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Structural material requirements in municipal building codes

August Wilhelm Gleason

Department: Civil, Architectural and Environmental Engineering

STRUCTURAL MATERIAL REQUIREMENTS

IN

MUNICIPAL BUILDING CODES.

BY

AUGUSTUS WILHELM GLEASON.

A

THESIS.

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Approved by ....

Assistant Professor of Civil Engineering.

Table of Contents.

Appendix.

Bibliography.

In making this investigation, through the offices of Mr. J. Cunningham, Librarian of the School of Mines, the codes of the following cities were secured and are now a part of the library collection:

Albany, New York.

Albuquerque, New Mexico.

Atlanta, Georgia.

Beaumont, Texas.

Buffalo, New York.

Cincinnati, Ohio.

Detroit, Michigan.

Erie, Pennsylvania.

Fitchburg, Massachusetts.

Gary, Indiana.

Kalamazoo, Michigan.

Louisville, Kentucky.

New Haven, Connecticut.

Newport, Rhode Island.

New Orleans, Louisiana.

City of New York, 1906.

City of New York, 1913.

Pasadena, California.

Providence, Rhode Island.

Roanoke, Virginia.

Bibliography (Continued)

Rochester, New York.

St. Louis, Missouri.

San Francisco, California.

Seattle, Washington.

Springfield, Massachusetts.

Trenton, New Jersey.

American Association of Steel Manufacturers Standards.

Structural Material Requirements in Municipal Building Codes.

An examination of the various Building Codes and ordinances of American cities shows some little variation in requirements and specifications for structural material. Each writer or engineer, to whom has been assigned the task of preparing the several codes, has had individual theory or rule which he embodies in the work while holding in the main to the generally accepted provisions. It is for the purpose of comparing the variations in the different codes with the hope of deducing what might be considered as standard practice, that this investigation has been started.

It is readily to be seen that a knowledge of the building requirements is necessary to the designer whose work may be erected in any part of the United States. While not intending to furnish an abstract of the codes of all cities it is the intention to point out those requirements most subject to variation and to show the range of the variation.

Quality of Materials.

Careful study of a large number of codes discloses the fact that many have been prepared from one original with only such changes as are demanded by materials and supplies which are produrable in a particular locality. Practically no large divergences of practice have been found. There appears to be a tendency for many cities to allow the head of the Building Department considerable latitude in the acceptance of materials. The Code of the City of St. Louis (Revised Building and Plumbing Laws, 1915) is a notable example of this, Section 345, on Quality of Materials, stating:

> "All materials are to be of such quality for the purpose for which they are to be used as to insure, in the judgment of the Commissioner of Public Buildings, ample safety and security to life, limb and neighboring property. Building materials are to conform to legal, trade and manufacturers' standards, and to be subject to the approval of the Commissioner of Public Buildings, who may require tests to be made by the architect, engineer, builder, or owner to determine the strength of the structural materials before or after they are

> incorporated in a building, and may require certified copies of results of tests made elsewhere from the architect, engineer, builder, owner, or other interested parties. (R. C., Sec. 70.)

In the same code this is limited by Section 471, Construction shall conform to accepted standards:-

> The materials and workmanship of construction for the framework of skeleton buildings shall not be inferior in quality to the requirements of the standard specifications of the "Association of American Steel Manufacturers." (R. C., Sec. 188.)

When a building commission is headed by a competent and reputable engineer, no better provision could be made to insure construction of the highest class and safety than Section 345 above quoted. In the hands of a political incompetant it is one of grave danger permitting abuse of office by favoritism and freedom for grafting. For a consideration, any material would be accepted with such disastrous results as may readily be foreseen. Section 471 safeguards this by stipulating that construction must be in conformity with accepted standards, that of the Association of American Steel Manufacturers being specified. Many cities are content to refer to this specification as their standard, some copying it at length and others by reference, and still others modifying it to suit their own particular requirements. In many cities reference is made to the accepted handbooks for "quality of materials" and "working stresses" but therein lies danger of dispute owing to much obsolete data being retained in many of the current handbooks. A clause of this sort should be modified by the phrase "and acceptable to the city engineer."

