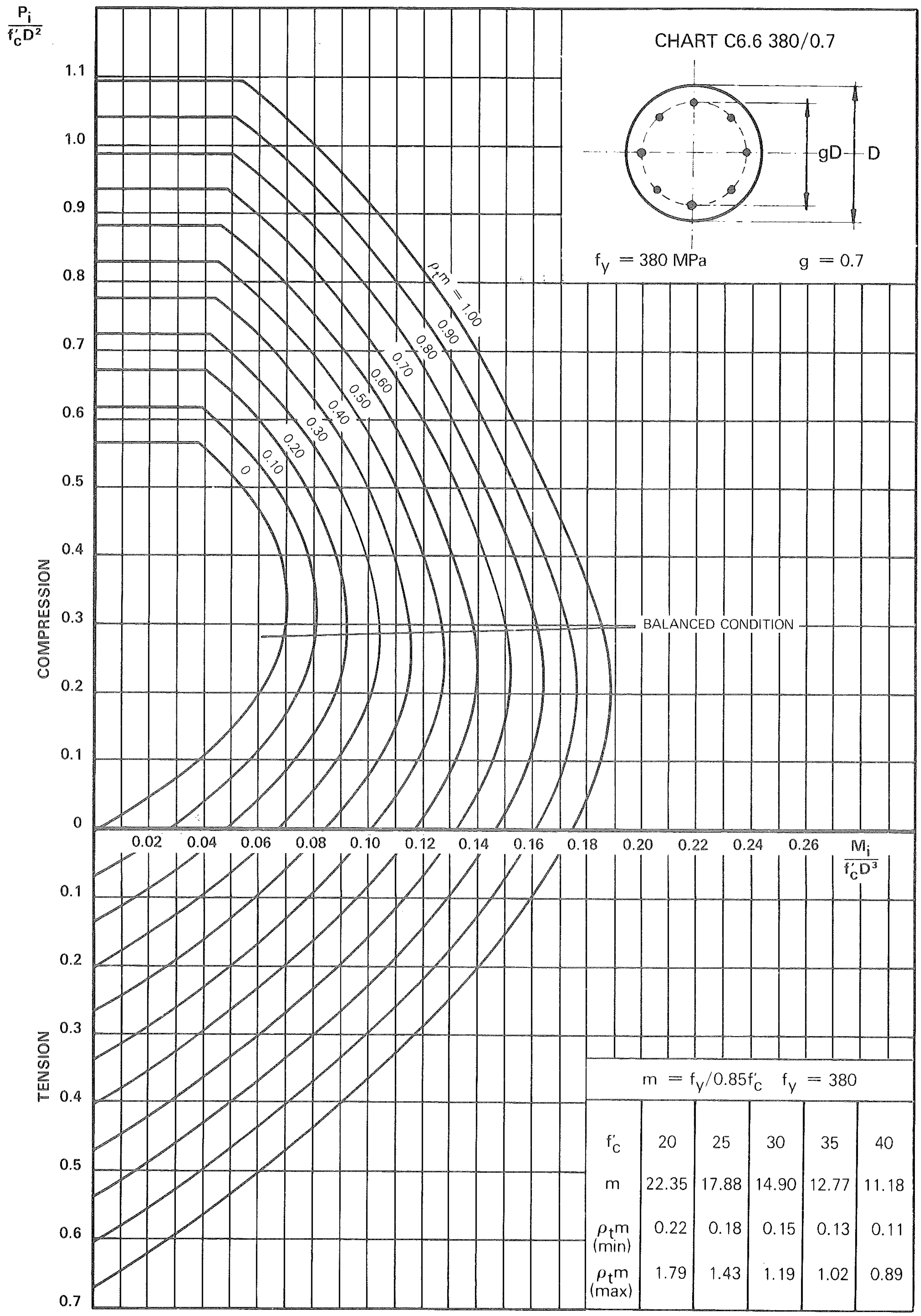
C6.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

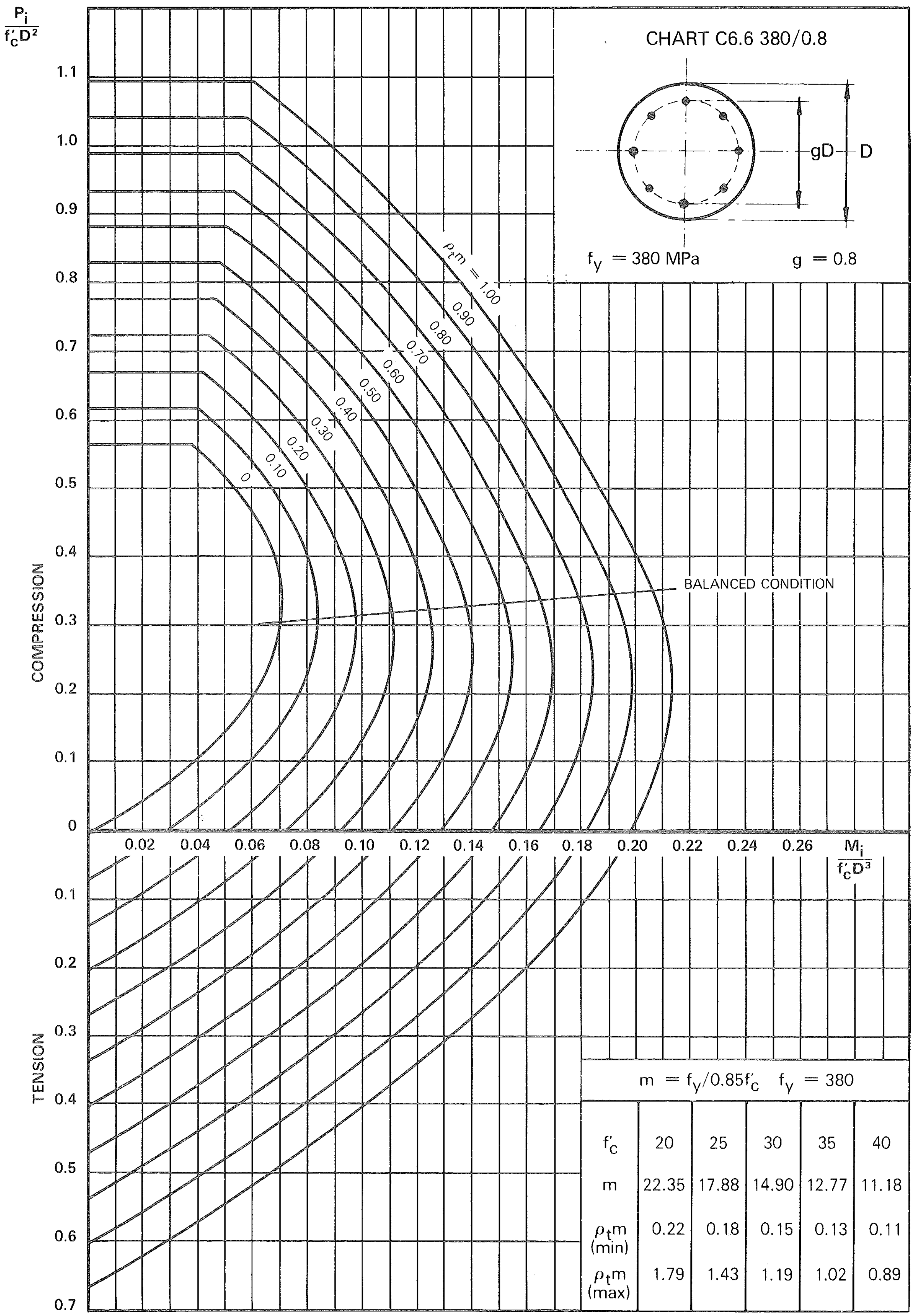
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C6.6 COLUMN DESIGN CHART



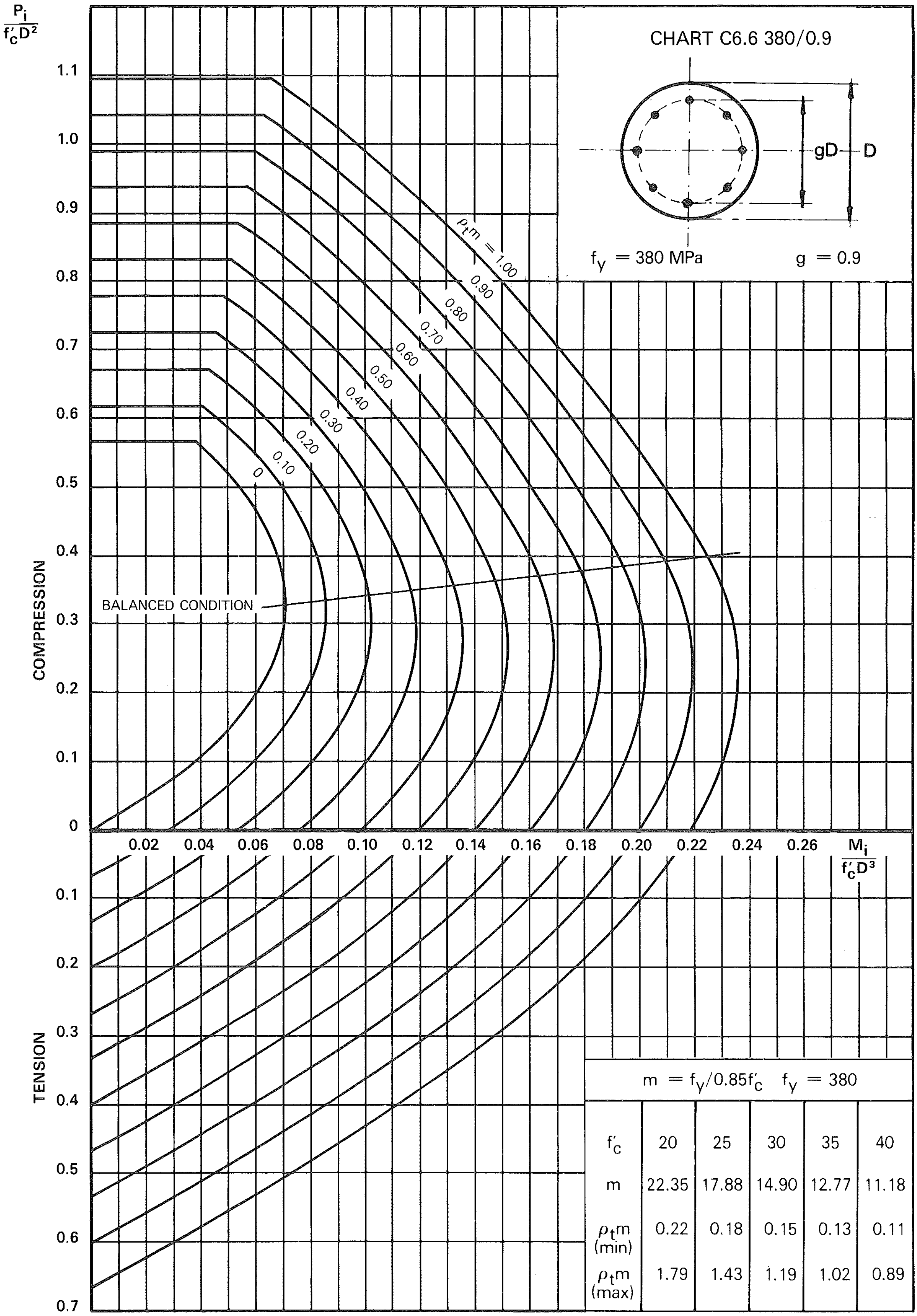
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C6.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 380					
f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

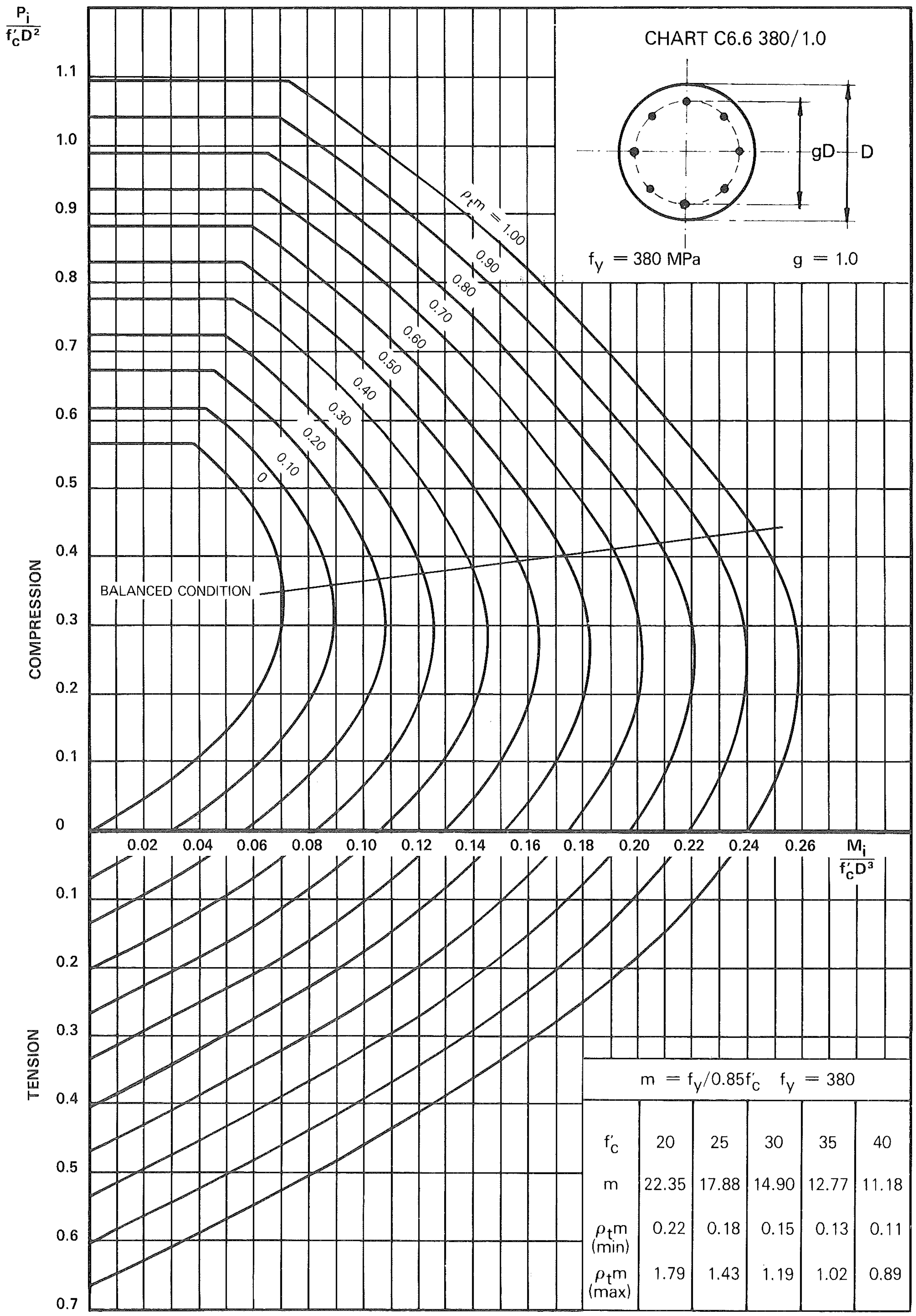
C6.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c \quad f_y = 380$

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

C6.6 COLUMN DESIGN CHART



$m = f_y/0.85f'_c$ f_y = 380

f'_c	20	25	30	35	40
m	22.35	17.88	14.90	12.77	11.18
$\rho_t m$ (min)	0.22	0.18	0.15	0.13	0.11
$\rho_t m$ (max)	1.79	1.43	1.19	1.02	0.89

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Development

Development

Introduction

This section of the handbook, prepared by the New Zealand Concrete Research Association, gives various items of guidance, both quantitative and qualitative, with regard to implementing the design requirements of Section 5 of NZS 3101: Part 1: 1982 as these relate to aspects of development.

