STRENGTH OF TIMBER vs. REINFORCED CONCRETE.*

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For all beam formulae assume the form $M = Kbd^2$, in which

M = resisting moment in inch pounds.
b = breadth in inches.
d = depth in inches.

For timber d is always the total depth, but with reinforced concrete it is the depth from the top of the beam or slab, to the centre of the steel, in the bottom near the tension edge. Concrete must be placed underneath the steel for protection. For thin slabs this should not be less than three-quarters of an inch. For ordinary beams about an inch and a half. For girders and columns about two inches.

The Section Modulus for a rectangular beam of homogeneous material is $\frac{bd^2}{6}$, and when multiplied by the fibre stress of the material it can be thrown into the form $M = Kbd^2$, by dividing the fibre stress by thus $K = \frac{f}{6}$ in which f is the fibre stress in pounds per square inch.

For timber there are several classes by which the fibre stress is determined. Class A is for structures freely exposed to the weather, such as railroad trestles, etc. The fibre stresses used in this class are as follows: White pine, cedar, spruce or eastern fir, 700 lb. per square inch. Short-leaf yellow pine, 1,000 lb. White oak and long-leaf yellow pine, 1,200 lb.

Class B is for structures under roof protected from rain, but without side shelter. White pine, cedar, spruce, eastern fir, 755 lb. Short-leaf yellow pine, 1,150 lb. White oak and long-leaf yellow pine, 1,380 lb.

Class C is for structures ent'rely enclosed and protected from outside moisture, but not exposed to heat, so that the timber will be thoroughly dried. White pine, cedar, spruce, eastern fir, 825 lb. Short leaf yellow pine, 1,400 lb. White oak and long leaf yellow pine, 1,680 lb.

Class D is for structures entirely enclosed and heated in the winter, thus keeping the timber dry. White p'ne, cedar, spruce, eastern fir, 875 lb. Short-leaf yellow pine, 1,550 lb. White oak and long-leaf yellow pine, 1,870 lb.

The values of K for the above classes are as follows:—

Class A. K = 117; 167; 200.
Class B. K = 126; 192; 230.
Class C. K = 138; 234; 270.
Class D. K = 146; 258; 312.

The foregoing may appear like a wide range, and the values of K for concrete are as great, because concrete varies in strength according to the aggregates of which it is composed, and the care with which they are mixed. In making a comparison between timber and concrete it is always well to remember that white oak weighs practically 50 lb. per cubic foot; white pine about 24 lb.; yellow pine, 32 to 38 lb.; cinder concrete, about 115 lb. per cubic foot; broken brick concrete, about 135 lb. per cubic foot, and first-class rock concrete, 150 lb. per cubic foot.

Assuming a value of 16,000 lb. per square inch for the fibre stress of the steel in tension, the value of K for different values of the fibre stress in the concrete are as follows:

For a comprehensive fibre stress at the top fibre of the beam or slab, of 700 lb. per sq. inch, which we can use with first-class concrete made of one part best Portland cement, two parts clean coarse sand, four parts clean washed gravel or broken stone ,the largest pieces being about three-quarters of an inch in their largest dimension; and K = 120. Ratio of steel to concrete = 0.0087.

A similar mix in which the stones may run as large as one inch, and in which a very small per cent. of finely-divided clay or loam is in the sand, will permit of the use of a fibre stress of 600 lb. per square inch, and K = 96. Ratio of steel to concrete = 0.0068.

In the foregoing it is of course taken for granted that the material is mixed in a good concrete mixer, preferably a batch mixer.

When either of the above are mixed by hand, or when a 1 : 2½ : 5 mix is used by mixing in a machine, or we use a 1 : 5 clean ready-mixed bank gravel, mixing same in a machine, then the fibre stress should not exceed 500 lb. per square inch, and K = 72. Ratio of steel to concrete =0.0051.

If we take the 1 : 2½ : 5 mix, or the 1 : 5 ready-mixed bank gravel, and mix them by hand, or use chats instead of broken stone, then the fibre stress should not exceed 400 lb. per square inch, and K = 49. Ratio of steel to concrete = 0.0035.

For a 1 : 2 : 5 : concrete made of broken brick, or certain kinds of slag of a porous nature, somewhat stronger than coal clinkers, the fibre stress should not exceed 300 lb. per square inch, no matter whether mixed by machine or by hand, and K = 38. Ratio of steel to concrete = 0.0027.

The ratio of steel to concrete is represented by $p = \frac{A}{bd}$

in which A = area of steel in square inches.
b = breadth of beam in inches = 12 in. for slabs
d = depth in inches from top of beam or slab to centre of the steel.

The following formulae enable us to figure the size of beams in reinforced concrete.

$$d = \sqrt{\frac{Kb}{M}}$$

$b = \frac{M}{Kd^2}$, b is the proper dimension to assume and then solve for d. The best value of b is one about one-twentieth or one twenty-fourth the span. It should be between two-thirds and three-fourths of d. Make several trials until this desirable set of conditions is secured:

$A = b \times d \times p$.

The amount of covering over the steel for fire protection has been already mentioned. When several bars or rods are used for reinforcement, the least distance between them should be one and one-half times their diameter or thickness. When using bars or rods in slabs they should never be spaced farther apart than one and one-half times d. If the smallest rods or bars that can be obtained will call for a spacing exceeding this limt, then use a fabricated mesh.

The concrete should be mixed so wet it will not be hard to get it out of the wheelbarrows. It should be sticky and pasty, rather than thin enough to run. Instead of tamping, it should be churned with rods or pipes in order to free the entrapped air and to permit the larger aggregates to move around and fit into place.

To compare wood and concrete it is necessary to remember the differences in weight per cubic foot. Then select the fibre stress for the wood and get the correct value of K. Select the K for the concrete and divide the K for the timber by the K for the concrete. The depth of the timber squared and divided by the difference between the two values of K will give the depth squared of the concrete beam, provided the same breadth is taken. To obtain the depth for the concrete beam there must be added the covering for protection of the steel.

The best way to do is to find the resisting moment for the timber, and then use this for M in the concrete formulae above given. The weight of the beam is of greater importance in the concrete designing than in the timber designing, but at the same time the deflection in a concrete beam is from one-third to one-fourth the deflection in a timber beam of equal strength.

This study is interesting, as it should enable one to make quick comparisons between timber and reinforced concrete construction, but there is nothing of a labor-saving nature

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