REINFORCED CONCRETE COLUMNS

volume II

Working Stress Design Charts for Spiral Columns

Eli Czerniak

Simplified solutions are given to hitherto difficult eccentricity problems in practical design situations. With hundreds of helpful interaction diagrams and data tables

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PREFACE

This volume, *Working Stress Design Charts for Spiral Columns*, and its companion volume, *Working Stress Design for Concrete Columns*, evolved from a series of articles published in *Consulting Engineer* magazine between November 1964 and April 1966. My purpose had been to present practically oriented information about the new working stress design method for reinforced concrete columns. The contents included an explanation of the method and guide to practical column design, detailed design examples showing specific applications, and a large number of time-saving design aids to facilitate the sizing of concrete columns subjected to axial loads and bending moments. Both, uniaxial and biaxial bending were considered, with simplified solutions given to the hitherto difficult eccentricity problems with which many of our engineers have grappled for so long. Reader reaction indicated that significant savings in time and labor were indeed possible with the described approach, with many of the readers suggesting that the articles be published in book form. The letters of interest, and what is believed to be a present need in the design community, inspired me to expand the series of articles into the two-volume project. I was further gratified to learn that *Consulting Engineer* entered my articles in the 1966 Industrial Marketing Competition, and they were awarded a Certificate of Merit in the "Best Series of Articles" category for Class, Institutional, and Professional Publications.

I am glad to take this opportunity to express my deep appreciation to A. M. Steinmetz, the editor of *Consulting Engineer*, and to the staff of the magazine for their valuable assistance and fullest cooperation in making this work possible.

That a work such as this includes information from many sources is self-evident, and I have endeavored to give credit where it is due. Special acknowledgment is given to the American Concrete Institute, Bethlehem Steel Corporation, Committee of Concrete Reinforcing Bar Producers of the American Iron and Steel Institute, Concrete Reinforcing Steel Institute, *Consulting Engineer,* Hydrocarbon Processing, Portland Cement Association, State of California Department of Public Works, and Western Concrete Reinforcing Steel Institute for permission to use material and illustrations from their publications.

Grateful acknowledgment is made to The Fluor Corporation, Ltd., Los Angeles, California for providing the physical facilities and the proper intellectual environment in which such work could be accomplished. My sincere thanks are particularly due to Frank B. Harvie, Chief Structural Engineer at Fluor, for helpful suggestions and his enthusiastic support over an extended period of time; to Darrel W. Harris and Yung B. Ryeom for checking the examples and design-aid charts; to Enrique P. Duenas for painstaking drawing of diagrams; to Mrs. Edith Dives and Miss Helen Olson for much of the artwork; to Mrs. Thelma Bradley and Mrs. Virginia Spillman for typing and secretarial services.

To my wife, Cynthia, I am particularly indebted for her continued encouragement and tireless assistance.

The preparation of the material for the two volumes has spanned several years during which constant effort was made to avoid errors. It would be, however, oversanguine to expect that none had crept in. For help in calling to my attention any errors that escaped detection I will be grateful.

ELI CZERNIAK

Los Angeles, California
January 1968

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INTRODUCTION

Volume II is a companion to Volume I, *Working Stress Design for Concrete Columns.* In Volume II we present working stress design-aid charts, each chart consisting of both interaction diagrams and data tables for round symmetrical spiral columns. Their sizes, in 1 in. increments, range from a 10 in. to a 30 in. diameter. The charts for the smaller columns sizes, 10 in. through 17 in. diameters, were given in Volume I, Chapter 12. They are also included in Volume II for the convenience of the user. Refer to Volume I for detailed information on the subject of reinforced concrete column design and on how to effectively use the design-aid charts in this volume.

The interaction diagrams are for f_c' equal to 3000 psi and f_y equal to 40,000 psi. The corresponding data tables are given for four concrete strengths: f_c' equal to 2500, 3000, 4000 and 5000 psi. The quadistrength data tables are useful for designing spiral columns in concrete strengths other than the 3000 psi used in the interaction diagrams.

The dashed lines within the shaded bands in the diagrams denote longitudinal reinforcement of less than 1 per cent of the gross area of the concrete section, which is not recommended. The edge clearance in all the charts was kept at 2 in. for bar sizes #5 through #14 and 2¼ in. for the large #18 bars, as generally required for columns exposed to the weather.

The design-aid charts presented in Volume II have been developed from the working stress design formulas for short columns given in Chapter 14 of Building Code Requirements for Reinforced Concrete (ACI 318-63). The charts apply only to short columns, where strength reduction for effects of length is not required by the provisions of Sections 915 and 916 of ACI 318-63. The charts may, however, also be used to aid in the design of long columns provided that before using the charts the column design loadings are properly magnified to account for the effects of the length of compression members.

The working stress design interaction diagrams and data tables in Volume II should be used only by those who are fully familiar with reinforced concrete column design.

NOMENCLATURE

Symbols

A_g Gross area of concrete section; for round columns $A_g = \pi t^2/4$.

A_{st} Total area of longitudinal reinforcement.

A_{tr} Area of transformed uncracked section; $A_{tr} = A_g + (2n - 1)A_{st}$.

d' Edge distance of reinforcement measured along the column diameter from the centers of the longitudinal bars to edge of concrete.

D_s Diameter of circle through centers of the longitudinal reinforcement; $D_s = t - 2d'$.

e Eccentricity of the resultant load on a column measured from centerline of concrete section; $e = M/P$.

e_a Maximum eccentricity permissible with no reduction in the maximum allowable axial compressive load; $e_a = M_s\ (P_o - P_a)/P_aP_o$.

e_b Maximum permissible eccentricity of P_b; for symmetrical spiral columns $e_b = 0.43\ p_g m D_s + 0.14\ t$.

e_k Distance from column centerline to edge of kern, within which axial compressive loads cause no tension anywhere in the section; $e_k = S_{tr}/A_{tr}$.

E_c Modulus of elasticity of concrete; $E_c = w^{1.5}33\sqrt{f_c'}$ in psi for values of w between 90 and 155 lb per cu ft.

E_s Modulus of elasticity of steel; $E_s = 29{,}000{,}000$ psi.

f_a Axial nominal unit stress; $f_a = P/A_g$.

f_b Bending unit stress; $f_b = M/S_{tr}$.

f_c' Specified compressive strength of concrete in psi determined by tests of standard 6 in. $\times$ 12 in. cylinders made and tested in accordance with ASTM specifications at 28 days or such earlier age as concrete is to receive its full-service load or maximum stress.

f_s Allowable compressive stress in longitudinal column reinforcement; for spiral columns $f_s = 0.4\ f_y \leqq 30{,}000$ psi.

f_t Allowable tensile stress in longitudinal column reinforcement; for billet-steel or axle-steel concrete reinforcing bars of structural grade, 18,000 psi; for deformed bars with a yield strength of 60,000 psi or more and in sizes #11 and smaller, 24,000 psi; for all other reinforcement, 20,000 psi.

Symbols

f_y Specified minimum yield strength or yield point of reinforcement in psi determined in tension according to applicable ASTM specifications.

F_a Nominal allowable axial unit stress; $F_a = 0.34\ (1 + p_g m) f_c'$.

F_b Allowable bending stress that would be permitted for bending alone; $F_b = 0.45\ f_c'$.

g Ratio of diameter of circle D_s through bar centerlines to overall column dimension t; $g = 1 - 2d'/t$.

m Plastic modular ratio; $m = f_y/0.85f_c'$.

M External bending moment.

