RIJKSWATERSTAAT
COMMUNICATIONS

No. 20

THE ROAD-PICTURE AS A TOUCHSTONE FOR THE THREEDIMENSIONAL DESIGN OF ROADS

PART II: PICTURES

BY

IR. J. F. SPRINGER

AND

IR. K. E. HUIZINGA

1975

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Part II: Pictures

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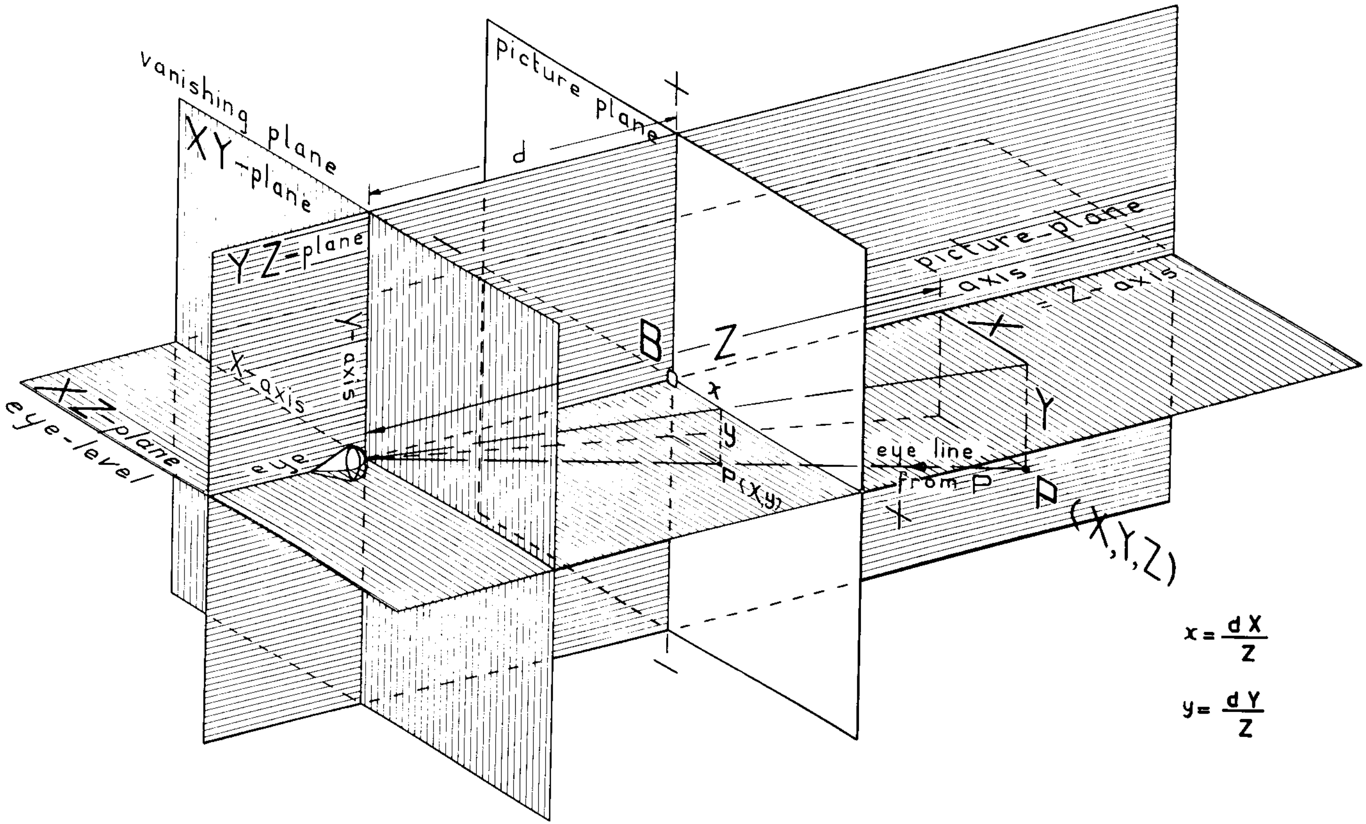


$$x = \frac{dX}{Z}$$

$$y = \frac{dY}{Z}$$

Figure 3.1 The principle of calculated perspective; calculation of the coordinates of a point in the picture.

