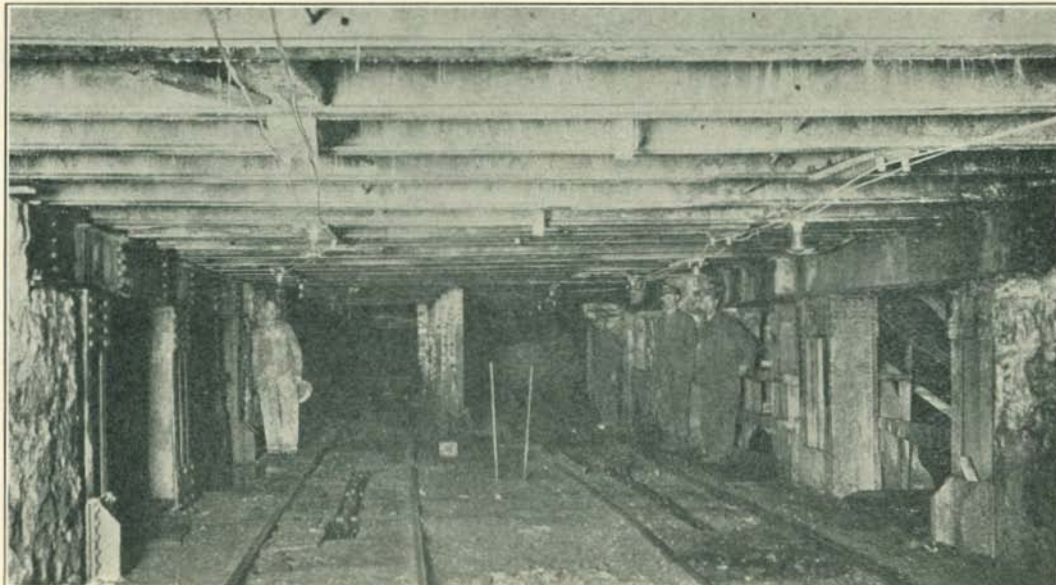
STEEL MINE TIMBER

...IE STEEL COMPANY

PITTSBURGH, PA.

EIGHTH ED...



Heavy Installation of Steel Mine Timbers in the Mine of the Monroe Coal Mining Company at Revloc, Pennsylvania

STEEL MINE TIMBER

TABLES AND DATA

ON THE

PROPERTIES AND USES

OF

MINE TIMBER SECTIONS

MANUFACTURED BY

CARNEGIE STEEL COMPANY

PITTSBURGH, PA.

6226MM525

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Carnegie Steel Company is the pioneer in the United States in the application of steel to underground timbering of mines and has contributed to the success of such timbering by recommending suitable and practicable forms of construction.

So long ago as 1894 this Company worked out a type of framing suitable for use in the bituminous coal fields of Western Pennsylvania, resulting during the ten following years in a few installations chiefly in the anthracite region, but the real impetus to the systematic timbering of mines dates from 1907, when this Company placed on the market a series of steel sections designed with special reference to this work. The H-beam has made steel framing as simple as the wooden framing which it displaced.

The data and tables which follow reflect the practical experience gained from these years of observation in the design and installation of many miles of steel timber in rooms and headings. They constitute a clear and safe guide to what is best from the standpoint of the manufacturer and most economical to the user.

Should need for further information arise, this Company will be glad to co-operate in the solution of mine-timbering problems.

STEEL FOR SERVICE. Steel, as a substitute for wood, is of greatest economical value in the timbering of mines when permanency of construction is desired. Generally the use of steel will be preferred for the reason that wood is not, from a standpoint of economic design, applicable to all constructions in connection with mining operations and that, in many other cases, its use is attended by unavoidable losses from deterioration.

The ultimate cost of an installation depends upon the different conditions for which it is to be used, the relative cost of material and the life of the installation, and is determined by the primary cost or investment plus cost of maintenance and the compound interest on both; the greatest economy is attained when a material is used which does not deteriorate and does not require replacement during the entire period of service.

The cost of steel installation, while primarily in excess of wood, is ultimately compensated for to its fullest extent by the economies effected due to permanency and serviceableness of steel under all conditions of mining operations, as generally outlined in the following:

ECONOMY IN DESIGN. Steel sets can be designed to support any weight under any condition of loading with regard to an economical selection of steel sections; at the same time it can be designed to obtain the most advantageous proportions of lateral and vertical clearance, the latter being of particular importance in determining the headroom necessary for mining operations.

Wooden sets are uneconomical on account of loss and waste resulting from the use of excess material due to the common and convenient practice of framing three-piece gangway sets from timbers of the same size, as it is considered impracticable to use sizes adapted to the stresses they have to sustain.

Steel sets are easily erected on account of the simplicity of the design and, as sets are frequently furnished of same design, so that the corresponding parts of the set are interchangeable, no time or material is lost in assembling.

ECONOMY IN SAFETY. Steel sets may remain permanently in position and need be removed only when it is intended to abandon the workings. The renewal of wooden sets is frequently necessary during the operation of a mine due to decay or other deterioration and is dangerous on account of the roof which must be supported during the removal of the old sets, or else the loose rock in roof must be taken down before removing the set; steel supports, therefore, add to the safety in the operating of the mine.

ECONOMY IN FIRE RISK. The use of steel practically eliminates the constant danger from fire risks inseparable from the use of wooden constructions. The preservation of the mine from fire loss warrants the most careful consideration in determining the economic value of steel as compared with wood.

ECONOMY IN MAINTENANCE. Steel in mine construction requires only to be well painted to be protected against the influence of dampness and water; the steel is then practically indestructible and can at any time be withdrawn and re-used for similar purposes.

Wood deteriorates, and in many cases rapidly, on account of decay under the unfavorable conditions of uniform temperature and great humidity prevalent in most mines.

In addition to the direct economic losses due to necessary renewal of deteriorated wooden sets, further losses are occasioned by the failure to withdraw and re-use wooden timbering from completed rooms, abandoned headings, etc. This neglect, which is caused in part by the relative worthlessness of wood after service, results in the menace of vitiated air due to decay and in increased fire risk, both of which contribute to the expense of mine maintenance.

The use of steel avoids all these elements of economic waste; its long life under all conditions of service amply compensates for the increased first cost of its installation. Wood may appear convenient, but steel is the material for service. Long endurance and minimum cost of maintenance mean ultimate economies in expenditure.

RELATIVE COST OF STEEL AND WOOD. Variable conditions at mines make it difficult to compare the cost of steel and wood mine timbers except on the basis of specific instances. As a general rule, when consideration is given to depreciation and ultimate expenditure, the operator can well afford to pay for correctly designed steel sets three or four times the cost of wood sets of equivalent strength.

Comparisons should always be based on first cost, length of service, cost of renewal and maintenance and interest on total investment. Consideration should also be given to such apparently extraneous matters as ventilation, fire risk and interruption of operations when wooden timbers must be removed.

Recent statistics covering bituminous coal mines show a consumption for underground timbering of 1.5 to 12 board feet of lumber per ton of coal produced. A large number of coal mines use about 6.5 board feet at prices ranging from 2 cents to 5 cents per foot with an equal cost for handling it. The substitution of steel, wherever possible, in underground timbering in place of lumber will result in a considerable reduction in the cost per ton of coal mined.

PROPER DESIGN OF STEEL MINE TIMBER. The cost of a durable material may be much increased by improper methods in its preparation for final use. Details of framing should be simple and connections should be of minimum weight so that the cost of fabrication may be the least possible, consistent with good engineering practice. Above all, the kind of steel sections to be used should be chosen with a view to the character of the stresses so as to insure proper and most economical distribution of the loading. Needless expense has been incurred in many installations by reason of the use of improper steel sections, heavy connections and base plates, and complications in the details of fabrication.

Of the numerous designs and proposals considered over a period of several years, the four designs or styles which are shown in Figs. 1 to 4, represent those which are best suited for average conditions and combine simplicity of fabrication and erection and lowest first cost.

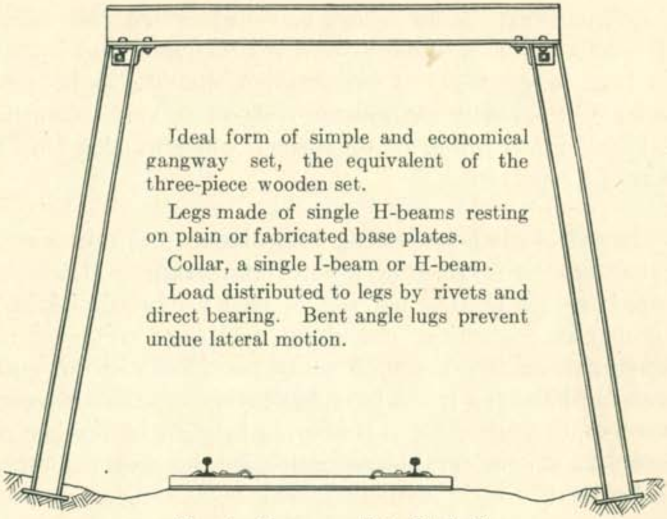


Fig. 1—Gangway Set, Style F

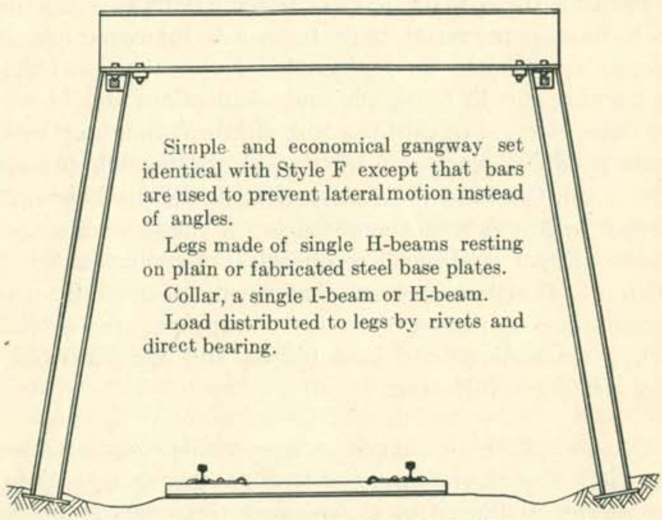


Fig. 2—Gangway Set, Style G

REPRESENTATIVE GANGWAY SETS

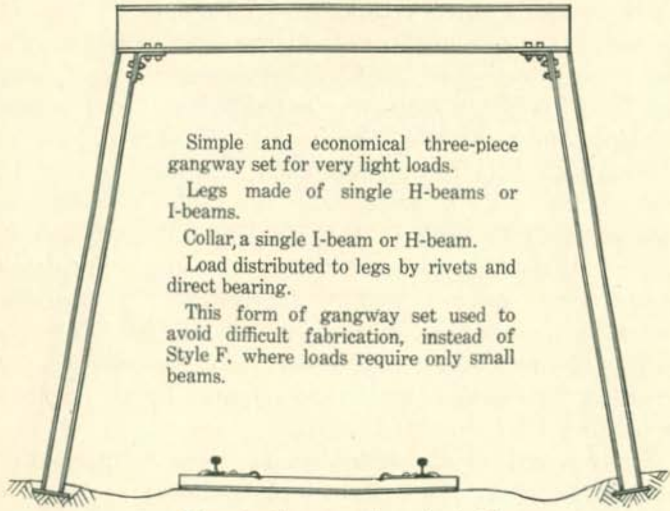


Fig. 3—Gangway Set, Style K

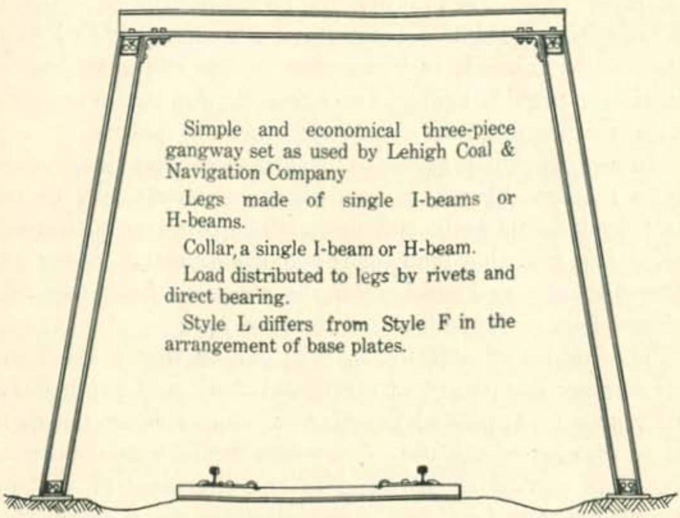


Fig. 4—Gangway Set, Style L

REPRESENTATIVE GANGWAY SETS

STRESSES IN MINE TIMBERS. In the use of steel for timbering, the safe guide is experience. The exact amount and exact direction of the pressures exerted by roof, walls and floor are in many cases indeterminate, and general principles only can be stated.

Where steel is to replace wood, the problem of the designer is merely to select from the tables steel sections equivalent in strength to the wooden timbers which are in use and then to work out connections and other details so as to insure minimum cost of fabrication. If experience indicates that the wood timbers are too light, and fail from over-strain rather than decay, the steel sections should be made somewhat heavier than required by the tables so as to cover that over-strain.

The strength of an assemblement is the strength of its weakest member. In a three-piece gangway set each leg seldom carries more than half the load on the collar and in most cases needs only to be proportioned thereto. Where this method of computation loads a leg to its full theoretical value, it is customary to use the next heavier section to provide against cross bending due to the wedging, weight of lagging and other indeterminate factors.

In new work it is safest to use somewhat heavier sections than required by the rules. Lighter sections may be put in later if found to be sufficient. The problem is to determine the probable load on the roof support or collar and the character and amount of the stresses in the legs, if a three-piece or four-piece set is to be used.

The tables of safe loads, etc., which follow are based on stresses customary in structural work and are believed to represent approved practice in mine timber construction. So far as the use of wooden timbers is concerned, the data should be adjusted to the character of the materials actually furnished, particularly in view of the fact that structural wooden timbers show a growing tendency toward inferiority in quality.