In regard to the quality of structural materials to be used four types of specification are met with. One refers certain materials to a standard specification, as in the Building Code of the City of Cincinnati, 1914, Section 393, Page 85:

> "Wrought or Cast Iron and Steel. All structural, wrought or cast iron, or steel, in quality requirements of tests, workmanship and in assemblage and interconnections of shapes shall be in accordance with the standard specifications of the Association of American Steel Manufacturers, as given in the hand books of the respective standard manufacturers."

Another form of this is that used by the city of Kalamazoo, Building Code of 1913, Page 17, Chapter 7, Paragraph 1, which makes its reference more general and covers all materials, it reads:

"Quality of Materials. All materials are to be of good quality for the purpose for which they are intended to be used, and conform to trade and manufacturers' standards. All materials must be free from imperfections whereby its strength and durability may be impaired; and no material will be classed as good when its strength falls below ten (10) per cent below the best of its kind."

The second type of specification is illustrated by that of the City of New Orleans where the City Engineer is given full power to reject any material that he may consider not amply safe. The same criticism applies to this as to Section 345 of the St. Louis Code, which has already been quoted.

City of New Orleans Building Laws, Part VII, Section 56, Page 18.

"Be it further ordained, etc., All materials shall be of such quality for the purpose for which they are to be used as, in the judgment of the City Engineer, will insure ample safety and security to life, limb and neighboring property. The City Engineer shall have the power to reject all materials which in his opinion are unsuitable, and may require tests to be made by the architect, engineer, builder, or owner to determine the strength of the structural materials before or after they are incorporated in a building, and may require certified copies of results of tests made elsewhere from the architect, engineer, builder, owner, or other interested persons.

Sections 13, 14, 15, and 16, Article IX, Building Code of the City of Detroit, illustrate a third type where part of the materials are specified at length and part provided for by reference.

Section 13. Wrought Iron. "All wrought iron shall be fibrous, tough and ductile, uniform in character and having an ultimate tensile strength of not less than forty-eight thousand (48,000) pounds per square inch with a yield point or commercial elastic limit of twenty-siz thousand (26,000) pounds and an elongation of eighteen (18) per cent in eight (8) inches, including fracture when tested in small specimens."

Section 14. Cast Iron. Except where chilled iron is specified, all castings shall be tough grey iron, free from injurious cold shuts or blow holes, true to pattern and having an ultimate tensile strength of not less than sixteen thousand (16,000) pounds per square inch.

Sample pieces one (1) inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of four (4) feet and eight (8) inches, a center load of five hundred (500) pounds when tested in a rough bar."

Section 15. Steel Castings. "Steel castings shall be made by the open hearth or crucible process and shall be free from injuries, and blow holes, and shall have the following minimum requirements:

All steel castings shall be annealed.

Sample bars to develop at least an ultimate strength of seventy thousand (70,000) pounds per square inch, with a yield point or commercial elastic limit of thirty-one thousand five hundred (31,500) pounds per square inch and an elongation of eighteen (18) per cent in two (2) inches, including fracture and a reduction of twenty-five (25) per cent in area."

Section 16. Structural Steel. "All structural steel, including rivets, shall have their physical and chemical properties in accordance with the Manufacturers' Standard Steel Specifications, as revised to February 6, 1903, and as found in the hand books of steel manufacturers.

The Building Code of the City of New York, Amended 1906, has been the model upon which the codes of many of the smaller cities have been based and is copied at length as an example of the fourth class where complete requirements for all materials are quoted at length. This is, in all probability, the safest form for all cities; yet, in the hands of competent authority, the specification of the City of St. Louis is by far the most rational.