Tables

D1.1	Development Lengths 1 Deformed bars in tension, unconfined, cover ≥ 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 50mm
D1.2	Development Lengths 1 Deformed bars in tension, unconfined, cover ≥ 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 60mm
D1.3	Development Lengths 1 Deformed bars in tension, unconfined, cover ≥ 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 70mm
D1.4	Development Lengths 1 Deformed bars in tension, unconfined, cover ≥ 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 80mm
D1.5	Development Lengths 1 Deformed bars in tension, unconfined, cover ≥ 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 90mm
D1.6	Development Lengths 1 Deformed bars in tension, unconfined, cover ≥ 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 100mm
D1.7	Development Lengths 1 Deformed bars in tension, unconfined, cover = 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 110mm
D1.8	Development Lengths 1 Deformed bars in tension, unconfined, cover = 50mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 110mm
D1.9	Development Lengths 1 Deformed bars in tension, unconfined, cover = 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 120mm
D1.10	Development Lengths 1 Deformed bars in tension, unconfined, cover = 50mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 120mm
D1.11	Development Lengths 1 Deformed bars in tension, unconfined, cover = 40mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 130mm
D1.12	Development Lengths 1 Deformed bars in tension, unconfined, cover = 50mm 2 Deformed bars in compression.	centre-to-centre bar spacing = 130mm
D2	Minimum development lengths (mm) for hooked deformed bars in tension: d_b = 6 – 40mm, f'_c = 20 – 40 MPa, f_y = 275 and 380 MPa.	
D3	Compressive splice lengths (mm): d_b = 6 – 32mm, various f'_c, f_y = 275 and 380 MPa.	

D4 Values of k_{tr} (mm) for condition $A_{tr} = A_t$: various A_t, s = 60 – 200mm.

D5 Values of ΣA_t (mm^2): stirrup sizes 6–24mm, 1–10 legs.

Charts

D6 Comparison of A_{tr}/s with either $A_b/1000$ or $A_b/600$

D7 Determination of k_{tr} as per formal notation:
D7.1: f_{yt} = 275 MPa
D7.2: f_{yt} = 380 MPa

D8 Tensile development lengths for deformed bars :various c or c + k_{tr}.
D8.1: d_b = 10mm, regular or top bars, f_y = 275 MPa
D8.2: d_b = 12mm, " " " " " "
D8.3: d_b = 16mm, " " " " " "
D8.4: d_b = 20mm, " " " " " "
D8.5: d_b = 24mm, " " " " " "
D8.6: d_b = 28mm, " " " " " "
D8.7: d_b = 32mm, " " " " " "
D8.8: d_b = 40mm, " " " " " "
D8.9: d_b = 10mm, regular or top bars, f_y = 380 MPa
D8.10: d_b = 12mm, " " " " " "
D8.11: d_b = 16mm, " " " " " "
D8.12: d_b = 20mm, " " " " " "
D8.13: d_b = 24mm, " " " " " "
D8.14: d_b = 28mm, " " " " " "
D8.15: d_b = 32mm, " " " " " "
D8.16: d_b = 40mm, " " " " " "

Notation

A_b area of an individual bar, mm^2

A_t area of bar formed into spiral reinforcement or rectangular stirrups, mm^2

A_{tr} smaller of area of transverse reinforcement within a spacing s crossing plane of splitting normal to concrete surface containing extreme tension fibres, or total area of transverse reinforcement normal to the layer of bars within a spacing s divided by n, mm^2
if longitudinal bars are enclosed within spiral reinforcement, A_t, mm^2

c the smaller of c_c or c_s, mm

c_c distance measured from extreme tension fibre to centre of bar, mm

c_s the smaller of the distance from the face of the concrete to the centre of bar measured along the line through the layer of bars, or half the centre-to-centre distance of bars in the layer, mm

For splices, c_s shall be the smaller of the distance from the concrete side face to the centre of the outside bar, or one-half the clear spacing of bars spliced at the same location plus a half bar diameter, mm

d_b nominal diameter of bar, wire, or prestressing strand, or, in a bundle, the diameter of a bar of equivalent area, mm

f'_c specified compressive strength of concrete, MPa

f_h tensile strength developed by standard hook, MPa

f_y specified yield strength of non-prestressed reinforcement, MPa

f_{yt}	specified yield strength of transverse reinforcement, MPa
k_{tr}	an index of the transverse reinforcement provided along the anchored bar, $A_{tr}f_{yt}/10s$, expressed as mm
l_a	additional embedment length at support or at point of inflection, mm
l_b	distance from critical section to start of bend, mm
l_d	development length, mm
l_{db}	basic development length of a straight bar, mm
l_{dh}	development length of hooked bars, equal to straight embedment between critical section and point of tangency of hook, plus bend radius, plus one bar diameter, mm
l_{hb}	basic development length for a hooked bar, mm
n	number of bars in a layer
s	maximum spacing of transverse reinforcement within l_d, or spacing of stirrups or ties or spacing of successive turns of a spiral, all measured centre-to-centre, mm

Design notes

The development length philosophy embodied within Section 5 of NZS 3101: Part 1: 1982 operates in terms of "basic" development lengths which may then be factored to take account of particular circumstances.

For the most part, the factor allocation rules are quite straightforward and should pose designers few difficulties. However, designers who wish to take full advantage of those allowances which derive from a formal recognition by NZS 3101 of the beneficial aspects of confinement will need to familiarise themselves with the meanings of, and limitations upon, the governing parameters A_{tr} and k_{tr}. Thus, for example, notwithstanding the given definition of k_{tr}, there are limits upon the values which may be used for this parameter as regards its numerical application; k_{tr} can not be allocated a value in excess of d_b; neither can $c + k_{tr}$ be taken as greater than $3d_b$ (the same restriction applies to c also).

Tables D1	These tables show required minimum tensile and compressive development lengths for various sizes of deformed bar (both f_y = 275 MPa and f_y = 380 MPa), a range of concrete strengths, and different bar spacings. The tensile values are equally valid for lap splices; no such correspondence prevails with regard to compressive lap splices – see instead Table D3. In the case of tension bars, required development lengths are not insensitive to concrete cover; the tables encompass three cover options – either $\geqslant$ 40mm, 40mm, or 50mm. Of course, the options are not mutually exclusive and, at first sight, there may appear to be gross redundancy. However, under certain circumstances, the broad option (i.e. cover $\geqslant$ 40mm) is quantitatively inadequate due to a transition in governing parameters which occurs within the range 40mm $<$ cover $<$ 50mm. While some elements of redundancy do exist, it has been felt that a total purging thereof would have detracted markedly from the intended "working" convenience of a tabular presentation. In the tensile context, necessary distinctions are drawn between development lengths for top and bottom steel; although no explicit allowance is made for confinement, the given (basic) development lengths may be factored appropriately where circumstances warrant such modification – see Example 2. For compression bars, values of both open (unconfined) and confined development lengths are listed; whether the latter may find actual use is governed by specific criteria relating to local aspects of confinement – see Example 3.
Table D2	This table gives minimum development lengths for hooked deformed bars in tension. Beyond the basic requirements, two levels of confinement are catered for via allowance factors of 0.7 and 0.8. Example 4 illustrates the relevance in applicability of each.
Table D3	Minimum compressive lap splice lengths for deformed bars under various circumstances are tabulated herein. Associated footnotes describe the conditions which must obtain before advantage can be taken of confinement allowances.

Table D4 This table lists values of the parameter k_{tr} appropriate to the conditions $A_{tr} = A_t$ and $f_{yt} = 275$ MPa. (Where $A_{tr} \neq A_t$, use should be made of Table D5 and Charts D7.) A footnote is given to Table D4 which emphasises the potentially overriding criterion that the value taken for k_{tr} can not exceed the main bar diameter, d_b.

Table D5 Values of the parameter ΣA_t ($=A_v$) are shown for various stirrup sizes and different numbers of legs. Particular values may be used in conjunction with Charts D7 to generate appropriate values of k_{tr}. Alternatively, values from Table D5 may be employed via Chart D6.

Chart D6 This chart enables a determination of A_{tr}/s to be made and allows for a comparison thereof with either $A_b/1000$ or $A_b/600$. Such information is needed to ascertain whether allowance for confinement can be invoked in the context of bars or splices in compression or standard hooks in tension.

Charts D7 These charts are used to obtain values of k_{tr} as per the notational definition thereof. Whether such values are actually valid for a particular case will depend upon the prevailing value of d_b (see introductory comments offered above and footnote to Table D4).

Charts D8 A variety of plots are given, showing the dependence of required minimum tensile development lengths upon appropriate values of c or $c + k_{tr}$ (effective confinement allowance). The charts, which distinguish between top and bottom steel, may also be used to generate minimum tensile splice lengths. Various sizes of deformed bar (both $f_y = 275$ MPa and $f_y = 380$ MPa) are covered, in conjunction with a working range of typical concrete strengths.

Examples in development

Example 1. — Tables D4 and D5, Charts D7

Selection of operational values for c, A_{tr}, k_{tr}, and $c + k_{tr}$.

1.1 The parameter, c:

Three factors need to be taken into account in allocating a value for c. The least must prevail.

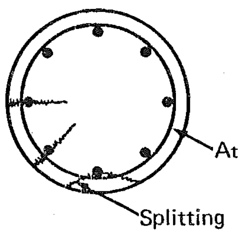
(i) minimum cover to centre of main bar (="cover" + $d_b/2$),
(ii) half the centre-to-centre distance of bars in a layer,
(iii) three times the main bar diameter ($=3d_b$).

For splices, the cover factor, (i), relates to the outer bar, and (ii) becomes half the clear spacing of bars spliced at the same location plus a half bar diameter.

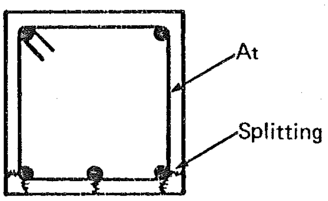
1.2 The parameter, A_{tr}:

Choose appropriate case, based upon examples shown below.

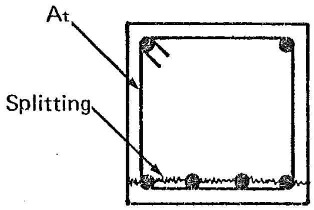
Case 1. Spiral $A_{tr} = A_t$

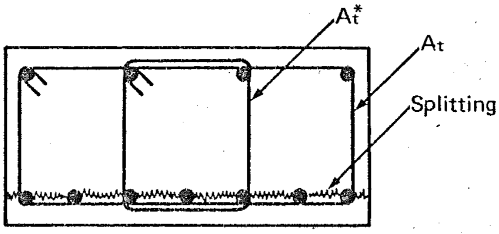


Case 2. For splitting through the cover concrete. $A_{tr} = A_t$



Case 3. For horizontal splitting through a layer of bars. $A_{tr} = \Sigma A_t/n$





eg (i) $A_{tr} = \frac{\Sigma A_t}{n} = \frac{2A_t}{4}$

eg (ii) $A_{tr} = \frac{\Sigma A_t}{n} = \frac{2(A_t + A_t^*)}{7}$

1.3 The parameters, k_{tr} and $c + k_{tr}$:

k_{tr} is defined as $A_{tr} f_{yt}/10s$. However, working values of k_{tr} are constrained by an **upper limit** of d_b. This supplementary constraint must be remembered when using Table D4 and Charts D7.

e.g. For $A_{tr} = A_t$, s = 100mm, and 12mm stirrups (f_{yt} = 275 MPa), Table D4 indicates a value of k_{tr} = 31mm. If, however, d_b is less than 31mm, say 20mm, this latter quantity overrides the given figure. Thus, for the case in question, k_{tr} = 20mm.

e.g. Consider the instance of six main tensile bars, with four 12mm stirrup legs (f_{yt} = 275 MPa) providing restraint against splitting through the layer (as per Case 3 of 1.2 above). Table D5 gives $\Sigma A_t = 452 mm^2$, which, when employed with n = 6 and, say, s = 100 in Chart D7.1, implies k_{tr} = 21mm. Again, however, if d_b = 20mm, the operating value of k_{tr} would reflect this upper limit (i.e. 20mm rather than 21mm). Conversely, with s = 120 the associated k_{tr} figure given by Chart D7.1, namely k_{tr} = 17mm, would prevail unaltered.

In certain circumstances, to be expanded upon in later examples, it is necessary to evaluate the combination $c + k_{tr}$. Beyond the individual constraints on c and k_{tr}, there exists an additional upper limit of $3d_b$ on the value which may be taken for the aggregated parameters.

e.g. with c = 40, k_{tr} = 15, and d_b = 20mm,
$c + k_{tr}$ = 55

but, with c = 40, k_{tr} = 15, and d_b = 16mm,
$c + k_{tr}$ = 48 (= 3 x 16)

Example 2. — Tables D1, Charts D8

Allowance for confinement — tension steel

Consider the case of tensile reinforcement comprising 4 deformed bars, d_b = 20mm, f_y = 275 MPa, located in a single layer at the bottom of a beam, with concrete cover = 45mm and centre-to-centre spacing = 80mm. If f'_c = 30 MPa and the transverse reinforcement is such that k_{tr} = 17mm, what development length is required?

Table D1.4 gives basic development length = 550mm.

Factor allowed for effects of confinement = $\frac{c}{c + k_{tr}}$

Here, c is least of (i) 55mm, (ii) 40mm, or (iii) 60mm (see example 1.1)
i.e. c = 40mm

$k_{tr} < d_b$ check OK
$c + k_{tr} = 57mm < 3d_b$ check OK

Thus, required development length = 550 x $\frac{40}{57}$ = 390mm

390mm > 300mm minimum check OK

or Read required devlopment length from Chart D8.4

Example 3. — Tables D1, Chart D6

Allowance for confinement — compression steel

Tables D1 give compressive development lengths which include allowances for confinement where applicable. Confined values may be adopted where:

(a) at least three sets of enclosing ties or turns of spiral are provided over the development length, and

(b) $\frac{A_{tr}}{s} \geqslant \frac{A_b}{1000}$

Chart D6 enables a quick check on the above inequality to be undertaken.

e.g. With single 12mm stirrups at 100mm centres enclosing

4 main compression bars,

Chart D6 gives $A_{tr}/s = 0.56$

It may also be seen that if d_b = 24mm or less then the inequality (b) would be satisfied ($A_b/1000 = 0.45$ for d_b = 24mm) and confined development lengths could be used. Since the minimum allowable development length for compression bars is 200mm, the chosen 100mm stirrup spacing automatically guarantees the viability of the "three sets" criterion (a).
If, however, d_b = 28mm or greater ($A_b/1000 = 0.62$ for d_b = 28mm), the confined development lengths of Tables D1 could not be used.

Note: The compressive development lengths given in Tables D1 are not governed by prevailing cover conditions.

Example 4. — Table D2, Chart D6

Standard hooks in tension

Table D2 offers two possible allowance factors for confinement, 0.7 and 0.8. (Of course, these only serve to reduce a required hooked development length where the basic value thereof exceeds the overall operational minimum — $8d_b$ or 150mm, whichever is the greater.)

How to determine the appropriate factor?

If side cover normal to the plane of the hooked bar is ⩾ 60mm and the cover on the tail extension of 90° hooks is ⩾ 40mm, then allowance factor = 0.7

If confinement is by way of closed hoops or stirrups at a spacing $\leqslant 6d_b$ and,

$\frac{A_{tr}}{s} \geqslant \frac{A_b}{1000}$ (check via Chart D6)

, then allowance factor = 0.8

For background to use of Chart D6, possibly involving Table D5 to ascertain ΣA_t, see example 3.