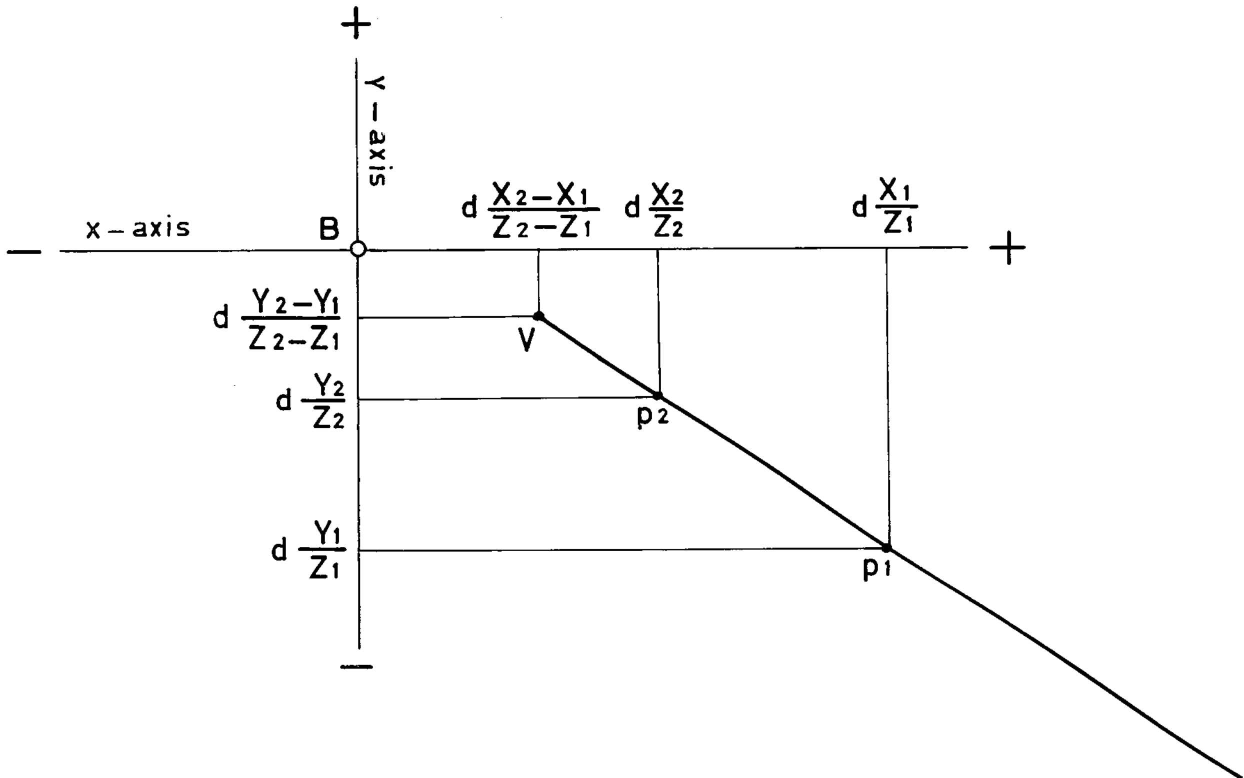


Figure 3.2 Picture of a straight line, defined by two points.

