THE INSTITUTION OF CIVIL ENGINEERS.

CORRESPONDENCE

ON PAPERS SUBMITTED FOR DISCUSSION AT MEETINGS OF THE ENGINEERING DIVISIONS DURING SESSION 1948–49.

ROAD ENGINEERING DIVISION.

Road Paper No. 27.

"The Co-ordination of Horizontal and Vertical Alignment of High-Speed Roads." †

By Wilfrid Hardy Spencer, A.M.I.C.E.

Correspondence.

Mr. P. E. Haines observed that the Paper gave very valuable information regarding the aesthetic design of road works. Whilst most road engineers agreed on the necessity of co-ordinating vertical curves, the present-day practice of locating roads having long curves of large radius, with the reduction or omission of straight sections, meant that very long vertical curves were also necessary. The use of long horizontal curves did not appreciably affect the cost of schemes, but, on the other hand, long vertical curves inevitably meant increased earthworks and increased land acquisition. (See *Fig. 5.*) Had the Author given consideration to the extra costs involved by long vertical curves and to the possibility of steepening the maximum gradient of, say, 1 in 30 in hilly country in cases where the vertical alignment was entirely curved and the maximum grade occurred only at points of contraflexure ? That might well be possible in view of the present development in heavy transport and the fact that motor road traffic would have good unobstructed approaches to gradients.

The Author's admission of the need to prepare a line picture at every view-point was very interesting and was fully borne out by the rapidly changing aspects of a road channel or kerb-line gained even while walking along a road. It seemed that the " setting up " of the road on a universal road model during the design stage might be more economical and satisfactory than the preparation of a considerable number of line pictures from different view-points on the carriageway and adjacent lands.

Mr. H. M. Horrocks observed that the difficulties mentioned by the

† Discussed at meeting on 30 November, 1948.

Author had been apparent for some time before the war and, whilst the method described was a workable solution, the necessary drawings required some time to prepare. The time spent was not out of keeping with the results required, but he wondered whether that was the most convenient means in practice, bearing in mind the need for maintaining a reasonable balance of cut and fill for earthworks.

An experienced engineer could and should be able to select suitably proportioned vertical curves to suit changing gradients incorporated with horizontal curves; the examples shown in *Fig. 5* would normally be suspect.

Mr. Horrocks considered that a simple model of the profile would give an adequate check on the design and, in fact, had several advantages over drawings. The model took the form of a single profile cut out in stiff card and set up in cardboard supports over the plan of the route being considered. The normal scales of horizontal 1/2,500 and vertical 1/250 usually gave sufficient exaggeration for visual study. The eye could be applied to any part of the profile to obtain a series of views very similar to those depicted in the Paper. As any view-point on the route could be studied, the saving in time was considerable; necessary adjustments in the profile could be made rapidly, and the engineer could be satisfied that no optical disfigurements had been overlooked.

The cardboard supports for the profile need to be accurately made and were the only items which took any time to prepare, but as they could be used over and over again that was not important. If the plan were fixed on a drawing-board, the supports could be firmly held in place by drawing-pins; they were generally required at from 2-inch to 6-inch centres, depending on the degree of horizontal curvature and also, to a certain extent, on the quality and flexibility of the card used for the vertical profile.

Mr. J. J. Jonker observed that the problem dealt with in the Paper had also received attention in Holland in connexion with the planning and construction of the motorways in that country. It had not yet been satisfactorily solved, as it seemed that the human eye could be struck and sometimes irritated by details so small that they were not registered on a photograph and could not be detected by the ordinary method of perspective drawing.

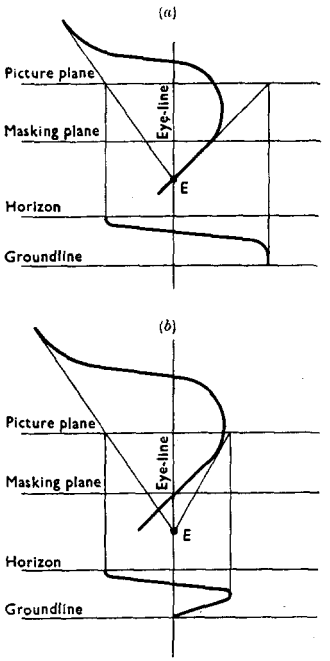
He believed that the only way to discover the points which would appear as misalignments when the road was actually constructed, would be to exaggerate the scale of the drawing in one direction or the other; but the correct solution had not yet been found.

He had studied the Author's method very carefully, but had at first encountered a difficulty in applying it to the design of a new motorway. On a rather winding part of that road he had placed the eyeline not, as usual, in the direction of the road, but on an angle as shown in *Fig. 13 (a)*. In the perspective drawing he had obtained the axis of the road perpendicular to the groundline at some distance from the point of view. Later

he understood, that that was in true correspondence with the theory and that he had to place the masking plane on the intersection of the eyeline and the road axis (or the travelling path of the vehicle) and the eye somewhat in front of it, as shown in *Fig. 13* (*b*), and he then obtained the desired perspective.

Mr. Jonker had found that the method enabled him to exaggerate just those dimensions of the drawing that were desired and would assist in detecting the points where the alignments needed correction.