TABLE D1.1 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 50MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars is ⩾40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	370	350	480	200	200	200	200
	25		340	320	430				
	30		310	300	400				
	40		300	300	340				
12	20	390	540	500	700	200	250	200	200
	25	350	480	450	620		220		
	30	320	440	410	570		210		
	40	300	380	360	490		200		
16	20	690	950	890	1230	240	330	200	250
	25	620	850	800	1100	220	300		220
	30	560	780	730	1010	200	270		210
	40	490	670	630	870	200	270		210
20	20	1070	1480	1390	1920	300	410	230	310
	25	960	1320	1250	1720	270	370	200	280
	30	880	1210	1140	1570	250	340	200	260
	40	760	1050	990	1360	250	340	200	260
24	20	1540	2130	2000	2770	360	490	270	370
	25	1380	1910	1790	2480	320	440	240	330
	30	1260	1740	1640	2260	290	410	220	310
	40	1090	1510	1420	1960	290	410	220	310
28	Not applicable for 50mm spacing								
32									
40									

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.2 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 60MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars is ⩾40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	410	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	330	450	420	580	200	250	200	200
	25	300	400	380	520		220		
	30	300	370	350	470		210		
	40	300	320	300	410		200		
16	20	570	790	750	1030	240	330	200	250
	25	510	710	670	920	220	300		220
	30	470	650	610	840	200	270		210
	40	410	560	530	730	200	270		210
20	20	890	1230	1160	1600	300	410	230	310
	25	800	1100	1040	1430	270	370	200	280
	30	730	1010	950	1310	250	340	200	260
	40	630	870	820	1140	250	340	200	260
24	20	1290	1780	1670	2310	360	490	270	370
	25	1150	1590	1490	2060	320	440	240	330
	30	1050	1450	1370	1880	290	410	220	310
	40	910	1260	1180	1630	290	410	220	310
28	20	1750	2420	2270	3140	420	580	310	430
	25	1560	2160	2030	2810	370	520	280	390
	30	1430	1970	1860	2560	340	470	260	360
	40	1240	1710	1610	2220	340	470	260	360
32	Not applicable for 60mm spacing								
40									

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.3 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 70MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars is ≥40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars regular fy 275	Tension Bars regular fy 380	Tension Bars top 275	Tension Bars top 380	Compression Bars open 275	Compression Bars open 380	Compression Bars confined 275	Compression Bars confined 380
6	20, 25, 30, 40	300	300	300	300	200	200	200	200
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	390	360	500	200	250	200	200
	25		340	320	450		220		
	30		310	300	410		210		
	40		300	300	350		200		
16	20	490	680	640	880	240	330	200	250
	25	440	610	570	790	220	300		220
	30	400	560	520	720	200	270		210
	40	350	480	450	620	200	270		210
20	20	770	1060	1000	1380	300	410	230	310
	25	690	950	890	1230	270	370	200	280
	30	630	870	810	1120	250	340	200	260
	40	540	750	710	970	250	340	200	260
24	20	1100	1520	1430	1980	360	490	270	370
	25	990	1360	1280	1770	320	440	240	330
	30	900	1240	1170	1620	290	410	220	310
	40	780	1080	1010	1400	290	410	220	310
28	20	1500	2070	1950	2690	420	580	310	430
	25	1340	1850	1740	2410	370	520	280	390
	30	1230	1690	1590	2200	340	470	260	360
	40	1060	1470	1380	1900	340	470	260	360
32	20	1960	2700	2540	3510	480	660	360	490
	25	1750	2420	2280	3140	430	590	320	440
	30	1600	2210	2080	2870	390	540	290	410
	40	1390	1910	1800	2490	390	540	290	410
40	Not applicable for 70mm spacing								

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.4 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 80MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars is ⩾40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		340	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	430	600	560	770	240	330	200	250
	25	390	530	500	690	220	300		220
	30	350	490	460	630	200	270		210
	40	310	420	400	550	200	270		210
20	20	670	930	870	1200	300	410	230	310
	25	600	830	780	1080	270	370	200	280
	30	550	760	710	980	250	340	200	260
	40	480	660	620	850	250	340	200	260
24	20	970	1330	1250	1730	360	490	270	370
	25	860	1190	1120	1550	320	440	240	330
	30	790	1090	1030	1410	290	410	220	310
	40	680	940	890	1230	290	410	220	310
28	20	1310	1810	1710	2350	420	580	310	430
	25	1170	1620	1530	2110	370	520	280	390
	30	1070	1480	1390	1920	340	470	260	360
	40	930	1280	1210	1670	340	470	260	360
32	20	1710	2370	2230	3070	480	660	360	490
	25	1530	2120	1990	2750	430	590	320	440
	30	1400	1930	1820	2510	390	540	290	410
	40	1210	1670	1580	2180	390	540	290	410
40	20	2670	3690	3480	4800	590	820	450	620
	25	2390	3300	3110	4290	530	730	400	550
	30	2180	3020	2840	3920	490	670	370	500
	40	1890	2610	2460	3400	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.5 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 90MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars is ⩾40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
		fy 275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		340	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	380	530	500	690	240	330	200	250
	25	340	470	450	620	220	300		220
	30	310	430	410	560	200	270		210
	40	300	380	350	490	200	270		210
20	20	600	820	780	1070	300	410	230	310
	25	540	740	700	960	270	370	200	280
	30	490	670	630	870	250	340	200	260
	40	420	580	550	760	250	340	200	260
24	20	860	1190	1120	1540	360	490	270	370
	25	770	1060	1000	1380	320	440	240	330
	30	700	970	910	1260	290	410	220	310
	40	610	840	790	1090	290	410	220	310
28	20	1170	1610	1520	2090	420	580	310	430
	25	1040	1440	1360	1870	370	520	280	390
	30	950	1320	1240	1710	340	470	260	360
	40	830	1140	1070	1480	340	470	260	360
32	20	1520	2100	1980	2730	480	660	360	490
	25	1360	1880	1770	2450	430	590	320	440
	30	1240	1720	1620	2230	390	540	290	410
	40	1080	1490	1400	1930	390	540	290	410
40	20	2380	3280	3090	4270	590	820	450	620
	25	2130	2940	2760	3820	530	730	400	550
	30	1940	2680	2520	3490	490	670	370	500
	40	1680	2320	2190	3020	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.6 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 100MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars is ⩾40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	540	740	700	960	300	410	230	310
	25	480	660	630	860	270	370	200	280
	30	440	610	570	790	250	340	200	260
	40	380	530	500	680	250	340	200	260
24	20	770	1070	1000	1390	360	490	270	370
	25	690	960	900	1240	320	440	240	330
	30	630	870	820	1130	290	410	220	310
	40	550	760	710	980	290	410	220	310
28	20	1050	1450	1370	1880	420	580	310	430
	25	940	1300	1220	1690	370	520	280	390
	30	860	1190	1120	1540	340	470	260	360
	40	740	1030	970	1330	340	470	260	360
32	20	1370	1890	1780	2460	480	660	360	490
	25	1230	1690	1590	2200	430	590	320	440
	30	1120	1550	1460	2010	390	540	290	410
	40	970	1340	1260	1740	390	540	290	410
40	20	2140	2960	2780	3840	590	820	450	620
	25	1920	2640	2490	3440	530	730	400	550
	30	1750	2410	2270	3140	490	670	370	500
	40	1520	2090	1970	2720	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.7 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 110MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars = 40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	540	740	700	960	300	410	230	310
	25	480	660	630	860	270	370	200	280
	30	440	610	570	790	250	340	200	260
	40	380	530	500	680	250	340	200	260
24	20	740	1030	970	1330	360	490	270	370
	25	670	920	860	1190	320	440	240	330
	30	610	840	790	1090	290	410	220	310
	40	530	730	680	940	290	410	220	310
28	20	970	1340	1260	1750	420	580	310	430
	25	870	1200	1130	1560	370	520	280	390
	30	800	1100	1030	1430	340	470	260	360
	40	690	950	900	1240	340	470	260	360
32	20	1250	1720	1620	2240	480	660	360	490
	25	1120	1540	1450	2000	430	590	320	440
	30	1020	1410	1320	1830	390	540	290	410
	40	880	1220	1150	1580	390	540	290	410
40	20	1950	2690	2530	3490	590	820	450	620
	25	1740	2400	2260	3120	530	730	400	550
	30	1590	2200	2070	2850	490	670	370	500
	40	1380	1900	1790	2470	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.8 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 110MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars = 50mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	490	680	640	880	300	410	230	310
	25	440	600	570	780	270	370	200	280
	30	400	550	520	720	250	340	200	260
	40	350	480	450	620	250	340	200	260
24	20	700	970	910	1260	360	490	270	370
	25	630	870	820	1130	320	440	240	330
	30	580	790	750	1030	290	410	220	310
	40	500	690	650	890	290	410	220	310
28	20	960	1320	1240	1710	420	580	310	430
	25	860	1180	1110	1530	370	520	280	390
	30	780	1080	1010	1400	340	470	260	360
	40	680	930	880	1210	340	470	260	360
32	20	1250	1720	1620	2240	480	660	360	490
	25	1120	1540	1450	2000	430	590	320	440
	30	1020	1410	1320	1830	390	540	290	410
	40	880	1220	1150	1580	390	540	290	410
40	20	1950	2690	2530	3490	590	820	450	620
	25	1740	2400	2260	3120	530	730	400	550
	30	1590	2200	2070	2850	490	670	370	500
	40	1380	1900	1790	2470	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.9 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 120MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars = 40mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	540	740	700	960	300	410	230	310
	25	480	660	630	860	270	370	200	280
	30	440	610	570	790	250	340	200	260
	40	380	530	500	680	250	340	200	260
24	20	740	1030	970	1330	360	490	270	370
	25	670	920	860	1190	320	440	240	330
	30	610	840	790	1090	290	410	220	310
	40	530	730	680	940	290	410	220	310
28	20	970	1340	1260	1750	420	580	310	430
	25	870	1200	1130	1560	370	520	280	390
	30	800	1100	1030	1430	340	470	260	360
	40	690	950	900	1240	340	470	260	360
32	20	1230	1690	1590	2200	480	660	360	490
	25	1100	1510	1420	1970	430	590	320	440
	30	1000	1380	1300	1800	390	540	290	410
	40	870	1200	1130	1560	390	540	290	410
40	20	1780	2460	2320	3200	590	820	450	620
	25	1600	2200	2070	2860	530	730	400	550
	30	1460	2010	1890	2620	490	670	370	500
	40	1260	1740	1640	2270	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.10 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 120MM

1. Deformed Bars in Tension:
Where (a) The cover to the bars = 50mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	450	620	580	800	300	410	230	310
	25	400	550	520	720	270	370	200	280
	30	370	510	480	660	250	340	200	260
	40	320	440	410	570	250	340	200	260
24	20	650	890	840	1160	360	490	270	370
	25	580	800	750	1030	320	440	240	330
	30	530	730	690	940	290	410	220	310
	40	460	630	590	820	290	410	220	310
28	20	880	1210	1140	1570	420	580	310	430
	25	780	1080	1020	1410	370	520	280	390
	30	720	990	930	1280	340	470	260	360
	40	620	860	810	1110	340	470	260	360
32	20	1140	1580	1490	2050	480	660	360	490
	25	1020	1410	1330	1840	430	590	320	440
	30	930	1290	1210	1680	390	540	290	410
	40	810	1120	1050	1450	390	540	290	410
40	20	1780	2460	2320	3200	590	820	450	620
	25	1600	2200	2070	2860	530	730	400	550
	30	1460	2010	1890	2620	490	670	370	500
	40	1260	1740	1640	2270	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.11 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 130MM

1. **Deformed Bars in Tension:**
   Where (a) The cover to the bars = 40mm.
   (b) No account is taken of confining steel.

2. **Deformed Bars in Compression:**
   For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	540	740	700	960	300	410	230	310
	25	480	660	630	860	270	370	200	280
	30	440	610	570	790	250	340	200	260
	40	380	530	500	680	250	340	200	260
24	20	740	1030	970	1330	360	490	270	370
	25	670	920	860	1190	320	440	240	330
	30	610	840	790	1090	290	410	220	310
	40	530	730	680	940	290	410	220	310
28	20	970	1340	1260	1750	420	580	310	430
	25	870	1200	1130	1560	370	520	280	390
	30	800	1100	1030	1430	340	470	260	360
	40	690	950	900	1240	340	470	260	360
32	20	1230	1690	1590	2200	480	660	360	490
	25	1100	1510	1420	1970	430	590	320	440
	30	1000	1380	1300	1800	390	540	290	410
	40	870	1200	1130	1560	390	540	290	410
40	20	1780	2460	2320	3200	590	820	450	620
	25	1600	2200	2070	2860	530	730	400	550
	30	1460	2010	1890	2620	490	670	370	500
	40	1260	1740	1640	2270	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D1.12 BAR DEVELOPMENT LENGTH FOR: CENTRE TO CENTRE = 130MM

1. Deformed Bars in Tension:

Where (a) The cover to the bars = 50mm.
(b) No account is taken of confining steel.

2. Deformed Bars in Compression:

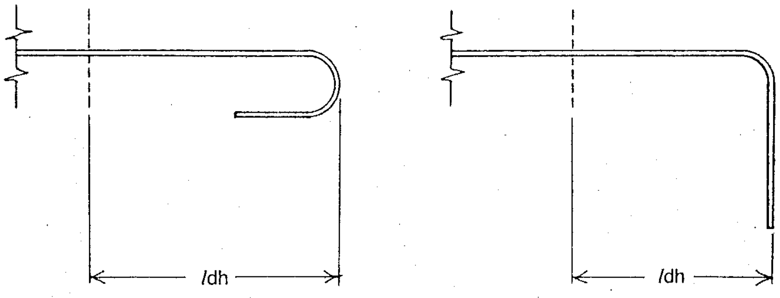
For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and also the design aid which evaluates A_{tr}/s and $A_b/1000$.

Bar Dia. mm	f'c MPa	Tension Bars				Compression Bars			
		regular		top		open		confined	
	fy	275	380	275	380	275	380	275	380
6	20	300	300	300	300	200	200	200	200
	25								
	30								
	40								
10	20	300	310	300	400	200	200	200	200
	25		300		360				
	30		300		330				
	40		300		300				
12	20	300	370	350	480	200	250	200	200
	25		330	320	430		220		
	30		310	300	400		210		
	40		300	300	340		200		
16	20	360	500	470	640	240	330	200	250
	25	320	440	420	580	220	300		220
	30	300	410	380	530	200	270		210
	40	300	350	330	460	200	270		210
20	20	450	620	580	800	300	410	230	310
	25	400	550	520	720	270	370	200	280
	30	370	510	480	660	250	340	200	260
	40	320	440	410	570	250	340	200	260
24	20	620	860	810	1120	360	490	270	370
	25	560	770	730	1000	320	440	240	330
	30	510	700	660	910	290	410	220	310
	40	440	610	570	790	290	410	220	310
28	20	820	1130	1070	1470	420	580	310	430
	25	740	1020	960	1320	370	520	280	390
	30	670	930	870	1200	340	470	260	360
	40	580	800	760	1040	340	470	260	360
32	20	1060	1460	1370	1890	480	660	360	490
	25	950	1300	1230	1690	430	590	320	440
	30	860	1190	1120	1550	390	540	290	410
	40	750	1030	970	1340	390	540	290	410
40	20	1650	2280	2140	2960	590	820	450	620
	25	1470	2040	1920	2640	530	730	400	550
	30	1350	1860	1750	2410	490	670	370	500
	40	1170	1610	1520	2090	490	670	370	500

Development length x 1.20 for a 3-bar bundle.
Development length x 1.33 for a 4-bar bundle.
Development length x 2.00 for plain bars.

TABLE D2 DEVELOPMENT LENGTHS FOR HOOKED DEFORMED BARS IN TENSION

For confinement conditions see NZS 3101 Clause 5.3.9.3(b) and the design aid which evaluates A_{tr}/s and $A_b/1000$.