M_a Bending moment permitted with maximum axial load; $M_a = M_s\ (1 - P_a/P_o)$.

M_b Bending moment corresponding to P_b; $M_b = P_b e_b$.

M_o Allowable moment when column section is in pure flexure; for symmetrical spiral columns $M_o = 0.12\ A_{st}\ f_y\ D_s$.

M_s Resisting moment of transformed uncracked section; $M_s = F_b S_{tr}$.

n Ratio of modulus of elasticity of steel to that of concrete; $n = E_s/E_c$.

p_g Ratio of area of longitudinal reinforcement to the gross column area; $p_g = A_{st}/A_g$.

P External load.

P_a Maximum allowable axial compressive load on a spiral column without reduction for length or eccentricity; $P_a = A_g\ (0.25\ f_c' + f_s p_g)$.

P_b Value of axial load below which the allowable eccentricity is controlled by tension and above which by compression; $P_b = P_o \div [1 + (P_o e_b/M_s)]$.

P_o Concentric load factor used in interaction formula; $P_o = F_a A_g$.

S_g Section modulus of gross concrete section; for round columns $S_g = \pi t^3/32$.

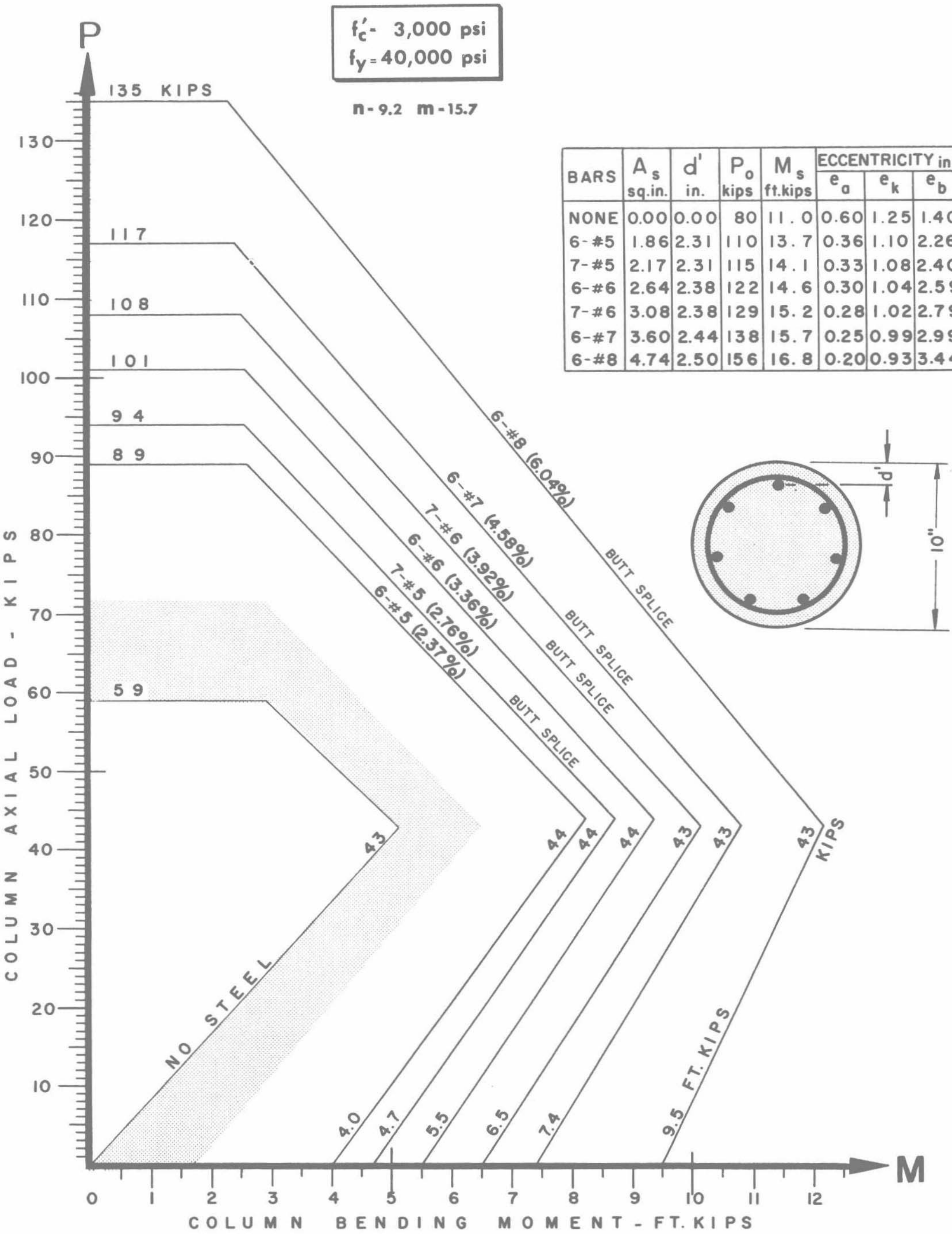
S_{tr} Section modulus of transformed uncracked section; for columns with longitudinal bars spaced uniformly around a ring $S_{tr} = S_g + (2n - 1) A_{st} D_s^2/4t$.

t Diameter of a round column.

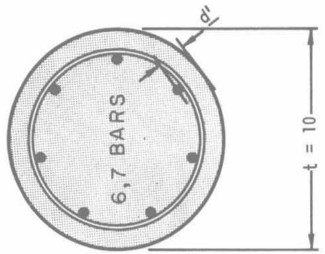
T_o Maximum allowable tensile load without reduction for eccentricity; $T_o = f_t A_{st}$

f'_c - 3,000 psi
f_y = 40,000 psi

n - 9.2 m - 15.7



BARS	A_s sq.in.	d' in.	P_o kips	M_s ft.kips	ECCENTRICITY in. e_a	e_k	e_b
NONE	0.00	0.00	80	11.0	0.60	1.25	1.40
6-#5	1.86	2.31	110	13.7	0.36	1.10	2.26
7-#5	2.17	2.31	115	14.1	0.33	1.08	2.40
6-#6	2.64	2.38	122	14.6	0.30	1.04	2.59
7-#6	3.08	2.38	129	15.2	0.28	1.02	2.79
6-#7	3.60	2.44	138	15.7	0.25	0.99	2.99
6-#8	4.74	2.50	156	16.8	0.20	0.93	3.44



ECCENTRICALLY LOADED SPIRAL COLUMNS

ALLOWABLE REINFORCEMENT STRESSES:

In tension	In compression
20,000 psi	16,000 psi

COLUMN DIAMETER = = in.

