DISCUSSION ON THE EVOLUTION OF RAILROAD BUILDING AND RAILROAD BRIDGEWORK IN AMERICA. (Vol. VIII No. 1.)

By Suetaro. Sakaoka, Dr. Eng. Memoer.

I have read his address with much interest I wish to give Dr. Waddell many thanks and gratitudes for his kind informations regarding the railroad building and bridgeworks of America. Dr. Waddell was formerly the professor of the civil engineering in the University of Tokyo, and published his valuable book "The system of Railroadbridges for Japan" while he was staying in Japan, which was extensively read by our engineering students and professors with much utility. Afterwards, he also published the books "De Pontibus" and "Bridge Engineering", both of which are well known among the Japanese students and specialists. As he says, Japan makes a remarkable progress in science and art as it is well in the political and social matters. The causes having induced Japan to such a state of advancement are of course manifold, but it is quite certain he made a great contribution to the japanese civilization—at least on the japanese engineering science: and for which we must pay our hearty esteem and reverence for him and never forget the services he rendered to the state.

Now I do'nt intend at the least to criticize his address delivered to the Japanese Civil Engineering Society, but simply wishing to be taught and supplemented by him on what I do'nt understand with respect to the some points of the railway building, I have a liberty to put down a few passages as follows —

Compensation for curvature.

His information about this point is very valuable and we wish our locating engineers would also apply it to our railway lines, pursuing his way. But in regard of the point how much of compensation may be allowed, there must be some diversity of opinion. To determine the amount of compensation, we must first of all know the amount of a train resistance. If the train resistance is .8 pound per ton per degree of curvature, his allowance is of course right. But if it is not .8 pound and amounts to be 1.0 or .6 pound, then we must take it as .05 or .03 % according to the case. Mr. A. M. Wellington takes this to be .03-.06 %. Remembering, however, his experiments were behaved on the cars of old type, we can not take it for granted as true as it was, when applied to the present type of the railway cars. Hence we wish him to show that even on the modern cars it is also the same with those of the old with respect to the train resistance.

Were .04 % taken as invariably true, the compensation must be different according to the case met. The followings serve to indicate the different amounts of compensation as the case may be. Let us extract the some passages given by Mr. Wellington as follows—

1. With short grades or under favorable topographical conditions compensate as liberally as possible up to a maximum at special points of 0.1 per cent per degree.
2. Where speed may sometimes be very low, and hence invariably on or very near to known stopping-places, this maximum rate appears, with our present knowledge, none too much.
3. On section where curves largely predominate over tangents it is particularly desirable to have ample compensation, and if excessive it will do least harm.
4. On sections where the amount of the curvature is small it is less important to have full compensation, and if excessive it will do most harm.
5. When the rate of compensation can only be increased at the certain cost of a corresponding increase in the rate of tangent grades, no larger rate than we feel practically certain will be required to balance the curve resistance (.03 to .04) should be chosen.
6. On any minor gradients where the curvature is not sufficient to bring the virtual profile up to the maximum is not important to compensate for curvature at all, although it is generally as well to do so, especially at points where to do so will slightly reduce the cost of construction, as is very apt to be the case on long curves.

Mr. Webb also gives the rules for cempensation which may be stated as follows:

1. On the upper side of a stopping-place for the heaviest trains compensate .10 % per degree of curve.
2. On the lower side of such a stopping-place don't compensate at all.
3. Ordinarily compensate about .05 % per degree of curve.
4. Reduce this rate to .04 % or even .03 % per degree of curve, if the grade on the tangents must be increased in order to reach the required summit.
5. Reduce the rate somewhat for curvature above 8° or 10°.
6. Curves on minor grades need not be compensated, unless the minor grade is not so heavy that the added resistance of the curve would make the total resistance greater than that of the ruling grade.

I extract these here simply wishing to be some help for the readers who intend to go further on this subject and therefore I don't mean the aboves are all right and invariably true for the present train as it was.

Spiral approaches to curves.