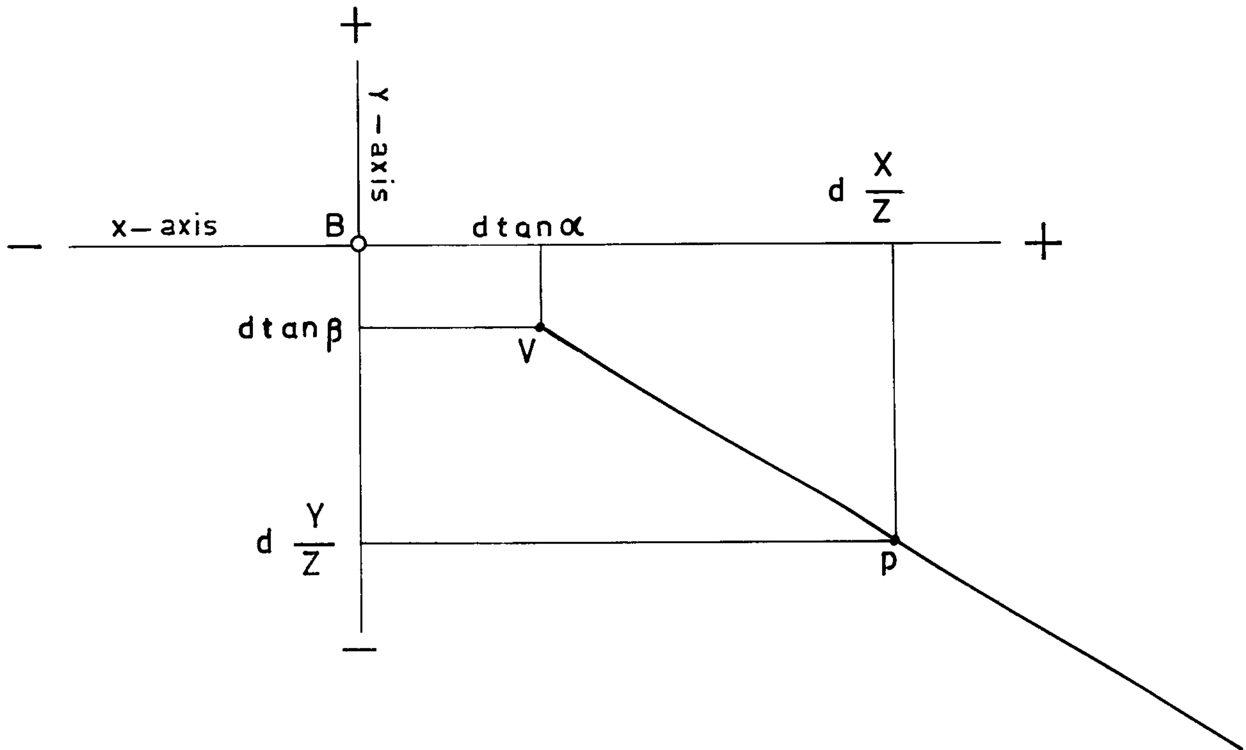


Figure 3.3 Picture of a straight line, defined by its direction and a point.

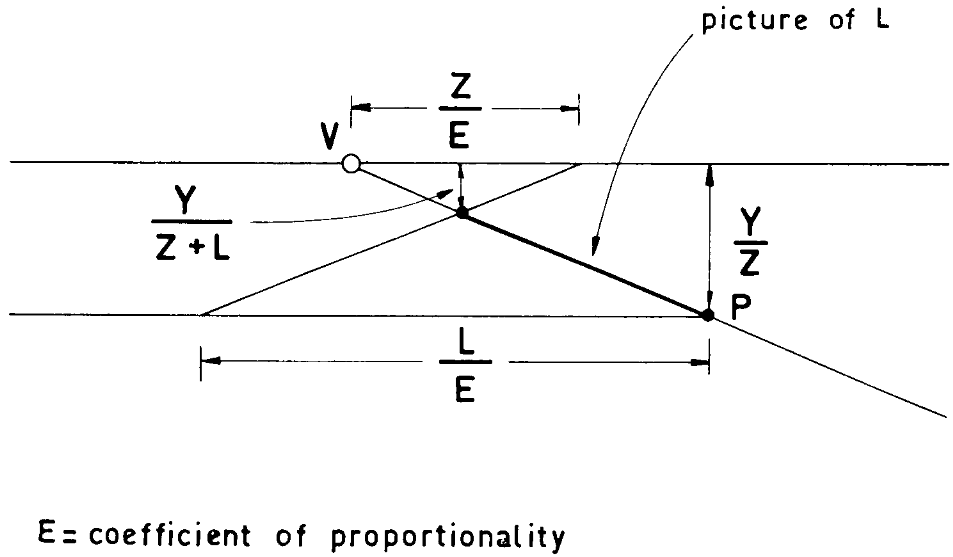


Figure 3.4 Construction of the picture of a section of a line of a certain length.