Section 21, New York Code, Page 14:

Structural Material, Wrought Iron. All wrought iron shall be uniform in character, fibrous, tough and ductile. It shall have an ultimate tensile resistance of not less than 48,000 pounds per square inch, an elastic limit of not less than 24,000 pounds per square inch, and an elongation of 20 per cent in eight inches, when tested in small specimens. Steel. All structural steel shall have an ultimate tensile strength of from 54,000 pounds to 64,000 pounds per square inch. Its elastic limit shall be not less than 32,000 pounds per square inch and a minimum elongation of not less than 20 per cent in eight inches. Rivet steel shall have an ultimate strength of from 50,000 to 58,000 pounds per square inch.

Cast Steel. Shall be made from open hearth steel, containing one-quarter to one-half per cent of carbon, not ower eight one-hundredths of one per cent of phosphorus, and shall be practically free from blow-holes.

Cast Iron. Shall be of good foundry mixture, producing a clean, tough, gray iron. Sample bars, five feet long, one inch square, cast in sand molds, placed on supports four feet six inches apart, shall bear a central load of 450 pounds before breaking. Castings shall be free of serious blow-holes, cinder spots and cold shuts. Ultimate tensile strength shall not be less than 16,000 pounds per square inch when tested in small specimens.

WORKING STRESSES IN STRUCTURAL METAL.

From the tables of working stresses (Tables A, B, C) appended to this can be seen at a glance the current practice in designing steel members and comment is hardly necessary. For the most part but little variation is found and in the extreme values given are not worthy of consideration as they are isolated cases and are quoted in only one or two Codes, most cities following closely the values given as average. The average table is practically coincident with the American Association of Steel Manufacturers' Standard.

WORKING STRESSES IN TIMBER.

A wide variation is found in the specified stresses for timber members, due in part to the variations in the results of the various tests upon which they are based and to the fact that various factors of safety have been used. Owing to the varying nature of wood in regard to knots and other growth irregularities and to the effect of drying or seasoning it is most difficult to get accurate test data. Timber specifications are continually in a state of revision as new tests are made and experience ripens. At present timber work must be designed for safety rather than economy. The following tables D, E, F, G, H, I, and J give examples of the variation to be met with and the designer must use experience and judgment in his selection of stresses. From the information given it appears that most values are based on tests of seasoned materials, free from checks and blemishes, and due consideration should be given this in design where first quality timber is not available.

LOADS ON COLUMNS.

The tendency of many cities is to follow the New York Specifications which specify the loads on Wrought Iron and Steel Columns up to a ratio of L/R = 120 and on Cast Iron columns with L/R = 70, where "L" is the length in inches and "R" is the least radius of gyration in inches. These values are from the formulae 15,200-58L/R for steel, 11,300-30L/R for Cast Iron, and 14,000-80L/R for Wrought Iron.

Most of the cities investigated specify the formulas that shall be used for finding the safe loads for columns and Table L is here appended showing the various formulae that are in use and also a calculation for each different formula to show the variation. The specification of the City of St. Louis is to be noted especially as allowing the ratio of L/R to be used as high as a value of 240. (See Table K.) In none of the standard texts on the subject can a justification for such a use be found and it would indeed seem foolhardy to incorporate a column of such dimension in any building. The general practice provides a maximum ratio of 120 for Wrought Iron and Steel and it is seldom that the ratio of 40 is exceeded.

New York is largely followed in the specifications for the loads on timber columns and again most cities specify formulae for the calculation of the load. The maximum ratio allowed in the majority of cities is L/D = 30, where L is the length in inches and D the least dimension in inches. The appended Tables M and N show the formulae used and a comparative example of the stresses given by them.

MASONRY.

There is a practical agreeance on Masonry Safe Loads in Compression as shown in Table O, and as all the cities quoting Extreme Fiber Stress (Bending) agree exactly, Table P gives the standard value for the various materials.

CONCLUSION.

From the topics investigated within the scope of this Thesis we may draw the following conclusions:

(1) The Specifications of the American Association of Steel Manufacturers are generally accepted as the standard specification for structural metal.