Bar Dia.	f'c	fy 275 MPa	Confinement x 0.7	Confinement x 0.8	fy 380 MPa	Confinement x 0.7	Confinement x 0.8
6	20	150	150	150	150	150	150
	25	150	150	150	150	150	150
	30	150	150	150	150	150	150
	40	150	150	150	150	150	150
10	20	150	150	150	210	150	170
	25	150	150	150	190	150	150
	30	150	150	150	170	150	150
	40	150	150	150	150	150	150
12	20	180	150	150	250	180	200
	25	160	150	150	220	160	180
	30	150	150	150	200	150	160
	40	150	150	150	180	150	150
16	20	240	170	190	330	230	270
	25	220	150	170	300	210	240
	30	200	150	160	270	190	220
	40	170	150	150	230	170	190
20	20	300	210	240	410	290	330
	25	270	190	220	370	260	300
	30	250	170	200	340	240	270
	40	210	150	170	290	210	230
24	20	360	250	290	490	350	400
	25	320	230	260	440	310	350
	30	290	210	240	400	280	320
	40	250	180	200	350	250	280
28	20	420	290	340	580	400	460
	25	370	260	300	520	360	410
	30	340	240	270	470	330	380
	40	300	210	240	410	290	330
32	20	480	340	380	660	460	530
	25	430	300	340	590	410	470
	30	390	270	310	540	380	430
	40	340	240	270	470	330	370
40	20	590	420	480	820	580	660
	25	530	370	430	730	520	590
	30	490	340	390	670	470	540
	40	420	300	340	580	410	470

TABLE D3 MINIMUM COMPRESSIVE SPLICE LENGTHS FOR LAPPED DEFORMED BARS

Bar Diameter	fy = 275 MPa		Tied* or Spiral** Comp. Mems.	fy = 380 MPa		Tied* or Spiral** Comp. Mems.
	f'c <20	f'c 20, 30, 40		f'c <20	f'c 20, 30, 40	
6	300	300	300	300	300	300
10	300	300	300	370	300	300
12	330	300	300	450	340	300
16	430	330	300	600	450	370
20	540	410	340	750	560	470
24	650	490	400	890	670	560
28	750	570	470	1040	780	650
32	860	650	540	1190	890	740
40	Not permitted			Not permitted		

* At least three sets of ties must be present over the length of the lap

and, $\frac{A_{tr}}{s} \geqslant \frac{A_b}{1000}$

or transverse reinforcement meets the requirements of NZS 3101:1982: Part 1, Clause 6.5.4.3(c).

** At least 3 turns of spiral must be present over the length of the lap

and, $\frac{A_{tr}}{s} \geqslant \frac{A_b}{600}$

NOTE Chart D6 may be employed to check upon either of the inequalities alluded to above.

TABLE D4 VALUES OF k_{tr} FOR $A_{tr} = A_t$ (and f_{yt} = 275 MPa)

Steel	At	s = 60	s = 80	s = 100	s = 120	s = 140	s = 160	s = 180	s = 200
6mm	28	13	10	8	6	6	5	4	4
10mm	79	36	27	22	18	16	14	12	11
12mm	113	d_b	39	31	26	22	19	17	16
16mm	201	d_b	d_b	d_b	d_b	39	35	31	28
20mm	314	d_b	d_b	d_b	d_b	d_b	d_b	d_b	d_b

NOTE The parameter, k_{tr}, cannot exceed the main bar diameter, d_b. Should a local value of k_{tr} indicated by the above table violate this condition, take $k_{tr} = d_b$.

TABLE D5 VALUES OF ΣA_t FOR VARIOUS STIRRUP COMBINATIONS

Stirrup Size mm	Number of legs									
	1	2	3	4	5	6	7	8	9	10
6	28	57	85	113	141	170	198	226	255	283
10	79	157	236	314	393	471	550	628	707	785
12	113	226	339	452	565	679	792	905	1018	1131
16	201	402	603	804	1005	1206	1407	1608	1810	2011
20	314	628	942	1257	1571	1885	2199	2513	2827	3142
24	452	905	1357	1810	2262	2714	3167	3619	4072	4524

