CHAPTER X.

LOAD AND DETAILS.

93. **Lateral Bracing.**—The principal trusses, if large, should be braced together in the planes of the rafters to prevent wind, in a direction perpendicular to the gable ends, from producing any lateral movement. The roof boards, if laid close, and well nailed, will stiffen trusses of moderate span. It is often customary also to fasten the trusses down to the walls, especially in those buildings where wind may get below the roof. In such cases it is proper to consider and provide for the tendency of the wind to reverse the stresses in a roof which has a light covering.

94. **Weight of Materials.**—The weight of the roof covering can be ascertained in advance. The bending moments on the jack-rafters and the purlins can then be found, their sizes computed and their weights added in. The weight of the truss must then be assumed from such data as may be at hand. After the diagrams have been drawn and the truss has been roughly designed, its weight should be calculated to see how well it agrees with the assumed weight. If this agreement is not sufficiently exact, the proper allowance is then to be made.

Trautwine says that, for spans not exceeding about 75 feet, and trusses 7 feet apart, of the type shown in Figs. 11 and 29, the total load per square foot, including the truss itself, purlins, etc., complete, may be taken as follows:

Roof covered with corrugated iron, unboarded, . .	8 lbs.
Same if plastered below the rafters, ...	18 "
Roof covered with corrugated iron, on boards, . .	11 "

Same if plastered below the rafters, ...	21 lbs.
Roof covered with slate, unboarded or on laths, . .	13 "
Same on boards $1\frac{1}{4}$ inches thick, ...	16 "
Same if plastered below the rafters, ...	26 "
Roof covered with shingles on laths, ...	10 "

For spans from 75 feet to 150 feet it will suffice to add 4 lbs. to each of these totals.

The weight of an ordinary lathed and plastered ceiling is about 10 lbs. per square foot; and that of an ordinary floor of 1-inch boards, together with the usual 2×12 inch joists, 12 inches apart from centre to centre, is from 9 to 12 lbs. per square foot. White pine timber, if dry, may be considered to weigh about 25 lbs., northern yellow pine 35 lbs., and southern yellow pine 45 lbs. per cubic foot; if wet, add from 20 to 50 per cent. Oak may be reckoned at from 40 to 50 lbs. per cubic foot; cast iron at 450 lbs. per cubic foot; wrought iron at 480 lbs. per cubic foot.

The allowance to be made for the weight of snow will depend upon the latitude; from 12 to 15 lbs. per square foot of roof will suffice for most places. In some situations snow may accumulate in considerable quantities, becoming saturated with water and turning to ice; but snow saturated with water will generally slide off from roofs of ordinary pitch. The weight of a cubic foot varies much; freshly fallen snow may weigh from 5 to 12 lbs.; snow and hail, sleet or ice may weigh from 30 to 50 lbs. per cubic foot, but the quantity on a roof will usually be small.

95. **Action of Materials under Stress.**—After the stresses in the frame are determined, the several parts must be designed to withstand them. While it is not the purpose of this work to explain minutely the method of proportioning the members of a truss and of working out the details, a few suggestions as to safe stresses and some points which should be borne in mind in designing may not be amiss.

As materials, if repeatedly strained to an amount at all approaching the breaking strain, will fail sooner or later, the severe action weakening them, and as we must provide for unforeseen and unknown defects of material and workmanship, as well as for more or less of shock and vibration, it is customary to so proportion the several parts of a structure that they will be able to resist without failure much larger forces than those obtained from the stress diagrams. The smaller the load or stress on a piece the greater number of applications and removals before the piece is injured or broken. If the stress is reduced so much by increase of cross-section of the member that the piece will safely sustain an indefinitely great number of repetitions of it, such cross-section will be the proper one for a piece in a bridge or machine.

The stress arising from a stationary load, such as the weight of the structure, which is constant, is not so trying as repeated application and release of the same stress. The heavy wind-stresses determined in the previous chapters are not likely to occur more than once or twice, if at all, in the life of the structure. Hence good practice will authorize the employment of stresses some fifty per cent. in excess of those considered allowable in first-class bridge structures and those subjected to frequent change of load, to shock and vibration.

96. **Allowable Stresses.**—In accordance with this view, the following values may be used, where the wind-pressure of Chapter IV. has been allowed for.