(2) Such divergencies as are found in Municipal Codes are mainly on the side of safety.

(3) That in the design of any city structure the code of that city should be secured and carefully studied.

(4) That there is some little divergence in the formulae for columns though all quoted appear to give safe results.

(5) Timber stresses are in a state of revision and owing to lack of homogenity of the material, should be used in design with a liberal factor of safety.

(6) Masonry stresses appear to be well standardized.

(7) It would be well for the Society of Municipal Engineers to prepare and publish a Standard Specification for Municipal Structural Material.

Limited time for the preparation of this investigation has prevented the incorporating of reinforced concrete specifications in this work. This subject alone would make material for future work along this line and such a work, in connection with a discussion of the accepted principles of design, would be a timely and valuable addition to Engineering Literature.

NOTE ON APPENDED TABLES:

CODE	CITY
1	Atlanta
2	Cincinnati
3	Detroit
4	Kalamazoo
5	New Orleans
6	New York
7	Pasadena
8	Saint Louis
9	San Francisco
Max.	Greatest Max. stress allowed in any city.
Ave.	Value most frequently given.
Min.	Least max. stress given by any city.

N.B.

The Max.-Ave.-Min., values quoted are from the codes listed in the Bibliography.

AW Henson '15.

STRESSES IN STRUCTURAL STEEL.

Stresses in 1000# units.

TABLE A.

City	Ult. Tensile Stress	Elastic Limit	% Elongation 8 inch.	Tension	Compression	Shear	Bending		Rivet Shear		Shear		Bending			Remarks.
							Rolled	Rivetted	Shop	Field	Bolts	Pins	Bolts	Rivets	Pins	
1	54:64	32	20	16	16	9	16	14	10	6	5.5	10	20	20	20	
2	A. A. S. M.			16	16	10	16	15	10	9	7.5	10	24	24	24	
3	A. A. S. M.			16		10			10	7.5						
4	54:64	32	20	16	16	9	16	14	10	8	7	10	20	20	20	
5	55:65	Ult. Str. / 2	1,400 / Ult. Str.	16	16	10	16	16	10		8	10	18	20	20	
6	54:64	32	20	16	16	9	16	14	10	8	7	10	20	20	20	
7	Standard				Handbooks											
8	Amply safe in judgement of Com. Public Buildings.															
9	60:70	Ult. Str. / 2	22	16	16	9	16	15	10	8		10	20	20	20	
Min.				16	14	7	16	14	9	6	5.5	9	20	20	20	
Ave.				16	16	9	16	15	10	8	7	10	20	20	20	
Max.				16.2	16.2	10	16	16	12	10	8	12	25	25	25	

A. W. Gleason. '15.

STRESSES IN WROT IRON

stresses in 1000# units.

TABLE B.

CODE	Ult. Tensile Stress	Elastic Limit	% Elongation 8 inches	Tension	Compression	Shear	Bending		Rivet Shear		Shear		Bending			Remarks.
							Rolled	Rivetted	Shop	Field	Bolts	Pins	Bolts	Rivets	Pins	
1	48	24	20	12	15	6	12	12	6	7.5	5.5	7.5	15	15	15	
2				12	12	6	12	12								
3				12	12											
4	48	→	As	No	1.											
5				12			12	12			9		18	15	15	
6			As	No.	1.											
7			Standard Handbooks.													
8			Amply Safe.													
9	A.A.	St.	Man.	12	12	6	12									
Min.				12	10	6	12	12	6	6	5.5	6	15	15	15	
Ave.	48	24	20	12	12	6	12	12	6	7.5	5.5	7.5	15	15	15	
Max.				12.5	12.5	9	12	12	9	9	7.2	9	18	18	18	

G W Gleason '15.

STRESSES IN CAST STEEL and IRON.

Stresses in 1000# units

TABLE C.