CHART D6 COMPARISON OF A_{tr}/s WITH EITHER $A_b/1000$ OR $A_b/600$

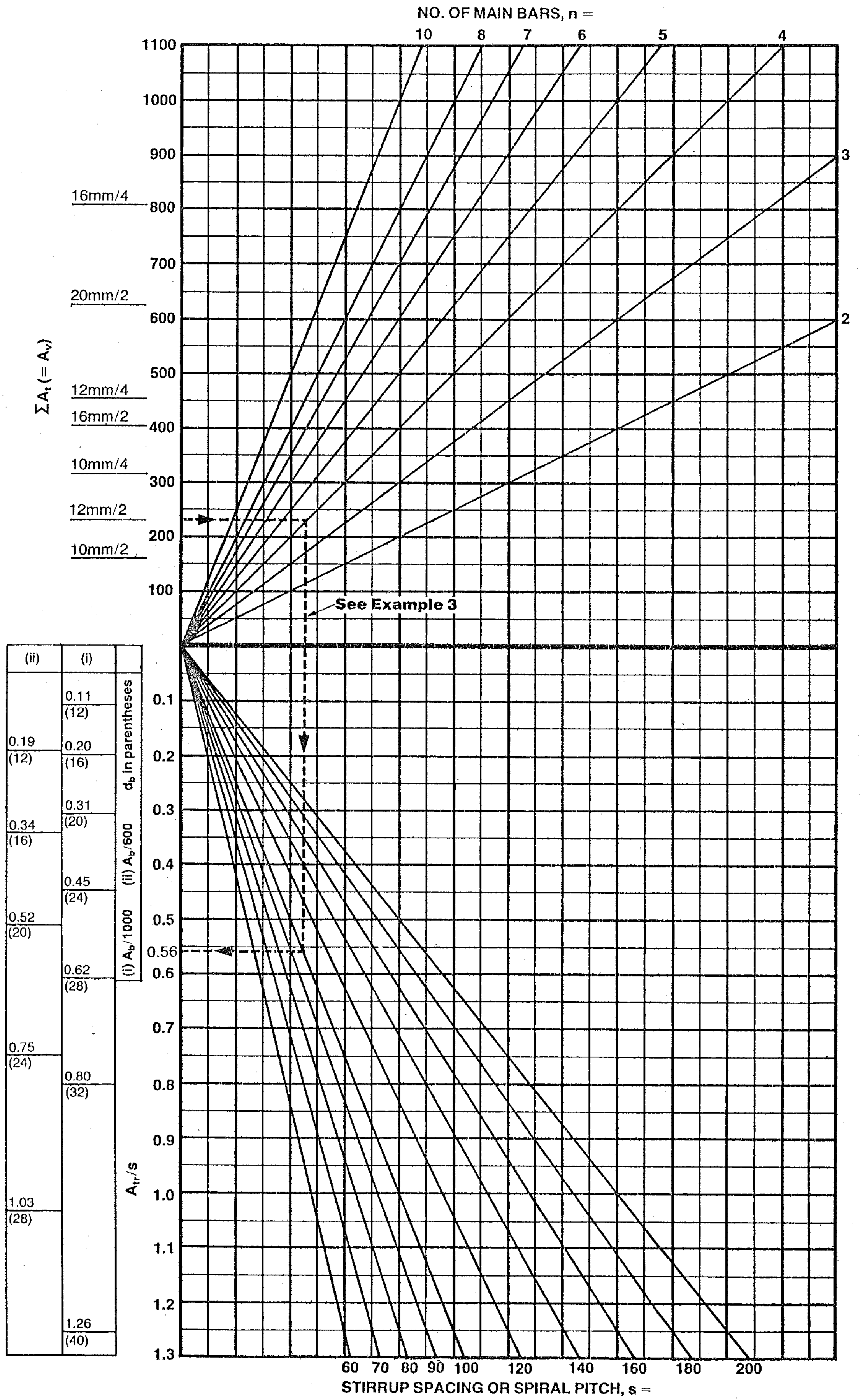


CHART D7.1 DETERMINATION OF k_{tr} : f_{yt} = 275MPa

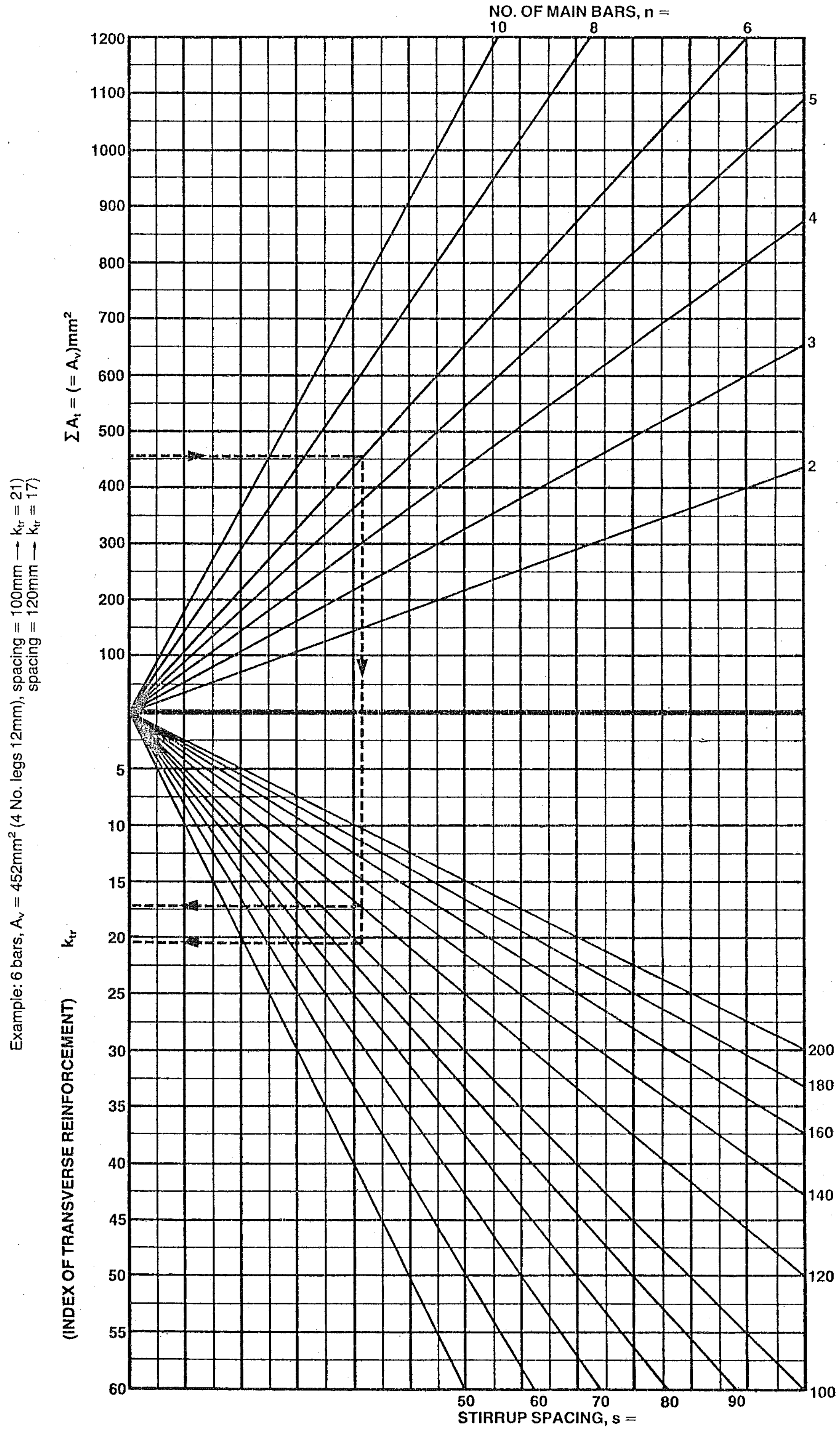


CHART D7.2 DETERMINATION OF k_{tr} : f_{yt} = 380MPa

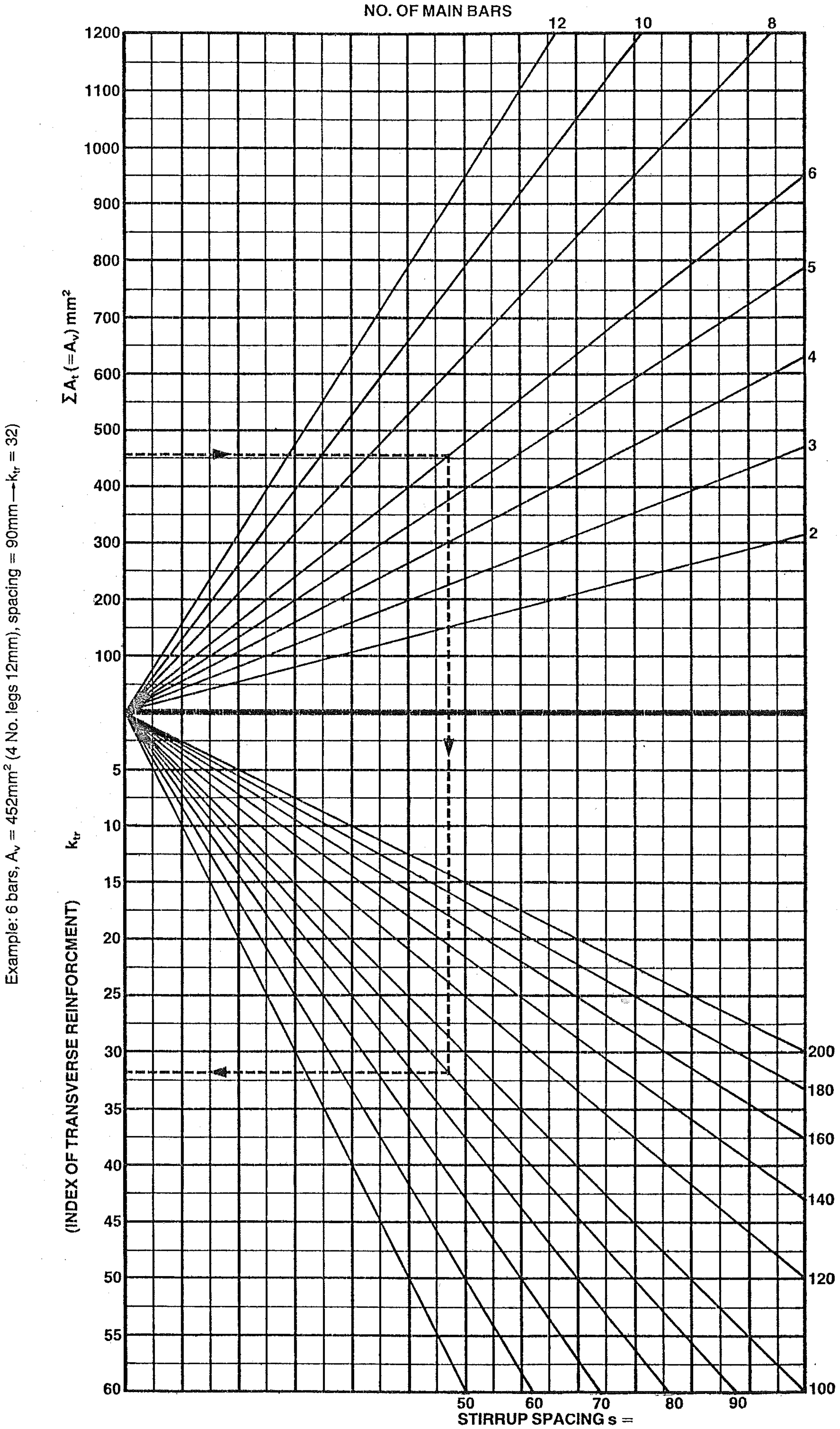


CHART D8.1 TENSILE DEVELOPMENT LENGTHS FOR:DEFORMED BARS $d_b = 10mm$, $f_y = 275$ MPa

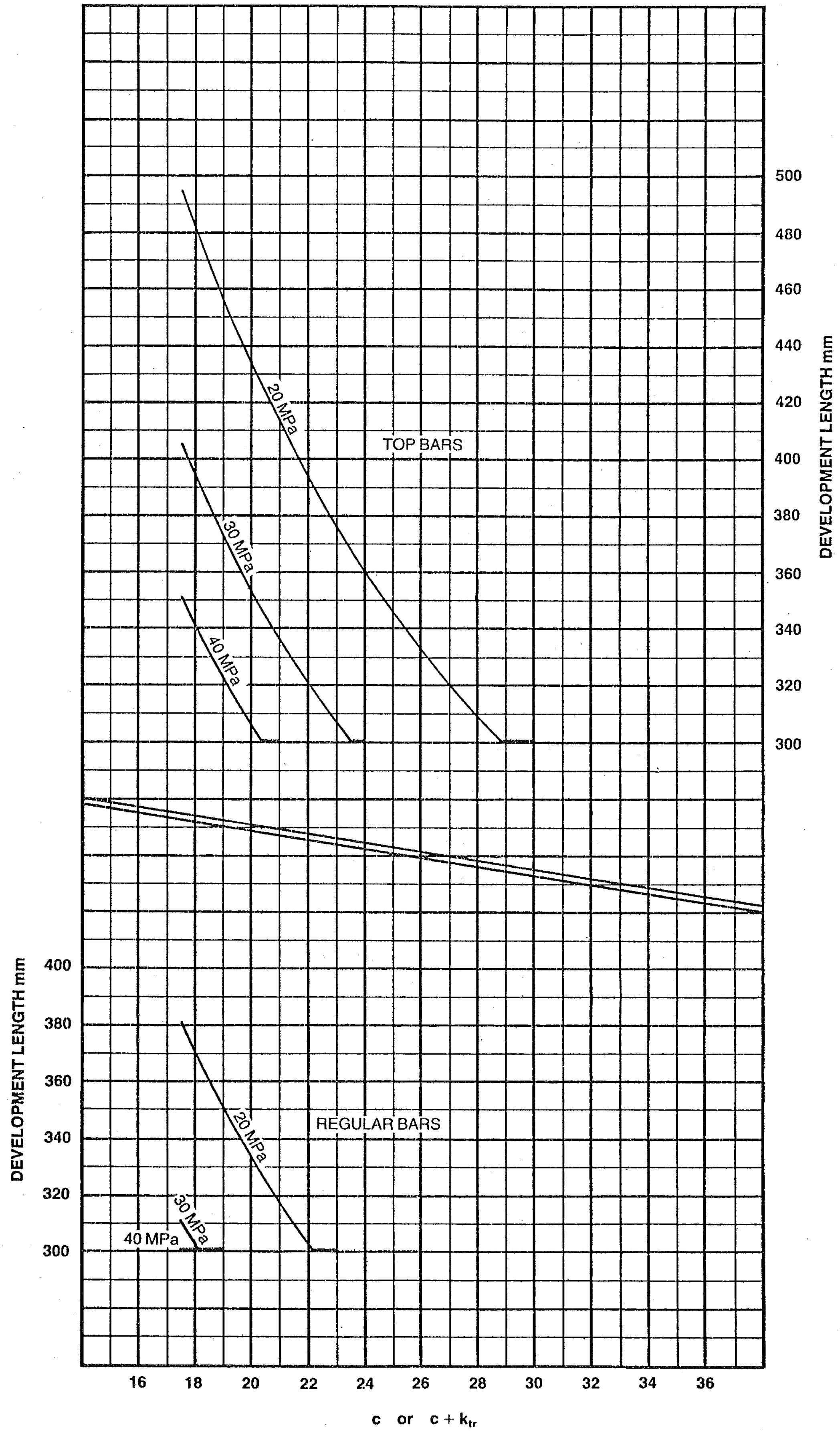


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CHART D8.2 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 12mm$, $f_y = 275$ MPa

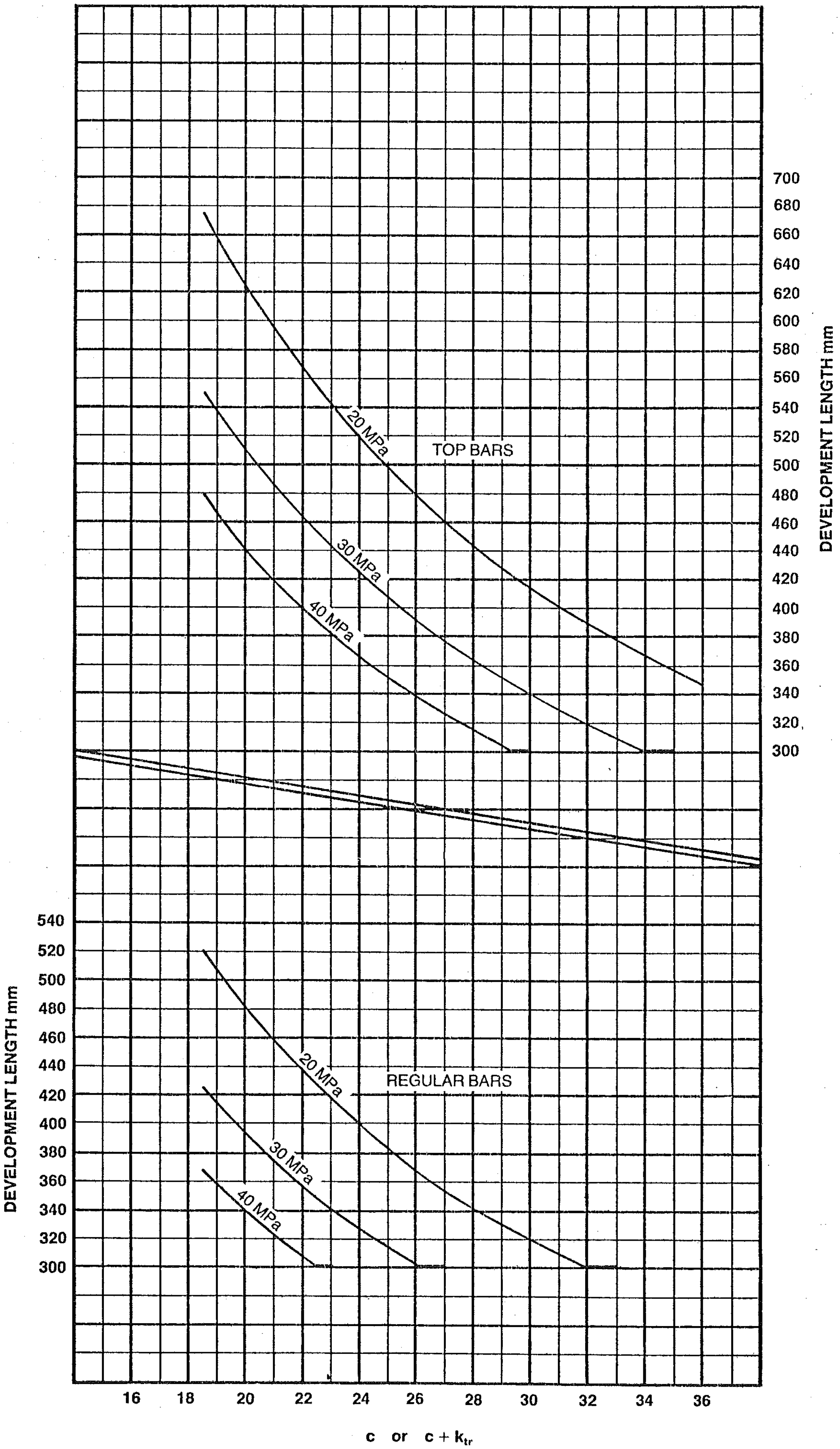


CHART D8.3 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS d_b = 16mm, f_y = 275MPa

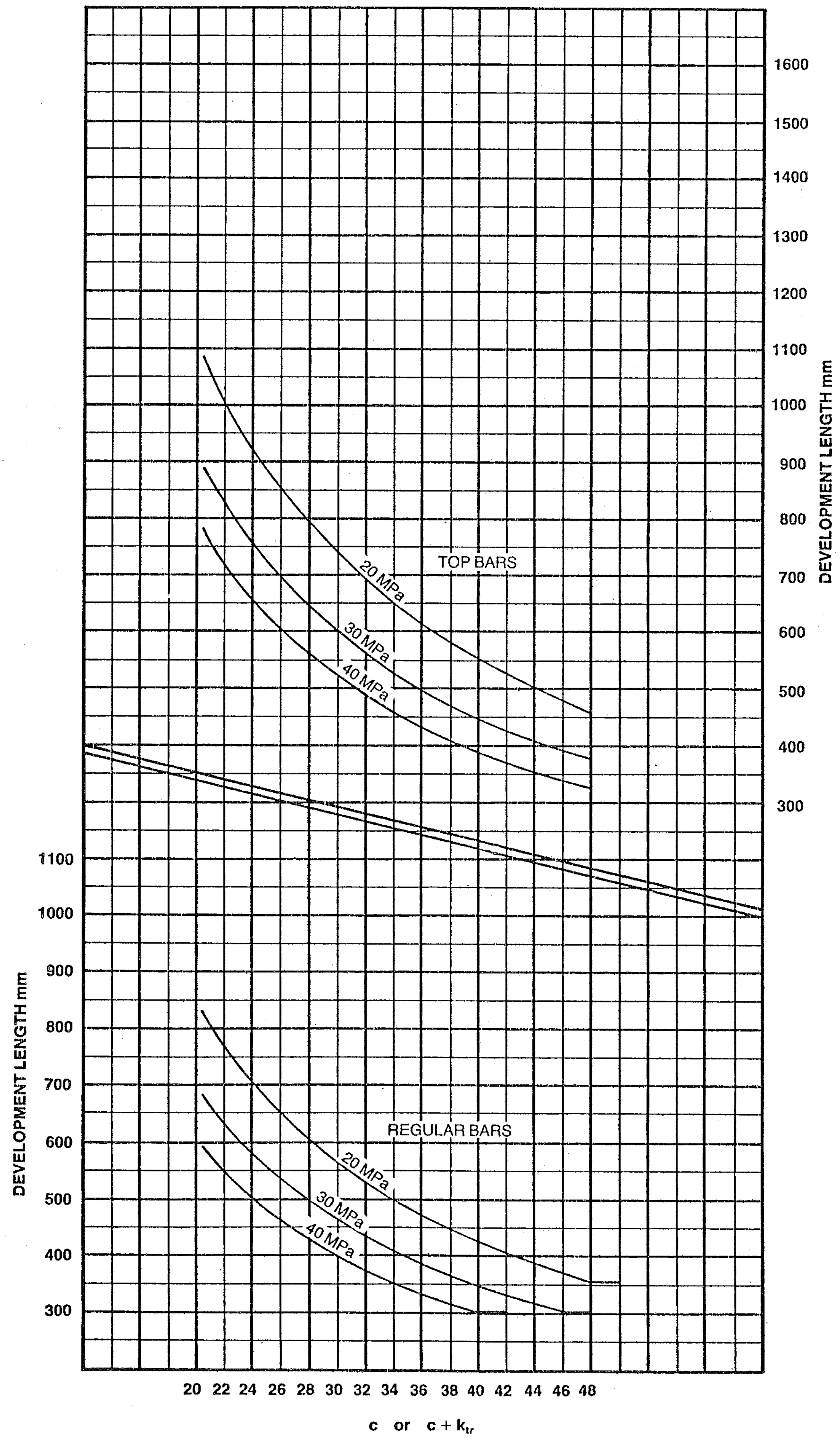


CHART D8.4 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 20mm$, $f_y = 275MPa$

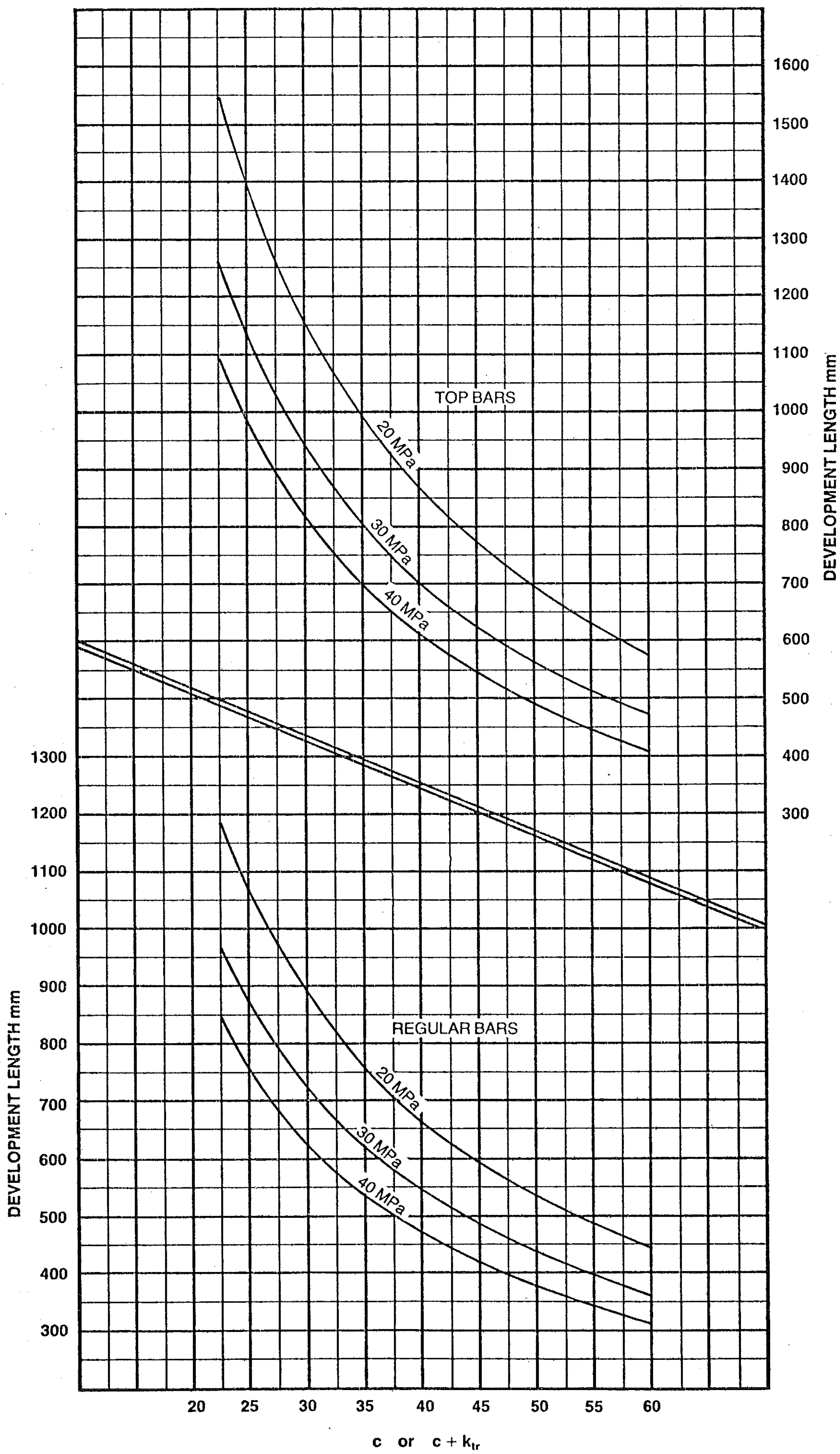


CHART D8.5 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 24mm$, $f_y = 275MPa$