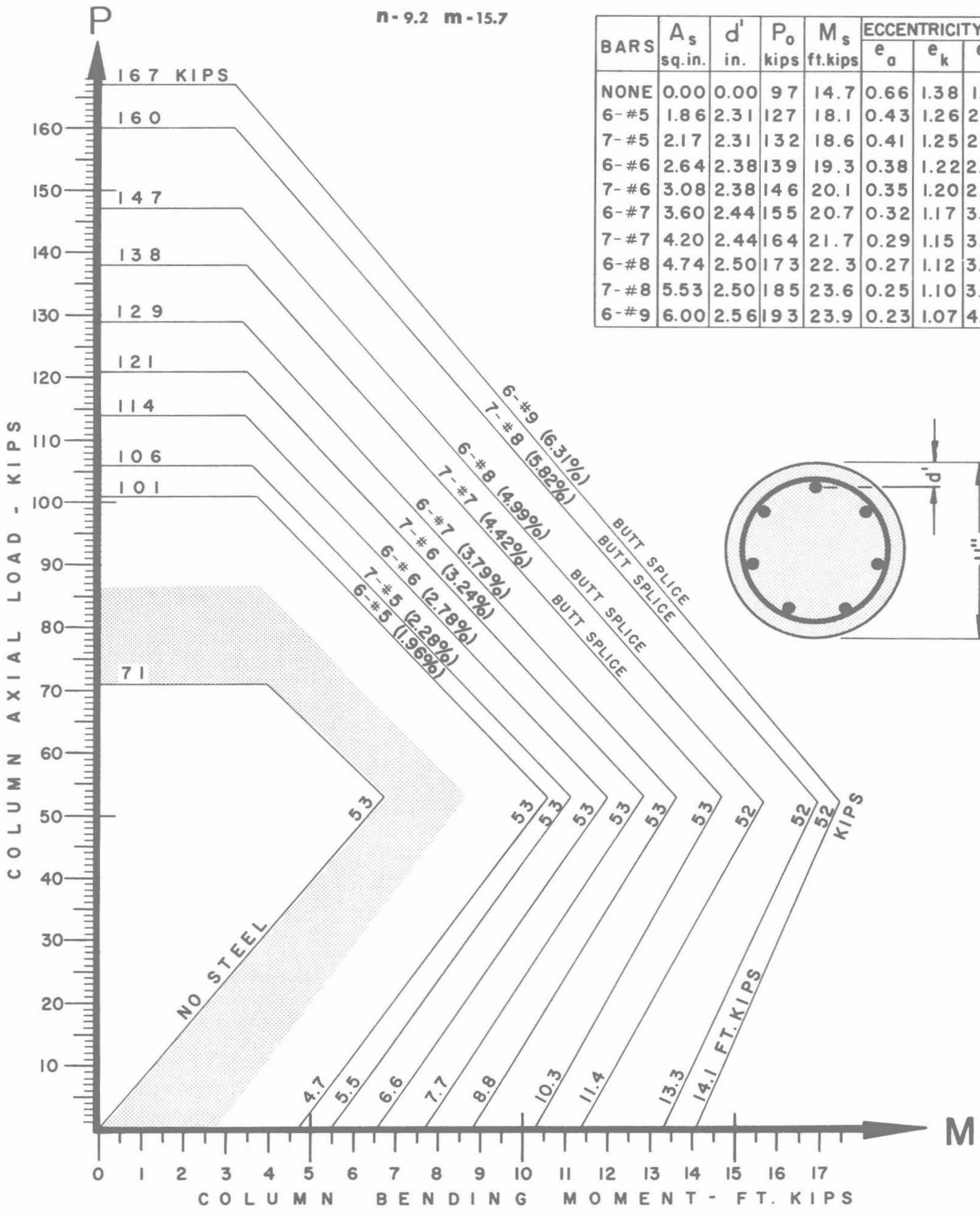
A_g = 78.54 in.^{2} S_g = 98.18 in.^{3} f_y = 40,000 psi

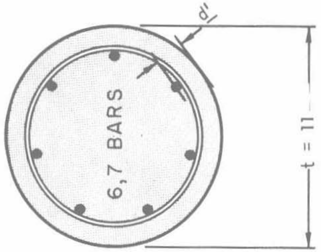
	BARS	A_{st} sq. in.	PER-CENT	d' inches	g	TRANSFORMED SECTION A_{tr}	TRANSFORMED SECTION S_{tr}	INTERACTION LINE AXIAL LOADS – kips $P_o = F_a A_g$	P_a	P_b	T_o	MOMENTS – ft. kips M_o	$M_s = F_b S_{tr}$	ECCENTRICITIES – inches e_a	e_k	e_b	BAR SPACING (℄ to ℄) inches
f_c' = 2,500 PSI		0.00	0.000	0.000	1.000	78.54	98.18	66.76	49.09	36.16	- 0.00	0.000	9.204	0.596	1.250	1.400	
n = 10.1	6-# 5	1.86	2.368	2.313	0.537	114.25	123.96	96.52	78.85	36.00	- 37.20	3.998	11.621	0.324	1.085	2.430	2.814
m = 18.82	6-# 6	2.64	3.361	2.375	0.525	129.23	133.10	109.01	91.33	35.65	- 52.80	5.544	12.478	0.266	1.030	2.828	2.749
	6-# 7	3.60	4.584	2.438	0.512	147.66	143.54	124.33	106.69	35.11	- 72.00	7.379	13.457	0.215	0.972	3.301	2.683
	6-# 8	4.74	6.035	2.500	0.500	169.55	155.06	142.55	124.93	34.45	- 94.80	9.480	14.536	0.172	0.915	3.842	2.618
	7-# 5	2.17	2.763	2.313	0.537	120.20	128.26	101.47	83.81	35.87	- 43.40	4.665	12.024	0.300	1.067	2.602	2.412
	7-# 6	3.08	3.922	2.375	0.525	137.68	138.92	116.00	98.37	35.41	- 61.60	6.468	13.024	0.242	1.009	3.066	2.356
f_c' = 3,000 PSI		0.00	0.000	0.000	1.000	78.54	98.18	80.11	58.90	43.40	- 0.00	0.000	11.045	0.596	1.250	1.400	
n = 9.2	6-# 5	1.86	2.368	2.313	0.537	110.90	121.54	109.88	88.66	43.72	- 37.20	3.998	13.673	0.358	1.096	2.259	2.814
m = 15.69	6-# 6	2.64	3.361	2.375	0.525	124.48	129.83	122.36	101.14	43.58	- 52.80	5.544	14.606	0.301	1.043	2.590	2.749
	6-# 7	3.60	4.584	2.438	0.512	141.18	139.29	137.76	116.50	43.24	- 72.00	7.379	15.670	0.249	0.987	2.985	2.683
	6-# 8	4.74	6.035	2.500	0.500	161.02	149.72	155.98	134.74	42.72	- 94.80	9.480	16.844	0.204	0.930	3.436	2.618
	7-# 5	2.17	2.763	2.313	0.537	116.30	125.44	114.82	93.62	43.69	- 43.40	4.665	14.112	0.334	1.079	2.402	2.412
	7-# 6	3.08	3.922	2.375	0.525	132.13	135.10	129.43	108.18	43.45	- 61.60	6.468	15.199	0.277	1.023	2.789	2.356
f_c' = 4,000 PSI		0.00	0.000	0.000	1.000	78.54	98.18	106.81	78.54	57.86	- 0.00	0.000	14.726	0.596	1.250	1.400	
n = 8.0	6-# 5	1.86	2.368	2.313	0.537	106.44	118.32	136.58	108.30	59.10	- 37.20	3.998	17.748	0.408	1.112	2.044	2.814
m = 11.76	6-# 6	2.64	3.361	2.375	0.525	118.14	125.46	149.07	120.78	59.34	- 52.80	5.544	18.819	0.355	1.062	2.292	2.749
	6-# 7	3.60	4.584	2.438	0.512	132.54	133.62	164.38	136.14	59.39	- 72.00	7.379	20.043	0.304	1.008	2.588	2.683
	6-# 8	4.74	6.035	2.500	0.500	149.64	142.61	182.60	154.38	59.27	- 94.80	9.480	21.392	0.257	0.953	2.926	2.618
	7-# 5	2.17	2.763	2.313	0.537	111.09	121.68	141.53	113.26	59.24	- 43.40	4.665	18.251	0.386	1.095	2.151	2.412
	7-# 6	3.08	3.922	2.375	0.525	124.74	130.01	156.06	127.82	59.41	- 61.60	6.468	19.501	0.331	1.042	2.441	2.356
f_c' = 5,000 PSI		0.00	0.000	0.000	1.000	78.54	98.18	133.52	98.17	72.33	- 0.00	0.000	18.408	0.596	1.250	1.400	
n = 7.1	6-# 5	1.86	2.368	2.313	0.537	103.09	115.90	163.28	127.93	74.25	- 37.20	3.998	21.731	0.441	1.124	1.915	2.814
m = 9.41	6-# 6	2.64	3.361	2.375	0.525	113.39	122.19	175.77	140.41	74.76	- 52.80	5.544	22.910	0.394	1.078	2.114	2.749
	6-# 7	3.60	4.584	2.438	0.512	126.06	129.37	191.09	155.77	75.14	- 72.00	7.379	24.256	0.346	1.026	2.350	2.683
	6-# 8	4.74	6.035	2.500	0.500	141.11	137.28	209.31	174.01	75.43	- 94.80	9.480	25.740	0.299	0.973	2.621	2.618
	7-# 5	2.17	2.763	2.313	0.537	107.18	118.86	168.23	132.89	74.50	- 43.40	4.665	22.286	0.422	1.109	2.001	2.412
	7-# 6	3.08	3.922	2.375	0.525	119.20	126.19	182.76	147.45	75.02	- 61.60	6.468	23.661	0.372	1.059	2.233	2.356