CODE	CAST STEEL. O.H. or Bess.	% of Carbon	% of Phosphorus	Compression	Tension	Shear	Bending		CAST IRON. Min. Ultimate Tensile Strength	Maximum Compression	Tension	Shear	Bending	Remarks.
1	O.H.	1/4 to 1/2	.08						16	16	3	3	16 3	
2	A. A. St. Man.			16	16					16	3	3	16 3	
3	O.H. Cruc.	A. A. St. Man.							16		3	3		
4	O.H.	1/4 to 1/2	.08	16	16				16	16	3	3	16 3	
5	Not Stated												16 3	
6	O.H	1/4 to 1/2	.08	16	16				16	16	3	3	16 3	C.I. sample bar 1"□ 5' long with clear span 4.5' bear a center load of 450#
7	Not Stated.													
8	Not Stated													
9	Ult. Tens. Str. 60 : 70		Elast. Lim. 45% Tens. Str.			Elong. 18%			16	16	3	3	16 3	C.I sample bar 1"□ 12" long, bear center load of 2400# with deflection 1/10".
Min.				10	10				16	10	5	3	10 2.5	
Ave.				16	16				16	16	3	3	16 3	
Max.				16	16				16	16	5	3	16 3	

A.W. Gleason. '15.

TIMBER STRESSES

TABLES D, E, F, G, H, I, J.

Stresses in 100 pound units.

OAK / YELLOW PINE

CODES	Oak: Compression With Grain	Oak: Compression Across Grain	Oak: Tension	Oak: Shear With Fibre	Oak: Shear Across Fibre	Oak: Safe Extreme Fibre Stress	Yellow Pine: Compression With Grain	Yellow Pine: Compression Across Grain	Yellow Pine: Tension	Yellow Pine: Shear With Fibre	Yellow Pine: Shear Across Fibre	Yellow Pine: Safe Extreme Fibre Stress
1	9	8	10	1	6	10	10	6	8	.7	5	12
2	9	8	10	1	6	10	10	6	12	.7	5	12
3				1.5		10				1.		12.5
4	9	8	10	1	6	10	10	6	12	.7	5	12
5		Cypress. 2	9	.5			S. Leaf L. Leaf	4 5	12 15	.65 .7		
6	9	8	10	1	6	10	10	6	12	.7	5	12
7	Standard Handbook											
8	Not	Stated										
9	Not	Stated										
A.R.E. and M.W.A.	13	4.5		1.1	2.1	11						
A.R.S. of B. and B.	10	5	12	2	10	10	10	3.5	12	1.5	12.5	12
Min.	9	4.5	10	1	2.1	10	10	3.5	8	1.5	5	12
Ave.	9	8	10	1	6	10	10	6	12	.7	5	12
Max.	13	8	12	2	10	11	10	6	15	.7	12.5	12.5

LOCUST / HEMLOCK

CODES	Locust: Compression With Grain	Locust: Compression Across Grain	Locust: Tension	Locust: Shear With Fibre	Locust: Shear Across Fibre	Locust: Safe Extreme Fibre Stress	Hemlock: Compression With Grain	Hemlock: Compression Across Grain	Hemlock: Tension	Hemlock: Shear With Fibre	Hemlock: Shear Across Fibre	Hemlock: Safe Extreme Fibre Stress
1	12	10		1	7.2	12	5	5	6	.4	2.7	6
2	12	As. 1					As	No 1.				
3												
4	12	As 1.					As	No 1.				
5												
6	12	As 1					As	No 1				
7	16 [a]	3	12	1.5	7.5	12	9 [b]	2.5	10	1.25	6	8
8												
9												
A.R.E. and M.W.A.							12	2.2		1.	1.6	11
A.R.S. of B. and B.							8	1.5	6	1	6	6
Min.							3.5	1.5	6	.35	2.5	6
Ave.	As No 1.						6.0	5.	6	.4	2.7	6
Max.							9.	5.	10	.75	6.	11