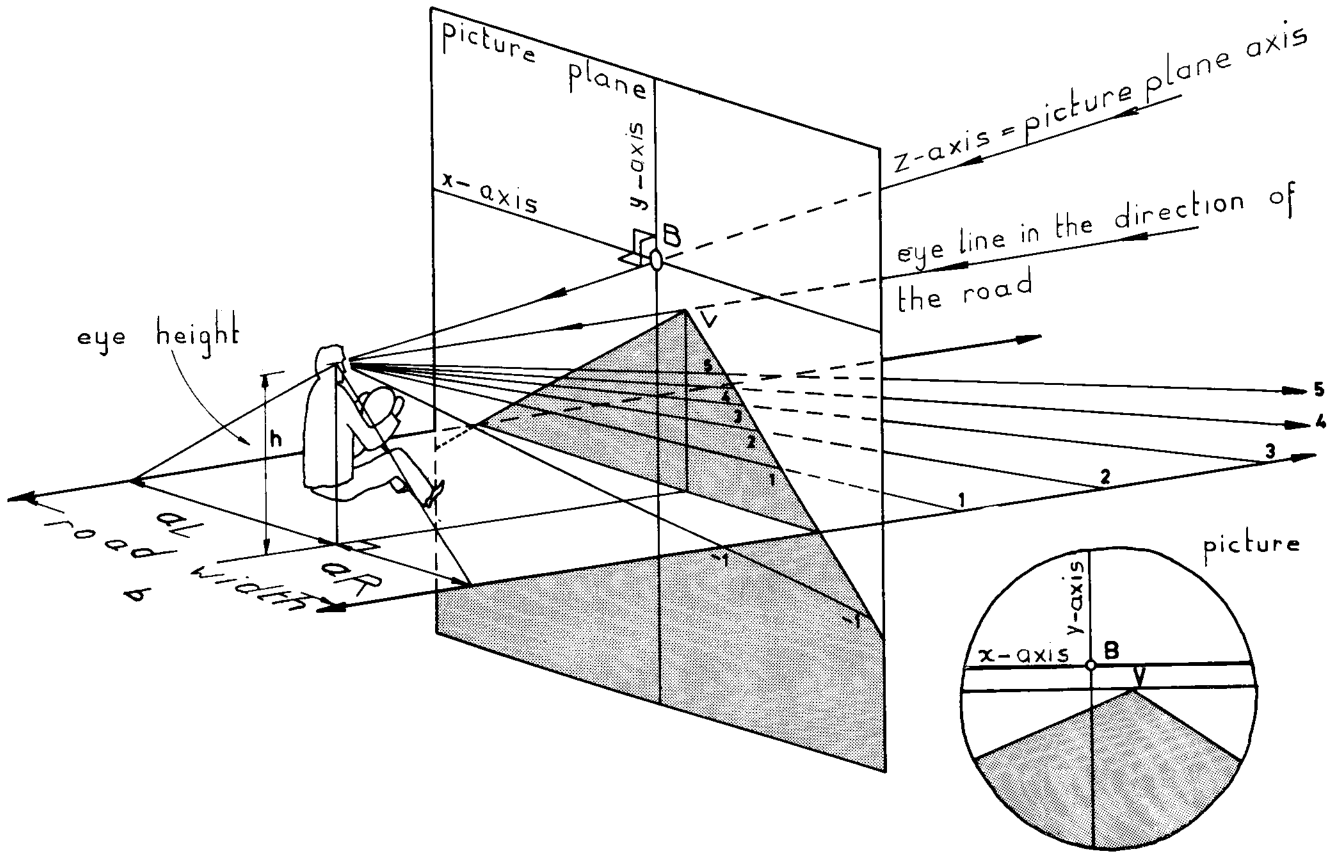
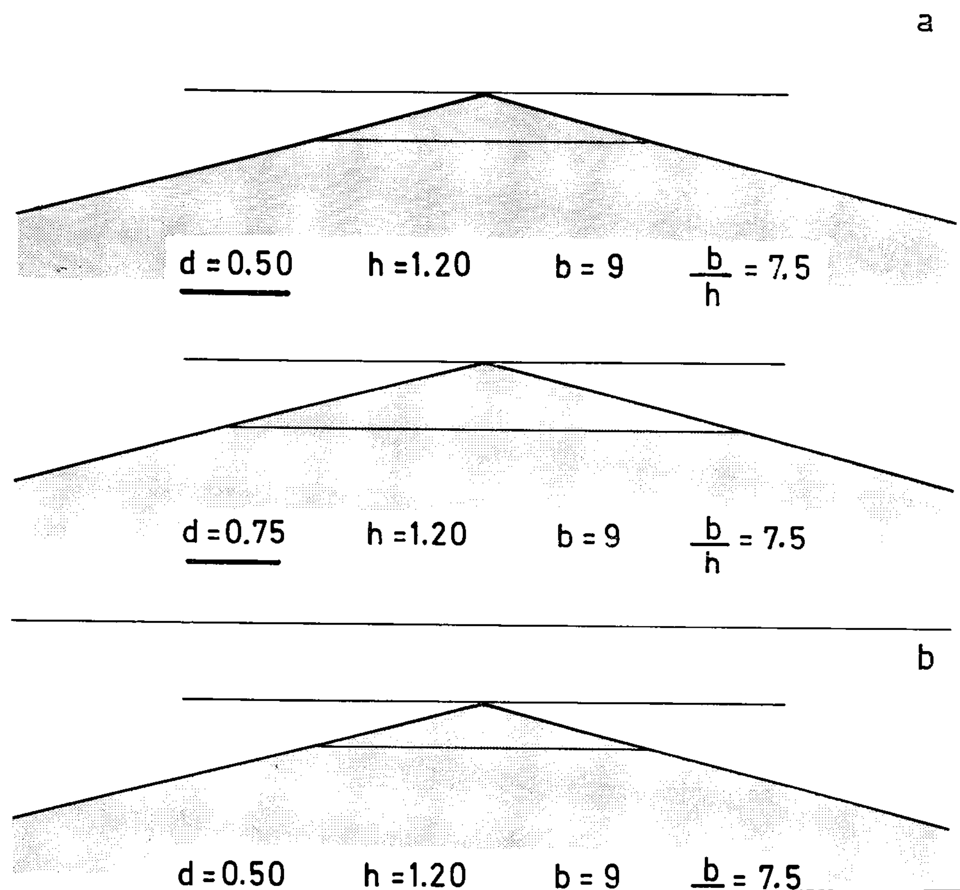


Figure 4.1 Development of the picture of a straight road section, the direction of which does not coincide with the picture plane axis.


a
d = 0.50
h = 1.20
b = 9
b/h = 7.5
d = 0.75
h = 1.20
b = 9
b/h = 7.5
b
d = 0.50
h = 1.20
b = 9
b/h = 7.5