f'_c - 3,000 psi
f_y = 40,000 psi

n - 9.2 m - 15.7

BARS	A_s sq.in.	d' in.	P_o kips	M_s ft.kips	ECCENTRICITY in. e_a	e_k	e_b
NONE	0.00	0.00	97	14.7	0.66	1.38	1.54
6-#5	1.86	2.31	127	18.1	0.43	1.26	2.38
7-#5	2.17	2.31	132	18.6	0.41	1.25	2.52
6-#6	2.64	2.38	139	19.3	0.38	1.22	2.71
7-#6	3.08	2.38	146	20.1	0.35	1.20	2.91
6-#7	3.60	2.44	155	20.7	0.32	1.17	3.11
7-#7	4.20	2.44	164	21.7	0.29	1.15	3.37
6-#8	4.74	2.50	173	22.3	0.27	1.12	3.56
7-#8	5.53	2.50	185	23.6	0.25	1.10	3.90
6-#9	6.00	2.56	193	23.9	0.23	1.07	4.04





ECCENTRICALLY LOADED SPIRAL COLUMNS

ALLOWABLE REINFORCEMENT STRESSES:

In tension	In compression
20,000 psi	16,000 psi

COLUMN DIAMETER = 11 in.

$A_g = 95.03 \text{ in.}^2$ $S_g = 130.67 \text{ in.}^3$

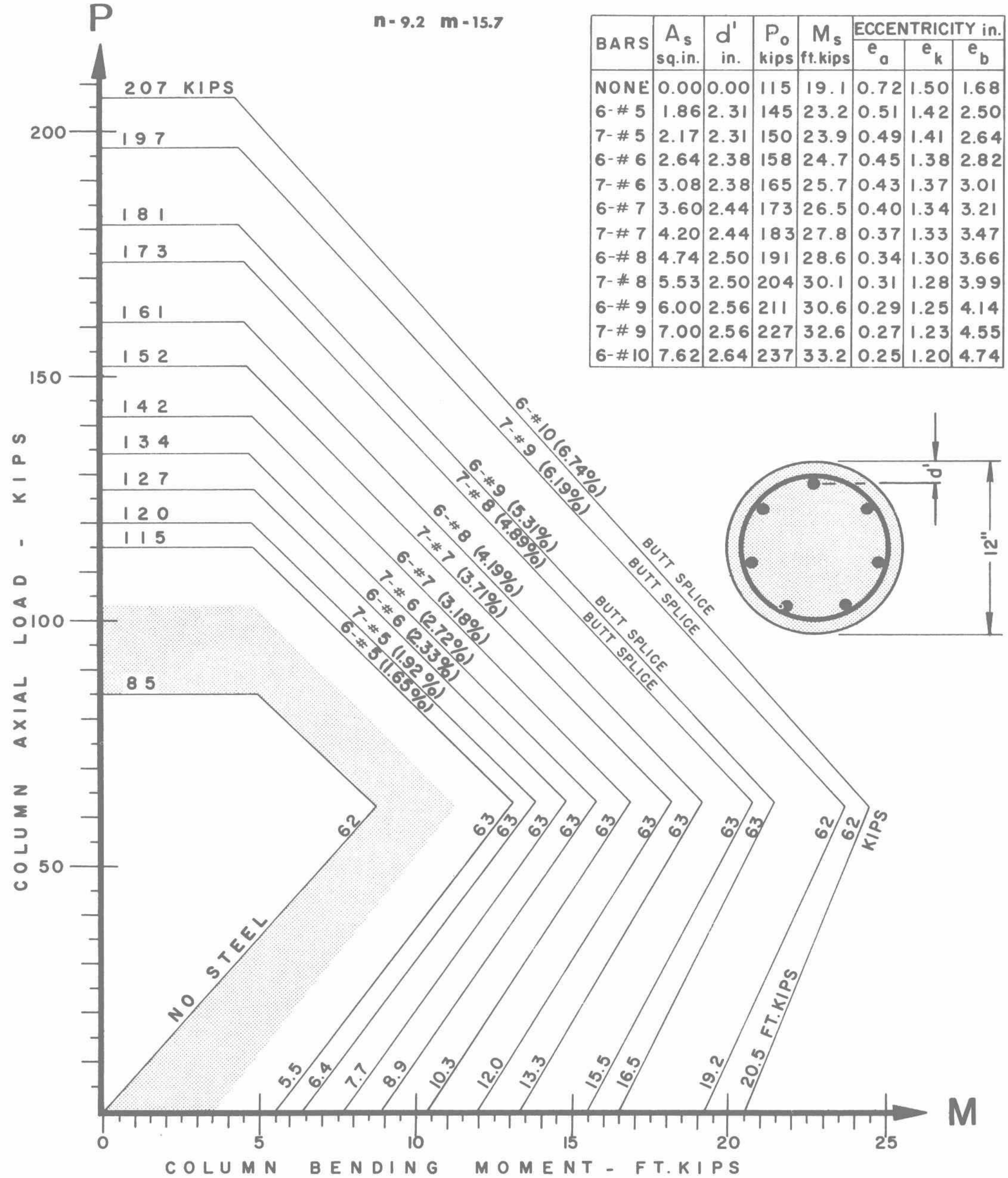
$f_y = 40{,}000$ psi

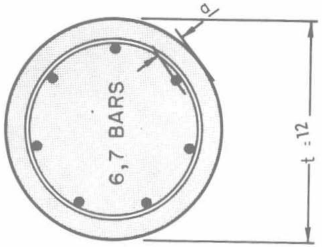
	BARS	A_{st} sq. in.	PER-CENT	d' inches	g	TRANSFORMED SECTION A_{tr}	TRANSFORMED SECTION S_{tr}	INTERACTION LINE AXIAL LOADS – kips $P_o = F_a A_g$	P_a	P_b	T_o	MOMENTS – ft. kips M_o	$M_s = F_b S_{tr}$	ECCENTRICITIES – inches e_a	e_k	e_b	BAR SPACING (℄ to ℄) inches
$f_c' = 2{,}500$ PSI		0.00	0.000	0.000	1.000	95.03	130.67	80.78	59.40	43.76	- 0.00	0.000	12.250	0.655	1.375	1.540	
$n = 10.1$	6-# 5	1.86	1.957	2.313	0.579	130.75	163.65	110.52	89.16	43.68	- 37.20	4.742	15.342	0.399	1.252	2.549	3.337
$m = 18.82$	6-# 6	2.64	2.778	2.375	0.568	145.72	175.67	122.97	101.64	43.42	- 52.80	6.600	16.469	0.337	1.206	2.945	3.272
	6-# 7	3.60	3.788	2.438	0.557	164.15	189.59	138.37	117.00	43.01	- 72.00	8.819	17.774	0.282	1.155	3.417	3.207
	6-# 8	4.74	4.988	2.500	0.545	186.04	205.13	156.61	135.24	42.48	- 94.80	11.376	19.231	0.232	1.103	3.962	3.142
	6-# 9	6.00	6.314	2.564	0.534	210.23	220.95	176.76	155.40	41.80	-120.00	14.093	20.714	0.194	1.051	4.540	3.075
	7-# 5	2.17	2.283	2.313	0.579	136.70	169.14	115.47	94.12	43.59	- 43.40	5.533	15.857	0.374	1.237	2.718	2.861
	7-# 6	3.08	3.241	2.375	0.568	154.17	183.17	130.01	108.68	43.26	- 61.60	7.700	17.172	0.311	1.188	3.179	2.805
	7-# 7	4.20	4.420	2.438	0.557	175.67	199.40	147.97	126.60	42.75	- 84.00	10.288	18.694	0.256	1.135	3.731	2.748
	7-# 8	5.53	5.819	2.500	0.545	201.21	217.54	169.25	147.88	42.12	-110.60	13.272	20.395	0.209	1.081	4.365	2.693
$f_c' = 3{,}000$ PSI		0.00	0.000	0.000	1.000	95.03	130.67	96.93	71.28	52.51	- 0.00	0.000	14.700	0.655	1.375	1.540	
$n = 9.2$	6-# 5	1.86	1.957	2.313	0.579	127.40	160.55	126.68	101.04	52.96	- 37.20	4.742	18.062	0.434	1.260	2.382	3.337
$m = 15.69$	6-# 6	2.64	2.778	2.375	0.568	140.97	171.45	139.22	113.52	52.94	- 52.80	6.600	19.288	0.376	1.216	2.711	3.272
	6-# 7	3.60	3.788	2.438	0.557	157.67	184.06	154.52	128.88	52.74	- 72.00	8.819	20.707	0.320	1.167	3.105	3.207
	6-# 8	4.74	4.988	2.500	0.545	177.51	198.15	172.77	147.12	52.37	- 94.80	11.376	22.292	0.270	1.116	3.559	3.142
