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“On Some Applications of Transition Curves.”

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THE subject of Transition Curves was carefully investigated by Mr. Froude more than 50 years ago, but their employment has been looked upon as a mathematical refinement, and their introduction in practical setting out may be safely said to be the exception and not the rule; yet there have been laid thousands of miles of railway, along which trains travel at the highest speeds, without any apparent inconvenience arising from the omission of transition curves. The platelayer in practice eases off the junction of the straight line and the curve at the expense of increasing the curvature at another place, and in the face of the experience of half a century it would be absurd to say that this rule-of-thumb method is fraught with danger.

In recent years, however, the construction of underground railways, on which carriages propelled by electricity are run through circular tubes which they practically completely fill, has introduced an entirely new element which appears to have escaped general notice, the tubes being, as a rule, set out with circular curves tangential to the straight lines. In a tube-railway, as elsewhere, a certain amount of superelevation must be given to the outer rail on curves, but as the carriage nearly fills the tube this can only be done by moving the permanent way to one side, following the curve of the tube (*Fig. 1*), and in this way the amount of superelevation and the position of the line become connected in a very curious and embarrassing manner. It is true that on quick curves the size of the tube is sometimes increased, but this is required to give clearance for the ends of the carriages at the outside and for the middle of the carriages at the inside of the curves. There is no clearance available for superelevation.

Let the tube be laid with a circular curve tangential to a straight, and, as a first attempt, let the centre line of the permanent way be laid out in the centre of the tube on the straight, and to one

side in the curve, in order to give superelevation; the result will then be as shown in *Fig. 2*. Easing off the junction, or rather want

Fig. 1.

Scale, $\frac{1}{4}$ inch = 1 foot.

of junction, of the straight line with the curve is here a much more serious matter than in the open. The straight line may be continued forward and gradually made to join the curve, but this means

Fig. 2.

entering a curve, and possibly a very quick curve, without any superelevation, and will be bad, although it may satisfy the eye. Probably the best method is to lay the rails in the manner

indicated in *Fig. 3 (a)*. In the open such a line would be unobjectionable, and would, as a matter of fact, be much better than the platelayers' rule-of-thumb line, since the proper amount of superelevation could be given at each point. In the tube, however, quite another state of affairs exists. Superelevation is no longer independent of line, but is absolutely dependent upon it, and where the line gradually moves to the left the inner rail of the curve is higher than the outer. It is true this curve may be made very flat, but the flatter it is the further on will be its connection with the circle, and the further it will be moved from the centre of the tube, so that at the point of change of curvature, where there may be a piece of straight, and where in any case there should be no superelevation, there will, as a matter of fact, be nearly the full amount due to the main curve. This may affect the working of the traffic in a very serious manner. When an ordinary railway-carriage runs round a curve, the principal disturbing forces arise from centrifugal force, from the parallelism of the axles, and from the difference of length between the outer and inner rails.¹ The first can be completely balanced by superelevation of the outer rail. The second and third can be abolished by the use of radial axles and one wheel loose on the axle (as in the rolling-stock used on the old railway over the Mont Cenis Pass and elsewhere); but the difficulty of making the moving parts so that they will stand rough usage and heavy traffic is so great, and the inconvenience to be avoided is so small when the wheel-base is short, that the system has not found favour, though it has lately been suggested by Mr. Farr² as a cure for other evils. The effect, such as it is, of the second and third disturbing forces is to cause the leading wheel to hug the outer rail and try to mount it, and this can be roughly if unscientifically corrected by giving a slightly increased amount of superelevation. If this is introduced, then with bogie stock there would appear to be very little danger in running round quick curves at a high speed, provided only the amount of superelevation is not so great as to be a source of danger at low speeds, or when standing still. A speed of 25 miles an hour on a 5-chain curve seems well within the limits of safety. It may well be, however, that while there is no danger in traversing a quick curve, there may be great danger in entering it on a tubular railway without transition curves. Assuming a 5-chain curve, a speed of 25 miles an hour, a super-

¹ See the Author's remarks in the discussion of Mr. Adams' Paper on "Train Resistance," Minutes of Proceedings Inst. C.E., vol. xxxi. p. 394.

² Minutes of Proceedings Inst. C.E., vol. cxli. p. 88.

elevation of 7 inches, and a side-shift of 8 inches to obtain this, there will be a point on the short intermediate straight where there is a superelevation of 5 inches or 6 inches; and this is the point where derailment is most likely to occur, when the train will appear to run off the rails on the inside of the curve. In the case of the accident at Amberswood Junction in July, 1900, the Board of Trade Inspector mentioned among the contributory causes that of running at 30 miles an hour round an $8\frac{1}{2}$ -chain curve with practically no superelevation, and this does not seem to be any more objectionable than running along a straight with 6 inches of superelevation on one rail, or running along a flat curve with superelevation on the wrong rail. It is apparent, therefore, that it is much more difficult and less efficacious to ease off the junction of straight line and curve by rule of

Figs. 3.

thumb in the case of a tube than in the open, and that the safe speed for trains depends, not upon the radius of the curves, but upon the method of entering them; and as the maximum speed at certain points may indirectly affect the time of transit of the trains to a very large extent, the introduction of transition curves in laying out the tube, so that the rails may be laid as indicated in *Fig. 3 (b)*, may materially affect the commercial success of the whole undertaking.

In conclusion, the Author would call attention to two points connected with the introduction of transition curves in the open, since, though not always necessary, they are often useful and in some countries their use is compulsory. The first is that

2 minutes is a full allowance for the time required to introduce such a curve in setting out, and the second is that if these curves are to be used, they must be introduced at the original setting-out of the line. For ordinary purposes, all transition curves should be of one length, say 2 chains (if 100-foot chains be used a length of 200 feet may be adopted). The amount of shift is one-third of the deviation of the main curve from the straight in a length of 1 chain, or :—

$$\text{Shift in feet} = \frac{11}{\text{radius of curve in chains}},$$

say 9 inches for a 15-chain curve, 13 inches for a 10-chain curve, etc. The straight line is set out to the tangent-point A, *Fig. 4*, the shift AB is put in, the curve is laid out as a circle from the point B, a peg is put in half way at C, and the work is done. The transition curve will run from D to E, and the platelayer will always put in a good curve. This matter is more fully dealt with

in a letter by the Author to the *Engineer*, 6th December, 1867. A moment's consideration will show that although 9 inches seems a very small matter in the original setting-out, it would be impossible to set out the rails eventually 18 inches nearer one side of a cutting than the other, and hence it is futile to attempt to put in transition curves in setting out the rails if they have not been allowed for in setting out the work originally. In the case of such curves in tunnels and stations, and more particularly in tubes, where points have to be given at shorter intervals than 1 chain, the matter must be gone into more fully, and for this purpose there can be no better guide than the Paper on "Transition Curves for Railways,"¹ by Mr. James Glover, recently published by the Institution.

The Paper is accompanied by drawings, from which the Figures in the text have been prepared.

¹ Minutes of Proceedings Inst. C.E., vol. cxl. p. 161.