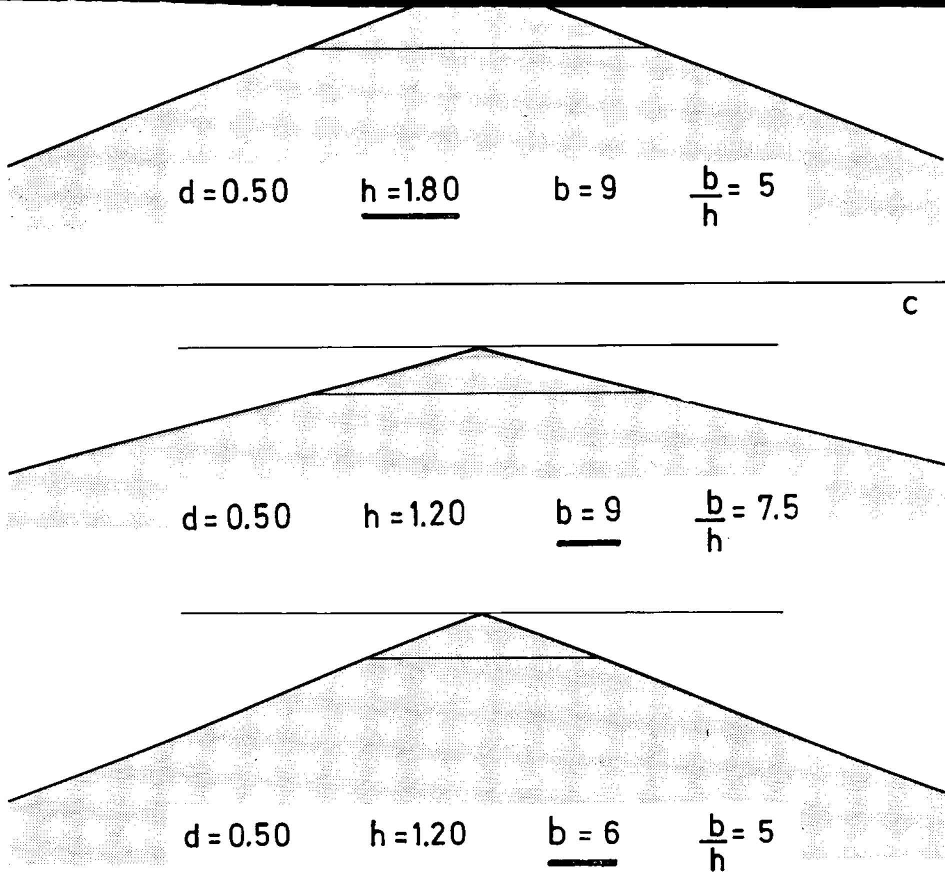
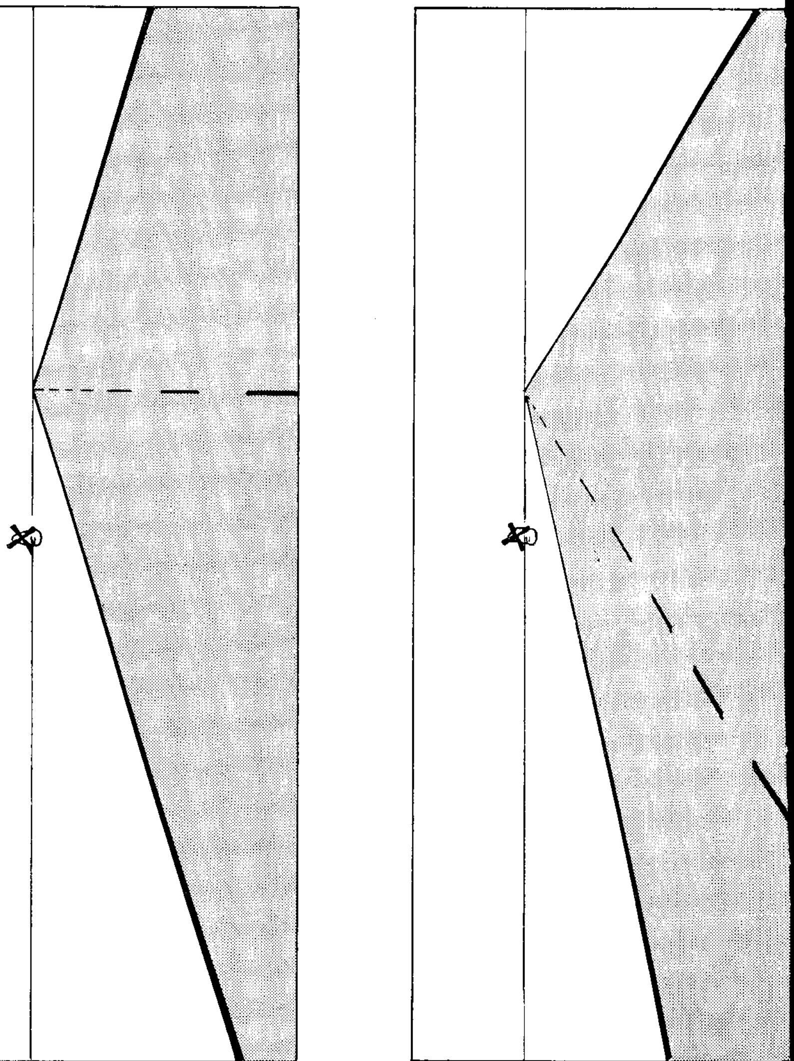


Figure 4.2 The influence of the distance to the picture plane d, the eye height h and the road width b on the picture. The horizontal line is in every picture at 100 m in front of the observer.