CHESTNUT / WHITE PINE

CODES	Chestnut: Compression With Grain	Chestnut: Compression Across Grain	Chestnut: Tension	Chestnut: Shear With Fibre	Chestnut: Shear Across Fibre	Chestnut: Safe Extreme Fibre Stress		White Pine: Compression With Grain	White Pine: Compression Across Grain	White Pine: Tension	White Pine: Shear With Fibre	White Pine: Shear Across Fibre	White Pine: Safe Extreme Fibre Stress
1					1.5	8		8	4	8	.4	2.5	8
2	10	5	6		1.5	8		8	4	8	.4	2.5	8
3	10										.8		7.5
4	10	5	6		1.5	8		8	4	8	.4	2.5	8
5													
6	10	5	6		1.5	8		8	4	8	.4	2.5	8
7	8 [c]	2	7	1	4	7.5		8	2	7.	1	5	7
8													
9													
A.R.E. and M.W.A.								10	1.5		.7	1.	9
A.R.S. of B. and B.	8	2.5	8.5	1.5	5	8		7	2	7	1	5	
Min.	5	4	6		1.5	8	6.3	2.		7	.4	2.5	7
Ave.	8	10?	6	1	1.5	8	8.	4.		8	.4	5.	8
Max.	18	10	8.5		1.5	8	9.	4.		10	1.2	5	10

SPRUCE / REMARKS

CODES	Spruce: Compression With Grain	Spruce: Compression Across Grain	Spruce: Tension	Spruce: Shear With Fibre	Spruce: Shear Across Fibre	Spruce: Safe Extreme Fibre Stress	Remarks.
1	8	4	[illegible]	.5	3.2	8	
2	8	4	[illegible]	.4	2.5	8	
3				.9		9.5	
4	8	4	[illegible]	.4	2.5	8	
5							
6	8	4	[illegible]	.4	3.2	8	
7	8	2	[illegible]	1	5	7	→ San Francisco. → No 7.
8							a. Yellow Fir b. Red Fir c. Red wood
9							No. 8 Pasadena.
A.R.E. and M.W.A.	11	1.[illegible]		.7	1.5	10	American Railway Engineering and Maintenance of Way Association.
A.R.S. of B. and B.	8	2	[illegible]	1.	7.5	7	Association Railway Superintendents of Bridges and Buildings.
Min.	5	2	[illegible]	.4	2.5	7	
Ave.	8	4	[illegible]	.5	3.2	8	
Max.	10	6.3	2.5	1.25	7.5	12.6	

COLUMN WORKING STRESSES. TABLE K.

1000# units per □" of section.

L/R values

CODE.	Material.	120	110	100	90	80	70	60	50	40	30	20	10	Remarks
1	1						9.2	9.5	9.8	10.1	10.4	10.7	11	1 = Cast Iron
	2	8.2	8.8	9.4	9.9	10.5	11.1	11.7	12.3	12.9	13.5	14.0	14.6	2 = Steel
	3	4.4	5.2	6	6.8	7.6	8.4	9.2	10.	10.8	11.6	12.4	13.2	3 = Wrot Iron
2	1	See note.												Hollow C.I. Rect. Section $\frac{10,000}{1+L^2/1067D^2}$; circ. section $\frac{10,000}{1+L^2/800D^2}$; other sections $\frac{10,000}{1+L^2/6900R^2}$
	2						↔		13.	-	- -	- -	←	
	3		Not					stated						
3	1													
	2		Not				Stated.							
	3													
4	1													
	2		Same			as		No 1.						
	3													
5	1				As	No 1.								W.I. $\frac{12,000}{1+\frac{12L^2}{20,000R^2}}$; Steel $\frac{16000}{1+\frac{12L^2}{20,000R^2}}$
	2													
	3													
6	1													L = Length in inches.
	2		Same			as		No 1						R = Rad. of Gyr. " "
	3													D = Least Dim. " "
7	1													
	2		Not				stated							
	3													
8	1											6.7	8.9	25 - 5.6 - 15 - 7.8
	2	8.92		9.78		10.61		11.26		12.44		13		Steel. 140 - 160 - 180 - 200 - 220 - 240
	3													8.18 7.3 6.6 6.0 5.3 4.8
9	1													C.I. Round $\frac{8000}{1+L^2/800D^2}$; Rect. $\frac{8000}{1+L^2/1067D^2}$
	2													Steel $L>30R$: $15000 - 50\frac{L}{R}$
	3													

A W Gleason '15.