	6-# 9	6.00	6.314	2.564	0.534	199.43	212.48	192.92	167.28	51.90	-120.00	14.093	23.904	0.228	1.065	4.041	3.075
	7-# 5	2.17	2.283	2.313	0.579	132.79	165.54	131.62	106.00	52.97	- 43.40	5.533	18.623	0.410	1.247	2.522	2.861
	7-# 6	3.08	3.241	2.375	0.568	148.63	178.25	146.26	120.56	52.86	- 61.60	7.700	20.053	0.351	1.199	2.907	2.805
	7-# 7	4.20	4.420	2.438	0.557	168.11	192.96	164.12	138.48	52.60	- 84.00	10.288	21.708	0.294	1.148	3.366	2.748
	7-# 8	5.53	5.819	2.500	0.545	191.26	209.40	185.41	159.76	52.17	-110.60	13.272	23.557	0.245	1.095	3.896	2.693
$f_c' = 4{,}000$ PSI		0.00	0.000	0.000	1.000	95.03	130.67	129.25	95.03	70.01	- 0.00	0.000	19.601	0.655	1.375	1.540	
$n = 8.0$	6-# 5	1.86	1.957	2.313	0.579	122.93	156.43	158.99	124.79	71.46	- 37.20	4.742	23.465	0.485	1.273	2.171	3.337
$m = 11.76$	6-# 6	2.64	2.778	2.375	0.568	134.63	165.83	171.44	137.27	71.79	- 52.80	6.600	24.874	0.433	1.232	2.418	3.272
	6-# 7	3.60	3.788	2.438	0.557	149.03	176.70	186.84	152.63	72.03	- 72.00	8.819	26.505	0.382	1.186	2.713	3.207
	6-# 8	4.74	4.988	2.500	0.545	166.13	188.84	205.08	170.87	72.16	- 94.80	11.376	28.326	0.332	1.137	3.053	3.142
	6-# 9	6.00	6.314	2.564	0.534	185.03	201.20	225.23	191.03	72.12	-120.00	14.093	30.180	0.288	1.087	3.415	3.075
	7-# 5	2.17	2.283	2.313	0.579	127.58	160.73	163.93	129.75	71.62	- 43.40	5.533	24.109	0.465	1.260	2.276	2.861
	7-# 6	3.08	3.241	2.375	0.568	141.23	171.69	178.47	144.31	71.96	- 61.60	7.700	25.753	0.409	1.216	2.564	2.805
	7-# 7	4.20	4.420	2.438	0.557	158.03	184.37	196.43	162.23	72.16	- 84.00	10.288	27.655	0.357	1.167	2.909	2.748
	7-# 8	5.53	5.819	2.500	0.545	177.98	198.54	217.72	183.51	72.24	-110.60	13.272	29.781	0.306	1.116	3.306	2.693
$f_c' = 5{,}000$ PSI		0.00	0.000	0.000	1.000	95.03	130.67	161.56	118.79	87.52	- 0.00	0.000	24.501	0.655	1.375	1.540	
$n = 7.1$	6-# 5	1.86	1.957	2.313	0.579	119.59	153.34	191.30	148.55	89.69	- 37.20	4.742	28.751	0.519	1.282	2.045	3.337
$m = 9.41$	6-# 6	2.64	2.778	2.375	0.568	129.88	161.61	203.75	161.03	90.32	- 52.80	6.600	30.302	0.473	1.244	2.243	3.272
	6-# 7	3.60	3.788	2.438	0.557	142.55	171.18	219.15	176.39	90.93	- 72.00	8.819	32.095	0.426	1.201	2.479	3.207
	6-# 8	4.74	4.988	2.500	0.545	157.60	181.86	237.39	194.63	91.48	- 94.80	11.376	34.099	0.378	1.154	2.751	3.142
	6-# 9	6.00	6.314	2.564	0.534	174.23	192.74	257.54	214.79	91.81	-120.00	14.093	36.138	0.335	1.106	3.040	3.075
	7-# 5	2.17	2.283	2.313	0.579	123.68	157.12	196.24	153.51	89.94	- 43.40	5.533	29.460	0.502	1.270	2.129	2.861
	7-# 6	3.08	3.241	2.375	0.568	135.69	166.77	210.78	168.07	90.66	- 61.60	7.700	31.268	0.453	1.229	2.360	2.805
	7-# 7	4.20	4.420	2.438	0.557	150.47	177.93	228.74	185.99	91.31	- 84.00	10.288	33.361	0.402	1.182	2.635	2.748
	7-# 8	5.53	5.819	2.500	0.545	168.03	190.40	250.03	207.27	91.82	-110.60	13.272	35.699	0.354	1.133	2.953	2.693