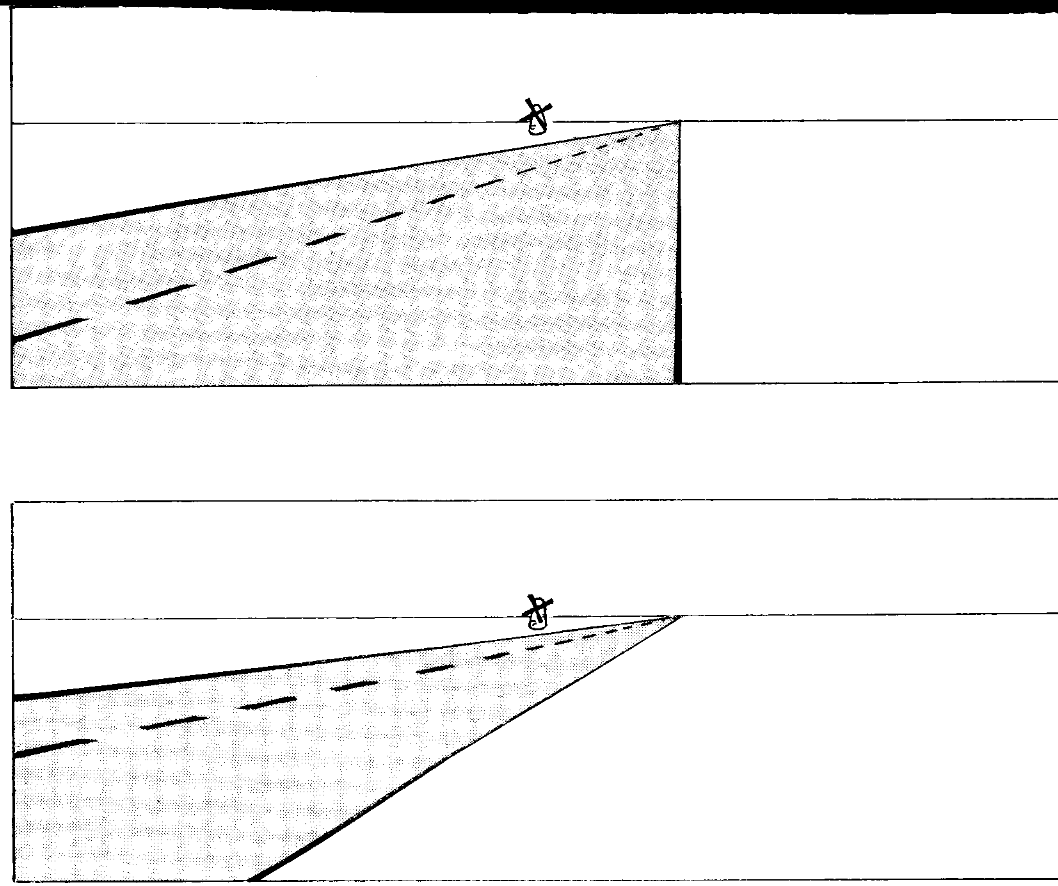


Figure 4.3 When crossing the road, the vanishing point retains its place.