Material.	Bending Stress.	Tension.	Compression with grain.	Compression across grain.	Shear with grain.
White Oak....	1,600	1,500	1,400	400	180
Long-leaf Southern Pine....	1,600	1,400	1,400	300	150
Oregon Pine or Fir........	1,600	1,800	1,300	250	200
White Pine (Eastern)......	1,400	800	1,200	200	100
Spruce	1,200	1,200	1,200	200	100
			Compression		Shear
Wrought Iron.	10,000	12,000	10,000		8,000
" " best quality..	12,000	15,000	12,000		10,000

The quality of the iron employed materially affects the force which it may safely resist

The above values must not be applied to parts subjected to moving loads, such as floor-beams and suspending rods for same, unless the load is moderate in total amount and very gradually applied and removed. For bridge work they must be reduced from 20 to 33 per cent.

97. **Tension Members.**—Pieces in tension will be liable to break at the smallest cross-section. It is therefore economical to enlarge the screw-ends of long iron rods and bolts so that the cross-section at the bottom of the threads shall be at least as large as at any other point. It is desirable that the centre of resistance of the cross-section of struts and ties shall coincide with the centre of figure, as a deviation from that position greatly weakens the piece. To calculate the net or smallest cross-section of a tension member where the pull is axial or central it is sufficient to divide the force by the safe working tensile stress. Allowance must be made for diminution of cross-section by any cutting away, bolt or rivet holes.

98. **Compression Members.**—For very short pieces or blocks in compression, whose lengths do not exceed six times the least dimension, the same process may be followed. But as the length increases the strut has a tendency to yield sideways when compressed, and the cross-section must be increased. The most comprehensive formula for such pieces is that known as Gordon's Formula. Letting l denote the length of the piece in inches, h its least external diameter in inches, S the cross-section in square inches, P the given force to be resisted in pounds, f the safe working compressive stress, and a a certain constant, this formula, for pieces with flat, securely bedded ends, or ends fixed in direction by bolting or riveting, may be written

$$P = \frac{fS}{1 + a\frac{l^2}{h^2}},$$

where $a = \frac{1}{250}$ for rectangular timber struts, and $\frac{1}{3000}$ for rectangular wrought-iron struts.

If the struts are jointed at their ends by pin connections, or are so narrow as to readily yield sideways at these points, use $2a$ in place of a; if one end is firmly fixed in direction while the other end is jointed use $\frac{4}{3}a$ in place of a.

It is convenient to assume h and compute S. If the other dimension then comes smaller than h, a less value must be taken for h than before, and the calculation made anew. For cross-sections in wrought iron not rectangles, such as L, T, and H sections, $1\frac{1}{2}l$ may be used in place of l.

Pieces subjected alternately to tension and compression should have a materially larger section than would be required for either stress alone.

Cast iron is not in favor with the best designers for any but short compression pieces, packing blocks and pedestals, although it is still employed for columns. The values in Gordon's Formula for cast iron may be $f = 15,000$; $a = \frac{1}{800}$.

99. **Beams.**—The values of f to be used in the moment of resistance, for pieces subjected to bending, are marked bending stress in the preceding table. In determining the moment of resistance of a piece exposed to bending, or in calculating the cross-section required at the point of maximum bending moment, allowance must be made for portions cut away on the tension side in attaching fastenings, bolting or riveting together parts, and also on the compression side unless the holes, etc., are so tightly filled that the compression can be fairly considered as resisted by those portions also.

Those pieces which resist both a bending moment and a direct stress may first be designed to safely carry the bending moment, and then the dimension transverse to that in which the piece will bend may be so much increased that the added slice will resist the direct pull or thrust. If that force is thrust, it will be well to test the size of the piece by Gordon's Formula also.

100. **Pins and Eyes.**—A reasonable rule for proportioning pins and eyes of tension bars is as follows:—Make the diameter of the pin from three-fourths to four-fifths of the width of the bar in flats, and one and one-fourth times the diameter of the bar in rounds, giving the eye a sectional area of fifty per cent. in excess of that of the bar. The thickness of flat bars should be at least one-fourth of the width in order to secure a good bearing surface on the pin, and the metal at the eyes should be as thick as the bars. As the bending moment on a pin generally determines its diameter, pieces assembled on a pin should be packed closely, and those having opposing stresses should be brought into juxtaposition if possible.

101. **Details.**—Very close attention must be given to all minor details; to so proportion all the parts of a joint that it will be no more likely to yield in one way than another; to weaken as little as possible the pieces connected at a splice; to give sufficient bearing surface so as to bring the intensity of the compression on the surface within proper limits; to distribute rivets and bolts so as to give the greatest resistance with the least cutting away of other parts; to keep the action line of every piece as near its axis as possible; and to examine all sections and parts for tension, compression, and shear. The failure of a joint or connection is as fatal to a frame as to have a member too small for the stress upon it.

The pocket and hand-books issued by the different iron companies, for the use of their patrons, give the sections and weights of the various shapes of rolled iron, the safe loads for beams of different spans, data for columns, details of construction, and much miscellaneous useful information.