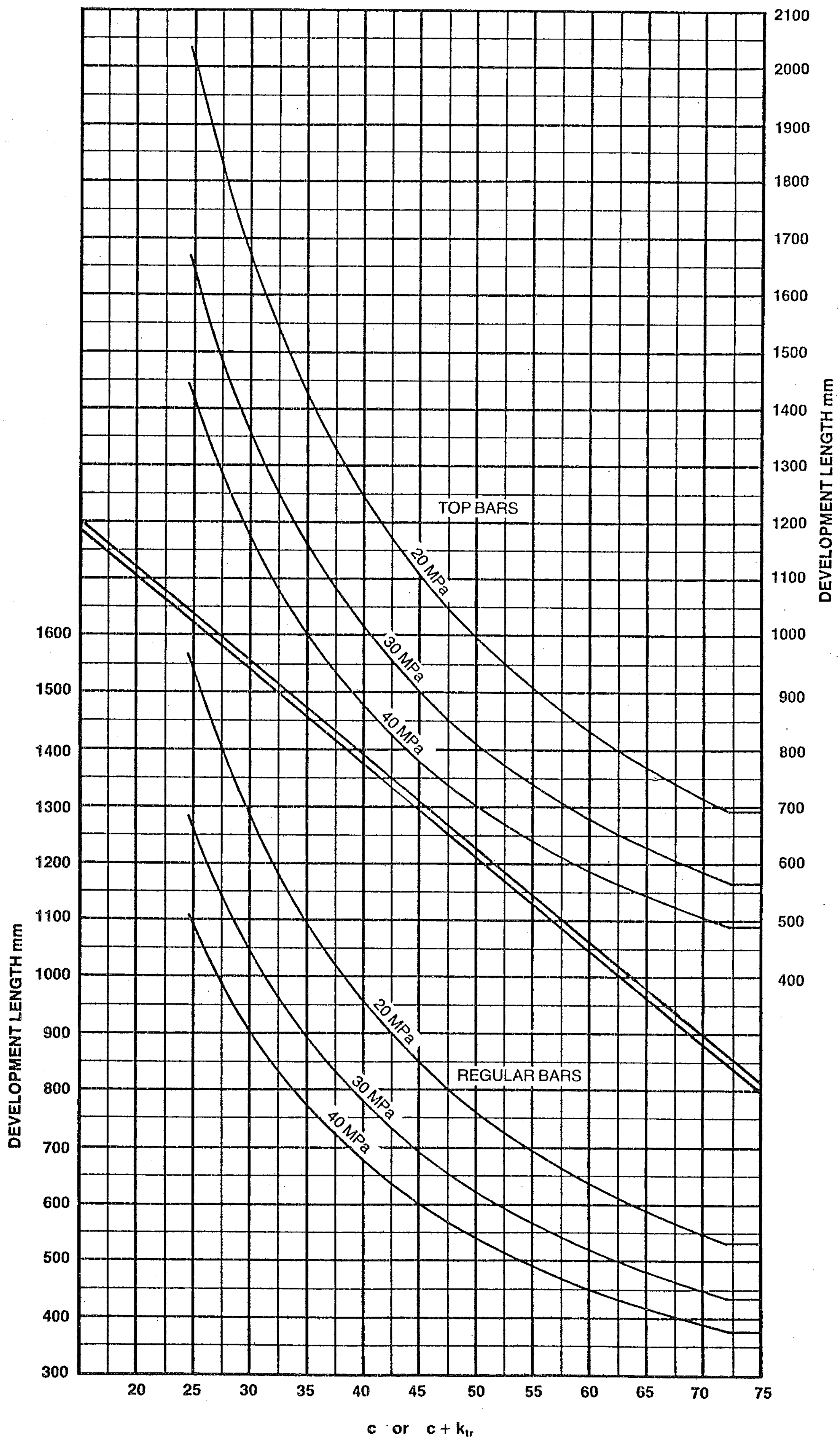


CHART D8.6. TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 28mm$, $f_y = 275MPa$

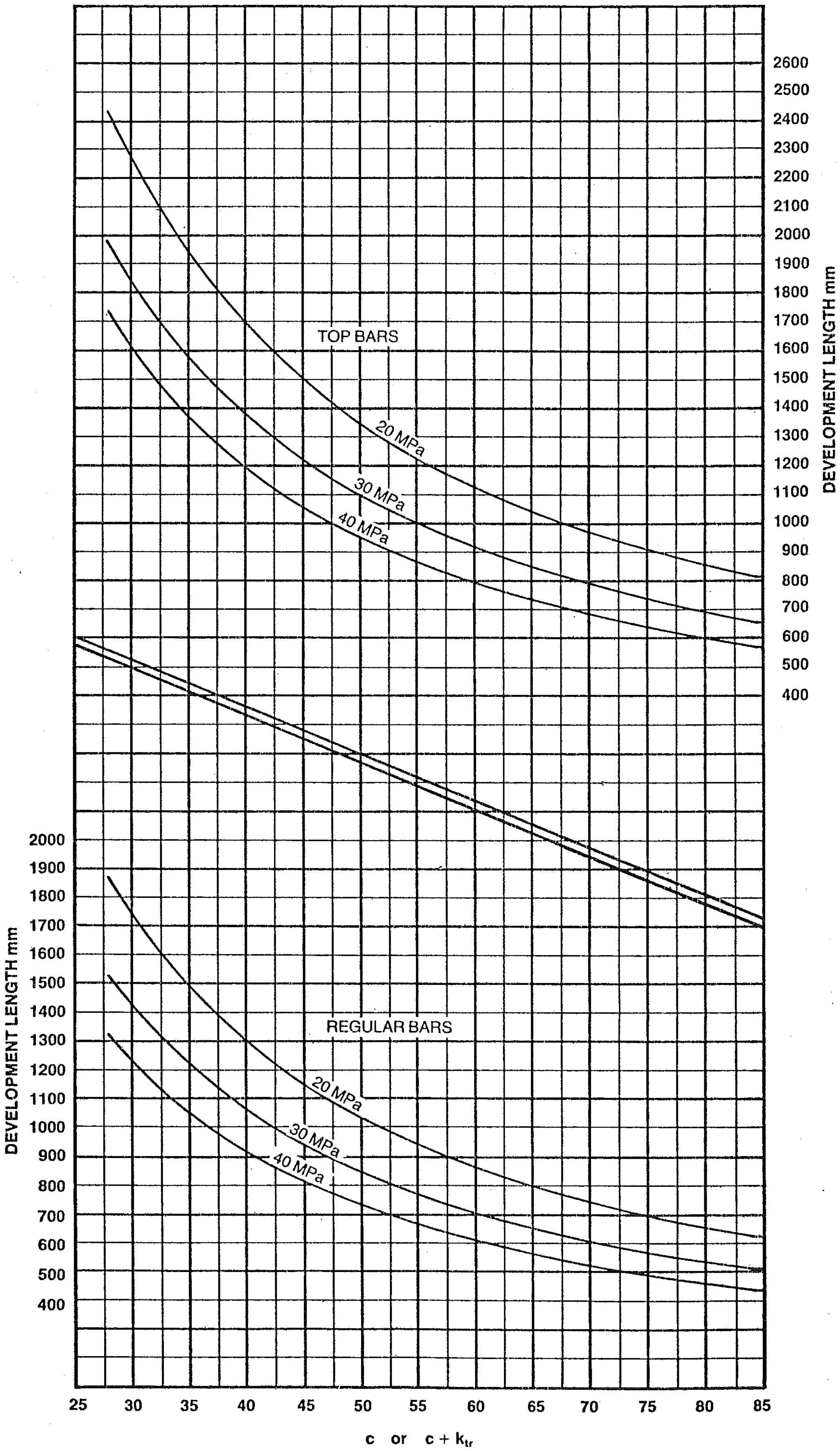


CHART D8.7 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 32mm$, $f_y = 275MPa$

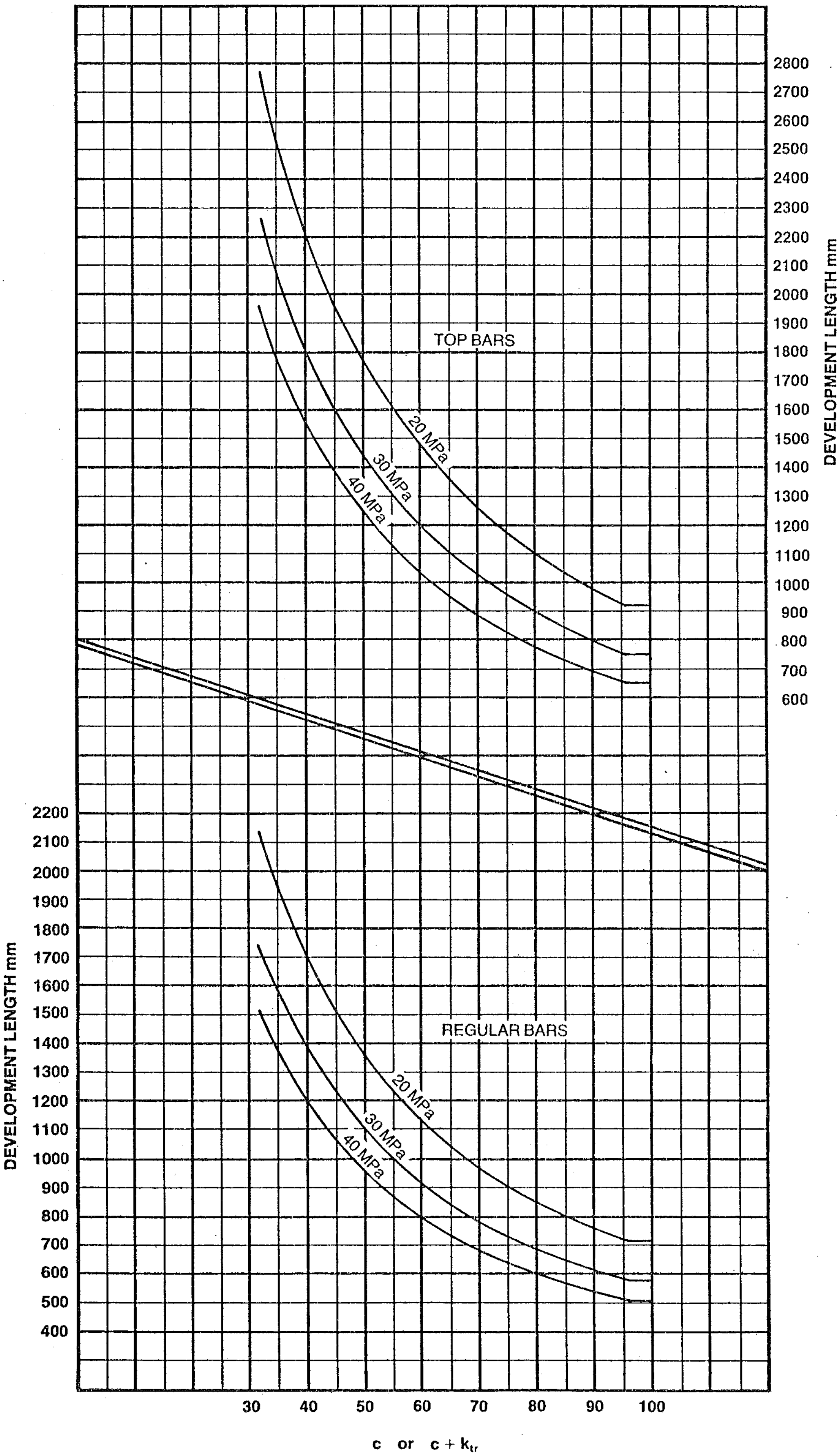


CHART D8.8 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 40mm$, $f_y = 275MPa$

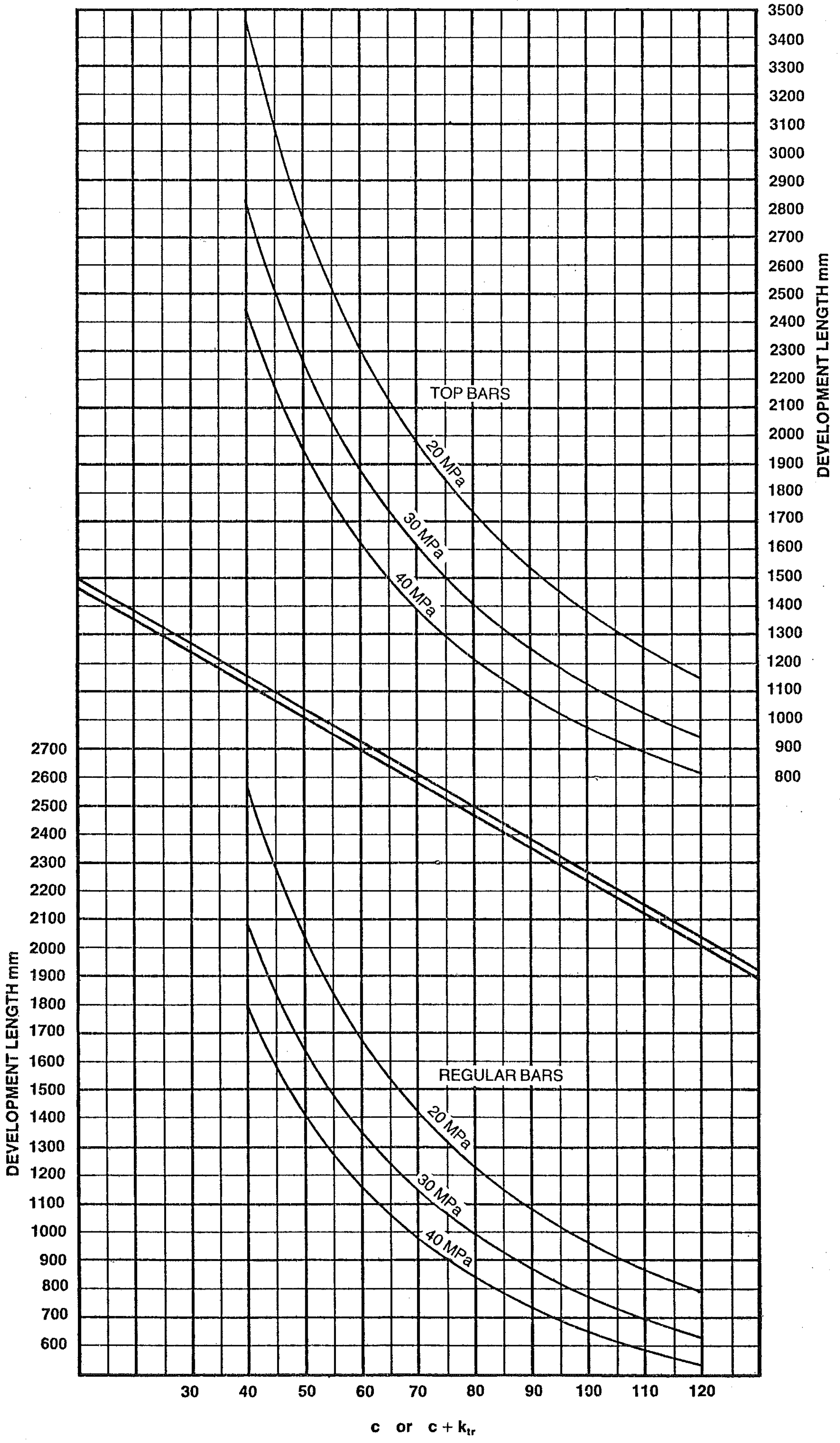


CHART D8.10 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS d_b = 12mm, f_y = 380MPa