COLUMN FORMULAE. TABLE L.

STRUCTURAL STEEL

Formula	L/R = 20	40	120	Remarks
I $15,200 - 58\frac{L}{R}$	14,090	12,880	8,240	stress per sq inch. in pounds.
II $\frac{15,000}{1+\frac{L^2}{13,500R^2}}$	14,590	13,400	7,350	The extreme value given
III $\frac{16000}{1+\frac{L^2}{20,000R^2}}$	15,700	14,800	9,300	for L/R = 240
IV $17,100 - 57\frac{L}{R}$	15,960	14,820	10,260	Ave. value = 120
V $\frac{16,250}{1+\frac{L^2}{11000R^2}}$	15,700	14,200	7,000	Formula I seems to
VI $15,000 - 50\frac{L}{R}$	14,000	13,000	9,000	be most used
VII $16,000 - 70\frac{L}{R}$	14,600	13,200	7,600	

CAST IRON.

Formula	L/R = 20	= 70	L/D = 20	Remarks
VIII $11,300 - 30\frac{L}{R}$	10,700	9,200		Stress per □" in pounds. The extreme value given
IX $\frac{11,670}{1+\frac{L^2}{400R^2}}$	5,835	890		for L/R = 120 L/D = 40
X $10,000 - 60\frac{L}{R}$	8,800	4,400		Ave. L/R = 70 L/D = 30
XI $9,000 - 40\frac{L}{R}$	8,200	6,200		
XII $\frac{10,000}{1+\frac{L^2}{800D^2}}$	6,60		6,600	
XIII $\frac{13,300}{1+\frac{L^2}{400D^2}}$			6650	
XIV $\frac{14,000}{1+\frac{L^2}{600D^2}}$			6000	
XV $\frac{14,000}{1+L^2/850D^2}$			9,000	
XVI $\frac{13,333}{1+L^2/500D^2}$			7,400	
XVII $\frac{10000}{1+L^2/1,067D^2}$			7,300	
XVIII				

A W Gleason. '15

COLUMN WORKING STRESSES.

TABLE M.

L/D values. 100# units per □" of section.

CODE	Material	30	25	20	15	12	10	NOTES.
1	1 2 3	4.6 3.5 3.9	5.5 4.25 4.75	6.4 5. 5.6	7.3 5.75 6.45	7.84 6.2 5.96	8.2 6.5 7.3	1 = Long Leaf Yellow Pine 2 = White Pine, Norway Pine. Spruce. 3 = Oak
2	1 2 3	10,000 - 10 L/D ↔ 10. 6250 - 6 L/D ↔ 7 7500 - 7.5 L/D ↔ 8.						L = length in inches D = least dimension in inches
3	1 2 3							L/D > 12 As in "2" L/D < 12 Safe Load = Area × "C" / Factor of Safety "C" = Oak 4,000; K.P. 5,000; W.P. 3,500; Cyp. 3,400; Hem. 3,000
4	1 2 3	Same as 1						
5	1 2 3		3.0 7.0 5.75	3.25 7.5 6.15	3.5 8.0 6.55	3.75 8.5 7.1	4.0 9.0 7.5	1 = Cypress 2 = Long leaf Yellow Pine 3 = Short " " "
6	1 2 3	Same as 1						
7	1 2 3	Not Stated						
8	1 2 3	3.6 4.4	4.45 5.30	5.30 6.20	6.15 7.10	7.0 8.0		35 / 40 1. 2.75 / 1.9 2. 3.50 / 2.6 1 = White Pine 2 = Yellow Pine and Oak.
9	1 2 3							Oregon Pine 13,000 - 20 L/D L/D < 12 Wh. Pine + Spr. 7. Ore. or Yell. Fir 10. Wash. Red " 8. Redwood 7.