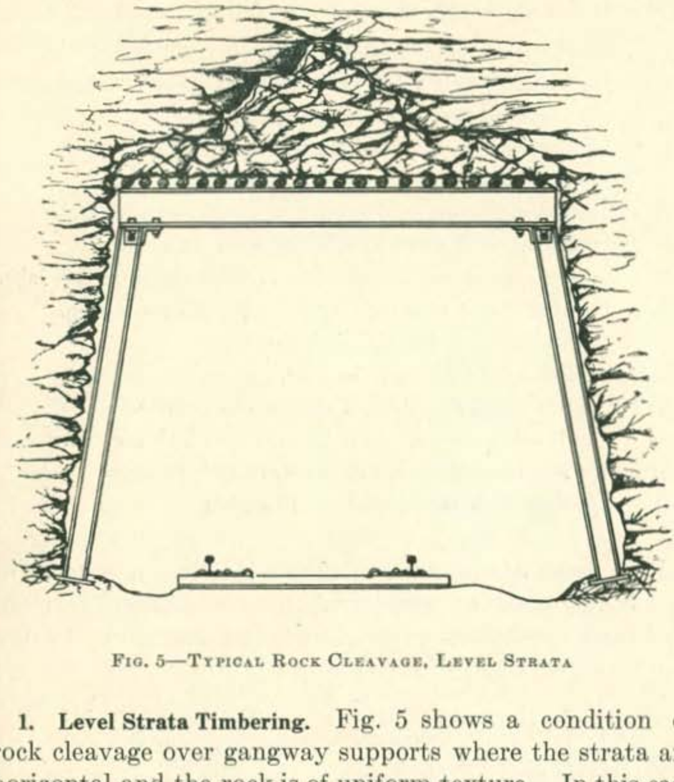


FIG. 5—TYPICAL ROCK CLEAVAGE, LEVEL STRATA

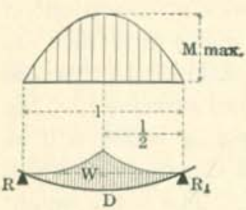
1. Level Strata Timbering. Fig. 5 shows a condition of rock cleavage over gangway supports where the strata are horizontal and the rock is of uniform texture. In this case the cleavage is symmetrical and the load sustained by the collar is the cleavage prism, the height of which will be the half span length by the tangent of the angle at which the roof would break away naturally. The total weight sustained by the collar will be the product of the area of the triangle of fracture by the distance between supports and by the weight per cubic unit of the rock; $W = \frac{swl^2 \tan \alpha}{4}$

Complete formulas for the computation of stresses for above and other conditions of loading are given on following pages.

Notation used in the formulas which follow is:

l	=Distance center to center of supports, in inches.
s	=Distance center to center of gangway sets, in inches.
α, β	=Angles of fracture in cleavage triangle.
c	=Distance to center of gravity of triangle, in inches.
w	=Weight, in pounds per unit of volume, etc.
W	=Superimposed load supported by beam, in pounds.
x	=Distance to any point of moments, in inches.
f	=Bending stress, extreme fiber, in pounds per square inch.
E	=Modulus of elasticity, in pounds per square inch.
I	=Moment of inertia, in inches^4.
S	=Section modulus, in inches^3.
R, R_1	=Reactions at points of support, in pounds.
M	=Bending moment at point given, in inch pounds.
M max	=Maximum bending moment, in inch pounds.
D	=Deflection at point given, in inches

The bending moment, deflection, etc., produced in the collar may be computed by the flexure formula for beams supporting a load increasing uniformly to the center: $W = \frac{swl^2 \tan \alpha}{4}$

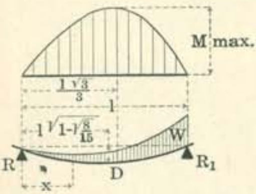


R (max. shear) $= R_1$	$= \frac{W}{2}$
M, distance x	$= Wx\left(\frac{1}{2} - \frac{2x^2}{3l^2}\right)$
M max., distance $\frac{l}{2}$	$= \frac{Wl}{6} = 0.1667\ Wl$
W max.	$= \frac{6fS}{l}$
D max.	$= \frac{Wl^3}{60EI}$

For above condition of loading the safe loads are equal to 0.75 of the uniformly distributed loads for corresponding spans in safe load tables for beams; the deflection of reduced load is 0.96 of that derived from coefficient in tables.

The load on each support is equal to one-half of total load.

If the apex of the cleavage prism is over a support, the maximum bending moment is the same as for a beam supporting a load increasing uniformly to one end:



$$R = \frac{W}{3}$$

$$R_1\text{(max. shear)} = \frac{2W}{3}$$

$$M\text{, distance } x = \frac{Wx}{3}\left(1-\frac{x^2}{l^2}\right)$$

$$M\text{ max., distance } \frac{l\sqrt{3}}{3} = \frac{2Wl}{9\sqrt{3}} = 0.1287\ Wl$$

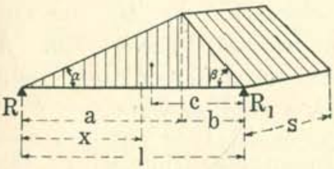
$$W\text{ max.} = \frac{27fS}{2l\sqrt{3}}$$

$$D\text{ max.} = \frac{.013044\ Wl^3}{EI}$$

For above condition of loading the safe loads are equal to 0.9743 of the uniformly distributed loads for corresponding spans in safe load tables of beams; the deflection of reduced load is 0.976 of that derived from coefficient in tables.

The loads on supports are one-third and two-thirds of total load.

If the apex of the cleavage prism is over the center of the beam, the maximum bending moment is the same as for a beam supporting a load increasing uniformly to the center. The values of M max. will, therefore, range within these two limits; that is, from .1287 Wl to .1667 Wl, but can be computed exactly from the formula given below:



$$W = \frac{swl\,(a \tan \alpha)}{2}$$

$$R = \frac{Wc}{l} \qquad R_1 = \frac{W(l-c)}{l}$$

$$c\text{ (center of gravity)} = \tfrac{1}{3}\left(l + \frac{a \tan \alpha}{\tan \beta}\right)$$

$$M\text{, distance } x = \frac{W\,(3\,cax - x^3)}{3\,al}$$

$$M\text{ max., distance } \sqrt{ca} = \frac{2\,Wc\sqrt{ca}}{3l}$$

Instead of the exact method of computation, the bending moment and the deflection may be computed as if for a load increasing uniformly from end to center.

The loads on the two supports are not equal and in their design the reaction at each end of the beam should be computed in accordance with the formula.

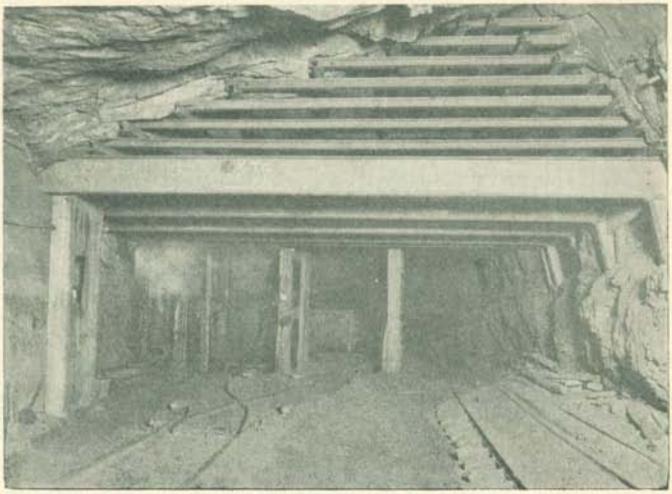


FIG. 6—ACTUAL ROCK CLEAVAGE, INCLINED STRATA

2. Inclined Strata Timbering. The loads in mine timber work are rarely symmetrical and in consequence computations must necessarily take into consideration actual conditions, the character of the strata, method in which fracture takes place, danger from squeeze and other circumstances. The prime consideration is to prevent fracture beyond the lines of the necessary excavation. A soft roof can be safely held if timbered immediately upon exposure to the air. Delay means needless work.

Fig. 6 shows the more common condition where the strata are inclined, the cleavage is not symmetrical and the arch is irregular. In this case the apex of cleavage is nearer one end of the collar than the other. The load is computed, as in the case of symmetrical cleavage, from the weight of the cleavage prism and the stresses in accordance with the formulas given on preceding page for the above condition of loading.

3. Size of Legs and Collar. Bending moments should be computed in, or reduced to, inch pounds. When so computed the size of section to be used may be taken from the table of elements by dividing the bending moment by the safe working stress; the result is the section modulus of the required section.

The size of leg sections can be taken directly from the tables of safe loads, noting that values used must be those corresponding to the length of the leg. Allowance should be made for the effect of bending stresses in the leg due to the inclined character of the strata, when the resultant line of pressure at the supports is not parallel with legs, so that the total resistance required may be greater than the end reactions computed from formulas.

ROOF SUPPORTS. The simplest use of steel in underground mine timbering is that in which single I-beams or rails are used to span a roadway. Where the coal is good, solid and not liable to crush, the supports may be laid directly on the coal with or without bearing plates made of steel, wood or stone. Places of unusual weakness may be taken care of by props of wood or steel, of such lengths as conditions may require to obtain solid bearing.

The following table shows the relative values of rail sections as compared with I-beams and indicates the superiority of the latter for mine timbering purposes:

First, for equivalent strength, beams are much lighter.

Second, for equivalent strength, beams are much deeper; consequently the deflection is much less and their use is, therefore, in the interest of greater stability.

Third, the wider flanges of the beams offer much better support for lagging.

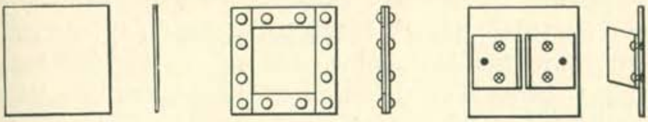
At normal prices, therefore, the substitution of rails for I-beam sections is uneconomical and should be considered only on the basis of very low prices.

RELATIVE VALUES OF STEEL RAILS AND BEAMS

RAILS				BEAMS			EXCESS WEIGHT PER FOOT OF RAILS	
Depth, Inches	Weight per Yard, Pounds	Weight per Foot, Pounds	Section Modulus, Inches³	Depth, Inches	Weight per Foot, Pounds	Section Modulus, Inches³	Pounds	Per Cent.
5 3/4	100	33.33	14.6	8	18.40	14.2	14.93	45
5 3/8	90	30.00	12.2	7	20.00	12.0	10.00	33
5 3/16	85	28.33	11.1	7	17.50	11.1	10.83	38
5	80	26.67	10.1	7	15.30	10.4	11.37	43
4 13/16	75	25.00	9.1	6	17.25	8.7	7.75	31
4 5/8	70	23.33	8.2	6	14.75	7.9	8.58	37
4 7/16	65	21.67	7.4	6	12.50	7.3	9.17	42
4 1/4	60	20.00	6.6	5	14.75	6.0	5.25	26
4 1/16	55	18.33	5.8	5	12.25	5.4	6.08	33
3 7/8	50	16.67	5.0	5	10.00	4.8	6.67	40
3 11/16	45	15.00	4.3	5	10.00	4.8	5.00	33
3 1/2	40	13.33	3.6	4	10.50	3.5	2.83	21
3 5/16	35	11.67	3.0	4	7.70	3.0	3.97	34
3 1/8	30	10.00	2.5	4	7.70	3.0	2.30	23
2 3/4	25	8.33	1.8	3	5.70	1.7	2.63	32
2 5/8	20	6.67	1.4	3	5.70	1.7	0.97	15

GANGWAY SETS. As already noted, many different types of construction have been devised for three-piece gangway sets. Practical experience indicates that Style F, Fig. 1, combines that simplicity of arrangement, economical distribution of material and ease of fabrication and erection which makes it the preferable style for all ordinary use.

The reason for this is that, while the I-beam is the most economical section in resistance to cross bending stresses, the H-beam is the most economical in resistance to compressive stresses. The use of the two sections, therefore, combines the resistance to bending of the one with the resistance to compression of the other. In addition the shape of the sections makes framing details simple, and, therefore, in the Style F set is contained the closest practical equivalent to the three-piece wooden set in general use previous to the introduction of steel.



Plain Plate — Any Style Legs | Fabricated Plate — H-Beam Legs | Fabricated Plate — H-Beam Legs

FIG. 7—BASE PLATE DETAILS

Where the loads are light and the leg sections quite small, there is hardly sufficient room in the leg for web connection angles. In such cases the Style F set is modified as shown in Fig. 3, Style K.

The base plates may be plain or fabricated, and may have upstanding angles, as shown in Fig. 7, the general arrangement of which is illustrated in Style L, Fig. 4. Modifications of this character do not affect the essential features of the Style F set and have relatively little influence on the cost. Their use is determined solely by the preference of the purchaser.

The Style F gangway set may be further modified by the use of bars, to prevent lateral motion, in place of the angle lugs as shown in Style G, Fig. 2.

Many kinds of lagging have been in use, such as wooden poles, boards, old rails, thin concrete slabs, tees supporting common bricks, steel plates and corrugated sheets.

PUMP HOUSES AND STABLES. Next to the gangway support the first use of structural shapes in the United States within the mines seems to have been made at the pump house of the Hazelton Shaft Colliery, No. 40 Slope, Lehigh Valley Coal Company, and a number of installations bear witness to the satisfaction which arises from the use of steel in such cases. Very extensive installations of steel have also been made in the way of underground stables, mine locomotive rooms, etc.

ERECTION METHODS. Inasmuch as steel mine timbers are fabricated complete in the shop, they are ready for erection when they reach the mine, and no further cutting or fitting is necessary. Erection, therefore, is quite simple and the only tools needed are wrenches, drift pins and hammers. The usual method of erection is to assemble the three pieces complete on the floor, bolt the connections together and raise the set into position.

Inasmuch as steel sets are only about one-third as heavy as wooden sets of equivalent strength, their erection not only requires less time, but also less physical effort. Their lightness is, therefore, a distinct advantage to be considered in estimating the relative cost of steel and wood.

Stiffness is as important as strength and the spacing of timbering should be such as to compel the different sets to act together as a unit under any sudden stress or shock. Light sections with close spacing are, therefore, preferable to heavy sections on wide spacing. The roof itself tends to distribute the load over two or more sets, whereas on wide spacing there is much more danger of the roof falling in between the sets. The closer spacing also permits the use of much lighter lagging.

PRESERVATION OF STEEL MINE TIMBERS. The economical use of steel within the mines requires the same care for its preservation as its use above ground. At the same time conditions underground are not nearly so severe as above ground; the steel is not exposed to alternations of high and low temperatures, strong light, dryness and wetness, which are especially accelerative in the deterioration of protective coatings. Early objections to the use of steel due to the presence in some mines of acid-laden waters have not stood the test of experience, which indicates that only the simplest means are necessary for the guarantee of an extremely long life for steel timbering.

