ON SOME COMMON ERRORS IN IRON BRIDGE DESIGN

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ON SOME COMMON ERRORS IN IRON BRIDGE DESIGN.

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ON SOME COMMON ERRORS IN IRON BRIDGE DESIGN.

In the Australian Colonies, as in other parts of the world, there is a large and increasing number of iron (in which is included steel) bridges. These bridges are of ages varying up to about fifty years. Many of them were designed at a time when the proper mode of proportioning the various parts was but imperfectly understood, while in some the material and workmanship is by no means up to the modern standards. Unlike wine, bridges do not improve with age—on the contrary, corrosion is always going on, sometimes rapidly, but generally very slowly, but no less surely, and is bound sooner or later to cause a perceptible diminution in strength. It is also thought by many that there is a tendency for the metal in course of time to become hard and brittle and so less able to endure shocks. Thus the bridges are without doubt growing weaker with effluxion of time. Meanwhile the loads they have to endure show a distinct tendency to increase. Steam rollers, traction engines, and other specially heavy loads, undreamt of at the time our earlier bridges were designed, are now common, while locomotives, with the universal call for more power, become constantly larger and heavier, and powerful continuous brakes, unknown when the earlier bridges were built, introduce longitudinal stresses of serious magnitude. From these combined causes it is plain that the margin of safety is steadily diminishing, and it is only a question of time for the point of absolute danger to be reached.

Again, there is reason to believe that many parts of the older bridges are excessively and unnecessarily strong while other portions are weak, and that the general arrangement of parts is often far from the most economical.

It appeared, therefore, that a criticism of existing bridges would be useful not only to the designer of new structures anxious to avoid the defects of the older ones, but also, and perhaps in an even greater degree, to the man who has received a legacy of imperfect structures from his predecessors, which he is desirous of utilizing as far as possible by judicious repairing and local strengthening, for it is to be noted as a good point of many of our defective bridges that they are like chains, most of the links of which are abundantly strong while occasionally a very weak one is found, which governs the strength of the whole and that thus a comparatively inexpensive local reinforcement may improve the whole structure to a very large and valuable extent.

I shall now proceed as briefly as is consistent with clearness to point out what I consider to be the principal errors in structures that have come under my notice, and indicate how their defects may be remedied, if remediable, in existing and avoided in future structures.

1. *Disproportion of foundation area to load carried.*—If a foundation is too small it gives way partially or wholly, injuring or destroying the structure; if too large it stands but represents waste of money. In every instance however some slight yielding when the load is applied takes place, and it is desirable, especially if continuous girders are employed, that all the supports should yield equally. Hence all foundations should be proportioned to the load carried—that is to say, under full load the pressure per unit area on the supporting material should be throughout equal. In calculating this pressure, it is to be remembered that it is not the total load on the foundation surface that is to be considered, but the excess over the load that existed previously. For example, at the great Hawkesbury Bridge, N.S.W., it has been stated, that the pressure on the foundation is 10 tons per square foot, and this is obtained by dividing the total weight of the structure by the area of foundation. But in order to reach the depth required a very large quantity of earth had to be removed, and the foundation was relieved to that extent. The true or effective pressure on the foundation is therefore the difference between these two amounts, and actually is only 5 tons per square foot. This I submit is the correct way of stating foundation pressure.

There is a further qualification, however, and that is the allowance for the effect of friction of earth upon the sides of a bridge cylinder or caisson, and if this be taken into account, the pressure on the base is still further reduced. This friction is somewhat variable and has been stated as high as 800 and as low as 50 lbs. per square foot in different strata.