Easement curves or transition curves are not used in the Japanese railway lines. I can not understand the reason why our governmental engineers ignore this question. Of course they know the importance of using this kind of curve, and hence I don't like to discuss of this at length, but let us only say about the utility from the practical observation made on the line actually operated and are lined all the time by section-men. They always use to say that although the curves in the beginning are perfectly circular, joined directly to the tangents, still, as time goes on, the circular curves invariably become changed into the rude forms of easement curves. This is of curse due to the impact given to the outside rails at the beginning of the curves by the sudden change in the direction of the train, and also to the gradual casing-off of the circular curves unconsciously done by the train force: and it shows how circular curves tend to become transition curves—the fact it necessiates the circulars to be connected with the transition curves.

Dr. Waddell's imformation on this point is quite noticeworthy and I with our engineers should keep it in mind and never forget it. In spite of this, I have some point which can not be convinced by him. His method adapted was to lengthen each circular curve 100' at each end, irrespective of the degree of curvature. I dare say the prolongation of the circular curve must vary to the degree of curvature, so that the sharper the curvature must be the longer

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the prolongation of the cı rve end.

A theoretically perfect transition curve should at least possess the following properties—

1. Beginning with a radius practically infinite, this radius should gradually decrease untill it becomes equal to the radius of the desired circular curve.
2. The radius of a transition curve should vary inversely as the distance from the starting point, although not necessarily in exactly the same inverse ratio.
3. A transition curve should begin a sufficient distance back on the tangent to allow the requisite amount of superelevation to be attained when the point of curve is reached, and the rate of grade being constant between the beginning point of and the end of a transition curve.

There are many kinds of easement curve, but the curve known as the cubic parabola approaches more nearly to the theoretical transition curve than any other. His way of easement is of course far better than nothing which is the general case with the Japanese railway lines. But let us wish more. As every one knows, the superelevation varies directly as the square of the train velocity and inversely as the radius of the curve. Hence, if the degree of curvature is greater, the superelevation must be proportionally greater than that of the less sharp curvature, if taking the velocity as constant: and therefore to overcome this greater superelevation, it needs the longer lengthening of the tangent, in order to conform the conditions properly aimed at for a transition curve. But his way of easying is not so because he took the lengthening as constant for all degree of curvature.

Paper Location.

Dr. Waddell earnestly asserts the advantages of paper location and says that "without an accurate contour map one cannot arrive at the most-truly-economic-and-best-line". I believe this is true in some degree but not in whole. About this point, Mr. Wellington gives a full discussion in his famous and immortal book "The Economic Theory of Railway Location", and therefore I don't like to say much about this, because his opinion is so complete and comprehensive that we can add, comment, or supplement no more. But as far as my experience is concerned, I have a boldness to say that the economic-and-best line could only be located by using "Cross-section method". I spent about four years as the Governmental locating engineer and the miles located by myself amounted more than 200 miles. In the smooth part of a country, we of course don't need the paper location,—the ground directly gives us the most economic-and-best line, but in the rough part of it or the mountainous district, it is very hard to get the best line or the line suited best to the ground, even the experienced engineer. On this occasion, if we use the cross-section method, any one could hardly fail to find the required best line. I agree him that a good railway locater is not "born and not made", but without some criterion or guidance to judge whether it is good or wrong, one could not get a good location. Cross-section method serves as a guidance of this kind. Let us dwell on this some time long.

I am sorry that I can not fully understand the meaning of "most-truly-economic-and-best-line". There are many ways of comparing the railway lines: They can be treated from construction point, maintenance point, or operation point. There is no line fulfilling all the conditions required from all these points of view. If the road is constructively cheaper, the future maintenance cost is far more, it is usaul, than that of the road more extravagantly constructed, and the same is true if operatively considered. If he means by the best-line only the economy of construction, it does not necessarily mean the economy of maintenance or operation. To combine all of those economics in one line, it is quite impossible or rather inconsistent thing. Now taking aside for a moment the point of operation, and only wishing to aquire the best line constructively and maintenancely considered, we may say to refer the cross section of each station, and shift the centre line some way to the right or left, as we may think it best, and then we are sure that we could get the best line, considered from the above two points of view. Suppose one cross section is surveyed and plotted in proper scale as the figure 1, and c is the centre stake-point which is the best suited to the ground; at a glance the best because there is no cut or fill in the centre.