f'_c - 3,000 psi
f_y = 40,000 psi

n - 9.2 m - 15.7

BARS	A_s sq.in.	d' in.	P_o kips	M_s ft.kips	ECCENTRICITY in. e_a	e_k	e_b
NONE	0.00	0.00	115	19.1	0.72	1.50	1.68
6-#5	1.86	2.31	145	23.2	0.51	1.42	2.50
7-#5	2.17	2.31	150	23.9	0.49	1.41	2.64
6-#6	2.64	2.38	158	24.7	0.45	1.38	2.82
7-#6	3.08	2.38	165	25.7	0.43	1.37	3.01
6-#7	3.60	2.44	173	26.5	0.40	1.34	3.21
7-#7	4.20	2.44	183	27.8	0.37	1.33	3.47
6-#8	4.74	2.50	191	28.6	0.34	1.30	3.66
7-#8	5.53	2.50	204	30.1	0.31	1.28	3.99
6-#9	6.00	2.56	211	30.6	0.29	1.25	4.14
7-#9	7.00	2.56	227	32.6	0.27	1.23	4.55
6-#10	7.62	2.64	237	33.2	0.25	1.20	4.74





ECCENTRICALLY LOADED SPIRAL COLUMNS

ALLOWABLE REINFORCEMENT STRESSES:

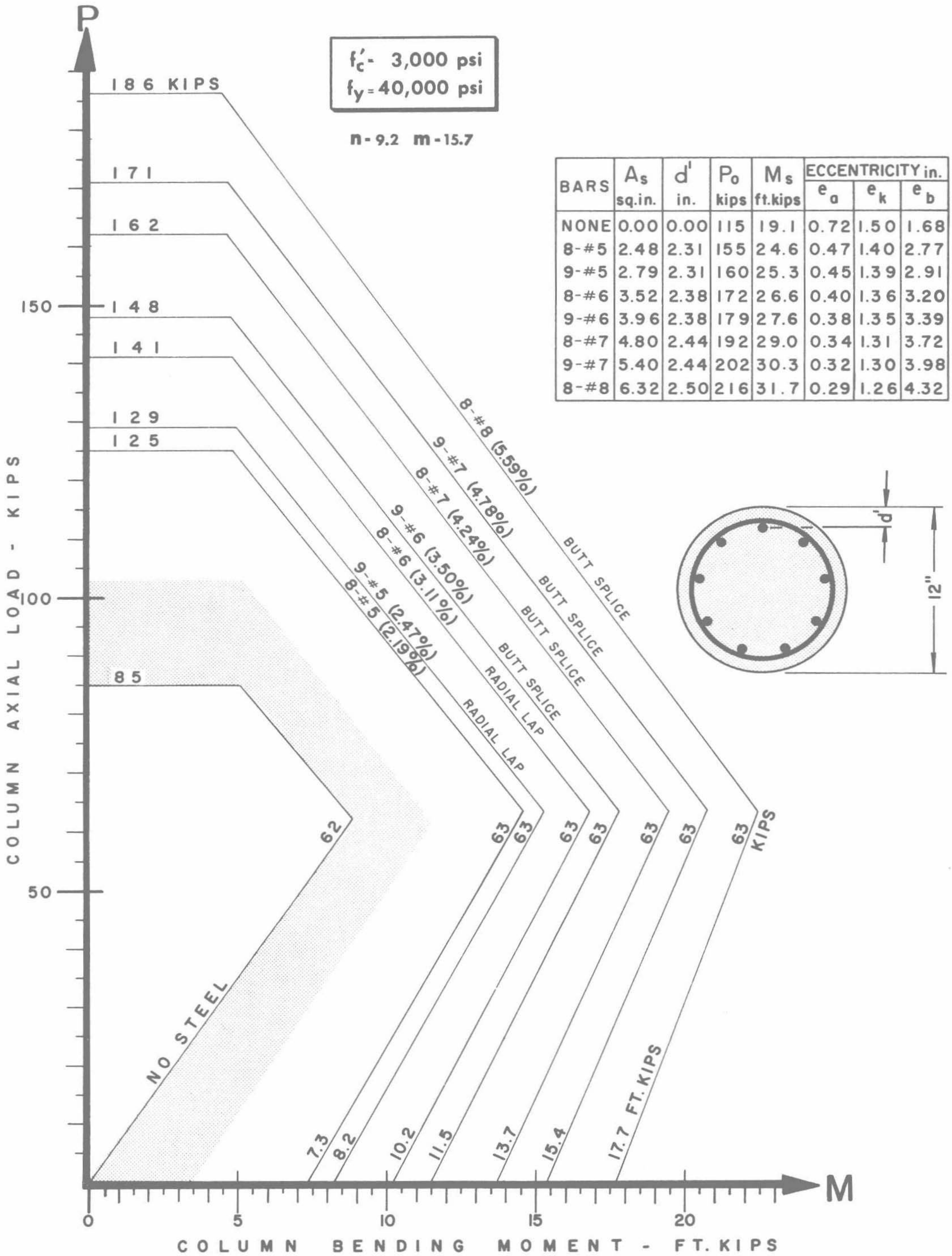
In tension	In compression
20,000 psi	16,000 psi

COLUMN DIAMETER = = in.

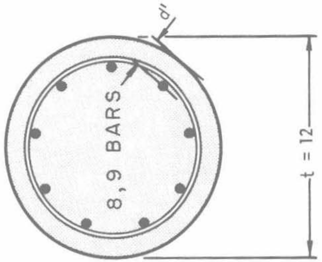
A_g = 113.10 in.^{2} S_g = 169.65 in.^{3}