Directing our attention to existing structures, great discrepancies appear in the size of cylinder foundations, not only between one structure and another, but between different piers of the same structure. For example the Intercolonial Railway Bridge at Albury consists of two continuous spans of 160 feet each, carried on three piers, each consisting of two cylinders of 10 feet diameter. The centre pair of these cylinders carry $\frac{10}{16}$ of the load, while the two end pairs together carry only $\frac{6}{16}$. Thus, while two cylinders carry a load represented by the number 10, four of equal size are provided to carry a load of 6 only, and these four are further surrounded by earth to a much greater height than the central ones, and therefore receive greater frictional support. It cannot, I think, be disputed that the bridge would have been both cheaper and safer had the end cylinders been reduced to 6 feet diameter, or even less, for then any yielding would have been approximately equal throughout, and the distribution of bending moment in the continuous girders consequently undisturbed. Similar remarks will apply to the Railway Bridges at Wagga, Bathurst, and Aberdeen, described in the Report of the Royal Commission on Railway Bridges, N.S.W., 1886. In all of these the terminal cylinders though carrying less than half the load, and more favourably circumstanced in other respects, are just as large in diameter as their heavily loaded companions, see Fig. 1, which represents to scale the railway bridge at Aberdeen, N.S.W. A reference to numerous successful cylinder and caisson bridge foundations leads to the conclusion that the subjoined are safe foundation pressures, the most unfavourable combination of load, wind and flood, being employed in the calculation. Rock 10 tons per square foot at least. Fine compact sand at considerable depths, 6 tons per square foot. Very good clay 5 tons per square foot. Ordinary sand, clay, or loam 1 to 3 tons per square foot. Knowing then the superincumbent load and the nature of the material there should be no difficulty in proportioning the cylinders of future bridges. As for those in existence, nothing can be done, but as they usually err on the side of excess there is not much cause for alarm.

2. *Excessive and disproportionate size of columns.*—By the term column is meant that part of the structure extending from the foundation to the girder seat. Its size is often made equal to that of the foundation, but there is no necessity that this should be the case, for while the size of the foundation depends on the resistance of the material upon which it rests, that of the column depends upon the material of which it is made and which sometimes offers a greater resistance per square inch than the foundation does per square foot. For the sake of lateral and frictional support, the cylinder is usually, and properly carried up the full size from the foundation to the surface of the ground. Above this, however, there is no reason why it should not be as economically designed as any compression element of the superstructure. In many of the older bridges the columns are of most unnecessary size, adding seriously to the cost of the structure, and impeding the flow of water in the case of river bridges in an undesirable manner. This is certainly the case with the older New South Wales railway bridges already referred to, and also with some in Victoria. As examples of what has been successfully done in the way of reducing this part of the structure to reasonable and economical proportions, two structures may be cited. The first is the Johnston Street Bridge, Collingwood, near Melbourne, shown in Fig. 2. This is an iron bridge built about 20 years since by C. Rowand, Esq., C.E., to replace a large timber arch that failed through decay. It consists of three spans of nearly 60 feet each, extending between the stone abutments of the old timber arch, and having as intermediate supports wrought iron columns filled with concrete, which for slightness present a most extraordinary contrast to the usual practice at the time it was built. Their dimensions are as follow :—

Height from top of cast iron cylinder to girder seat	45 feet
Diameter	2 feet
Thickness of metal	$\frac{5}{16}$ inch
Dead load for each column... ...	40 tons
Live load for each column	50 tons

Each pair of these columns supports an area of bridge decking 70 feet long and 32 feet wide.

The proof of the practical success of these columns is in every way most conclusive, for not only is the bridge on an important main road with heavy traffic, but it is also at the part of the Yarra where the hydraulic conditions are of the severest kind. During the great flood of July, 1891, when two iron bridges were washed away and hundreds of suburban dwellings inundated, the water stood at the level shown in Fig. 2. The gradient of the flood surface for 50 chains above the bridge was at the rate of over 5 feet per mile, the hydraulic radius about 30 feet, and floating timber and other wreckage abounded. Nevertheless these slender columns stood absolutely uninjured, and that, although the bracing between them is by no means as massive as, in my opinion, it should be.

The second example is the bridge carrying the North-Eastern Railway over the Racecourse Road, Flemington, near Melbourne. The railway is double line and is traversed by a busy suburban traffic propelled by tank engines of 49 tons weight. The bridge is situated at the entrance of the Newmarket Station and is exposed to the constant action of the Westinghouse brake. There are two spans of 51 feet each (discontinuous), four main girders to each span, and the central support consists of four columns each made of four $3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{1}{2}$ angles of mild steel, with single rivetted lacing. The foundations are of Victorian bluestone, a 3 inch cube of which crushes with 40 tons pressure, and are $2\frac{1}{2}$ feet square for each column. The compressive stress on the metal of the angles is 4 tons per square inch. The columns are 15 feet high from stone foundation to girder seat and are 18 inches square.

Strange to relate a second railway, carrying a practically identical traffic crosses the same road at a short distance, and here the columns are of cast iron filled with cement, 2ft. 3in. diameter, 1 inch thick, and the girders 44 feet span. Judging from experiments made with the University testing machine it would take 300 tons to crush a column of the former bridge and 4000 tons to crush one of the latter, and yet the latter carries a smaller load than the former.