A W Gleason '15.

COLUMN FORMULAE.

TABLE N.

LONGLEAF YELLOW PINE.

Formula.	$L/D = 10$	$L/D = 30$	Remarks.
I $1000 - 18\frac{L}{D}$	820	460	"C" is allowable compressive stress (with grain) "C" = 1000#
II $C(1 - \frac{L}{80D})$	875	625	When $L < 12D$ values from 1000 to 1250 are allowed.
III $C(1 - \frac{L}{100D})$	900	700	Stress given in lbs/□" of section.
IV $C(1 - \frac{L}{70D})$	860	570	For Chestnut:– Formulae:– II, III, IV, ⅝ VII and V.
V $(C - 125\frac{L}{12D})$	896	688	
VI $(1000 - 10\frac{L}{D})$	900	700	
WHITE PINE, NORWAY PINE, SPRUCE "C" = 800#			
VII $800 - 15\frac{L}{D}$	650	350	When $L < 12D$ values from 700 to 875 are allowed.
II $C(1 - \frac{L}{80D})$	700	500	For Hemlock:– Formulae:– II, III, IV, V, IX, XIII, XIV.
VIII $700 - 7\frac{L}{D}$	630	490	XIII = $500 - 9\frac{L}{D}$
IX $625 - 6\frac{L}{D}$	565	445	XIV = $C(1 - \frac{L}{60D})$
IV $C(1 - \frac{L}{70D})$	685	457	
III $C(1 - \frac{L}{100D})$	720	560	
OAK. "C" = 900#			
I $900 - 9\frac{L}{D}$	810	630	When $L < 12D$ values from 800 to 1125 are allowed
II $900 - 17\frac{L}{D}$	730	390	For Locust: Formulae:– 1½ VII, I, II, III, IV, V, VII.
II $C(1 - \frac{L}{80D})$	790	560	Maximum Ratio L/D "L" = Length in inches
III $750 - 7.5\frac{L}{D}$	675	525	"D" = Least dimension in inches. Min. Ave. Max.
IV $C(1 - \frac{L}{70D})$	770	515	20 30 40
V $C - 125\frac{L}{12D}$	796	588	

Note.

A.W. [illegible] '15.

MASONRY SAFE LOADS.

Tons per Superficial foot.

TABLE O.

CODE.	Brickwork: Lime Mortar	Brickwork: Lime and Cement	Brickwork: Cement Mortar		Rubble-Stone: Portland Cement Mortar	Rubble-Stone: Other Cement Mortar	Rubble-Stone: Lime & Cement Mortar	Rubble-Stone: Lime Mortar		Concrete: Portland Cement	Concrete: Other Cement
1	6-8	8-11½	11½-15		6-10	6-8	6-8	4		15	8
2	18	12	18		6	9		12		15	
3	17	11	15		10	8	6	5		30	8
4	8½	11½	15		10	8	7	5		15	8
5	10		21.6							36	
6	8	11½	15		10	8	7	5		15	8
7	8	10	15		10		5	6		15	
8											
9	7	10	15							20	8
Max.	10	12	21.6		10	9	8	12		36	8
Ave.	8	11	15		10	8	6.5	6		15	8
Min	7	8	11½		6	6	5	5		15	8

TABLE P.

FIBRE STRESS.

100# Units

Material	Extreme Fibre Stress (Bending)
Granite	1.8
Greenwich Stone	1.5
Gneiss	1.5
Limestone	1.5
Slate	4.0
Marble	1.2
Sandstone	1.0
Bluestone	3.0
Port. Cem. 1:2:4	.3
" " 1:2:5	.2
Nat. " 1:2:4	.16
Hard Brick	.5
" " in cem.	.3

[illegible] '15.