a rolled mild steel beam as a binder in lieu of a wood binder is shown at M, Fig. 7. Mild steel is much stronger than timber (the safe strength in compression and tension of mild steel is 18,000-lb. per sq. in. and that of a good graded softwood may not exceed 1,200-lb. per sq. in.) and therefore the size of the steel beam is less than that of a wood binder; the 9-in. by 4-in. by 21-lb. steel beam shown at M will support the same load as the 15-in. by 7-in. timber binder (compare M with E). One result of this reduction in size is the corresponding decrease in the amount of walling, equivalent in this case to approximately two courses of brickwork.

Second year students attending a complete course of instruction which includes the subject of Building Science in addition to Building Construction, will probably be taught to design simple rectangular beams, but the determination of sizes of rolled steel beams is usually deferred to a later stage. The following examples are therefore stated briefly and are included for reference purposes only.

Determination of Sizes of Bridging Joists and Binders.—The Timber Bye-laws of the London County Council apply to two classes of timber, *i.e.*, "non-graded" and "grade 1,200-lb. f"; f is the permissible working stress. The permissible maximum compression and tension stresses due to bending (to which joists and binders are subjected) are therein stated to be 800 and 1,200-lb. per sq. in. for non-graded and graded timbers respectively. The sizes of wood joists and binders can be obtained by reference to tables. Thus, assuming the floor illustrated at A, Fig. 7, is that of a residential building, the sizes of the bridging joists which are spaced at $15\frac{1}{2}$-in. centres with an effective span (distance between bearings) of 9-ft. are computed to be 6·4-in. by 2-in. if of non-graded timber, and 5·4-in. by 2-in. if of graded timber. Reference to the same tables shows that the sizes of the binders, which have an effective span of 18-ft. and are spaced at 9-ft. centres, are 15-in. by 9·4-in. if of non-graded timber, and 15-in. by 6-in. if the wood is of the graded class.

The size of the bridging joists is determined by calculation as follows: (1) The total weight (W) that one of the joists supports is obtained; this equals the decided live or superimposed load [1] plus the dead weight,[2] multiplied by the area of the floor supported by the member. (2) The bending moment (M) is found; this equals the moment of resistance (MR), and the latter equals the product of the modulus of section (Z) and the permissible stress (f). (3) Either the breadth (b) or depth (d) of the joist is assumed and its second dimension then obtained. The size of the binders is ascertained in a similar manner.

Applying this to the floor shown at A, Fig. 7:—

Bridging Joist A′.

1. *Weight.*—Assume the superimposed load is 50-lb. per sq. ft. The dead weight of the timber can be obtained from Tables I and II, pp. 17-24); the general figure taken for softwoods is 30-lb. per cub. ft. (41-lb. for pitch pine) and 45-lb. per cub. ft. for hardwoods. If $1\frac{1}{8}$-in. softwood boards are used, their weight $=\frac{9}{8}\times\frac{1}{12}\times 30$-lb. $=3$-lb. (approx.) per sq. ft. The bridging joists are spaced at $15\frac{1}{2}$-in. centres, and therefore 1-lin. ft. of joist A′ supports $\frac{15\frac{1}{2}}{12}$ ft. $\times$ 1-ft. $=\frac{31}{24}$ sq. ft. of floor. *Assume*, for the purpose of obtaining its weight, that the size of the joist is 6-in. × 2-in. Hence its weight $=\frac{6}{12}\times\frac{2}{12}\times 1\times 30$-lb. $=2\frac{1}{2}$-lb. per lin. ft. and the proportionate weight of joist per square foot of floor = weight of joist ÷ area of floor supported by it $=\frac{5}{2}\div\frac{31}{24}=2$-lb. (approx.). Therefore, total dead load $=3+2=5$-lb. per sq. ft.

Total load = superimposed load + dead weight
$= 50 + 5 = 55$-lb. per sq. ft.