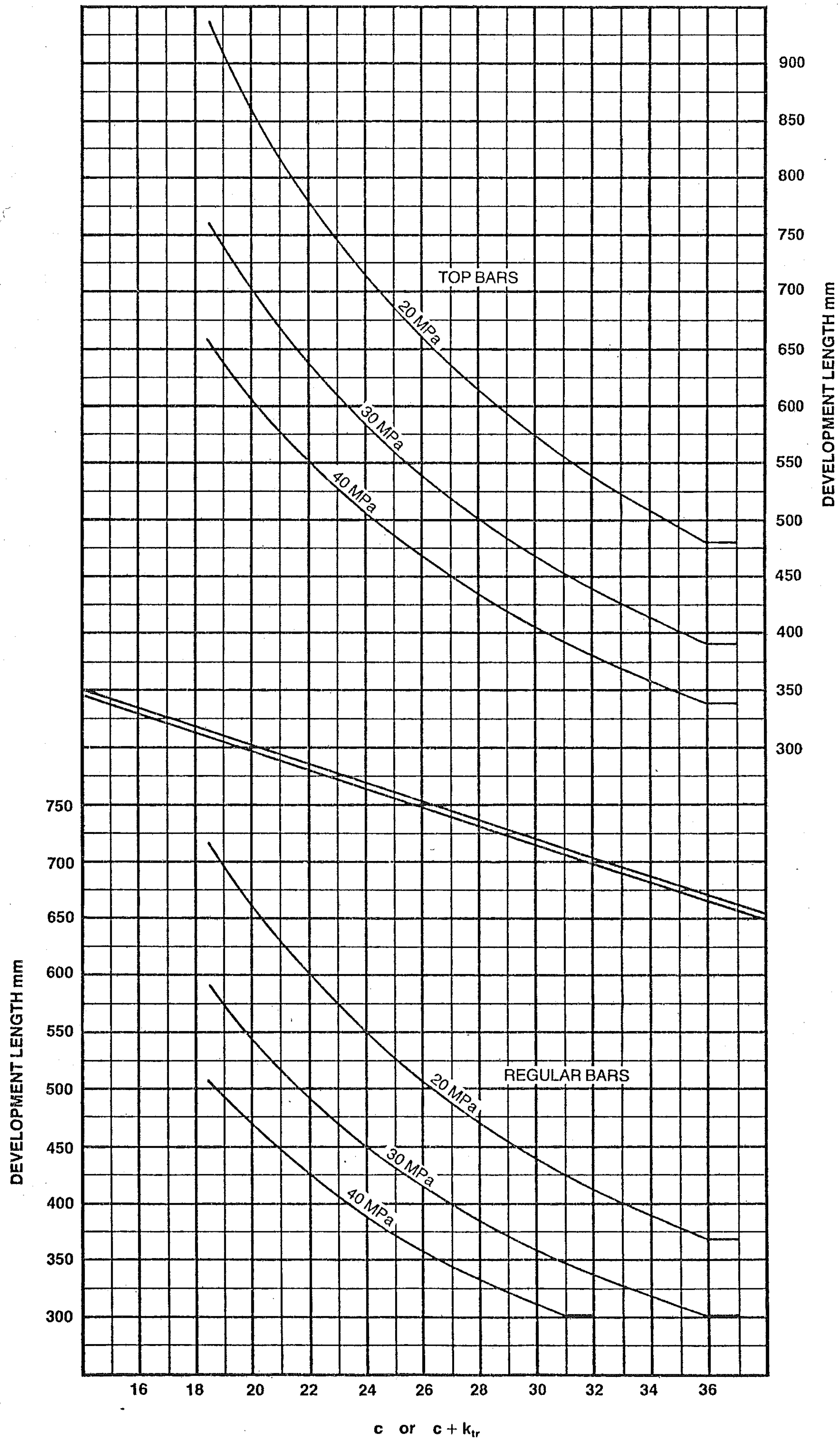


CHART D8.11 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 16mm$, $f_y = 380MPa$

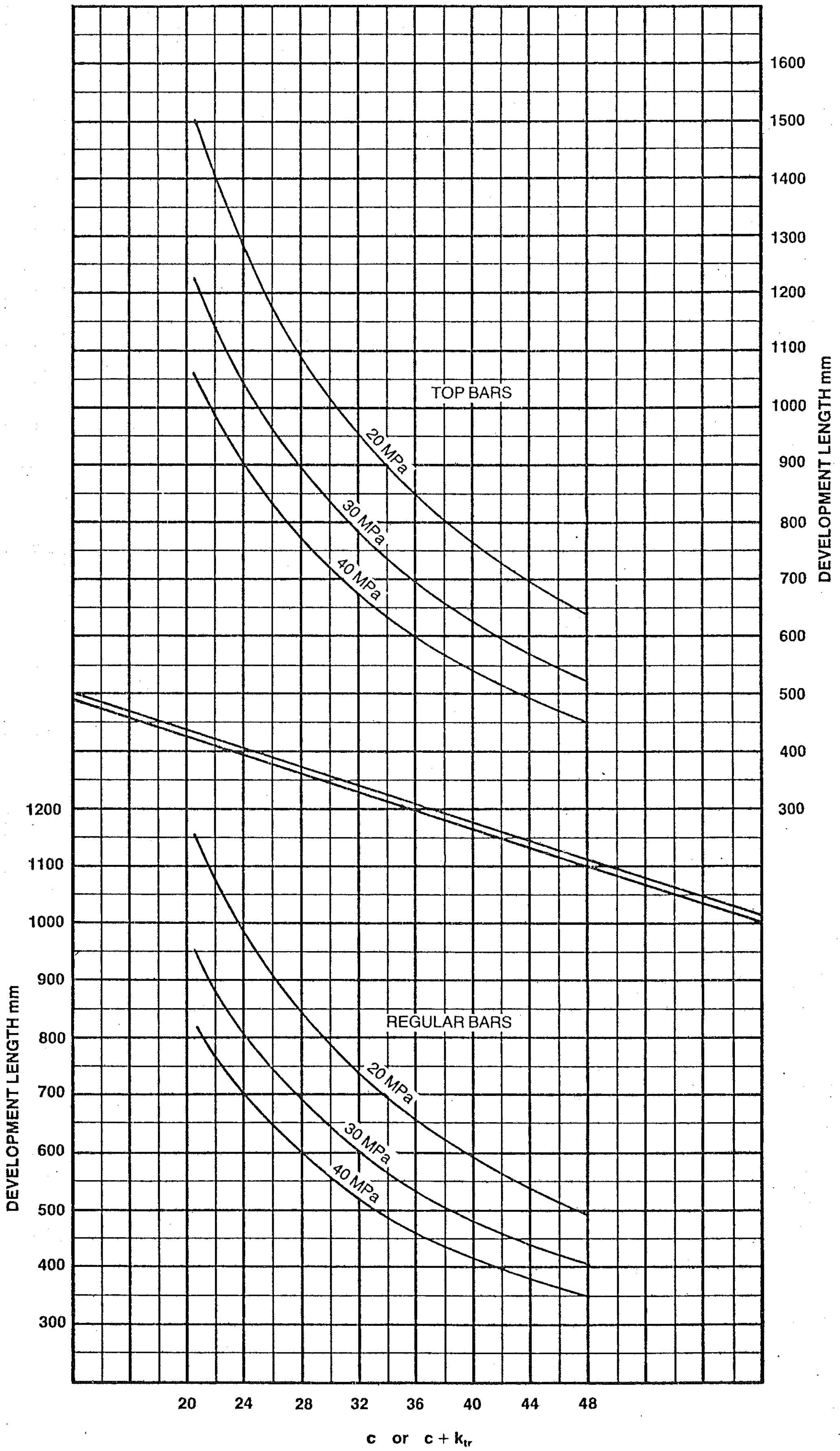


CHART D8.12 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 20mm$, $f_y = 380MPa$

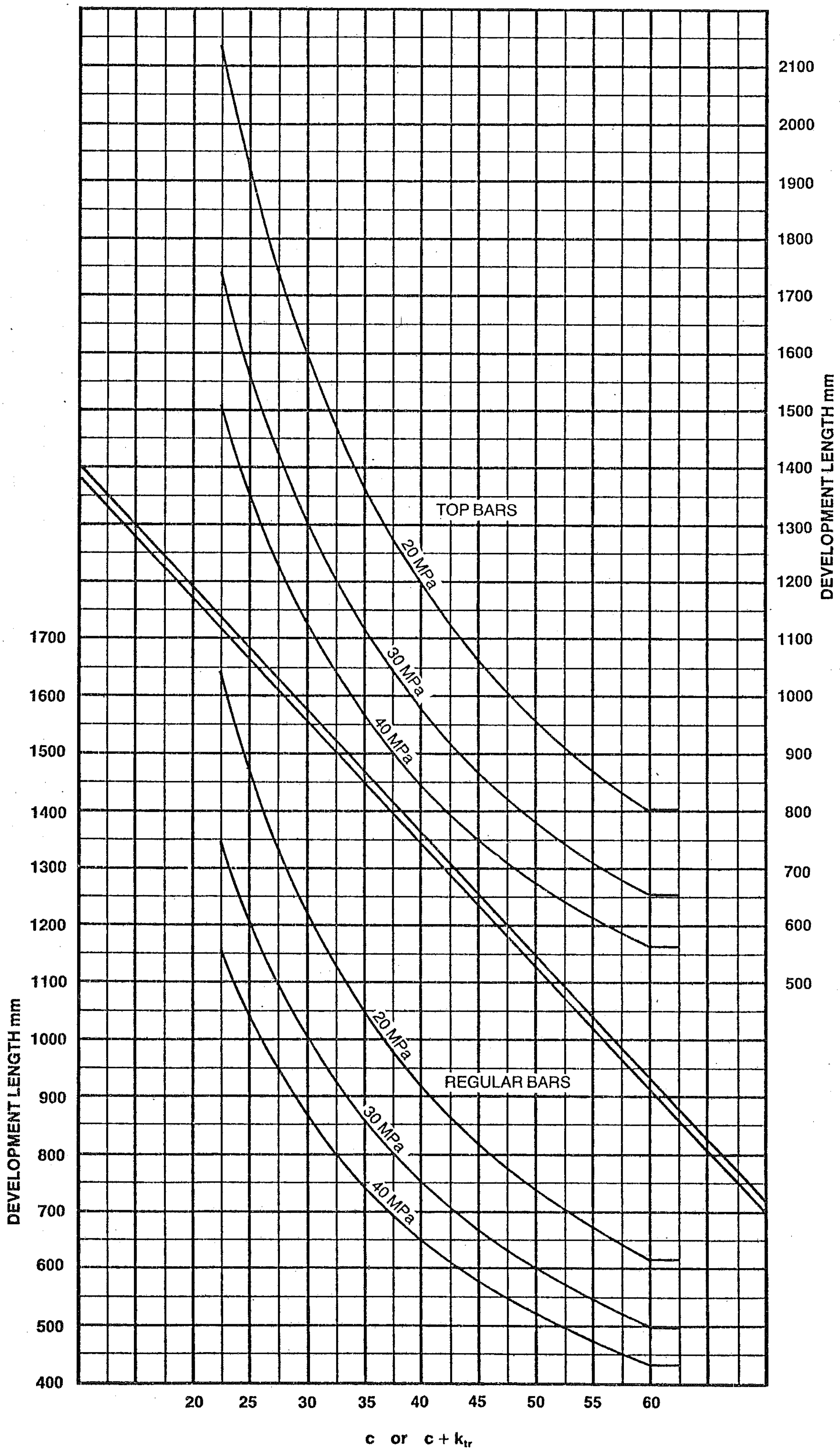


CHART D8.13 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS $d_b = 24mm$, $f_y = 380MPa$

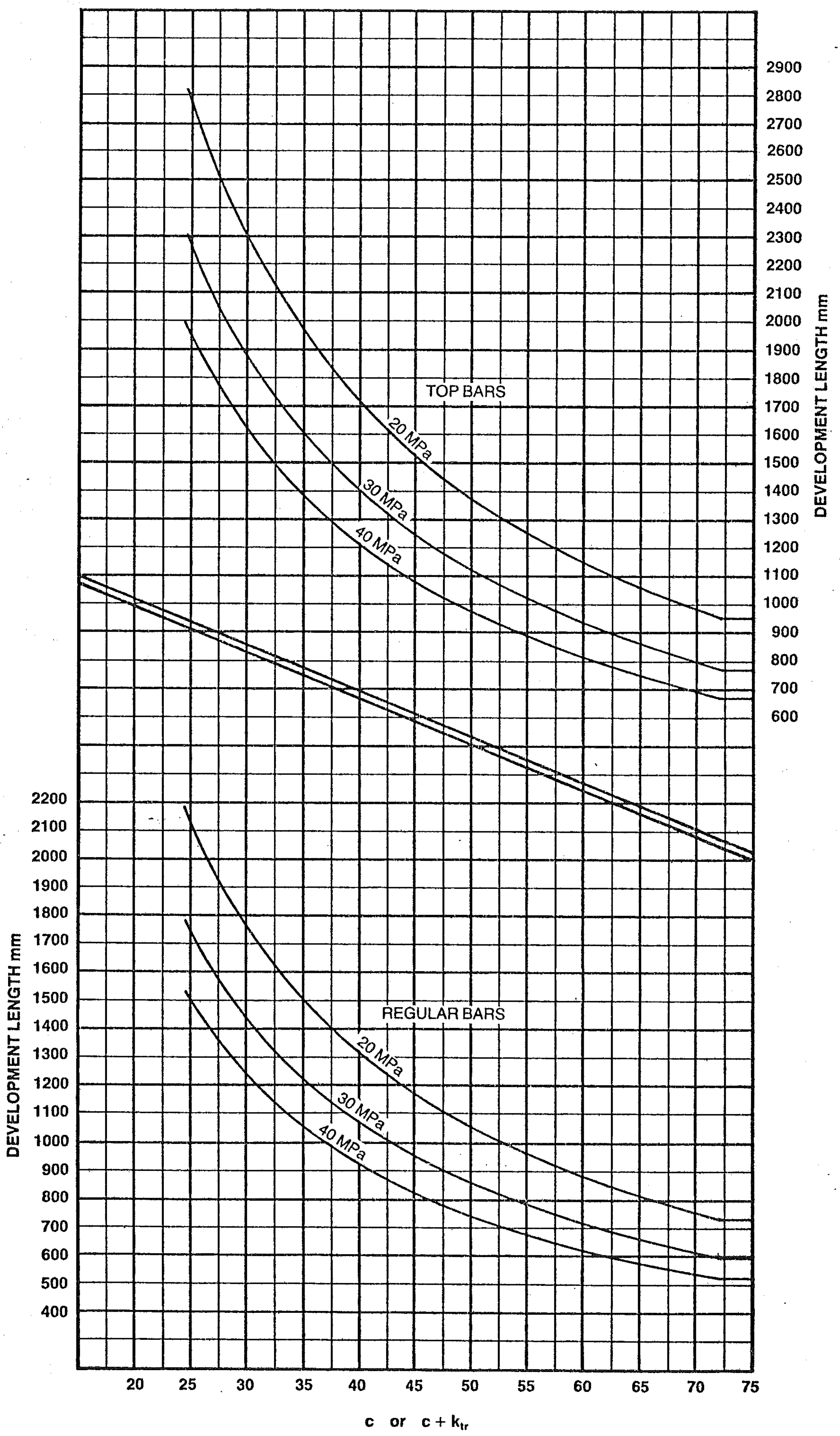
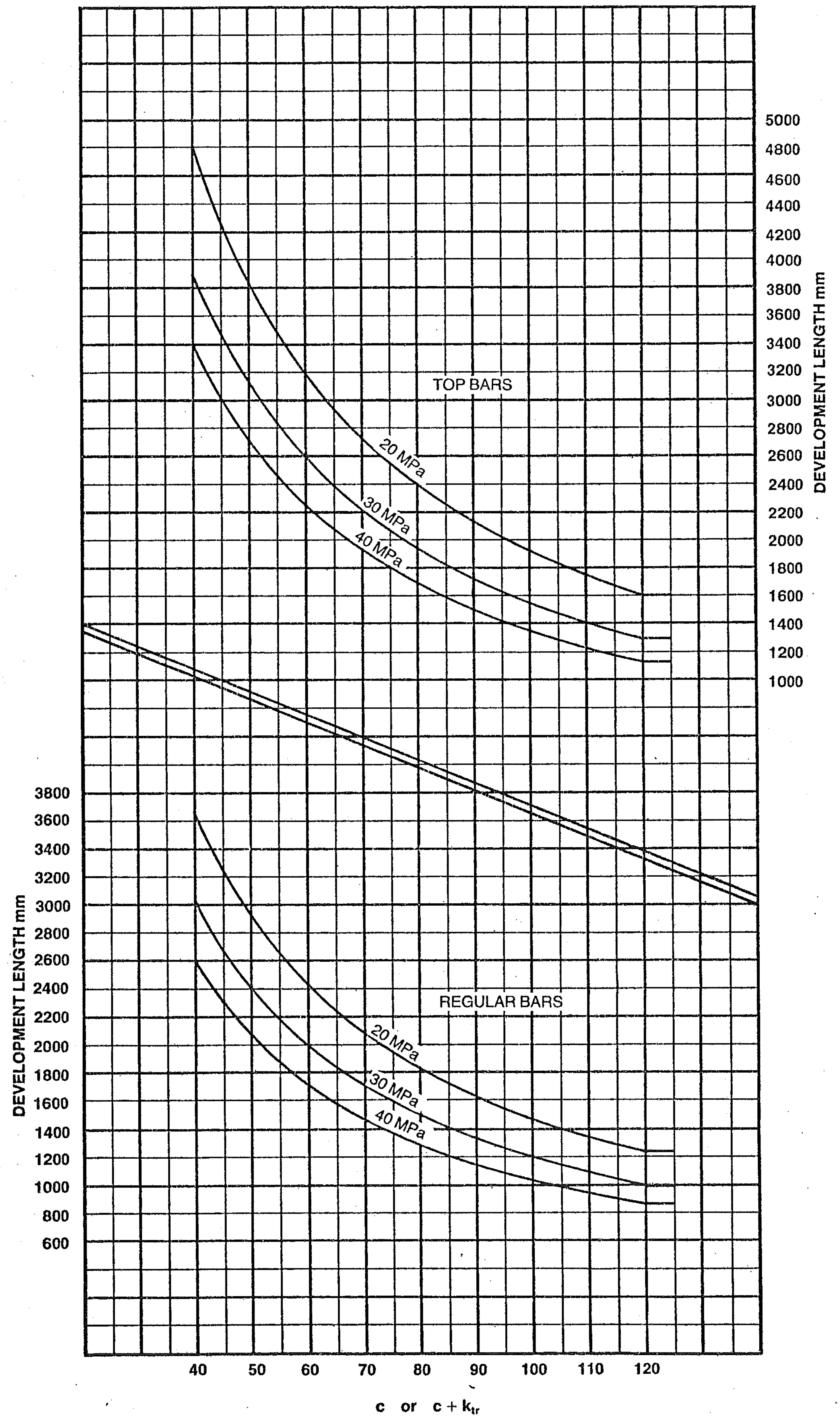