Figs 13.



Mr. J. R. Whitehead observed that the Author had undoubtedly performed a useful service by drawing attention to the improvement in alignment which could be effected by the proper co-ordination of horizontal and vertical curves, but his case for using perspective drawings to illustrate that would have been stronger had he not used a 2 : 1 exaggeration in the vertical scale. Up to the stage of the preparation of those perspectives the engineer would almost certainly have been working on an exaggerated profile and it was, therefore, all the more important that the perspective should present an undistorted view of the road as it would appear to the road user. That misapprehensions could occur if that were not done could be seen from an examination of the photographs and

drawings in *Figs 8*. In *Fig. 8 (a)* the vertical curve, as shown in perspective (*d*), appeared as a kink and seemed to need a larger radius and lengthening, involving probably a longer and higher embankment. In *Fig. 8 (b)*, however, the kink was not apparent and the curve appeared to be quite satisfactory. Had a natural scale perspective been prepared in the first instance it would have shown, apart from considerations farther along the line which might have affected it, that the additional expenditure on the embankment for that particular curve was not necessary.

With regard to the distance of the view-point to the the picture plane, Mr. Whitehead had found that the perspective appeared far more realistic if the distances of view-point to picture plane and viewer's eye to perspective drawing were the same when drawn to scale. Taking 2 feet as a convenient distance at which to examine the drawing, and a picture scale of 1 : 50, that gave a distance of 100 feet from view-point to picture plane.

In designing motor roads in gently undulating country long, flat, horizontal curves generally fitted well into the landscape, but if the continuous-flow principle was to be carried out to the letter that would involve vertical curves of an inconveniently large radius. A curve of 150,000 feet radius had an intercept between the tangent and the arc of 0·033 foot at the end of a 100-foot chord. It would seem to be a wise precaution to limit vertical curves to that radius, as beyond it the intercept would become so small that difficulties in setting out would be likely to occur. The appearance of a straight in plan or profile would probably afford as much relief to the road user as to the engineer.

In general, Mr. Whitehead considered that the principle of three-dimensional design was sound and should be applied wherever possible to modern high-speed roads, provided that it did not conflict with basic principles such as fitting the road to the landscape, balancing cut and fill, and the avoidance of unduly deep cuttings and embankments.

The Author, in reply, observed that the idea that the application of the principles of flowing alignment would add to the amount of earthworks was not correct and might be based upon efforts to apply the principles to fixed horizontal alignments which were stilted in the first place. He had found repeatedly that where the development of the alignment of a road could be approached with the principles in mind from the outset and before the horizontal alignment had been fixed, then an economy of earthworks would be effected.

Mr. Aldington, at the end of his Paper,[1] had indicated that gradients of up to 1 in 20 for short distances might be acceptable in extreme circumstances, and it was a feature of co-ordinated curvature that the maximum gradient was gradually built up and existed for the minimum distance only.

The use of cardboard profiles, as suggested by Professor Royal-Dawson and Mr. Horrocks, had been developed in Germany during the period of

[1] See reference 3 in the Bibliography, p. 15.

study of the later road alignments, and that line of approach was undoubtedly helpful.

In the Author's opinion, the difficulty represented in *Fig. 13* (*a*) by Mr. Jonker was due to the plotting of a single axis only and should disappear when the width of the road band was plotted and the perspective opened out to embrace the eye-point. In that type of picture it was not essential to place the masking place on the crossing of the eyeline and the road line, since the purpose of that mask was to control the size of picture in the foreground. *Fig. 13* (*b*) illustrated the more useful position for the drawing of the picture, since it would show the relationship between the straight and the curve.

Figs. 8, Plate 2, illustrated an actual example taken from German experience, and the purpose of their inclusion was to demonstrate that optical deficiences from one direction could give peculiarities in alignment when viewed from the reverse direction. The Author considered that Mr. Whitehead would find, on full analysis, that the small correction called for by the misalignment in *Fig. 8* (*b*) would be insufficient to correct the illusion shown in *Fig. 8* (*a*); that required stronger treatment.

With regard to the limit of vertical curve which was practical in use, experience might show that the figure of 150,000 feet was too low, since what was desired for the free flow of alignment was the development of the sweep of the vertical curve within the horizontal alignment. That could not be achieved in all cases if limits were set to the radius to be used. The following effect was created by the building up of the vertical curve of no matter how large a radius correcting the apparent dropping away which was normally inseparable from a long straight gradient.

RAILWAY ENGINEERING DIVISION.

Railway Paper No. 34.

"The Design and Strength of Standard Flat-footed Rail and Fishplate Sections." †

By ARTHUR MITFORD SIMS, C.I.E., B.Sc. (Eng.), A.M.I.C.E.

Railway Paper No. 35.

"Practical Considerations in Regard to the Design of Flat-bottomed Rail Track." †

By NOEL WILLIAM SWINNERTON.

Correspondence.

Mr. C. G. Cumming observed that Mr. Swinnerton had given some well-founded arguments based on years of research in the design of flat-bottomed

† Discussed at meeting on 1 February, 1949.