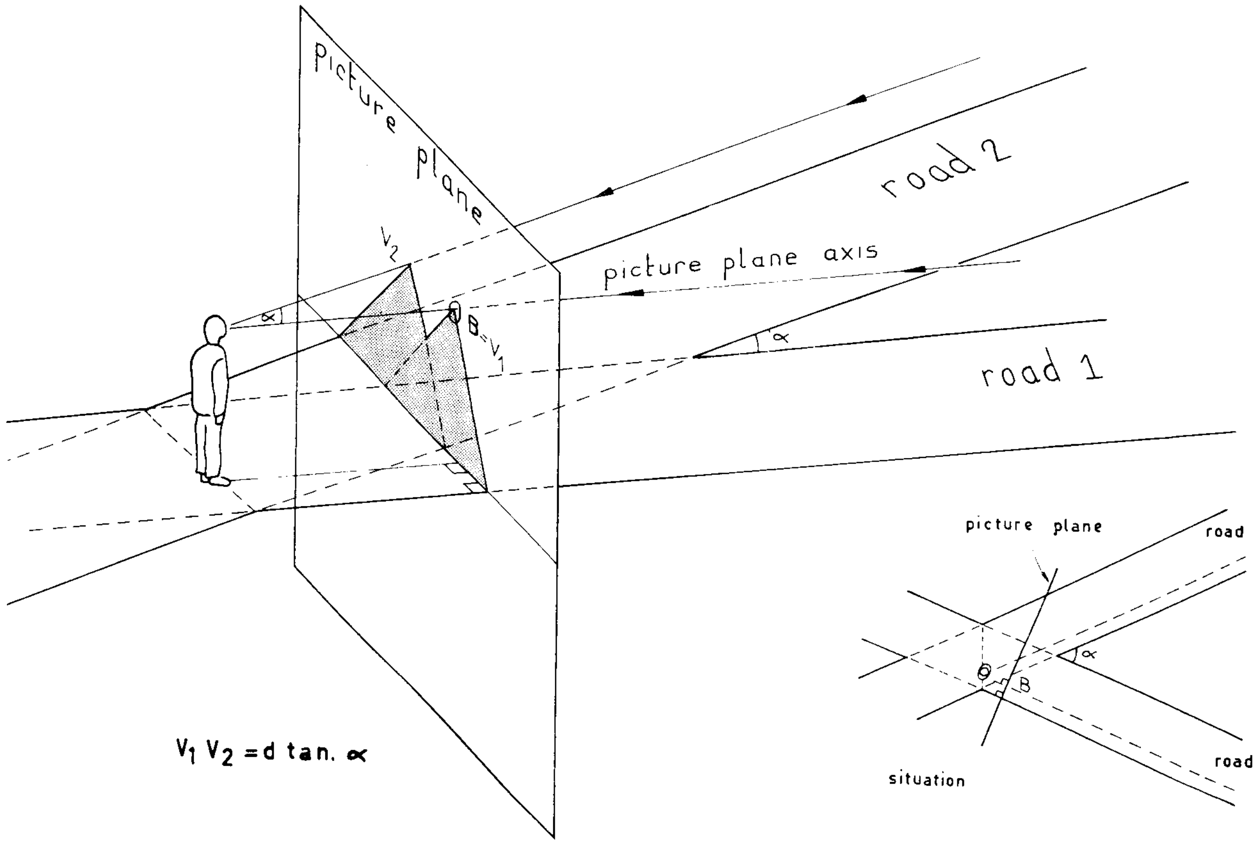
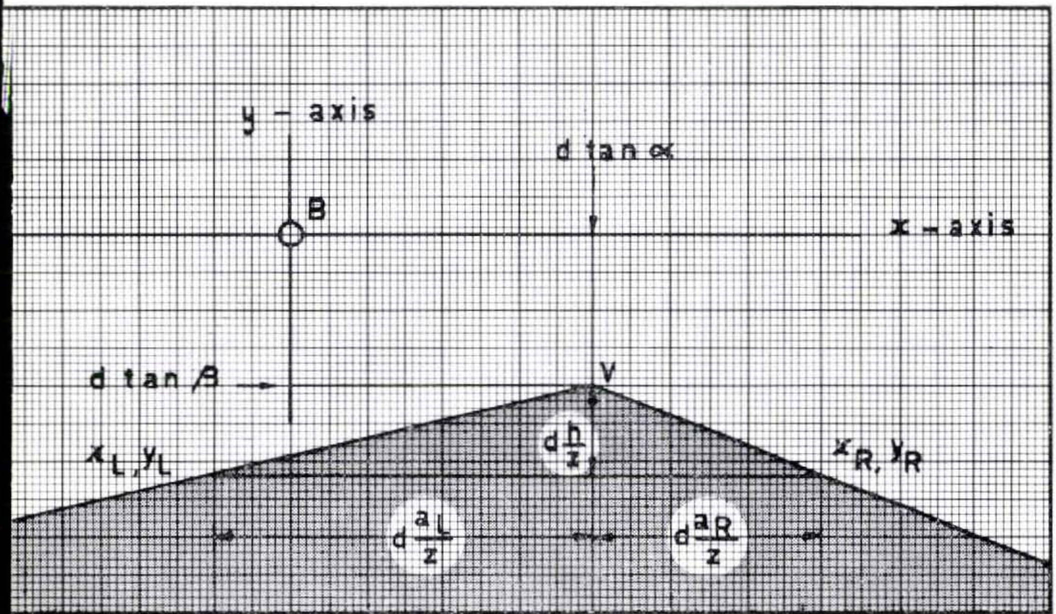


Figure 4.4 Picture of intersecting roads. The picture plane is perpendicular to the direction of one of them. The pictures are different, but by correct observation they give the same impression.