CHART D8.16 TENSILE DEVELOPMENT LENGTHS FOR: DEFORMED BARS d_b = 40mm, f_y = 380MPa



General

General

GI. New Zealand Standards relating to cement and concrete

Standards or Draft Standards marked with an asterisk (*) are in the process of revision as at publication date (September 1979)

Admixtures

NZS 3119:1979	Chemical admixtures in concrete

Aggregates

NZS 3111:1974*	Methods of test for water and aggregate for concrete
NZS 3121:1974*	Water and aggregate for concrete
NZS 1958:1965*	Lightweight aggregate for structural concrete
NZS 1959:1965*	Lightweight aggregate for concrete masonry units
NZS 1960:1965*	Lightweight aggregate for insulating concrete

Asbestos cement

NZS 3202:1977	Asbestos cement pressure pipes (Revision of NZS 285: 1969)
NZS 284:1950	The dimensions and workmanship of asbestos cement spigot and socket rainwater pipes, gutters, spoutings and fittings
NZS 3202:1978	Asbestos cement sewer and drain pipes and fittings (Revision of NZS 1573: 1961)
NZS 2082:1968	Unimpregnated asbestos cement boards (incombustible) for electrical purposes
NZS 2083:1968	Bitumen-impregnated asbestos cement boards (self-extinguishing) for electrical purposes
NZS 3204:1979	Asbestos cement sheets comprising Part 1. Asbestos cement corrugated sheets for roofing and cladding. Part 2. Code of recommended practice for the fixing of corrugated asbestos cement sheets. Part 3. Asbestos cement flat sheets

Cements

NZS 3122:1974	Portland cement (ordinary, rapid hardening and modified)
NZS 3123:1974	Portland pozzolan cement

Concrete design and construction

NZS 3101P:1970*	Code of practice for reinforced concrete design DZ 3101 Parts 1 & 2, 1978
NZS 1900: Chapter 4:1964	Residential buildings
NZS 1900:Chapter 9*	Design and construction — Division 9.3A:1970 Concrete — General requirements and materials and workmanship. DZ 3109
MP 190093A:1973	Metric handbook to NZS 1900:Chapter 9.3A:1970 Concrete design and construction — General requirements
NZS 1900:Chapter 11	Special structures — Division 11.1:1978 Structures for the storage of liquids
MP 1900040:1972	Metric handbook to NZS 1900: Chapter 4:1964 Residential buildings
NZS 3106P:1978	Concrete structures for the storage of liquids

NZS 5902	Drawing Practice Part 1. General and architectural Part 2. Structural — concrete, steel, timber

Fencing posts

NZS 3153:1974	Concrete posts and other concrete units for wire fencing in rural areas

Fire hydrant boxes

NZS 2237:1968	Fire hydrant boxes

Fire resistance

MP 9:1979	Fire properties of building materials and elements of building structures approved by the Fire Ratings Committee
NZS 1900:Chapter 5	Fire resisting construction and means of egress

Flues

NZS 1912:1965	Precast flue blocks for interior use with slow combustion stoves

Floors residential

See Foundations

Foundations

NZS 4204P:1973	Code of practice for foundations for buildings not requiring specific design
NZS 4205P:1973	Code of practice for design of foundations for buildings
MP 420400:1973	Metric handbook to NZS 4204P:1973 Code of practice for foundations for buildings not requiring specific design
MP 420500:1973	Metric handbook to NZS 4205P:1973 Code of practice for design for foundations for buildings
NZS 3604:1978	Code of Practice for light timber frame construction includes concrete foundation and floor requirements.

Lightweight concrete
(see also Aggregates)

NZS 3152:1974	Manufacture and use of structural and insulating lightweight concrete
NZS 3151:1974	Precast lightweight concrete panels and slabs

Limes

NZS 781:1951	Building limes (Amended from BS 890:1940 to suit NZ requirements)

Loadings

NZS 4203:1976	Code of practice for general structural design and design loadings for buildings

Masonry

NZS 3102P:1974*	Concrete masonry units

Masonry construction

NZS 1900:Chapter 6*	Construction requirements for buildings not requiring specific design — Division 6.2:1964 Masonry

NZS 1900:Chapter 9*	Design and construction — Division 9.2:1964 Masonry

Mixers

NZS 3105:1975	Concrete mixers (batch type and truck type)

Paints

NZS 1127:1954	Portland cement paint powder (white and light tints)
NZS 693:1962	Pigments for cement, magnesium oxy-chloride and concrete (Amended from BS 1014:1961 to suit NZ requirements)

Pipes

NZS 3202:1977	Asbestos cement pressure pipes
NZS 3203:1978	Asbestos cement sewer and drain pipes and fittings
NZS 3107:1978	Precast concrete drainage and pressure pipes

Plasters

NZS 4251:1974	Code of practice for solid plastering

Poles

NZS 1054:1966	Concrete poles for electrical transmission

Precast concrete

NZS 3151:1974	Precast lightweight concrete panels and slabs

Prestressed concrete

NZS R32:1968*	Prestressed concrete
NZS 1417:1971	Steel wire for prestressed concrete (Amended from BS 2691:1969 to suit NZ requirements)
MP 32X000:1974	Metric handbook to NZS R32:1968 Prestressed concrete

Ready mixed concrete

NZS 2086:1974*	Ready mixed concrete production
MP 208600:1975	Metric handbook to NZS 2086: 1968 Ready mixed concrete (DZ 3104)

Reinforced concrete

NZS 3101P:1970*	Code of practice for reinforced concrete design
MP 310100:1973	Metric handbook for NZS 3101P:1970 Code of Practice for reinforced concrete design (DZ 3101)

Reinforcement

NZS 3402P:1973	Hot rolled steel bars for concrete reinforcement
NZS 3421:1975	Hard drawn mild steel wire for concrete reinforcement
NZS 3422:1975	Welded fabric of drawn steel wire for concrete reinforcement

NZS 1417:1971	Steel wire for prestressed concrete (Amended from BS 2691:1969 to suit NZ requirements)

Roof tiles

NZS 4206:1973	Concrete interlocking roofing tiles

Sands

NZS 3103:1976	Sands for mortars, plasters and external renderings

Septic tanks

NZS 758:1961	Household septic tanks
CP 44:1961*	Code of recommended practice for the disposal of effluent from household septic tanks

Shells

NZS 1826:1964	The design and construction of shell roofs

Surface finishes

DZ 3114:1979*	Specification for concrete surface finishes

Swimming pools

NZS 4441:1972	Code of practice for swimming pools

Testing

NZS 3112:1974*	Methods of test for concrete

Thermal insulation

NZS 4214:1977	Methods of determining the total thermal resistance of parts of buildings
NZS 4218P:1977	Minimum insulation requirement for building services

G2. MASSES AND DEAD LOADS OF CONCRETE AND OTHER MATERIALS

Ordinary concrete (dense aggregates)

			kg/m³	kN/m³
Non-reinforced plain or mass concrete	Nominal		2305	22.6
	Aggregate: limestone		2162 to 2407	21.2 to 23.6
	greywacke		2244 to 2407	22.0 to 23.6
	basalt		2345 to 2650	23.0 to 26.0
Reinforced concrete	Nominal		2407	23.6
	Reinforcement: 1%		2305 to 2468	22.6 to 24.2
	2%		2356 to 2519	23.1 to 24.7
	4%		2448 to 2611	24.0 to 25.6
	Solid slabs	Thickness	kg/m²	kN/m²
	(floors,	75 mm	184	1.80
	walls etc)	100 mm	245	2.40
		150 mm	367	3.60
		250 mm	612	6.00
		300 mm	734	7.20

Lightweight concrete

Aggregate or type	Compressive Strength MPa	kg/m³	kN/m³
Perlite	0.5 to 14.0	585 to 1601	5.7 to 15.7
Pumice (1:6 semi-dry)	1.4 to 3.8	724 to 1122	7.1 to 11.0
Vermiculite (expanded mica)	0.5 to 3.5	397 to 1122	3.9 to 11.0
No-fines (gravel)	—	1601 to 1928	15.7 to 18.9
Cellular (aerated or gas concrete)	1.4	397 (min.)	3.9 (min.)
ditto structural	10.3 to 15.5	1438 to 1601	14.1 to 15.7

Special concretes, etc.

		kg/m³	kN/m³
Heavy concrete	Aggregates: barytes, magnetite,	3212 (min.)	31.5 (min.)
	steel shot, punchings	5284	51.8
Lean mixes	Dry-lean (gravel aggr.)	2244	22.0
	Soil-cement (normal mix)	1601	15.7
Finishes, etc.	Rendering, screed, etc	kg/m² per mm thick	N/m² per mm thick
	Granolithic, terrazzo	1.93 to 2.40	18.9 to 23.6
	Glass-block (hollow) concrete	1.73 (approx.)	17.0 (approx.)
Prestressed concrete	weights as for reinforced concrete (upper limits)		
Air-entrained concrete	weights as for plain or reinforced concrete		

Construction with concrete products

		kg/m²			
Concrete block walls	Blocks Density 1750kg/m³	All cores filled	2nd cores filled	3rd cores filled	4th cores filled
	100 mm	170	150	145	135
	150 mm	290	210	185	170
	200 mm	400	280	245	220
	Block Density 2200 kg/m³				
	100 mm	205	180	175	165
	150 mm	335	285	260	250
	200 mm	450	370	335	320

		kg/m²	kN/m²
Brick walls	Brickwork: 100 mm (nominal)	221	2.16

G2. MASSES AND DEAD LOADS OF CONCRETE AND OTHER MATERIALS CONT.

Other products

	kg/m^2	kN/m^2
Paving slabs (flags) 50 mm	117	1.15
Roofing tiles	48	0.47

Miscellaneous materials

	kg/m^3	kN/m^3
Tarmacadam	2305	22.6
Macadam (waterbound)	2560	25.1
Snow: compact	245-816	2.4 to 8.0
loose	82-194	0.8 to 1.9
Terracotta	2122	20.8
Glass	2724	26.7
Cork: granular	123	1.2
compressed	388	3.8

	kg/m^2 per mm thickness	N/m^2 per mm thickness
Felt (insulating)	0.195	1.9
Paving slabs (stone)	2.7	26.4
Granite setts	2.9	28.3
Asphalt	2.3	22.6
Rubber paving	1.55	15.1
Polyvinylchloride	1.9 (av.)	19 (av.)
Glass-fibre (forms)	0.19	1.9
	kg/m^2	**N/m^2**
Clay floortiles	59	575
Pavement lights	123	1200
Damp-proof course	9	48

Timber

General	kg/m^3	kN/m^3
green	806 (av.)	7.9 (av.)
12% MC	500 (av.)	4.9 (av.)
Wooden boarding & blocks	kg/m^2 per mm	N/m^2 per mm
Softwood	0.48	4.7
Hardwood	0.77	7.5
Fibreboard	0.29	2.8
Plasterboard	0.96	9.4

	kg/m^2 per mm thickness	N/m^2 per mm thickness
Hardboard	1.06	10.4
Chipboard	0.77	7.5
Plywood	0.62	6.1
Blockwood	0.48	4.7
Wood-wool	0.58	5.7
Weatherboarding	0.39	3.8

Stone & other materials

Natural stone (solid)		
granite	2560 to 2927	25.1 to 28.7
limestone: general	2080 to 2244	20.4 to 22.0
limestone: marble	2724	26.7
sandstone	2244 to 2407	22.0 to 23.0

	kg/m^3	kN/m^3
Stone rubble (packed)	2244	22.0
Quarry waste	1438	14.1
Hardcore (consolidated)	1928	18.9
All-in aggregate	2000	19.6

Metals, steel construction etc.

	kg/m^3	kN/m^3
Iron: cast	7212	70.7
wrought	7691	75.4
Steel (see also below)	7854	77.0
Copper: cast	8732	85.6
wrought	8945	87.7
	g/mm^2 per metre	
Steel bars	7.85	

	kg/m^3	kN/m^3
Brass	8497	83.3
Bronze	8945	87.7
Aluminium	2775	27.2
Lead	11322	111.0
Zinc (rolled)	7140	70.0

G2. MASSES AND DEAD LOADS OF CONCRETE AND OTHER MATERIALS CONT.

Brickwork & blockwork

Concrete blocks & bricks	See earlier		
		kg/m^2 per mm thick	N/m^2 per mm thick
Common clay blocks		1.93	18.9
Engineering clay bricks		2.3	22.6
Refractory bricks		1.15	11.3
Sand-lime (and similar) bricks		2.02	19.8

Plaster

	kg/m^2	N/m^2
Gypsum: two-coat 12 mm	21.93	215
plasterboard ditto	11.02	108
Lath and plaster (two-faced including studding)	48.96	480

Liquids and semi-liquids

	kg/m^3	kN/m^3		kg/m^3	kN/m^3
Acids: acetic	1061	10.4	Mineral oils: naptha	755	7.4
nitric	1540	15.1	Paraffin (kerosene)	806	7.9
sulphuric	1846	18.1	Petrol (gasolene)	704	6.9
Alcohol (commercial)	806	7.9	Petroleum oil	877	8.6
Ammonia	898	8.8	Pulp (wood)	724	7.1
Beer: in bulk	1020	10.0	Slurry: cement	1438	14.1
Benzine, benzol	478	8.6	clay	1214	11.9
Bitumen (prepared)	1397	13.7	clay-chalk	1601	15.7
Methylated spirit	836	8.2	Sewage	989 to 1204	9.7 to 11.8
Turpentine	867	8.5	Tar, pitch	1204	11.8
Linseed oil	898	8.8	Water: fresh	1000	9.81
Milk	1040	10.2	sea water	1025	10.05
			Wine: in bulk	989	9.7

Solid & packed materials

	kg/m^3	kN/m^2		kg/m^3	kN/m^3
Brewer's grains (wet)	561	5.5	Lime (slaked) dry	561	5.5
Bricks (stacked)	1765	17.3	wet	1520	14.9
Cement	1440	14.1	Paper (packed)	959	9.4
Flour: in bulk	724	7.1	(waste pressed)	561	5.5
in sacks	643	6.3	Salt: dry	1520	9.4
Hay (pressed in bales)	133	1.3	loose	1438	14.1
Hops (in sacks)	173	1.7	Sawdust	245	2.4
Ice	918	9.0	Sugar (loose)	806	7.9
			Tea in chests	449	4.4

Sheeting

	kg/m^2	N/m^2
Corrugated steel or asbestos-cement sheeting (including bolts, sheeting rails, etc.)	43.86	430
Asbestos cement	kg/m^2 per mm	N/m^2 per mm
Building board	1.6	15.7
Flat sheet	1.75	17.1
Steel sheet	kg/m^2	N/m^2
Profiled	3.5 to 10.5	34.3 – 102.9
Aluminium sheet – Profiled	3.0 to 5.0	29.4 – 58.8