THE WROUGHT COMPRESSIVE MEMBER FOR BRIDGE TRUSSES.*

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It is subtle and illusive and may side step.

It is composite, and not homogeneous.

No law written of proper relation and proportion of constituent parts.

Cannot deform without shear. Accept and fully provide for it, that is, the shear.

Applied science useful. Be sure you have the right basis in making application.

Successful practice the only sure instructor.

Mathematical investigation only safe when justified by practice.

Sound judgment and clear perception necessary to recognize proportion and relation.

The engineering profession has the ability to understand relations and proportion.

With understanding of relation and proportions, wrought compressive members may be so designed and built of any size with all the certainty of satisfactory result, as of any physical thing designed and built by man.

A leading engineering journal of international reputation in a recent issue has made the broad statement that failures in wrought metal frame structures have all developed from buckling of the compression members, proving the general rule, by noting only one exception where tension members had failed and that due to deterioration by rust. As this was a review of a large number of cases, it is surely evidence that research as to the compression member is not only desirable but necessary. We also have at this time in the columns of the technical press, by correspondence, evidence of a renaissance in the mathematical investigation of compression members and nothing as to the proportion of the elements from which a compressive member is built up.

The design and proportion of compressive members for an open frame structure, like a bridge span, is one of compromise and concession. If the conditions demand only the ability to support weight like an individual column supporting a girder, with uniform distribution of load over the entire area of the column, it is well established that a section of uniform thickness of material in a triangle, in a circle or a square figure, are the most efficient; provided that we can produce by process of manufacture such a figure of homogenous material. However, it is idle to speculate on the efficiency of any exact form of column when the conditions demand that the compressive member must be built up of sections or segments, in practice generally riveted together.

Further the difficulties of making panel connections in truss work are such as to suggest the compressive members, open on one or more sides. This open or lattice member is always made with a material loss of efficiency as to the total weight of material in the member. A typical case will represent a direct loss of full 30 per cent. when two channels or similar sections are used, laced on two sides and will generally reach 100 per cent. when four angles or similar sections are used, laced on four sides; illustrating the good engineering maxim that you cannot "eat your cake and keep it."

We cannot economically connect to an enclosed triangular or circular section; in fact the cost of such connections to either of these figures will generally represent more cost than the percentage lost, as indicated above, in developing the open figure.

The enclosed box section presents greater possibilities of connection and lacks but a trifle in efficiency as compared with the triangle, which is greatest, and circle next; these differences can readily be ignored. It may, and probably will develop that such box figures, in the evolution of design, will find its place when maximum sections are required.

Flanged plates with riveted connections were used 30 years ago to form triangular sections. More recent years we have seen circular columns built up of longitudinal sections generally with projecting flanges through which the rivet connections were made. This section was popular and in very extensive use for many years. Box sections have been in use through all periods and with favorable conditions are at the present day.

We have little experimental and definite knowledge of the action of steel in built up compression members. Specimen tests have been carried out on solids and small pipes through many years. Our experience shows full sized members, tested to destruction, fail at less than the computed strength. It is a case of the strength of the composite member being determined by the weakest elementary unit and the further fact of want of cohesion of the parts.

It is quite usual practice in building a structure of any considerable importance to have tests to destruction of tension members, while with the compression members tests are only made on samples to be certain as to the character of the material used. An individual tension member, maximum eye bar, will scarcely cost $200, while we see in practice compression members of size to require a testing machine of 15,000 tons' capacity and one such column would cost $10,000. It is scarcely to be hoped that comprehensive tests of such sizes will be undertaken.

It is in fragments only that we have knowledge of such tests as have been made. It seems reasonable to hope that the records of tests of steel that have been made in compression, both in individual pieces and combined members, might be gathered together, edited and published.

Our understanding is that steel of the character used in construction of a composite column or in rolled sections of 100 "radii" yields by bending at somewhere from 30,000 to 35,000 pounds per square inch; that the elastic limit and ultimate strength are essentially the same, that is, the column yields and fails at once under the same load and at the same time.

Our experience and tests as to the reliability and strength of full sized members has been limited generally to pieces not ever 30 ft. long and 25 square in. of section. In fact our knowledge of the action of such members in the testing machine is very slight, but our knowledge from practice shows rectangular compression members very reliable when designed to standard specifications and sizes within our usual experience in all the well-known forms. That we have scarcely more than practice to direct us, is to be regretted.

Length, divided by least Radius of Gyration (expressed herein as "Radii"), is accepted by engineers as an indication of unit value in a compressive member, the application being made by formulæ with somewhat varying constants. The least "radii" in all cases showing the largest compressive unit value for material, and here the fact is apparent that the thinner the material the larger the radius. To illustrate:

Member	Section Sq. in.	Radius of Gyration	8 ft. 4-in. equal to	100 "Radii" equal to
4-in. Solid Round	12.5	1	100 Radii	8 ft. 4-in. long
8-in. Pipe, ½-in. thick	12.5	2.5	40 Radii	20.66 ft. long
16-in. Pipe, ¼-in. thick	12.5	5.5	18 Radii	45.8 ft. long
32-in. Pipe, ⅛-in. thick	12.5	11.3	8.8 Radii	94.1 ft. long
64-in. Pipe, 1-16-in. thick	12.5	24.0	4.1 Radii	200 ft. long

These illustrations clearly indicate the necessity for a definite and clear limitation or thickness of material forming a composite column. We recognize the fact that a 4-in. solid round 8 ft. 4 in. long, 100 "radii," is safe to carry 11,000 pounds per square inch; that an 8-in. pipe ½-in. thick at 40 "radii" is safe to carry 16,000 pounds per square inch. In the circular form we can readily believe that a 16-in. pipe ¼-in. thick, at 18 "radii" will also safely carry 16,000 pounds per square inch. But a pipe 32 in. in diameter ⅛-in. thick, 8.8 "radii" will also carry a goodly load per square inch, but I doubt if anyone would expect to load it to 16,000 pounds per square inch. A 64-in. pipe 1-16-in. thick 4.1 "radii" we have reason to believe will collapse and fail at less than the load per square inch that the 4-in. solid round at 100 "radii" will sustain.

Let me cite the following as an illustration of the necessity of recognizing some rational thickness of material to radius of gyration: developed in personal practice, a circular section 20 ft. in diameter ¼-in. thick, radius of gyration 85, "radii" 13½, to support a compression of 5,000 pounds per

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