To insure such long life and, therefore, the utmost economy in ultimate expenditure, the base plates should be set in the dry. Where they come on edges of ditches, it may be desirable to set them on low concrete piers.

All steel within the mines should be well painted and kept painted. The pigments should be good and applied with care. Carbon paints in whose manufacture sulphuric acid has been used, and oxides of iron manufactured by chemical processes or recovered as a by-product of metallurgical processes are to be avoided. A metallic paint should be used for the first or shop coat by reason of its adhesive qualities. The second coat should be a moisture excluder. For the first coat, therefore, red leads, natural iron oxides or pigments with zinc base should be employed. Natural carbons, such as graphite, and hydro-carbons, such as asphalt, gilsonite and ozokerite, may be recommended for second coat work if properly ground and mixed with a good vehicle.

For the best service it is recommended that the steel be painted at the shop with a mixture of red lead, oil and asbestine, in the proportions of 15 pounds of red lead and 2 pounds of asbestine to a gallon of pure raw linseed oil, with sufficient japan dryer to work well; and that a first class graphite paint be applied thoroughly as a field or second coat to protect the shop coat and to fill up any vacancies or voids therein.

Repainting within the mines should be done on clean surfaces absolutely free from all rust, paint skins, dirt, etc. It is not sufficient to apply a new coat of paint over an old paint surface under which traces of corrosion already appear. The new paint will cover the old surface and may adhere firmly thereto, but the corrosion goes on underneath just the same. Attention to these small details will insure a high degree of durability.

WORKING STRESSES IN STEEL

Beams

Structural parts used as beams are so proportioned that the sum of the dead and live loads will not exceed the following unit stresses, given in pounds per square inch.

Bending Stress, extreme fiber of section	16,000
Compressive Stress, direct, gross section	16,000
Tensile Stress, net section	16,000
Shearing Stress (average), gross web section	10,000
Modulus of Elasticity	29,000,000

The safe loads given in tables are for uniformly distributed quiescent loads, and include the weight of the beam. The loads are assumed to act in a plane coincident with the center line of the web and to produce a deflection in this plane only. For beams which are not secured against lateral deflection, the tabular safe loads should be reduced in accordance with the ratio of the unbraced length of beam and its flange width, given in the following table:

Up to 10 x Flange Width: Full Tabular Load

Unbraced Length	Tabular Safe Load	Unbraced Length	Tabular Safe Load	Unbraced Length	Tabular Safe Load
15 x Flange	90.6%	25 x Flange	71.9%	35 x Flange	53.1%
20 x "	81.2%	30 x "	62.5%	40 x "	43.8%

To obtain the vertical deflection in inches, in center of span, for the full tabular load of beam, divide the corresponding coefficient of deflection by the depth of the beam, in inches. Loads in small figures below dotted lines produce deflections which exceed $\frac{1}{360}$ of the span.

The small figures above upper horizontal lines are the safe loads for shear based upon the gross area of the web, at 10000 pounds per square inch.

For beams loaded in the center of the span, use one-half the tabular safe loads and four-fifths of the corresponding coefficients of deflection.

Columns

Structural parts used as columns are so proportioned that the sum of the dead and live loads will not exceed the following unit stresses given in pounds per square inch.

Primary Members—Unsupported Length, l, not to exceed 120 times the least radius of gyration:

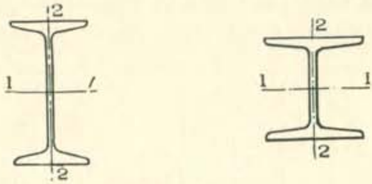
19000—100 l/r.................... maximum 13000

Secondary Members—Unsupported length, l, not to exceed 200 times the least radius of gyration:

13000—50 l/r.................... minimum 6000

The safe loads given in tables are for direct loads equally distributed over the cross section of column or balanced on opposite sides.

ELEMENTS OF STRUCTURAL SECTIONS



STRUCTURAL BEAMS

Section Index	Depth of Section	Weight per Foot	Area of Section	Width of Flange	Thickness of Web	Axis 1-1			Axis 2-2		
						I	r	S	I	r	S
	In.	Lbs.	$In.^2$	In.	In.	$In.^4$	In.	$In.^3$	$In.^4$	In.	$In.^3$
B 18	24	105.9	30.98	7.875	0.625	2811.5	9.53	234.3	78.9	1.60	20.0
B 1		79.9	23.33	7.000	0.500	2087.2	9.46	173.9	42.9	1.36	12.2
B 2	20	81.4	23.74	7.000	0.600	1466.3	7.86	146.6	45.8	1.39	13.1
B 3		65.4	19.08	6.250	0 500	1169.5	7.83	116.9	27.9	1.21	8.9
B 19	18	75.6	22.04	7.000	0.560	1141.8	7.20	126.9	46.3	1.45	13.2
B 4		54.7	15.94	6.000	0.460	795.5	7.07	88.4	21.2	1.15	7.1
B 6	15	60.8	17.68	6.000	0.590	609.0	5.87	81.2	26.0	1.21	8.7
B 7		42.9	12.49	5.500	0.410	441.8	5.95	58.9	14.6	1.08	5.3
B 8	12	40.8	11.84	5.250	0.460	268.9	4.77	44.8	13.8	1.08	5.3
B 9		31.8	9.26	5.000	0.350	215.8	4.83	36.0	9.5	1.01	3.8
B 10	10	25.4	7.38	4.660	0.310	122.1	4.07	24.4	6.9	0.97	3.0
B 11	9	21.8	6.32	4.330	0.290	84.9	3.67	18.9	5.2	0.90	2.4
B 12	8	18.4	5.34	4.000	0.270	56.9	3.26	14.2	3.8	0.84	1.9
B 13	7	15.3	4.43	3.660	0.250	36.2	2.86	10.4	2.7	0.78	1.5
B 14	6	12.5	3.61	3.330	0.230	21.8	2.46	7.3	1.8	0.72	1.1
B 15	5	10.0	2.87	3.000	0.210	12.1	2.05	4.8	1.2	0.65	0.82
B 16	4	7.7	2.21	2.660	0.190	6.0	1.64	3.0	0.77	0.59	0.58
B 17	3	5.7	1.64	2.330	0.170	2.5	1.23	1.7	0.46	0.53	0.40

H-BEAMS

Section Index	Depth of Beam	Weight per Foot	Area of Section	Width of Flange	Thickness of Web	Axis 1-1			Axis 2-2		
						I	r	S	I	r	S
	In.	Lbs.	$In.^2$	In.	In.	$In.^4$	In.	$In.^3$	$In.^4$	In.	$In.^3$
H 4	8	37.7	11.00	8.125	0.500	120.8	3.31	30.2	36.9	1.83	9.1
		34.3	10.00	**8.000**	**0.375**	115.5	3.40	28.9	35.1	1.87	8.8
		32.6	9.50	7.938	0.313	112.8	3.45	28.2	34.2	1.90	8.6
H 3	6	26.7	7.76	6.125	0.438	47.4	2.47	15.8	15.7	1.42	5.1
		24.1	7.01	**6.000**	**0.313**	45.1	2.54	15.0	14.7	1.45	4.9
		22.8	6.63	5.938	0.250	44.0	2.58	14.7	14.2	1.46	4.8
H 2	5	**18.9**	5.47	**5.000**	**0.313**	23.8	2.08	9.5	7.8	1.20	3.1
H 1	4	**13.8**	3.99	**4.000**	**0.313**	10.7	1.64	5.3	3.6	0.95	1.8

STEEL BEAMS

Allowable Uniform Loads in Thousands of Pounds

Maximum Bending Stress, 16,000 Pounds per Square Inch

Span in Feet	I-Beams												Coefficient of Deflection
	24 In.		20 In.		18 In.		15 In.		12 In.		10 In.	9 In.	
	105.9 lb.	79.9 lb.	81.4 lb.	65.4 lb.	75.6 lb.	54.7 lb.	60.8 lb.	42.9 lb.	40.8 lb.	31.8 lb.	25.4 lb.	21.8 lb.	
4							177.0		110.4	84.0	62.0	52.2 / 50.3	0.27
5						165.6	173.2	123.0	95.6	76.7	52.1	40.3	0.41
6			240.0	200.0	201.6	157.1	144.4	104.7	79.7	63.9	43.4	33.6	0.60
7		240.0	223.4	178.2	193.3	134.7	123.7	89.7	68.3	54.8	37.2	28.8	0.81
8	300.0	231.9	195.5	155.9	169.2	117.9	108.3	78.5	59.8	48.0	32.6	25.2	1.06
9	277.7	206.1	173.8	138.6	150.4	104.8	96.2	69.8	53.1	42.6	28.9	22.4	1.34
10	249.9	185.5	156.4	124.7	135.3	94.3	86.6	62.8	47.8	38.4	26.0	20.1	1.66
11	227.2	168.7	142.2	113.4	123.0	85.7	78.7	57.1	43.5	34.9	23.7	18.3	2.00
12	208.3	154.6	130.3	104.0	112.8	78.6	72.2	52.4	39.8	32.0	21.7	16.8	2.38
13	192.2	142.7	120.3	96.0	104.1	72.5	66.6	48.3	36.8	29.5	20.0	15.5	2.80
14	178.5	132.5	111.7	89.1	96.7	67.3	61.9	44.9	34.2	27.4	18.6	14.4	3.24
15	166.6	123.7	104.3	83.2	90.2	62.9	57.7	41.9	31.9	25.6	17.4	13.4	3.72
16	156.2	116.0	97.8	78.0	84.6	58.9	54.1	39.3	29.9	24.0	16.3	12.6	4.24
17	147.0	109.1	92.0	73.4	79.6	55.5	50.9	37.0	28.1	22.6	15.3	11.8	4.78
18	138.8	103.1	86.9	69.3	75.2	52.4	48.1	34.9	26.6	21.3	14.5	11.2	5.36
19	131.5	97.6	82.3	65.7	71.2	49.6	45.6	33.1	25.2	20.2	13.7	10.6	5.98
20	125.0	92.8	78.2	62.4	67.7	47.1	43.3	31.4	23.9	19.2	13.0	10.1	6.62
21	119.0	88.3	74.5	59.4	64.4	44.9	41.2	29.9	22.8	18.3	12.4		7.30
22	113.6	84.3	71.1	56.7	61.5	42.9	39.4	28.6	21.7	17.4	11.8		8.01
23	108.7	80.7	68.0	54.2	58.8	41.0	37.7	27.3	20.8	16.7			8.76
24	104.1	77.3	65.2	52.0	56.4	39.3	36.1	26.2	19.9	16.0			9.53
25	100.0	74.2	62.6	49.9	54.1	37.7	34.6	25.1	19.1	15.3			10.35
26	96.1	71.4	60.2	48.0	52.0	36.3	33.3	24.2	18.4	14.8			11.19
27	92.6	68.7	57.9	46.2	50.1	34.9	32.1	23.3					12.07
28	89.2	66.3	55.9	44.6	48.3	33.7	30.9	22.4					12.98
29	86.2	64.0	53.9	43.0	46.7	32.5	29.9	21.7					13.92
30	83.3	61.8	52.1	41.6	45.1	31.4	28.9	20.9					14.90
31	80.6	59.8	50.5	40.2	43.7	30.4	27.9	20.3					15.91
32	78.1	58.0	48.9	39.0	42.3	29.5	27.1	19.6					16.95
33	75.7	56.2	47.4	37.8	41.0	28.6							18.03
34	73.5	54.6	46.0	36.7	39.8	27.7							19.13
35	71.4	53.0	44.7	35.6	38.7	26.9							20.28
36	69.4	51.5	43.4	34.7	37.6	26.2							21.45
37	67.5	50.1	42.3	33.7	36.6	25.5							22.66
38	65.8	48.8	41.2	32.8	35.6	24.8							23.90
39	64.1	47.6	40.1	32.0									25.18
40	62.5	46.4	39.1	31.2									26.48
41	61.0	45.3	38.1	30.4									27.82
42	59.5	44.2	37.2	29.7									29.20
43	58.1	43.1											30.60
44	56.8	42.2											32.04
45	55.5	41.2											33.52
46	54.3	40.3											35.02
47	53.2	39.5											36.56
48	52.1	38.7											38.14
49	51.0	37.9											39.74
50	50.0	37.1											41.38

In the tables of beam safe loads on this and the following page, note that:
Loads above upper horizontal lines produce maximum shear in webs.
Loads below lower horizontal lines produce deflections exceeding 1/360 of span.

STEEL BEAMS

Allowable Uniform Loads in Thousands of Pounds

Maximum Bending Stress, 16,000 Pounds per Square Inch

Span in Feet	I-Beams					H-Beams								Coefficient of Deflection
	8 in.	7 in.	6 in.	5 in.	4 in.	8 in.			6 in.			5 in.	4 in.	
	18.4 lb.	15.3 lb.	12.5 lb.	10.0 lb.	7.7 lb.	37.7 lb.	34.3 lb.	32.6 lb.	26.7 lb.	24.1 lb.	22.8 lb.	18.9 lb.	13.8 lb.	
			27.6	21.0	15.2								25.0	
3	43.2	35.0	25.8	17.2	10.6				52.5			31.3	19.0	0.15
4	37.9	27.6	19.4	12.9	8.0	80.0			42.1	37.5		25.4	14.3	0.27
5	30.3	22.1	15.5	10.3	6.4	64.4	60.0		33.7	32.1	30.0	20.3	11.4	0.41
6	25.3	18.4	12.9	8.6	5.3	53.7	51.4	50.0	28.1	26.7	26.1	16.9	9.5	0.60
7	21.7	15.8	11.1	7.4	4.5	46.0	44.0	43.0	24.1	22.9	22.3	14.5	8.1	0.81
8	19.0	13.8	9.7	6.4	4.0	40.3	38.5	37.6	21.1	20.1	19.6	12.7	7.1	1.06
9	16.9	12.3	8.6	5.7	3.5	35.8	34.2	33.4	18.7	17.8	17.4	11.3	6.3	1.34
10	15.2	11.0	7.7	5.2	3.2	32.2	30.8	30.1	16.8	16.0	15.6	10.1	5.7	1.66
11	13.8	10.0	7.0	4.7		29.3	28.0	27.3	15.3	14.6	14.2	9.2		2.00
12	12.6	9.2	6.5	4.3		26.8	25.7	25.1	14.0	13.4	13.0	8.5		2.38
13	11.7	8.5	6.0			24.8	23.7	23.1	13.0	12.3	12.0			2.80
14	10.8	7.9	5.5			23.0	22.0	21.5	12.0	11.5	11.2			3.24
15	10.1	7.4				21.5	20.5	20.1						3.72
16	9.5	6.9				20.1	19.3	18.8						4.24
17	8.9					18.9	18.1	17.7						4.78
18	8.4					17.9	17.1	16.7						5.36

Examples for Use of Beam Safe Load Tables

Size and Vertical Deflection of Beams Laterally Braced

1. Load 33000 pounds, uniformly distributed over a span of 19 feet. Nearest safe load is that of a 15 inch, 42.9 lb. beam, viz.: 33100 pounds. Deflection for this load and span from coefficient: 5.98÷15=0.40 inch.