f_y = 40,000 psi

	BARS	A_{st} sq. in.	PER-CENT	d' inches	g	TRANSFORMED SECTION A_{tr}	TRANSFORMED SECTION S_{tr}	INTERACTION LINE AXIAL LOADS – kips $P_o = F_a A_g$	P_a	P_b	T_o	MOMENTS – ft. kips M_o	$M_s = F_b S_{tr}$	ECCENTRICITIES – inches e_a	e_k	e_b	BAR SPACING (℄ to ℄) inches
		C.00	C.000	C.00C	1.C00	113.10	169.65	153.81	113.10	83.32	- 0.00	0.000	25.447	0.715	1.500	1.680	
	6-# 5	1.86	1.645	2.313	0.615	141.00	201.25	183.56	142.86	84.94	- 37.20	5.486	30.188	0.562	1.427	2.293	3.861
	6-# 6	2.64	2.334	2.375	0.604	152.70	213.01	196.00	155.34	85.36	- 52.80	7.656	31.952	0.512	1.395	2.536	3.796
	6-# 7	3.60	3.183	2.438	0.594	167.10	226.74	211.38	170.70	85.79	- 72.00	10.259	34.011	0.460	1.357	2.827	3.730
f_c' = 2,500 PSI	6-# 8	4.74	4.191	2.50C	0.583	184.20	242.23	229.59	188.94	86.12	- 94.80	13.272	36.334	0.409	1.315	3.164	3.665
	6-# 9	6.C0	5.305	2.564	0.573	2C3.10	258.19	249.72	209.10	86.32	-120.00	16.493	38.729	0.362	1.271	3.524	3.598
n = 10.1	6-#10	7.62	6.738	2.635	0.561	227.40	277.50	275.73	235.02	86.38	-152.40	20.513	41.625	0.313	1.220	3.973	3.524
	7-# 5	2.17	1.919	2.313	0.615	154.76	216.84	130.85	105.41	52.03	- 43.40	6.401	20.329	0.450	1.401	2.825	3.309
m = 18.82	7-# 6	3.C8	2.723	2.375	0.604	172.23	234.40	145.44	119.97	51.80	- 61.60	8.932	21.975	0.385	1.361	3.278	3.254
	7-# 7	4.20	3.714	2.438	0.594	193.74	254.91	163.31	137.89	51.44	- 84.00	11.968	23.898	0.324	1.316	3.821	3.197
	7-# 8	5.53	4.89C	2.50C	0.583	219.27	278.03	184.57	159.17	50.92	-110.60	15.484	26.066	0.270	1.268	4.450	3.142
	7-# 9	7.00	6.189	2.564	0.573	247.50	301.87	208.10	182.69	50.29	-140.00	19.242	28.301	0.227	1.220	5.122	3.084
		0.C0	0.000	C.00C	1.C00	113.10	169.65	192.27	141.37	104.15	- 0.00	0.000	31.809	0.715	1.500	1.680	
	6-# 5	1.86	1.645	2.313	0.615	137.65	197.46	222.01	171.13	1C6.53	- 37.20	5.486	37.024	0.595	1.435	2.171	3.861
	6-# 6	2.64	2.334	2.375	0.604	147.95	207.81	234.45	183.61	107.25	- 52.80	7.656	38.964	0.552	1.405	2.365	3.796
	6-# 7	3.6C	3.183	2.438	0.594	160.62	219.89	249.83	198.97	1C8.06	- 72.00	10.259	41.229	0.507	1.369	2.598	3.730
f_c' = 3,000 PSI	6-# 8	4.74	4.191	2.5CC	0.583	175.67	233.52	268.04	217.21	108.87	- 94.80	13.272	43.785	0.459	1.329	2.867	3.665
	6-# 9	6.00	5.305	2.564	0.573	192.30	247.57	288.28	237.37	109.49	-120.00	16.493	46.419	0.415	1.287	3.155	3.598
n = 9.2	6-#1C	7.62	6.738	2.635	0.561	213.68	264.56	314.18	263.29	110.09	-152.40	20.513	49.604	0.366	1.238	3.515	3.524
	7-# 5	2.17	1.919	2.313	0.615	150.86	212.42	150.08	119.54	63.11	- 43.40	6.401	23.897	0.488	1.408	2.635	3.309
m = 15.69	7-# 6	3.C8	2.723	2.375	0.604	166.69	228.33	164.67	134.10	63.14	- 61.60	8.932	25.687	0.427	1.370	3.012	3.254
	7-# 7	4.20	3.714	2.438	0.594	186.18	246.91	182.54	152.02	63.01	- 84.C0	11.968	27.778	0.367	1.326	3.465	3.197
	7-# 8	5.53	4.890	2.50C	0.583	2C9.32	267.87	203.91	173.30	62.76	-110.60	15.484	30.136	0.314	1.280	3.989	3.142
	7-# 9	7.00	6.189	2.564	0.573	234.90	289.48	227.33	196.82	62.35	-140.00	19.242	32.566	0.267	1.232	4.549	3.084
		0.00	0.000	C.00C	1.000	113.10	169.65	96.13	70.69	52.08	- 0.00	0.000	15.904	0.715	1.500	1.680	
	6-# 5	1.86	1.645	2.313	0.615	148.81	210.10	125.88	100.45	52.08	- 37.20	5.486	19.697	0.475	1.412	2.662	3.861
	6-# 6	2.64	2.334	2.375	0.604	163.79	225.15	138.32	112.93	51.90	- 52.80	7.656	21.108	0.412	1.375	3.049	3.796
	6-# 7	3.60	3.183	2.438	0.594	182.22	242.73	153.70	128.29	51.61	- 72.00	10.259	22.756	0.352	1.332	3.515	3.730
f_c' = 4,000 PSI	6-# 8	4.74	4.191	2.50C	0.583	204.11	262.55	171.91	146.53	51.18	- 94.80	13.272	24.614	0.298	1.286	4.054	3.665
	6-# 9	6.C0	5.305	2.564	0.573	228.30	282.99	192.15	166.69	50.65	-120.00	16.493	26.530	0.253	1.240	4.630	3.598
n = 8.0	6-#10	7.62	6.738	2.635	0.561	259.40	307.70	218.05	192.61	49.91	-152.40	20.513	28.847	0.209	1.186	5.350	3.524
	7-# 5	2.17	1.919	2.313	0.615	145.65	206.52	188.53	147.82	85.12	- 43.40	6.401	30.978	0.543	1.418	2.396	3.309
m = 11.76	7-# 6	3.C8	2.723	2.375	0.604	159.30	220.24	203.12	162.38	85.67	- 61.60	8.932	33.036	0.489	1.383	2.678	3.254
	7-# 7	4.20	3.714	2.438	0.594	176.10	236.26	220.99	180.30	86.06	- 84.00	11.968	35.439	0.435	1.342	3.018	3.197
	7-# 8	5.53	4.890	2.50C	0.583	196.05	254.32	242.25	201.58	86.40	-110.60	15.484	38.149	0.381	1.297	3.411	3.142
	7-# 9	7.00	6.189	2.564	0.573	218.10	272.95	265.78	225.1C	86.54	-140.00	19.242	40.942	0.334	1.251	3.831	3.084
		0.00	C.000	0.0CC	1.C00	113.10	169.65	115.36	84.82	62.49	- 0.00	0.000	19.085	0.715	1.500	1.680	
	6-# 5	1.86	1.645	2.313	0.615	145.46	206.31	145.10	114.58	63.06	- 37.20	5.486	23.210	0.512	1.418	2.498	3.861
	6-# 6	2.64	2.334	2.375	0.604	159.03	219.95	157.66	127.06	63.11	- 52.80	7.656	24.744	0.454	1.383	2.822	3.796
	6-# 7	3.60	3.183	2.438	0.594	175.74	235.88	172.93	142.42	63.04	- 72.00	10.259	26.536	0.395	1.342	3.210	3.730
f_c' = 5,000 PSI	6-# 8	4.74	4.191	2.50C	0.583	195.57	253.84	191.25	160.66	62.89	- 94.80	13.272	28.557	0.341	1.298	3.659	3.665
	6-# 9	6.00	5.305	2.564	0.573	217.50	272.36	211.38	180.82	62.54	-120.00	16.493	30.640	0.294	1.252	4.140	3.598
n = 7.1	6-#10	7.62	6.738	2.635	0.561	245.69	294.76	237.28	206.74	62.03	-152.40	20.513	33.160	0.248	1.200	4.739	3.524
	-# 5	2.17	1.919	2.313	0.615	141.74	202.10	226.99	176.09	106.87	- 43.40	6.401	37.893	0.579	1.426	2.253	3.309
m = 9.41	7-# 6	3.C8	2.723	2.375	0.604	153.75	214.17	241.58	190.65	107.75	- 61.60	8.932	40.156	0.533	1.393	2.479	3.254
	7-# 7	4.20	3.714	2.438	0.594	168.54	228.26	259.45	208.57	108.60	- 84.00	11.968	42.800	0.482	1.354	2.751	3.197
	7-# 8	5.53	4.890	2.50C	0.583	186.09	244.16	280.71	229.85	109.39	-110.60	15.484	45.780	0.433	1.312	3.065	3.142
	7-# 9	7.C0	6.189	2.564	0.573	205.50	260.55	304.23	253.37	110.07	-140.00	19.242	48.854	0.387	1.268	3.401	3.084



BARS	A_s sq.in.	d' in.	P_o kips	M_s ft.kips	ECCENTRICITY in. e_a	e_k	e_b
NONE	0.00	0.00	115	19.1	0.72	1.50	1.68
8-#5	2.48	2.31	155	24.6	0.47	1.40	2.77
9-#5	2.79	2.31	160	25.3	0.45	1.39	2.91
8-#6	3.52	2.38	172	26.6	0.40	1.36	3.20
9-#6	3.96	2.38	179	27.6	0.38	1.35	3.39
8-#7	4.80	2.44	192	29.0	0.34	1.31	3.72
9-#7	5.40	2.44	202	30.3	0.32	1.30	3.98
8-#8	6.32	2.50	216	31.7	0.29	1.26	4.32



ECCENTRICALLY LOADED SPIRAL COLUMNS

ALLOWABLE REINFORCEMENT STRESSES:

In tension	In compression
20,000 psi	16,000 psi

COLUMN DIAMETER = 12 in.