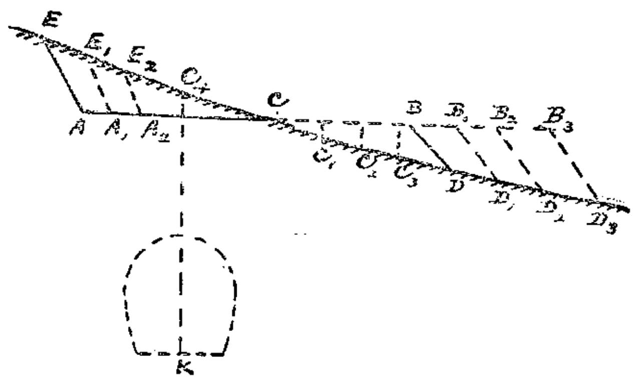

Fig. 1.

Granting this is the most economic point, if all the stake-points coincide the ground like this, we must say the line connecting all these points, of course, the best. But it is a superficial view. The line whose stake-points all justly coincide the ground is not necessarily the best. If the fill just balances the cut, we may say, in ordinary case, it is right. But if the point of earth contraction or expansion after digging or embanking and the point of the ground nature of the selected line-site are taken into account, the balance method is not satisfactory. The fill CBD is less than the cut ACE, because the breadth CB is always less than AC, and hence in order to balance, the centre must be shifted rightward in some measure, for instance, to C_1, and thereby CB_1D_1 just balances CA_1E_1. When the nature of the ground is ordinary, the case is quite right, but if the cut is rock, the above does not hold true, owning the expansion of the rock when loosen, and the calculated area from the paper in cut must be less than that in fill, in proportion to the rate of the rock expansion. Suppose CA_1E_1 is the rock cut, then the excavated amount is more voluminous than that of the not-yet-loosen rock: and hence we must take E_2A_2C equal CB_2D_2 for balancing. In this case, the best line's centre must be C_2 instead of C or C_1; quite different compared with that of the line at first assumed.

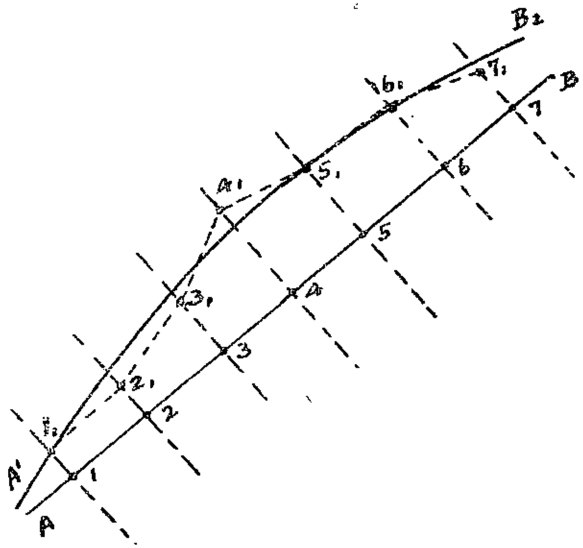

Fig. 2.

AB, Trial line.
1, 2, 3, 4, ..., Brocken line connecting first requisite points.
A_1B_1, Final line to be fixed to ground.

Assume C is the centre of the trial line—the line not yet corrected to finality—then pursuing the above method, we can determine the best contre-point and the distance of the two points C and C_2, can be got from the plotted map properly scaled. Then this new point C_2 is the best which we should fix it to the ground as the required point. This method is repeated as many times as a number of the cross sections, and then we get the broken line as 1,2,3,4,5, ...

shown in the figure 2. The line thus got is not proper as a railway line, on account of too short tangents and too much crook. Therefore if we take a line pasaing through the mean of these points such as A_1B_2, then this must be the most economic-and-best-line, fulfilling very nearly the conditions mostiy required, and which must be actually fixed to the ground, whose position can easily be measured and determined from the map. If the ground consists of the loose soil whose natural equilibrium could be disturbed by the digging of it and cause much trouble to maintain it we must avoid the cut as possible and there by shift the centre like C_3, so that by this the road would consist of fill only. If in the district where might occur a great avalanche and the fear of blocking the traffic is very much, we must avoid both the cut and fill, and must prefer to run in by means of tunnel, so that the centre in this case must be in C_4, All of these kinds of the centre shifting, can be determined from the cross section map without any difficulty, and hence even the engineer not naturally gifted can be made a good locater. I am afraid that the readers can not convey a true idea about the cross section method, for I have made much haste to explain the process necessary to perform the method. If some readers wish to have the more detailed comment, I declare that I will do that very willingly.

(THE END)