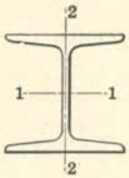
2. Load 12500 pounds, concentrated in center of span of 15 feet. Equivalent uniformly distributed load is 2 x 12500=25000 pounds. Nearest safe load is that of a 12 inch, 31.8 lb. beam, viz.: 25600 pounds. Deflection=4/5 of deflection for 25000 pounds=4/5 x 3.72÷12=0.25 inch.

Safe Load and Vertical Deflection of Beams not Laterally Braced

3. 18 inch, 54.7 lb. beam, uniform load, span 15 feet=62900 pounds.
Ratio: length of span ÷ flangewidth=15 x 12÷6.0=30.
Reduced uniform load=62900 x 62.5%=39300 pounds.
Deflection for reduced load=3.72 ÷ 18 x 62.5% =0.13 inch.

Safe Load and Vertical Deflection of Beams for other Fiber Stresses

4. 8 inch, 32.6 lb. H-Beam, span 13 feet, fiber stress 18000 pounds.
Ratio of fiber stress 18000÷16000=9/8.
Tabular load=23100; load for increased stress; 23100 x 9/8=26000 pounds.
Deflection for increased load=2.80÷8 x 9/8=0.39 inch.



STEEL BEAM COLUMNS

SAFE LOAD IN THOUSANDS OF POUNDS

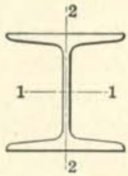
Allowable Fiber Stress per square inch, 13,000 pounds for lengths of 60 radii or under, reduced for lengths over 60 radii; see in accordance with formulas:

19,000—100 l/r, up to l/r = 120. 13,000—50l/r, up to l/r=200

Weights do not include details.

Effective Length in Feet	I-Beams											
	24 in.		20 in.		18 in.		15 in.		12 in.		10 in.	9 in.
	105.9 lb.	79.9 lb.	81.4 lb.	65.4 lb.	75.6 lb.	54.7 lb.	60.8 lb.	42.9 lb.	40.8 lb.	31.8 lb.	25.4 lb.	21.8 lb.
3	402.7	303.2	308.5	248.0	286.5	207.1	229.7	162.3	153.9	120.3	95.9	82.1
4	402.7	303.2	308.5	248.0	286.5	207.1	229.7	162.3	153.9	120.3	95.9	82.1
5	402.7	303.2	308.5	248.0	286.5	207.1	229.7	162.3	153.9	120.3	94.3	78.0
6	402.7	303.2	308.5	248.0	286.5	207.1	229.7	154.1	146.0	110.1	85.1	69.7
7	402.7	298.6	307.4	229.8	286.5	186.7	213.3	140.3	132.9	99.1	76.0	61.3
8	402.3	278.0	286.9	210.9	272.7	170.1	195.8	126.4	119.7	88.2	66.8	52.9
9	379.0	257.4	266.4	192.0	254.5	153.5	178.3	112.6	106.6	77.2	57.7	44.5
10	355.7	236.7	245.9	173.0	236.2	136.9	160.8	98.7	93.4	66.2	50.1	40.2
11	332.4	216.1	223.4	154.0	218.0	120.3	142.3	86.1	81.6	60.0	45.5	36.0
12	309.1	195.4	204.9	135.1	199.7	107.6	125.8	79.2	75.0	54.5	40.9	31.8
13	285.8	174.8	184.4	124.8	181.5	99.3	116.0	72.3	68.4	49.1	36.3	27.6
14	262.5	158.7	165.0	115.4	163.2	91.1	107.3	65.4	61.8	43.6	31.7	23.4
15	239.2	148.4	154.8	105.9	149.6	82.8	98.5	58.4	55.3	38.1	27.2	19.2
16	215.9	138.1	144.5	96.4	140.5	74.5	89.8	51.5	48.7	32.6	22.6	
17	204.7	127.8	134.3	86.9	131.4	66.2	81.0	44.6	42.1	27.1		
18	193.1	117.4	124.0	77.5	122.2	57.9	72.3	37.7	35.5			
19	181.4	107.1	113.8	68.0	113.1	49.6	63.5					
20	169.8	96.8	103.5	58.5	104.0		54.8					
21	158.2	86.5	93.3		94.9							
22	146.5	76.2	83.0		85.7							
23	134.9	65.8	72.7		76.6							
24	123.2				67.5							
25	111.6											
26	99.9											
27	88.3											
28												
29												
30												
Area, in.^{2}	30.98	23.33	23.74	19.08	22.04	15.94	17.68	12.49	11.84	9.26	7.38	6.32
I_{1-1}, in.^{4}	2811.5	2087.2	1466.3	1169.5	1141.8	795.5	609.0	441.8	268.9	215.8	122.1	84.9
r_{1-1}, in.	9.53	9.46	7.86	7.83	7.20	7.07	5.87	5.95	4.77	4.83	4.07	3.67
I_{2-2}, in.^{4}	78.9	42.9	45.8	27.9	46.3	21.2	26.0	14.6	13.8	9.5	6.9	5.2
r_{2-2}, in.	1.60	1.36	1.39	1.21	1.45	1.15	1.21	1.08	1.08	1.01	0.97	0.90
Weight, Lbs. per Foot	105.9	79.9	81.4	65.4	75.6	54.7	60.8	42.9	40.8	31.8	25.4	21.8

Safe load values above upper zigzag line are for ratios of l/r not over 60, those between the zigzag line are for ratios up to 120 l/r and those below lower zigzag line are for ratios not over 200 l/r.



STEEL BEAM COLUMNS

SAFE LOADS IN THOUSANDS OF POUNDS

Allowable Fiber Stress per square inch, 13,000 pounds for lengths of 60 radii or under, reduced for lengths over 60 radii; see in accordance with formulas:

$19{,}000 - 100\,l/r$, up to $l/r = 120$. $13{,}000 - 50\,l/r$, up to $l/r = 200$

Weights do not include details.

Effective Length in Feet	I-Beams					H Beams							
	8 in.	7 in.	6 in.	5 in.	4 in.	8 in.			6 in.			5 in.	4 in.
	18.4 lb.	15.3 lb.	12.5 lb.	10.0 lb.	7.7 lb.	37.7 lb.	34.3 lb.	32.6 lb.	26.7 lb.	24.1 lb.	22.8 lb.	18.9 lb.	13.8 lb.
3	69.3	57.5	46.9	37.3	28.5	143.0	130.0	123.6	100.9	91.1	86.2	71.1	51.9
4	69.3	56.7	44.4	33.5	24.0	143.0	130.0	123.6	100.9	91.1	86.2	71.1	51.9
5	63.3	49.9	38.3	28.2	19.5	143.0	130.0	123.6	100.9	91.1	86.2	71.1	50.5
6	55.7	43.1	32.3	22.9	15.2	143.0	130.0	123.6	100.9	91.1	86.2	71.1	45.5
7	48.1	36.2	26.2	18.9	13.0	143.0	130.0	123.6	100.9	91.1	86.2	65.6	40.4
8	40.5	30.2	22.7	16.3	10.8	143.0	130.0	123.6	95.1	86.7	82.5	60.1	35.3
9	35.1	26.8	19.7	13.6	8.5	143.0	130.0	123.6	88.5	80.9	77.1	54.6	30.3
10	31.3	23.4	16.7	11.0	6.3	136.9	126.0	120.5	82.0	75.1	71.7	49.1	26.6
11	27.5	19.9	13.6	8.3		129.7	119.6	114.5	75.4	69.3	66.2	43.7	24.0
12	23.7	16.5	10.6			122.5	113.2	108.5	68.9	63.5	60.8	38.2	21.5
13	19.9	13.1				115.3	106.8	102.5	62.4	57.6	55.4	35.5	19.0
14	16.1					108.1	100.4	96.5	55.8	51.8	49.9	32.7	16.4
15						100.9	93.9	90.4	51.8	47.5	45.5	30.0	13.9
16						93.7	87.5	84.4	48.5	44.6	42.7	27.3	
17						86.4	81.1	78.4	45.2	41.7	40.0	24.5	
18						79.2	74.7	72.4	42.0	38.8	37.3	21.8	
19						74.5	69.2	66.5	38.7	35.9	34.6	19.1	
20						70.9	66.0	63.5	35.4	33.0	31.9	16.3	
21						67.3	62.8	60.5	32.2	30.1	29.2		
22						63.7	59.6	57.5	28.9	27.2	26.5		
23						60.1	56.4	54.4	25.6	24.3	23.7		
24						56.5	53.2	51.4	22.3	21.4	21.0		
25						52.9	50.0	48.4					
26						49.3	46.8	45.4					
27						45.7	43.6	42.4					
28						42.1	40.4	39.4					
29						38.5	37.2	36.4					
30						34.9	33.9	33.4					
Area, in.^{2}	5.34	4.43	3.61	2.87	2.21	11.00	10.00	9.50	7.76	7.01	6.63	5.47	3.99
I_{1-1}, in.^{4}	56.9	36.2	21.8	12.1	6.0	120.8	115.5	112.8	47.4	45.1	44.0	23.8	10.7
r_{1-1}, in.	3.26	2.86	2.46	2.05	1.64	3.31	3.40	3.45	2.47	2.54	2.58	2.08	1.64
I_{2-2}, in.^{4}	3.8	2.7	1.8	1.2	0.77	36.9	35.1	34.2	15.7	14.7	14.2	7.8	3.6
r_{2-2}, in.	0.84	0.78	0.72	0.65	0.59	1.83	1.87	1.90	1.42	1.45	1.46	1.20	0.95
Weight, Lbs. per Foot	18.4	15.3	12.5	10.0	7.7	37.7	34.3	32.6	26.7	24.1	22.8	18.9	13.8

Safe load values above upper zigzag line are for ratios of l/r not over 60, those between the zigzag lines are for ratios up to 120 l/r and those below lower zigzag line are for ratios not over 200 l/r.

WORKING STRESSES IN WOOD

The strength of structural wooden timbers depends upon a number of factors; the kind of wood, the age of the tree, the time of year in which it was felled, the method of sawing, the character of seasoning, its moisture content, its proportion of heartwood to sapwood and of knots to clear wood, etc.

The most recent studies in this direction have been made by the American Railway Engineering Association and the tables which follow are based on the working unit stresses adopted by that Association for railway bridges. The values are based on carefully selected timbers purchased under the standard specifications of the Association and subject to careful inspection.

These unit stresses are intended, as noted, for railway bridges and trestles. For highway bridges and trestles and for buildings and similar structures, the unit stresses may be increased in accordance with the more quiescent character of the loading and freedom from deleterious weather conditions.

The commercial timbers, which are in common use in building construction, will not meet A. R. E. A. specifications, and, therefore, the unit stresses approved in the building laws of various cities are lower. The tables, as they stand, are in accord with the average practice as represented by these building laws, and may, therefore, be used for ordinary building work executed with the commercial grades of timber, such as can be purchased in the open market.

In inside mine work where the timbers are often green and, in the case of round timbers, unpeeled, and all subject to stress under rather humid conditions, the tabular values are generally applicable, but no greater values should be used where steel is to be substituted for wooden timbers already in place.

WOODEN BEAMS

The safe load tables of wooden beams which follow, give the uniformly distributed safe loads for rectangular sections one inch thick; the safe load for a beam of any thickness is found by multiplying the tabular value by the thickness of the beam in inches. The safe loads include the weight of the beams and apply only when the beams are braced against lateral deflection. Tables also give minimum and maximum spans and coefficients of deflection.

The maximum safe loads as limited by the allowable shearing stresses along horizontal axes of beams, indicated by horizontal lines in the tables, should not be exceeded to avoid failure of the beam in horizontal direction of the grain of the wood.

The theoretical deflection in the center of the span for uniformly distributed and permanently applied loads is obtained from the coefficients of deflection by dividing the depth of the beam, in inches, into the corresponding coefficient; the result obtained only approximates the actual deflection, as the modulus of elasticity varies with the moisture content of the wood.

The deflection of beams intended to carry plastered ceilings should not exceed 1/360 of the span; the table gives the maximum spans for this limit, for uniformly distributed and permanently applied loads.

For loads concentrated in center of span, use one-half the values of tabular loads and four-fifths of coefficients of deflection.

Tables of safe loads are also given for common sizes of square and round beams frequently used in the timbering of mines, convenient for ready reference.

EXAMPLE 1.—Required the thickness and the approximate deflection of a beam of white oak, 14 inches deep, supporting a uniformly distributed and permanent dead and live load of 10,000 pounds over a span of 19 feet.

The tabular value for a beam one inch thick and for a span of 19 feet is 1,261 pounds; the required thickness is therefore 10,000 ÷ 1,261 = 8 inches, and the deflection is 20.72 ÷ 14 = 1.48 inches.

EXAMPLE 2.—Required the safe load of a beam of white pine, 8 inches deep and 6 inches thick, without exceeding the longitudinal shearing stress.

The table gives for a corresponding beam 1 inch thick a safe load of 747 pounds; the total safe load is therefore 6 x 747 = 4,482 pounds, or the safe load which can be safely supported over a span of 8.6 feet.

EXAMPLE 3.—Required the safe load of a beam of longleaf pine, 18 inches deep and 12 inches thick, concentrated in the center of a span 26 feet long and the deflection of beam under this concentrated load.

The table gives for a corresponding beam 1 inch thick a uniformly distributed safe load of 1,800 pounds, or for a load in center of span 1,800 ÷ 2 = 900 pounds; for a beam 12 inches wide the safe load is therefore 900 x 12 = 10,800 pounds; the deflection is approximately 4/5 x 32.75 ÷ 18 = 1.46 inches.