Portion of floor supported by joist A′ is *abcd* (see broken lines) and its area

$$=\frac{15\frac{1}{2}}{12}\text{ ft.}\times 9\text{-ft.}=\frac{279}{24}\text{ sq. ft.}$$

Therefore, W (total load) = area × load per sq. ft.

$$=\frac{279}{24}\times 55=640\text{-lb. (approx.).}$$

2. *Bending Moment.*—The load being uniformly distributed,

$$M=\frac{WL}{8}=\frac{640\times 9\times 12}{8}=8{,}640\text{-in.lb.}$$

3. *Sizes.* $M=MR=fZ$. Z is a measure of the shape of the section $=\frac{bd^2}{6}$.

As already stated, $f=800$-lb. per sq. in. for ungraded timber and 1,200-lb. per sq. in. for graded timber; for this example, assume $f=1{,}000$-lb. per sq. in. $Z=\frac{bd^2}{6}$.

Assume $b=2$-in.

Therefore, $8{,}640=1{,}000\times\frac{2d^2}{6}$, and $d=\sqrt{8{,}640\times\frac{3}{1{,}000}}=5{\cdot}1$-in., say 6-in.

The size of the bridging joists shown at A, Fig. 7, is 6-in. × 2-in.

Binder B′.

1. *Weight.*—The portion of floor supported by binder B′ is *efgh* (see broken lines) and its area is $17\frac{1}{4}\times 9=155$-sq. ft. The dead weight equals that of the floor boards and bridging joists (5-lb. per sq. ft.—see above), together with the approximate weight of the binder per square foot of floor, ceiling joists and plaster. *Assume*, for the purpose of obtaining its weight, that the size of the binder is 15-in. by 6-in. Hence its weight $=\frac{15}{12}\times\frac{6}{12}\times 18\times 30=338$-lb.; this, divided by the area of the floor supported by the binder, equals the additional weight $=\frac{338}{155}=2\frac{1}{2}$-lb. (approx.) per sq. ft. The additional weight of the 4-in. by 2-in. ceiling joists $=\frac{14\text{ (number)}\times 4\times 2\times 9\times 30}{12\quad 12}$ ÷ by area of floor $=\frac{210}{155}=1\frac{1}{2}$-lb. per sq. ft. The approximate weight of $\frac{3}{4}$-in. thick plaster is 9-lb. per sq. ft. Hence the total dead weight $=5+2\frac{1}{2}+1\frac{1}{2}+9=18$-lb. per sq. ft. Superimposed load + dead weight $=50+18=68$-lb. per sq. ft.

$$W=\text{area}\times\text{load per sq. ft.}=155\times 68=10{,}540\text{-lb. } (4{\cdot}7\text{ tons}).$$

2. *Bending Moment.*—The load may be considered to be uniformly distributed.

Hence, $$M=\frac{WL}{8}=\frac{10{,}540\times 18\text{ (effective span)}\times 12}{8}=284{,}580\text{-in.lb.}$$

3. *Sizes.* $$M=fZ=f\frac{bd^2}{6}.$$

$f=1{,}200$-lb. per sq. in. (graded timber—see preceding column). Assume $d=15$-in.

Therefore, $$284{,}580=1{,}200\times\frac{b\times 15^2}{6}$$

$$b=\frac{284{,}580}{45{,}000}=6{\cdot}3\text{-in., say 7-in.}$$

The size of the wood binders shown at A, Fig. 7, is 15-in. by 7-in.

[1] In accordance with the L.C.C. Timber Bye-laws, the *minimum* superimposed loads in lb. per square foot are as follows: 40 for rooms of houses, 80 for offices (floors above entrance floor), 90 for offices (entrance floor and those below), 150 for workshops and factories, 200 for warehouses and 50 for flat roofs (with not more than 20° inclination).

[2] The dead weight includes the weight per square foot of the floor boards and the *equivalent* weight per square foot of a bridging joist.