A_g = 113.10 in.^{2} S_g = 169.65 in.^{3}

f_y = 40,000 psi

	BARS	A_{st} sq. in.	PER-CENT	d' inches	g	TRANSFORMED SECTION A_{tr}	TRANSFORMED SECTION S_{tr}	INTERACTION LINE AXIAL LOADS – kips $P_o = F_a A_g$	P_a	P_b	T_o	MOMENTS – ft. kips M_o	$M_s = F_b S_{tr}$	ECCENTRICITIES – inches e_a	e_k	e_b	BAR SPACING (℄ to ℄) inches
f_c' = 2,500 PSI		0.00	0.000	0.000	1.000	113.10	169.65	96.13	70.69	52.08	- 0.00	0.000	15.904	0.715	1.500	1.680	
n = 10.1	8-# 5	2.48	2.193	2.313	0.615	160.71	223.59	135.83	110.37	51.98	- 49.60	7.315	20.961	0.427	1.391	2.989	2.896
m = 18.82	8-# 6	3.52	3.112	2.375	0.604	180.68	243.65	152.46	127.01	51.70	- 70.40	10.208	22.843	0.360	1.349	3.506	2.847
	8-# 7	4.80	4.244	2.438	0.594	205.26	267.09	172.93	147.49	51.25	- 96.00	13.678	25.040	0.299	1.301	4.127	2.798
	8-# 8	6.32	5.588	2.500	0.583	234.44	293.52	197.24	171.81	50.65	-126.40	17.696	27.517	0.248	1.252	4.846	2.749
	9-# 5	2.79	2.467	2.313	0.615	166.67	230.33	140.81	115.33	51.90	- 55.80	8.229	21.593	0.407	1.382	3.152	2.574
	9-# 6	3.96	3.501	2.375	0.604	189.13	252.91	159.47	134.05	51.56	- 79.20	11.484	23.710	0.339	1.337	3.734	2.531
	9-# 7	5.40	4.775	2.438	0.594	216.78	279.27	182.54	157.09	51.06	-108.00	15.388	26.181	0.279	1.288	4.433	2.487
f_c' = 3,000 PSI		0.00	0.000	0.000	1.000	113.10	169.65	115.36	84.82	62.49	- 0.00	0.000	19.085	0.715	1.500	1.680	
n = 9.2	8-# 5	2.48	2.193	2.313	0.615	156.25	218.53	155.06	124.50	63.13	- 49.60	7.315	24.585	0.467	1.399	2.771	2.896
m = 15.69	8-# 6	3.52	3.112	2.375	0.604	174.35	236.72	171.68	141.14	63.12	- 70.40	10.208	26.631	0.403	1.358	3.202	2.847
	8-# 7	4.80	4.244	2.438	0.594	196.62	257.95	192.15	161.62	62.96	- 96.00	13.678	29.020	0.343	1.312	3.720	2.798
	8-# 8	6.32	5.588	2.500	0.583	223.07	281.91	216.47	185.94	62.64	-126.40	17.696	31.714	0.289	1.264	4.319	2.749
	9-# 5	2.79	2.467	2.313	0.615	161.64	224.64	160.03	129.46	63.15	- 55.80	8.229	25.272	0.447	1.390	2.907	2.574
	9-# 6	3.96	3.501	2.375	0.604	182.00	245.10	178.69	148.18	63.12	- 79.20	11.484	27.574	0.381	1.347	3.392	2.531
	9-# 7	5.40	4.775	2.438	0.594	207.06	268.99	201.77	171.22	62.89	-108.00	15.388	30.262	0.321	1.299	3.975	2.487
f_c' = 4,000 PSI		0.00	0.000	0.000	1.000	113.10	169.65	153.81	113.10	83.32	- 0.00	0.000	25.447	0.715	1.500	1.680	
n = 8.0	8-# 5	2.48	2.193	2.313	0.615	150.30	211.79	193.51	152.78	85.32	- 49.60	7.315	31.768	0.525	1.409	2.498	2.896
m = 11.76	8-# 6	3.52	3.112	2.375	0.604	165.90	227.47	210.13	169.42	85.84	- 70.40	10.208	34.120	0.469	1.371	2.821	2.847
	8-# 7	4.80	4.244	2.438	0.594	185.10	245.77	230.61	189.90	86.27	- 96.00	13.678	36.866	0.412	1.328	3.209	2.798
	8-# 8	6.32	5.588	2.500	0.583	207.90	266.42	254.92	214.22	86.59	-126.40	17.696	39.963	0.358	1.281	3.658	2.749
	9-# 5	2.79	2.467	2.313	0.615	154.95	217.06	198.49	157.74	85.52	- 55.80	8.229	32.558	0.509	1.401	2.600	2.574
	9-# 6	3.96	3.501	2.375	0.604	172.50	234.69	217.15	176.46	86.07	- 79.20	11.484	35.204	0.449	1.361	2.964	2.531
	9-# 7	5.40	4.775	2.438	0.594	194.10	255.29	240.22	199.50	86.50	-108.00	15.388	38.293	0.390	1.315	3.400	2.487
f_c' = 5,000 PSI		0.00	0.000	0.000	1.000	113.10	169.65	192.27	141.37	104.15	- 0.00	0.000	31.809	0.715	1.500	1.680	
n = 7.1	8-# 5	2.48	2.193	2.313	0.615	145.83	206.73	231.96	181.05	107.19	- 49.60	7.315	38.762	0.564	1.418	2.334	2.896
m = 9.41	8-# 6	3.52	3.112	2.375	0.604	159.56	220.53	248.59	197.69	108.13	- 70.40	10.208	41.349	0.514	1.382	2.593	2.847
	8-# 7	4.80	4.244	2.438	0.594	176.46	236.64	269.06	218.17	109.11	- 96.00	13.678	44.369	0.461	1.341	2.903	2.798
	8-# 8	6.32	5.588	2.500	0.583	196.52	254.81	293.37	242.49	109.92	-126.40	17.696	47.777	0.410	1.297	3.263	2.749
	9-# 5	2.79	2.467	2.313	0.615	149.93	211.37	236.94	186.01	107.55	- 55.80	8.229	39.631	0.550	1.410	2.416	2.574
	9-# 6	3.96	3.501	2.375	0.604	165.37	226.89	255.60	204.73	108.53	- 79.20	11.484	42.541	0.496	1.372	2.707	2.531
	9-# 7	5.40	4.775	2.438	0.594	184.38	245.01	278.67	227.77	109.54	-108.00	15.388	45.940	0.442	1.329	3.056	2.487