WORKING UNIT STRESSES FOR STRUCTURAL TIMBER

ADOPTED BY THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

The working unit stresses given in the table are intended for railroad bridges and trestles. For highway bridges and trestles, the unit stresses may be increased 25 per cent. For buildings and similar structures, in which the timber is protected from the weather and practically free from impact, the unit stresses may be increased 50 per cent. To compute the deflection of a beam under long continued loading instead of that when the load is first applied, only 50 per cent. of the corresponding modulus of elasticity given in the table is to be employed.

Unit Stresses in Pounds per Square Inch

Kind of Timber	Bending			Shearing				Compression					
	Extreme Fiber Stress		Modulus of Elasticity	Parallel to the Grain		Longitudinal Shear in Beams		Perpendicular to the Grain		Parallel to the Grain		Working Stresses for Columns	
	Average Ultimate	Working Stress	Average	Average Ultimate	Working Stress	Average Ultimate	Working Stress	Elastic Limit	Working Stress	Average Ultimate	Working Stress	Length under 15 x d	Length over 15 x d
Douglas Fir	6100	1200	1510000	690	170	270	110	630	310	3600	1200	900	1200(1—l/60d)
Longleaf Pine	6500	1300	1610000	720	180	300	120	520	260	3800	1300	975	1300(1—l/60d)
Shortleaf Pine	5600	1100	1480000	710	170	330	130	340	170	3400	1100	825	1100(1—l/60d)
White Pine	4400	900	1130000	400	100	180	70	290	150	3000	1000	750	1000(1—l/60d)
Spruce	4800	1000	1310000	600	150	170	70	370	180	3200	1100	825	1100(1—l/60d)
Norway Pine	4200	800	1190000	590*	130	250	100		150	2600*	800	600	800(1—l/60d)
Tamarack	4600	900	1220000	670	170	260	100		220	3200*	1000	750	1000(1—l/60d)
Western Hemlock	5800	1100	1480000	630	160	270*	100	440	220	3500	1200	900	1200(1—l/60d)
Redwood	5000	900	800000	300	80			400	150	3300	900	675	900(1—l/60d)
Bald Cypress	4800	900	1150000	500	120			340	170	3900	1100	825	1100(1—l/60d)
Red Cedar	4200	800	800000					470	230	2800	900	675	900(1—l/60d)
White Oak	5700	1100	1150000	840	210	270	110	920	450	3500	1300	975	1300(1—l/60d)

Unit stresses are for green timber and are to be used without increasing the live load stresses for impact. Values noted* are for partially air dry timbers.

In the formulas given for columns, l=length of column, in inches, and d=least side or diameter, in inches.

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

Maximum Safe Loads and Limiting Spans

Depth of Beam, Inches	White Oak		Longleaf Pine		Shortleaf Pine		White Pine		Douglas Fir		Western Hemlock		Spruce	
	Max. Load, Lbs.	Min. Span, Ft.	Max. Load, Lbs.	Min. Span, Ft.	Max. Load, Lbs.	Min. Span, Ft.	Max. Load, Lbs.	Min. Span, Ft.	Max. Load, Lbs.	Min. Span, Ft.	Max. Load, Lbs.	Min. Span, Ft.	Max. Load, Lbs.	Min. Span, Ft.
2	293	1.7	320	1.8	347	1.4	187	2.1	293	1.8	267	1.8	187	2.4
4	587	3.3	640	3.6	693	2.8	373	4.3	587	3.6	533	3.7	373	4.8
6	880	5.0	960	5.4	1040	4.2	560	6.4	880	5.5	800	5.5	560	7.1
8	1173	6.7	1280	7.2	1387	5.6	747	8.6	1173	7.3	1067	7.3	747	9.5
10	1467	8.4	1600	9.0	1733	7.1	933	10.7	1467	9.1	1333	9.2	933	11.9
12	1760	10.0	1920	10.8	2080	8.5	1120	12.9	1760	10.9	1600	11.0	1120	14.3
14	2053	11.7	2240	12.6	2427	9.9	1307	15.0	2053	12.8	1867	12.8	1307	16.7
16	2347	13.4	2560	14.4	2773	11.3	1493	17.1	2347	14.6	2133	14.7	1493	19.0
18	2640	15.0	2880	16.3	3120	12.7	1680	19.3	2640	16.4	2400	16.5	1680	21.4
20	2933	16.7	3200	18.1	3467	14.1	1867	21.4	2933	18.2	2667	18.3	1867	23.8
22	3227	18.4	3520	19.9	3813	15.5	2053	23.6	3227	20.0	2933	20.2	2053	26.2
24	3520	20.0	3840	21.7	4160	16.9	2240	25.7	3520	21.9	3200	22.0	2240	28.6

Coefficients of Deflection for Permanent Loads

Span in Feet	White Oak	Longleaf Pine	Shortleaf Pine, Western Hemlock	White Pine, Douglas Fir	Spruce	Span in Feet	White Oak	Longleaf Pine	Shortleaf Pine, Western Hemlock	White Pine, Douglas Fir	Spruce
1	0.06	0.05	0.05	0.05	0.05	21	25.31	21.37	19.67	21.05	20.20
2	0.23	0.19	0.18	0.19	0.18	22	27.78	23.44	21.59	23.10	22.17
3	0.52	0.44	0.40	0.43	0.41	23	30.37	25.63	23.59	25.25	24.23
4	0.92	0.78	0.71	0.76	0.73	24	33.06	27.91	25.69	27.49	26.38
5	1.44	1.21	1.12	1.19	1.15	25	35.88	30.28	27.88	29.83	28.63
6	2.07	1.74	1.61	1.72	1.65	26	38.80	32.75	30.15	32.27	30.96
7	2.81	2.37	2.19	2.34	2.24	27	41.85	35.32	32.51	34.80	33.39
8	3.67	3.10	2.85	3.06	2.93	28	45.00	37.99	34.97	37.42	35.91
9	4.65	3.92	3.61	3.87	3.71	29	48.27	40.75	37.51	40.14	38.52
10	5.74	4.85	4.46	4.77	4.58	30	51.66	43.61	40.14	42.96	41.22
11	6.95	5.86	5.40	5.78	5.54	31	55.16	46.56	42.86	45.87	44.01
12	8.27	6.98	6.42	6.87	6.60	32	58.78	49.61	45.67	48.88	46.90
13	9.70	8.19	7.54	8.07	7.74	33	62.51	52.76	48.57	51.98	49.88
14	11.25	9.50	8.74	9.36	8.98	34	66.35	56.01	51.56	55.18	52.95
15	12.92	10.90	10.04	10.74	10.31	35	70.32	59.35	54.64	58.47	56.11
16	14.69	12.40	11.42	12.22	11.73	36	74.39	62.79	57.80	61.86	59.36
17	16.59	14.00	12.89	13.79	13.24	37	78.58	66.33	61.06	65.34	62.70
18	18.60	15.70	14.45	15.47	14.84	38	82.89	69.96	64.40	68.92	66.14
19	20.72	17.49	16.10	17.23	16.53	39	87.31	73.69	67.84	72.60	69.66
20	22.96	19.38	17.84	19.09	18.32	40	91.84	77.52	71.36	76.37	73.28

Maximum Spans in Feet for Deflections = 1/360 Span

Species of Timber	Depth of Beam in Inches											
	2	4	6	8	10	12	14	16	18	20	22	24
White Oak	1.2	2.3	3.5	4.6	5.8	7.0	8.1	9.3	10.5	11.6	12.8	13.9
Longleaf Pine	1.4	2.8	4.1	5.5	6.9	8.3	9.6	11.0	12.4	13.8	15.1	16.5
Shortleaf Pine, Hemlock	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.4	17.9
White Pine, Douglas Fir	1.4	2.8	4.2	5.6	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.7
Spruce	1.5	2.9	4.4	5.8	7.3	8.7	10.2	11.6	13.1	14.6	16.0	17.5

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

LONGLEAF PINE

ALLOWABLE UNIFORM LOAD IN POUNDS

Maximum Bending Stress, 1300 Pounds per Square Inch

Span in Feet	Depth of Beam in Inches											
	2	4	6	8	10	12	14	16	18	20	22	24
2	320 289											
3	193											
4	144	640 578										
5	116	462										
6	96	385	960 867									
7	83	330	743									
8	72	289	650	1280 1156								
9		257	578	1027								
10		231	520	924	1600 1444							
11		210	473	840	1313	1920 1891						
12		193	433	770	1204	1733						
13			400	711	1111	1600	2240 2178					
14			371	660	1032	1486	2022					
15			347	616	963	1387	1887	2560 2465				
16			325	578	903	1300	1769	2311				
17				544	850	1224	1665	2175	2880 2753			
18				514	802	1156	1573	2054	2600			
19				487	760	1095	1490	1946	2463	3200 3041		
20				462	722	1040	1416	1849	2340	2889	3520 3496	
21					688	991	1348	1761	2229	2751	3329	
22					657	945	1287	1681	2127	2626	3178	3840 3782
23					628	904	1231	1608	2035	2512	3040	3617
24					602	867	1180	1541	1950	2407	2913	3467
25						832	1132	1479	1872	2311	2796	3328
26						800	1089	1422	1800	2222	2689	3200
27						770	1049	1370	1733	2140	2589	3082
28						743	1011	1321	1671	2064	2497	2971
29							976	1275	1614	1992	2411	2869
30							944	1233	1560	1926	2330	2773
31							913	1193	1510	1864	2255	2684
32							885	1156	1463	1806	2185	2600
33								1121	1418	1751	2119	2521
34								1088	1377	1699	2056	2447
35								1057	1337	1651	1998	2377
36								1027	1300	1605	1942	2311
37									1265	1562	1890	2249
38									1232	1521	1840	2189
39									1200	1482	1793	2133
40									1170	1444	1748	2080

Horizontal lines indicate the limit for resistance to shear in the horizontal direction of the grain.

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

DOUGLAS FIR

Allowable Uniform Load in Pounds

Maximum Bending Stress, 1200 Pounds per Square Inch

Span in Feet	Depth of Beam in Inches											
	2	4	6	8	10	12	14	16	18	20	22	24
2	293 267											
3	178											
4	133	587 533										
5	107	427										
6	89	356	880 800									
7	76	305	686									
8	67	267	600	1173 1067								
9		237	533	948								
10		213	480	853	1467 1333							
11		194	436	776	1212	1760 1745						
12		178	400	711	1111	1600						
13			369	656	1026	1477	2053 2010					
14			343	610	952	1371	1867					
15			320	569	889	1280	1742	2347 2276				
16			300	533	833	1200	1633	2133				
17				502	784	1129	1537	2008	2640 2541			
18				474	741	1067	1452	1896	2400			
19				449	702	1011	1375	1796	2274	2933 2807		
20				427	667	960	1307	1707	2160	2667	3227 3227	
21					635	914	1244	1625	2057	2540	3073	
22					606	873	1188	1552	1964	2424	2933	3520 3491
23					580	835	1136	1484	1878	2319	2806	3339
24					556	800	1089	1422	1800	2222	2689	3200
25						768	1045	1365	1728	2133	2581	3072
26						738	1005	1313	1662	2051	2482	2954
27						711	968	1264	1600	1975	2390	2844
28						686	933	1219	1543	1905	2305	2743
29							901	1177	1490	1839	2225	2648
30							871	1138	1440	1778	2151	2560
31							843	1101	1394	1720	2082	2477
32							817	1067	1350	1667	2017	2400
33								1034	1309	1616	1956	2327
34								1004	1271	1569	1898	2259
35								975	1234	1524	1844	2194
36								948	1200	1481	1793	2133
37									1168	1441	1744	2076
38									1137	1404	1698	2021
39									1108	1368	1655	1969
40									1080	1333	1613	1920

Horizontal lines indicate the limit for resistance to shear in the horizontal direction of the grain.

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

SHORTLEAF PINE, WESTERN HEMLOCK AND WHITE OAK

Allowable Uniform Load in Pounds

Maximum Bending Stress, 1100 Pounds per Square Inch

Span in Feet	Depth of Beam in Inches											
	2	4	6	8	10	12	14	16	18	20	22	24
	347											
2	245	693										
3	163	652										
4	122	489	1040									
5	98	391	880	1387								
6	82	326	733	1304								
7	70	279	629	1117	1733							
8	61	245	550	978	1528	2080						
9		217	489	869	1358	1956	2427					
10		196	440	782	1222	1760	2396					
11		178	400	711	1111	1600	2178	2773				
12		163	367	652	1019	1467	1996	2607	3120			
13			338	602	940	1354	1843	2407	3046			
14			314	559	873	1257	1711	2235	2829	3467		
15			293	522	816	1173	1597	2086	2640	3259	3813	
16			275	489	764	1100	1497	1956	2475	3055	3697	4160
17				460	719	1035	1409	1841	2329	2876	3480	4141
18				435	679	978	1331	1738	2200	2716	3287	3911
19				412	643	926	1261	1647	2084	2573	3113	3705
20				391	611	880	1198	1564	1980	2444	2958	3520
21					583	838	1141	1490	1886	2328	2817	3352
22					556	800	1089	1422	1800	2222	2689	3200
23					531	765	1042	1361	1722	2126	2572	3061
24					509	733	998	1304	1650	2037	2465	2933
25						704	958	1252	1584	1956	2366	2816
26						677	921	1203	1523	1880	2275	2708
27						652	887	1159	1467	1811	2191	2608
28						629	856	1118	1414	1746	2113	2514
29							826	1079	1366	1686	2040	2428
30							799	1043	1320	1630	1973	2348
31							773	1009	1278	1577	1908	2271
32							749	978	1238	1528	1849	2200
33								948	1200	1482	1793	2133
34								920	1165	1438	1740	2071
35								894	1131	1397	1690	2011
36								869	1100	1358	1643	1956
37									1070	1321	1599	1903
38									1042	1287	1557	1853
39									1015	1254	1517	1805
40									990	1222	1479	1760

Upper, middle, and lower horizontal lines indicate the limits for resistance to shear in the horizontal direction of the grain of Shortleaf Pine, White Oak, and Hemlock respectively.

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

SPRUCE

Allowable Uniform Load in Pounds

Maximum Bending Stress, 1000 Pounds per Square Inch

Span in Feet	Depth of Beam in Inches											
	2	4	6	8	10	12	14	16	18	20	22	24
2	187											
3	148											
4	111	373										
5	89	356										
6	74	296										
7	63	254	560									
8	56	222	500									
9		198	444	747								
10		178	400	711								
11		162	364	646	933							
12		148	333	593	926							
13			308	547	855							
14			286	508	794	1120						
15			267	474	741	1067						
16			250	444	694	1000	1307					
17				418	654	941	1281					
18				395	617	889	1210					
19				374	585	842	1146	1493				
20				356	556	800	1089	1422				
21					529	762	1037	1354	1680			
22					505	727	990	1293	1636			
23					483	696	947	1237	1565	1867		
24					463	667	907	1185	1500	1852		
25						640	871	1138	1440	1778		
26						615	838	1094	1385	1709	2053	
27						593	807	1053	1333	1646	1992	
28						571	778	1016	1286	1587	1921	2240
29							751	981	1241	1533	1854	2207
30							726	948	1200	1481	1793	2133
31							703	918	1161	1434	1735	2065
32							681	889	1125	1389	1681	2000
33								862	1091	1347	1630	1939
34								837	1059	1307	1582	1882
35								813	1029	1270	1537	1829
36								790	1000	1235	1494	1778
37									973	1201	1453	1730
38									947	1169	1415	1684
39									923	1140	1379	1641
40									900	1111	1344	1600

Horizontal lines indicate the limit for resistance to shear in the horizontal direction of the grain.

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

WHITE PINE

ALLOWABLE UNIFORM LOAD IN POUNDS

Maximum Bending Stress, 900 Pounds per Square Inch

Span in Feet	Depth of Beam in Inches											
	2	4	6	8	10	12	14	16	18	20	22	24
2	187											
3	133											
4	100	373										
5	80	320										
6	67	267	560									
7	57	229	514									
8	50	200	450	747								
9		178	400	711								
10		160	360	640	933							
11		145	327	582	909							
12		133	300	533	833	1120						
13			277	492	769	1108						
14			257	457	714	1029	1307					
15			240	427	667	960	1307					
16			225	400	625	900	1225					
17				377	588	847	1153	1493				
18				356	556	800	1089	1422				
19				337	526	758	1032	1347	1680			
20				320	500	720	980	1280	1620			
21					476	686	933	1219	1543	1867		
22					455	655	891	1164	1473	1818		
23					435	626	852	1113	1409	1739	2053	
24					417	600	817	1067	1350	1667	2017	
25						576	784	1024	1296	1600	1936	2240
26						554	754	985	1246	1538	1862	2215
27						533	726	948	1200	1481	1793	2133
28						514	700	914	1157	1429	1729	2057
29							676	883	1117	1379	1669	1986
30							653	853	1080	1333	1613	1920
31							632	826	1045	1290	1561	1858
32							613	800	1013	1250	1513	1800
33								776	982	1212	1467	1746
34								753	953	1176	1424	1694
35								731	926	1143	1383	1646
36								711	900	1111	1344	1600
37									876	1081	1308	1557
38									853	1053	1274	1516
39									831	1026	1241	1477
40									810	1000	1210	1440

Horizontal lines indicate the limit for resistance to shear in the horizontal direction of the grain.

SQUARE WOODEN BEAMS

Allowable Uniform Loads in Thousands of Pounds

American Railway Engineering Association Fiber Stresses

	Span in Feet	Side of Square, Inches							
		6	8	10	12	14	16	18	20
LONGLEAF PINE 1300 lb./sq. in.		*6.2*	*10.2*						
	8	3.9	9.2						
	9	3.5	8.2	*16.0*					
	10	3.1	7.4	14.4	*23.0*				
	11	2.8	6.7	13.1	22.7				
	12	2.6	6.2	12.0	20.8	*31.4*			
	13	2.4	5.7	11.1	19.2	30.5			
	14	2.2	5.3	10.3	17.8	28.3	*41.0*		
	15	2.1	4.9	9.6	16.6	26.4	39.4		
	16	2.0	4.6	9.0	15.6	24.8	37.0	*51.8*	
	17		4.4	8.5	14.7	23.3	34.8	49.6	
	18		4.1	8.0	13.9	22.0	32.9	46.8	*64.0*
	19		3.9	7.6	13.1	20.9	31.1	44.3	60.8
	20		3.7	7.2	12.5	19.8	29.6	42.1	57.8
SHORTLEAF PINE WHITE OAK—HEMLOCK 1100 lb./sq. in.		*5.3*	*9.4*						
	8	3.3	7.8	*14.7*					
	9	2.9	7.0	13.6	*21.1*				
	10	2.6	6.3	12.2	21.1				
	11	2.4	5.7	11.1	19.2	*28.7*			
	12	2.2	5.2	10.2	17.6	27.9			
	13	2.0	4.8	9.4	16.3	25.8	*37.5*		
	14	1.7	4.5	8.7	15.1	24.0	35.8	*47.5*	
	15	1.8	4.2	8.2	14.1	22.4	33.4	47.5	
	16	1.7	3.9	7.6	13.2	21.0	31.3	44.6	*58.7*
	17		3.7	7.2	12.4	19.7	29.4	41.9	57.5
	18		3.5	6.8	11.7	18.6	27.8	39.6	54.3
	19		3.3	6.4	11.1	17.7	26.4	37.5	51.5
	20		3.1	6.1	10.6	16.8	25.0	35.6	48.9
SPRUCE 1000 lb./sq. in.		*3.4*							
	8	3.0							
	9	2.7	*6.0*						
	10	2.4	5.7						
	11	2.2	5.2	*9.3*					
	12	2.0	4.7	9.3					
	13	1.8	4.4	8.5					
	14	1.7	4.1	7.9	*13.4*				
	15	1.7	3.8	7.4	12.8				
	16	1.5	3.6	6.9	12.0	*18.3*			
	17		3.3	6.5	11.3	17.9			
	18		3.2	6.2	10.7	16.9			
	19		3.0	5.8	10.1	16.0	*23.9*		
	20		2.8	5.6	9.6	15.2	22.8	*30.2*	*37.3*
WHITE PINE 900 lb./sq. in.		*3.4*							
	8	2.7	*6.0*						
	9	2.4	5.7						
	10	2.2	5.1	*9.3*					
	11	2.0	4.7	9.1					
	12	1.8	4.3	8.3	*13.4*				
	13	1.7	3.9	7.7	13.3				
	14	1.5	3.7	7.1	12.3	*18.3*			
	15	1.4	3.4	6.7	11.5	18.3			
	16	1.4	3.2	6.3	10.8	17.2			
	17		3.0	5.9	10.2	16.1	*23.9*		
	18		2.8	5.6	9.6	15.2	22.8		
	19		2.7	5.3	9.1	14.4	21.6	*30.2*	
	20		2.6	5.0	8.6	13.7	20.5	29.2	*37.3*

Loads in small figures are the limit for resistance to horizontal shear.

ROUND WOODEN BEAMS

Allowable Uniform Loads in Thousands of Pounds

American Railway Engineering Association Fiber Stresses

	Span in Feet	Diameter, Inches 6	8	10	12	14	16	18	20
LONGLEAF PINE 1300 lb./sq. in.		5.1	9.1	14.1	20.4				
	8	2.3	5.4	10.6	18.4	27.7			
	9	2.0	4.8	9.5	16.3	25.9	36.2		
	10	1.8	4.4	8.5	14.7	23.4	34.9	45.8	
	11	1.7	4.0	7.7	13.4	21.2	31.7	45.1	
	12	1.5	3.6	7.1	12.3	19.5	29.0	41.4	56.6
	13	1.4	3.4	6.6	11.3	18.0	26.8	38.2	52.4
	14	1.3	3.1	6.1	10.5	16.7	24.9	35.4	48.6
	15	1.2	2.9	5.7	9.8	15.6	23.2	33.1	45.4
	16	1.1	2.7	5.3	9.2	14.6	21.8	31.0	42.5
	17		2.6	5.0	8.7	13.7	20.5	29.2	40.0
	18		2.4	4.7	8.2	13.0	19.4	27.6	37.8
	19		2.3	4.5	7.7	12.3	18.3	26.1	35.8
	20		2.2	4.3	7.4	11.7	17.4	24.8	34.0
SHORTLEAF PINE WHITE OAK—HEMLOCK 1100 lb./sq. in.		4.7	8.3	13.0	18.7	25.4			
	8	1.9	4.6	9.0	15.6	24.7	33.2		
	9	1.7	4.1	8.0	13.8	22.0	32.8		
	10	1.6	3.7	7.2	12.4	19.8	29.5	42.0	
	11	1.4	3.4	6.6	11.3	18.0	26.8	38.2	51.8
	12	1.3	3.1	6.0	10.4	16.5	24.6	35.0	48.0
	13	1.2	2.8	5.5	9.6	15.2	22.7	32.3	44.3
	14	1.1	2.6	5.1	8.9	14.1	21.1	30.0	41.1
	15	1.0	2.5	4.8	8.3	13.2	19.7	28.0	38.4
	16	1.0	2.3	4.5	7.8	12.4	18.4	26.2	36.0
	17			4.2	7.3	11.6	17.4	24.7	33.9
	18			4.0	6.9	11.0	16.4	23.3	32.0
	19			3.8	6.6	10.4	15.5	22.1	30.3
	20			3.6	6.2	9.9	14.8	21.0	28.8
SPRUCE 1000 lb./sq. in.		3.0	5.3	8.2					
	8	1.8	4.2	8.2					
	9	1.6	3.7	7.3	11.9				
	10	1.4	3.4	6.5	11.3				
	11	1.3	3.0	6.0	10.3	16.2			
	12	1.2	2.8	5.5	9.4	15.0	21.1		
	13	1.1	2.6	5.0	8.7	13.8	20.6		
	14	1.0	2.4	4.7	8.1	12.8	19.1	26.7	
	15	0.9	2.2	4.4	7.5	12.0	17.9	25.4	33.0
	16	0.9	2.1	4.1	7.1	11.2	16.8	23.9	32.7
	17		2.0	3.9	6.7	10.6	15.8	22.5	30.8
	18		1.9	3.6	6.3	10.0	14.8	21.2	29.1
	19		1.8	3.4	6.0	9.5	14.1	20.1	27.6
	20		1.7	3.3	5.7	9.0	13.4	19.1	26.2
WHITE PINE 900 lb./sq. in.		3.0	5.3	8.3					
	8	1.6	3.8	7.4	11.9				
	9	1.4	3.3	6.6	11.3	16.2			
	10	1.3	3.0	5.9	10.2	16.2			
	11	1.2	2.7	5.4	9.3	14.7	21.1		
	12	1.1	2.5	4.4	8.5	13.5	20.1	26.7	
	13	1.0	2.3	4.5	7.8	12.4	18.6	26.4	
	14	0.9	2.2	4.2	7.3	11.5	17.2	24.5	33.0
	15	0.8	2.0	3.9	6.8	10.8	16.1	22.9	31.4
	16	0.8	1.9	3.7	6.4	10.1	15.1	21.5	29.5
	17		1.8	3.5	6.0	9.5	14.2	20.2	27.7
	18		1.7	3.3	5.7	9.0	13.4	19.1	26.2
	19		1.6	3.1	5.4	8.5	12.7	18.1	24.8
	20		1.5	2.9	5.1	8.1	12.1	17.2	23.6

Loads in small figures are the limit for resistance to horizontal shear.

WOODEN COLUMNS

The safe load tables of wooden columns which follow, based upon the working unit stresses adopted by the American Railway Engineering Association, give the allowable direct compressive loads for square and round columns.

The safe loads of rectangular columns may be found from the safe loads of square columns by direct proportion of areas, using the safe load unit stress of the square column whose side is equal to the least side of the rectangular section.

The following table gives the safe load in pounds per square inch of sectional area for ratios of

$$\frac{l}{d}=\frac{\text{effective length of column, in inches}}{\text{least side or diameter, in inches}},$$

ranging between limits of 15 and 30.

UNIT WORKING STRESSES IN POUNDS PER SQUARE INCH

$\frac{l}{d}$	Longleaf Pine, White Oak	Douglas Fir, Western Hemlock	Shortleaf Pine, Spruce, Bald Cypress	White Pine, Tamarack	Red Cedar, Redwood	Norway Pine
	1300 (1—l/d60)	1200 (1—l/d60)	1100 (1—l/d60)	1000 (1—l/d60)	900 (1—l/d60)	800 (1—l/d60)
15	975	900	825	750	675	600
16	953	880	807	733	660	587
17	931	860	788	717	645	573
18	910	840	770	700	630	560
19	888	820	752	683	615	547
20	867	800	733	667	600	533
21	845	780	715	650	585	520
22	823	760	697	633	570	507
23	802	740	678	617	555	493
24	780	720	660	600	540	480
25	758	700	642	583	525	467
26	737	680	623	567	510	553
27	715	660	605	550	495	440
28	693	640	587	533	480	427
29	672	620	568	517	465	413
30	650	600	550	500	450	400

EXAMPLE 1.—Required the allowable load for a column of white oak 10″ x 8″, 14 feet long.

The safe load given in the table for a square white oak column 8″ x 8″, 14 feet long, is 54,100 pounds. The load for the 10″ x 8″ section is 10 x 54,100 ÷ 8 = 67,600 pounds.

EXAMPLE 2.—Required the allowable load for a spruce pile, 9″ diameter and 18 feet long.

The unit stress given in the above table for the corresponding ratio of l/d, 18 x 12 ÷ 9 = 24 is 660 pounds, and the sectional area for a 9″ round is 63.62 square inches. The safe load, therefore, is 63.62 x 660=42,000 pounds.

SQUARE WOODEN COLUMNS

Safe Loads in Thousands of Pounds

American Railway Engineering Association Formulas

	Length, Feet	Side of Square, Inches								
		4	6	8	10	12	14	16	18	20
LONGLEAF PINE WHITE OAK 1300 (1—1/60d)		15.6								
	5	15.6								
	6	14.6								
	7	13.5	35.1							
	8	12.5	34.3							
	9	11.4	32.8	62.4						
	10	10.4	31.2	62.4						
	11		29.6	60.3						
	12		28.1	58.2	97.5					
	14		25.0	54.1	93.6	140.4				
	16			49.9	88.4	137.3	191.1			
	18			45.8	83.2	131.0	189.3	249.6		
	20			41.6	78.0	124.8	182.0	249.6	315.9	390.0
DOUGLAS FIR WESTERN HEMLOCK 1200 (1—1/60d)		14.4								
	5	14.4								
	6	13.4								
	7	12.5	32.4							
	8	11.5	31.7							
	9	10.6	30.2	57.6						
	10	9.6	28.8	57.6						
	11		27.4	55.7						
	12		25.9	53.8	90.0					
	14		23.0	49.9	86.4	129.6				
	16			46.1	81.6	126.7	176.4			
	18			42.2	76.8	121.0	174.7	230.4		
	20			38.4	72.0	115.2	168.0	230.4	291.6	360.0
SHORTLEAF PINE SPRUCE 1100 (1—1/60d)		13.2								
	5	13.2								
	6	12.3								
	7	11.4	29.7							
	8	10.6	29.0							
	9	9.7	27.7	52.8						
	10	8.8	26.4	52.8						
	11		25.1	51.0						
	12		23.8	49.3	82.5					
	14		21.1	45.8	79.2	118.8				
	16			42.2	74.8	116.2	161.7			
	18			38.7	70.4	110.9	160.2	211.2		
	20			35.2	66.0	105.6	154.0	211.2	267.3	330.0
WHITE PINE 1000 (1—1/60d)		12.0								
	5	12.0								
	6	11.2								
	7	10.4	27.0							
	8	9.6	26.4							
	9	8.8	25.2	48.0						
	10	8.0	24.0	48.0						
	11		22.8	46.4						
	12		21.6	44.8	75.0					
	14		19.2	41.6	72.0	108.0				
	16			38.4	68.0	105.6	147.0			
	18			35.2	64.0	100.8	145.6	192.0		
	20			32.0	60.0	96.0	140.0	192.0	243.0	300.0

Loads in small figures above horizontal lines are the maximum allowable safe loads.

ROUND WOODEN COLUMNS

Safe Loads in Thousands of Pounds

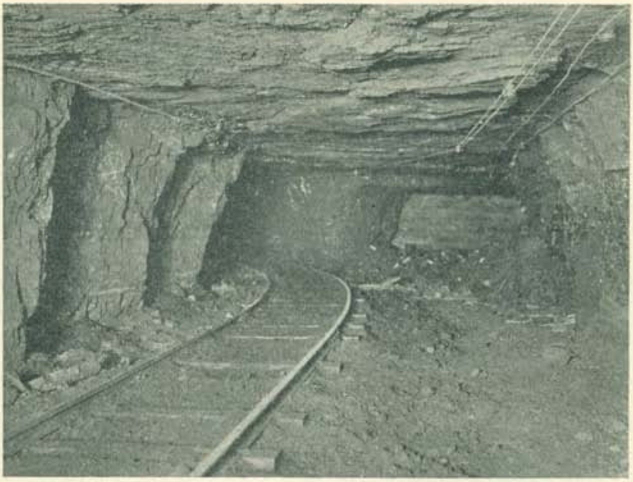
American Railway Engineering Association Formulas

	Length, Feet	Diameter, Inches 4	6	8	10	12	14	16	18	20
LONGLEAF PINE WHITE OAK 1300 (1—1/60d)		*12.3*								
	5	12.3								
	6	11.4								
	7	10.6	*27.6*							
	8	9.8	27.0							
	9	9.0	25.7	*49.0*						
	10	8.2	24.5	49.0						
	11		23.3	47.4						
	12		22.1	45.7	*76.6*					
	14		19.6	42.5	73.5	*110.3*				
	16			39.2	69.4	107.8	*150.1*			
	18			35.9	65.3	102.9	148.7	*196.0*		
	20			32.7	61.3	98.0	142.9	196.0	*248.1*	*306.3*
DOUGLAS FIR WESTERN HEMLOCK 1200 (1—1/60d)		*11.3*								
	5	11.3								
	6	10.6								
	7	9.8	*25.4*							
	8	9.1	24.9							
	9	8.3	23.7	*45.2*						
	10	7.5	22.6	45.2						
	11		21.5	43.7						
	12		20.4	42.2	*70.7*					
	14		18.1	39.2	67.9	*101.8*				
	16			36.2	64.1	99.5	*138.5*			
	18			33.2	60.3	95.0	137.2	*181.0*		
	20			30.2	56.5	90.5	132.0	181.0	*229.0*	*282.7*
SHORTLEAF PINE SPRUCE 1100 (1—1/60d)		*10.4*								
	5	10.4								
	6	9.7								
	7	9.0	*23.3*							
	8	8.3	22.8							
	9	7.6	21.8	*41.5*						
	10	6.9	20.7	41.5						
	11		19.7	40.1						
	12		18.7	38.7	*64.8*					
	14		16.6	35.9	62.2	*93.3*				
	16			33.2	58.7	91.2	*127.0*			
	18			30.4	55.3	87.1	125.8	*165.9*		
	20			27.6	51.8	82.9	121.0	165.9	*209.9*	*259.2*
WHITE PINE 1000 (1—1/60d)		*9.4*								
	5	9.4								
	6	8.8								
	7	8.2	*21.2*							
	8	7.5	20.7							
	9	6.9	19.8	*37.7*						
	10	6.3	18.9	37.7						
	11		17.9	36.4						
	12		17.0	35.2	*58.9*					
	14		15.1	32.7	56.5	*84.8*				
	16			30.2	53.4	82.9	*115.5*			
	18			27.6	50.3	79.2	114.4	*150.8*		
	20			25.1	47.1	75.4	110.0	150.8	*190.9*	*235.6*

Loads in small figures above horizontal lines are the maximum allowable safe loads.

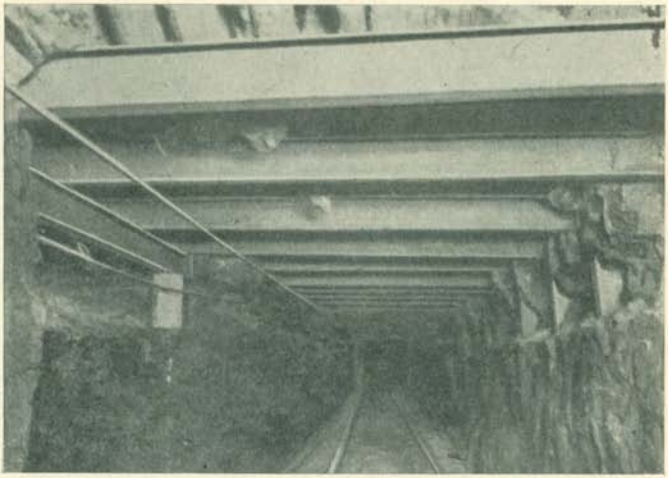
DECIMAL OF AN INCH AND OF A FOOT

Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions
	.0052	1/16		.2552	3 1/16		.5052	6 1/16		.7552	9 1/16
	.0104	1/8		.2604	3 1/8		.5104	6 1/8		.7604	9 1/8
1/64	.015625	3/16	17/64	.265625	3 3/16	33/64	.515625	6 3/16	49/64	.765625	9 3/16
	.0208	1/4		.2708	3 1/4		.5208	6 1/4		.7708	9 1/4
	.0260	5/16		.2760	3 5/16		.5260	6 5/16		.7760	9 5/16
1/32	.03125	3/8	9/32	.28125	3 3/8	17/32	.53125	6 3/8	25/32	.78125	9 3/8
	.0365	7/16		.2865	3 7/16		.5365	6 7/16		.7865	9 7/16
	.0417	1/2		.2917	3 1/2		.5417	6 1/2		.7917	9 1/2
3/64	.046875	9/16	19/64	.296875	3 9/16	35/64	.546875	6 9/16	51/64	.796875	9 9/16
	.0521	5/8		.3021	3 5/8		.5521	6 5/8		.8021	9 5/8
	.0573	11/16		.3073	3 11/16		.5573	6 11/16		.8073	9 11/16
1/16	.0625	3/4	5/16	.3125	3 3/4	9/16	.5625	6 3/4	13/16	.8125	9 3/4
	.0677	13/16		.3177	3 13/16		.5677	6 13/16		.8177	9 13/16
	.0729	7/8		.3229	3 7/8		.5729	6 7/8		.8229	9 7/8
5/64	.078125	15/16	21/64	.328125	3 15/16	37/64	.578125	6 15/16	53/64	.828125	9 15/16
	.0833	1		.3333	4		.5833	7		.8333	10
	.0885	1 1/16		.3385	4 1/16		.5885	7 1/16		.8385	10 1/16
3/32	.09375	1 1/8	11/32	.34375	4 1/8	19/32	.59375	7 1/8	27/32	.84375	10 1/8
	.0990	1 3/16		.3490	4 3/16		.5990	7 3/16		.8490	10 3/16
	.1042	1 1/4		.3542	4 1/4		.6042	7 1/4		.8542	10 1/4
7/64	.109375	1 5/16	23/64	.359375	4 5/16	39/64	.609375	7 5/16	55/64	.859375	10 5/16
	.1146	1 3/8		.3646	4 3/8		.6146	7 3/8		.8646	10 3/8
	.1198	1 7/16		.3698	4 7/16		.6198	7 7/16		.8698	10 7/16
1/8	.1250	1 1/2	3/8	.3750	4 1/2	5/8	.6250	7 1/2	7/8	.8750	10 1/2
	.1302	1 9/16		.3802	4 9/16		.6302	7 9/16		.8802	10 9/16
	.1354	1 5/8		.3854	4 5/8		.6354	7 5/8		.8854	10 5/8
9/64	.140625	1 11/16	25/64	.390625	4 11/16	41/64	.640625	7 11/16	57/64	.890625	10 11/16
	.1458	1 3/4		.3958	4 3/4		.6458	7 3/4		.8958	10 3/4
	.1510	1 13/16		.4010	4 13/16		.6510	7 13/16		.9010	10 13/16
5/32	.15625	1 7/8	13/32	.40625	4 7/8	21/32	.65625	7 7/8	29/32	.90625	10 7/8
	.1615	1 15/16		.4115	4 15/16		.6615	7 15/16		.9115	10 15/16
	.1667	2		.4167	5		.6667	8		.9167	11
11/64	.171875	2 1/16	27/64	.421875	5 1/16	43/64	.671875	8 1/16	59/64	.921875	11 1/16
	.1771	2 1/8		.4271	5 1/8		.6771	8 1/8		.9271	11 1/8
	.1823	2 3/16		.4323	5 3/16		.6823	8 3/16		.9323	11 3/16
3/16	.1875	2 1/4	7/16	.4375	5 1/4	11/16	.6875	8 1/4	15/16	.9375	11 1/4
	.1927	2 5/16		.4427	5 5/16		.6927	8 5/16		.9427	11 5/16
	.1979	2 3/8		.4479	5 3/8		.6979	8 3/8		.9479	11 3/8
13/64	.203125	2 7/16	29/64	.453125	5 7/16	45/64	.703125	8 7/16	61/64	.953125	11 7/16
	.2083	2 1/2		.4583	5 1/2		.7083	8 1/2		.9583	11 1/2
	.2135	2 9/16		.4635	5 9/16		.7135	8 9/16		.9635	11 9/16
7/32	.21875	2 5/8	15/32	.46875	5 5/8	23/32	.71875	8 5/8	31/32	.96875	11 5/8
	.2240	2 11/16		.4740	5 11/16		.7240	8 11/16		.9740	11 11/16
	.2292	2 3/4		.4792	5 3/4		.7292	8 3/4		.9792	11 3/4
15/64	.234375	2 13/16	31/64	.484375	5 13/16	47/64	.734375	8 13/16	63/64	.984375	11 13/16
	.2396	2 7/8		.4896	5 7/8		.7396	8 7/8		.9896	11 7/8
	.2448	2 15/16		.4948	5 15/16		.7448	8 15/16		.9948	11 15/16
1/4	.2500	3	1/2	.5000	6	3/4	.7500	9	1	1.0000	12



Majestic Coal & Coke Co. Mine, Duquoin, Illinois.

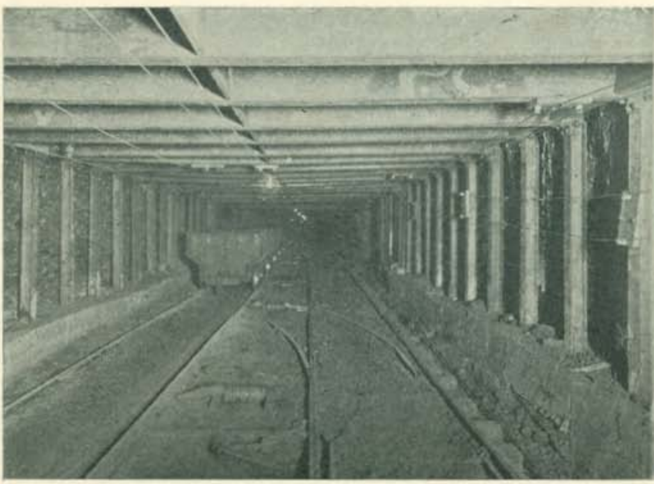
Heavy Wooden Timbering, Anthracite Mine



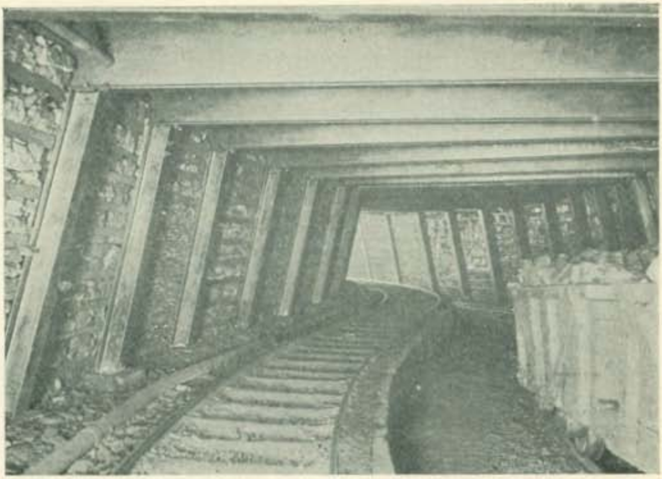
Steel Beams laid on Coal and Short Posts

Heavy Steel Timbering, Anthracite Mine

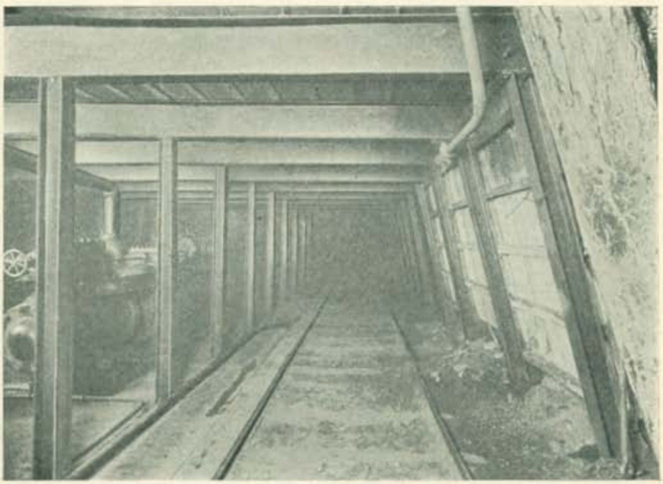
Youghiogheny & Ohio Coal Co., Florence Mine, Martins Ferry, O.



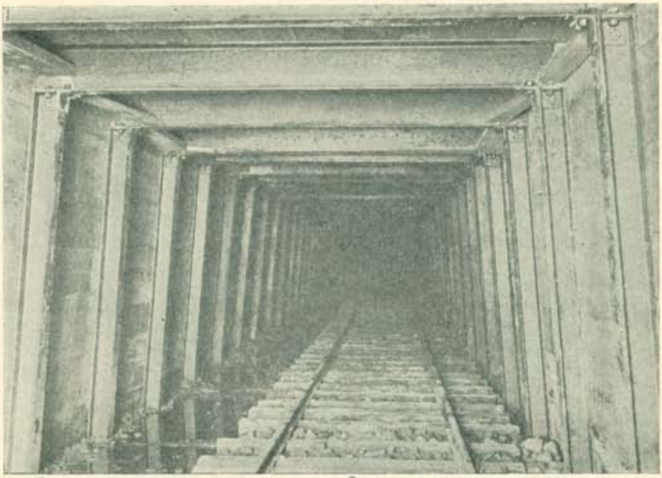
W. J. Rainey Royal Works Mine, Uniontown, Pa.



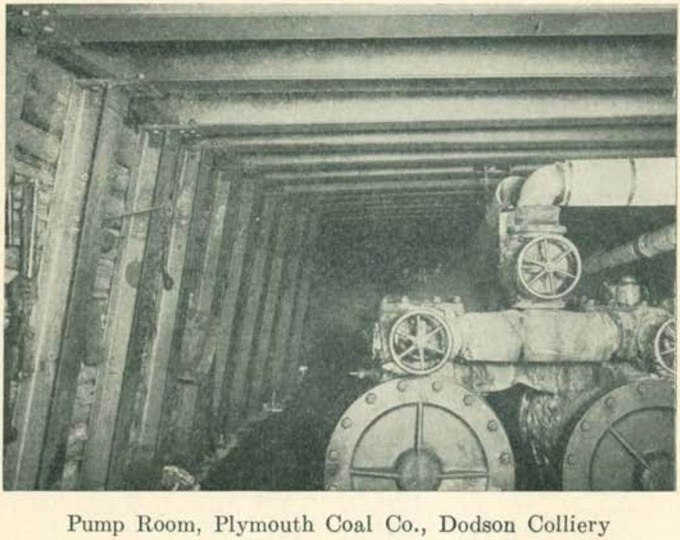
Maxwell Colliery 20, Lehigh & Wilkes-Barre Coal Co., Ashton, Pa.



Honeybrook Colliery 5, Lehigh & Wilkes-Barre Coal Co., Audenried, Pa.



Moshannon Coal Mining Co., Osceola Mills, Pa.



Pump Room, Plymouth Coal Co., Dodson Colliery

PRODUCTS

Blast Furnace Products

Pig Iron, Ferro-Manganese and Spiegeleisen.

Open-Hearth and Bessemer Products

Ingots, Blooms, Billets, Slabs, Sheet Bars.

Structural Mill Products

Beams, H-Beams, Channels, Angles, Tees, Zees,
Ship and Car Building Sections, Bulb Angles,
Steel Sheet Piling and Cross Tie Sections.

Bar Mill Products

Beams, Channels, U-Bars, Angles, Tees, Zees,
Merchant Bars, Squares, Rounds, Hexagons,
Welding and Threading Steel, Spring Steel,
Flat Steel, Square, Band and Round Edge,
Hoop and Band Steel, Cotton Ties,
Tire Steel, Shovel and Saw Blade Steel,
Concrete Bars, Rounds and Squares,
Cold Twisted Squares, Deformed Bars,
Agricultural Sections, Automobile Sections,
Window Sections, Miscellaneous Bar Sections.

Alloy Steel for Various Purposes

Plate Mill Products

Sheared Plates and Universal Mill Plates,
Checkered Floor Plates and Skelp.

Rail Mill Products

Standard, Miscellaneous and Light Rails,
Angle Splice Bars and Fish Plates,
Steel Cross Ties and Track Accessories.

Forged and Wrought Products

Axles for Steam, Electric and Industrial Service.
Wheels for Steam, Electric and Industrial Service.
Wheel and Gear Blanks, Miscellaneous Circular Forgings.

Fabricated Products

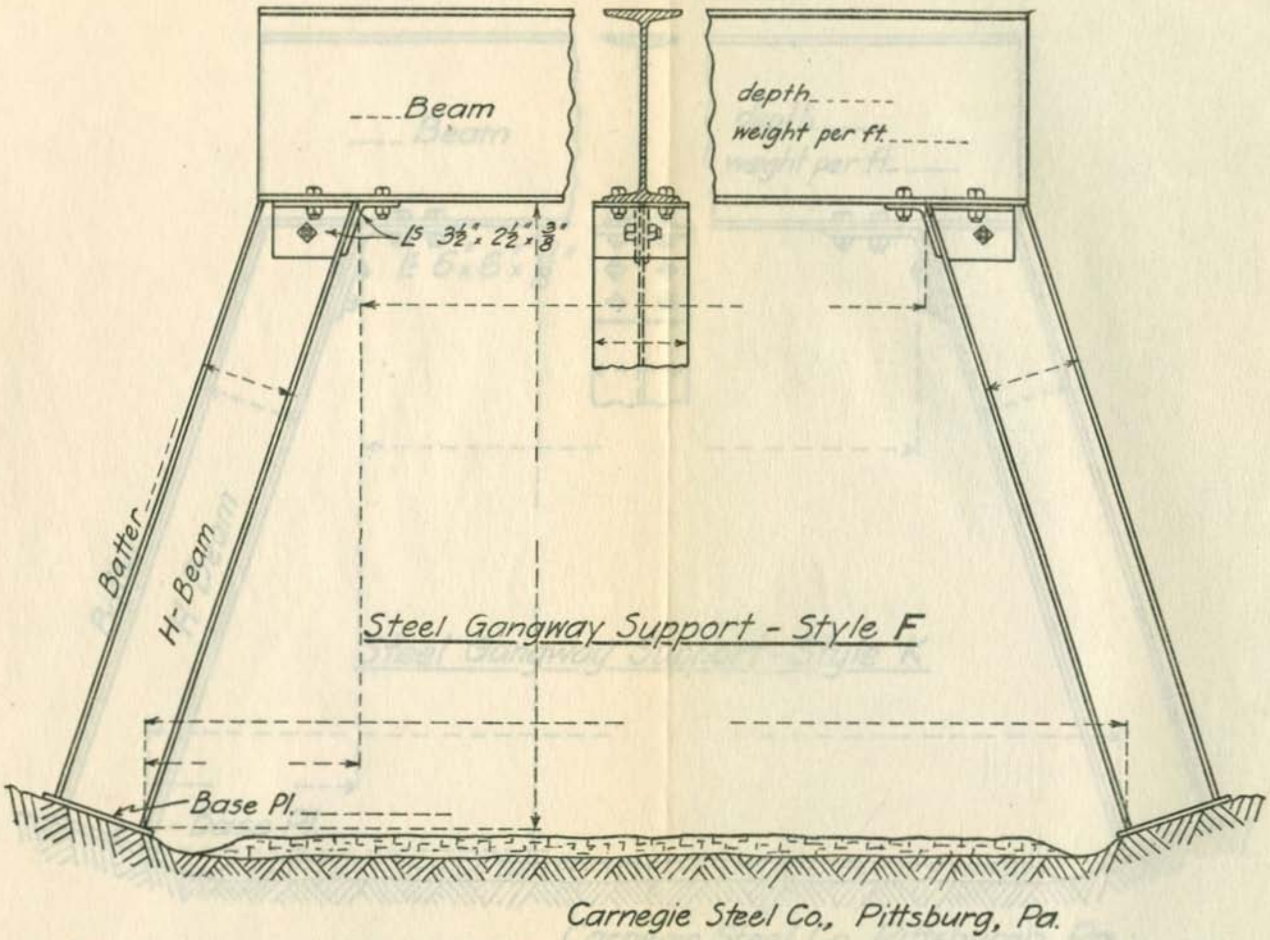
Steel Drilling Rigs, Derricks, Accessories,
Steel Mine Timber, Gangway Sets,
Steel Sheet Piling.

Coke By-Products

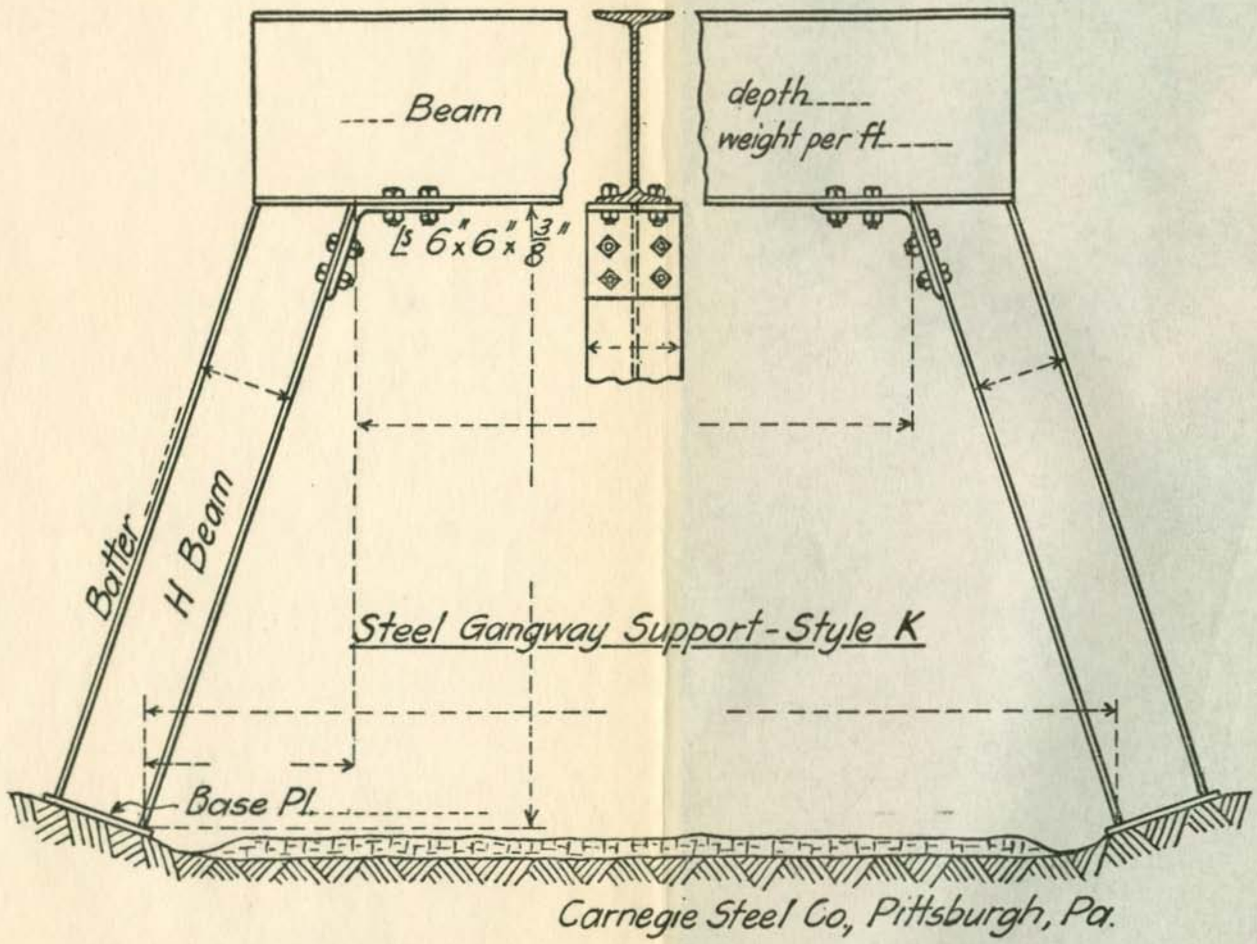
Ammonia Liquor, Ammonium Sulphate,
Naphtha, Napthalene, Benzol, Toluol.

Blast Furnace Slag

Crushed, Granular, Sand and Concrete Slag.



This form may be used on inquiries for Steel Mine Timbers, Style F. Additional copies may be secured on application to any district office of the Carnegie Steel Company.



This form may be used on inquiries for Steel Mine Timbers, Style K. Additional copies may be secured on application to any district office of the Carnegie Steel Company.

CARNEGIE STEEL COMPANY

OFFICES

GENERAL OFFICES:

Pittsburgh, Carnegie Building, 434 Fifth Avenue.

DISTRICT OFFICES:

Birmingham, Brown-Marx Building, 2000 First Avenue, North,
Boston, 120 Franklin Street,
Buffalo, The Marine Trust Co. Building, 233–239 Main Street,
Chicago, 208 South La Salle Street,
Cincinnati, Union Trust Building, Fourth and Walnut Streets,
Cleveland, Rockefeller Building, 704 Superior Avenue, N. W.,
Denver, First National Bank Building, 17th and Stout Streets,
Detroit, 2130 Buhl Building, 535 Griswold Street,
New Orleans, Maison Blanche, 921 Canal Street,
New York, Empire Building, 71 Broadway,
Philadelphia, Widener Building, Juniper and Chestnut Streets,
Pittsburgh, Carnegie Building, 434 Fifth Avenue,
St. Louis, 506 Olive Street,
St. Paul, 1308 Merchants National Bank Building, 4th & Robert Sts.

EXPORT REPRESENTATIVES:

UNITED STATES STEEL PRODUCTS CO.,
New York, Hudson Terminal, 30 Church Street.

PACIFIC COAST REPRESENTATIVES:

UNITED STATES STEEL PRODUCTS CO., PACIFIC COAST DEPT.
Los Angeles, 2087 East Slauson Avenue,
Portland, Selling Building, Sixth and Alder Streets,
San Francisco, Rialto Building, 116 New Montgomery Street,
Seattle, Fourth Avenue South and Connecticut Street.