Picture, drawn with a distance to the picture plane d = 1 m, of a road 8 m wide, with the observet at a_R = 3 m inside of the right edge (so at a_L = 5 m to the left), and with an eye height h = 1,20 m.
The direction of the road diverges horizontally from the picture plane axis with an angle α to the right, tan α being $+\frac{1}{25}$, and the road has a downward slope with an angle β, tan β being — 2%. The picture is found as follows:
The coordinates of the points (x_R, y_R) and (x_L, y_L) at an assumed distance Z of 100 m from the observer are:

$$x_R = d\frac{a_R}{Z} + d\tan\alpha = 1\cdot\frac{+3}{100} + 1\cdot\frac{1}{25} = +0{,}07 \text{ m}$$

$$x_L = d\frac{a_L}{Z} + d\tan\alpha = 1\cdot\frac{-5}{100} + 1\cdot\frac{1}{25} = -0{,}01 \text{ m}$$

$$Y_R = y_L = d\frac{h}{Z} + d\tan\beta = 1\cdot\frac{-1{,}20}{100} + 1\cdot\frac{-2}{100} = -0{,}032 \text{ m}$$

The coordinates of the vanishing point V are:

$$x_V = d\tan\alpha = 1\cdot\frac{+1}{25} = +0{,}04 \text{ m}$$

$$y_V = d\tan\beta = 1\cdot\frac{-2}{100} = -0{,}02 \text{ m}$$

Connecting V with (x_R, y_R) and (x_L, y_L) gives the road edges.

Figure 4.5 The calculated perspective of a straight section.

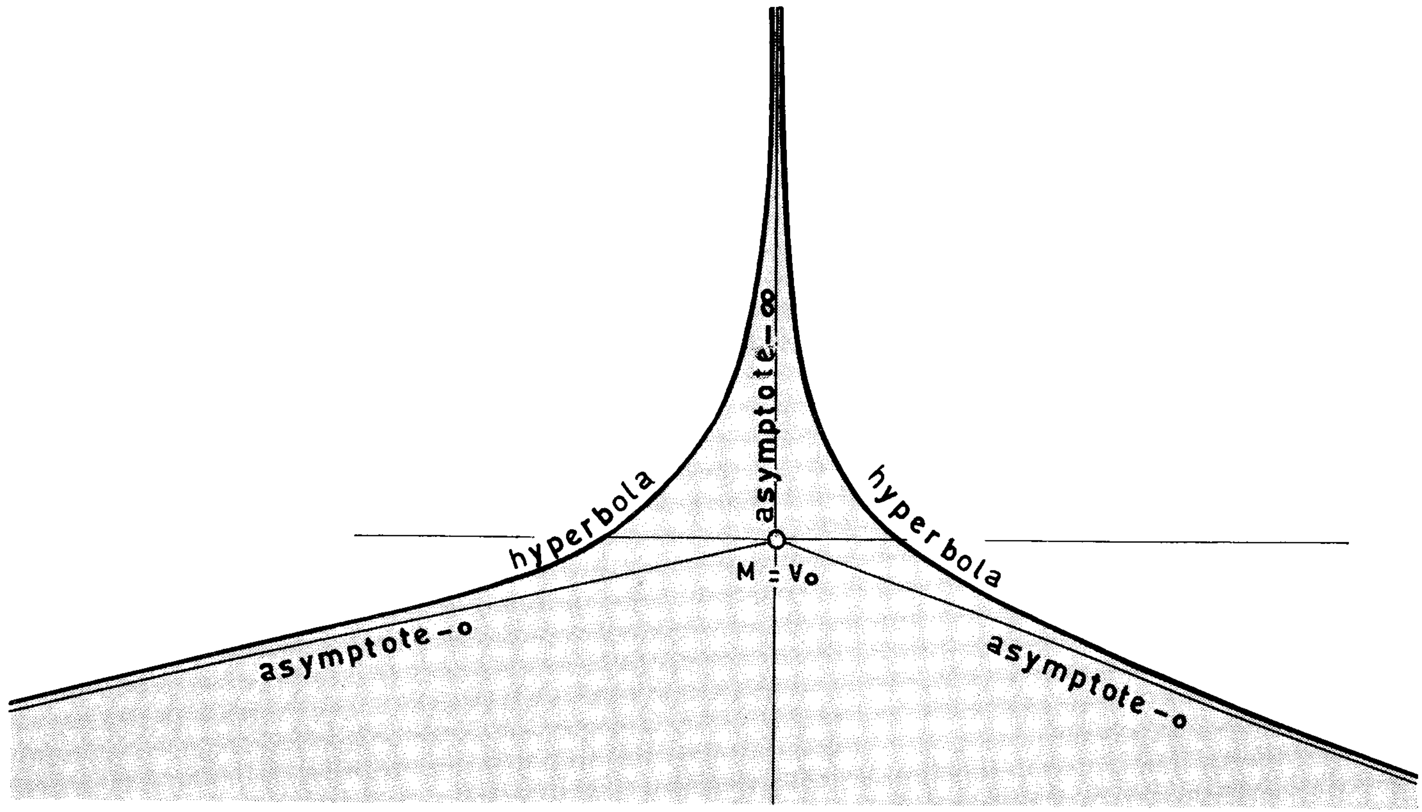


Figure 5.1 Picture when driving in a vertical curve.

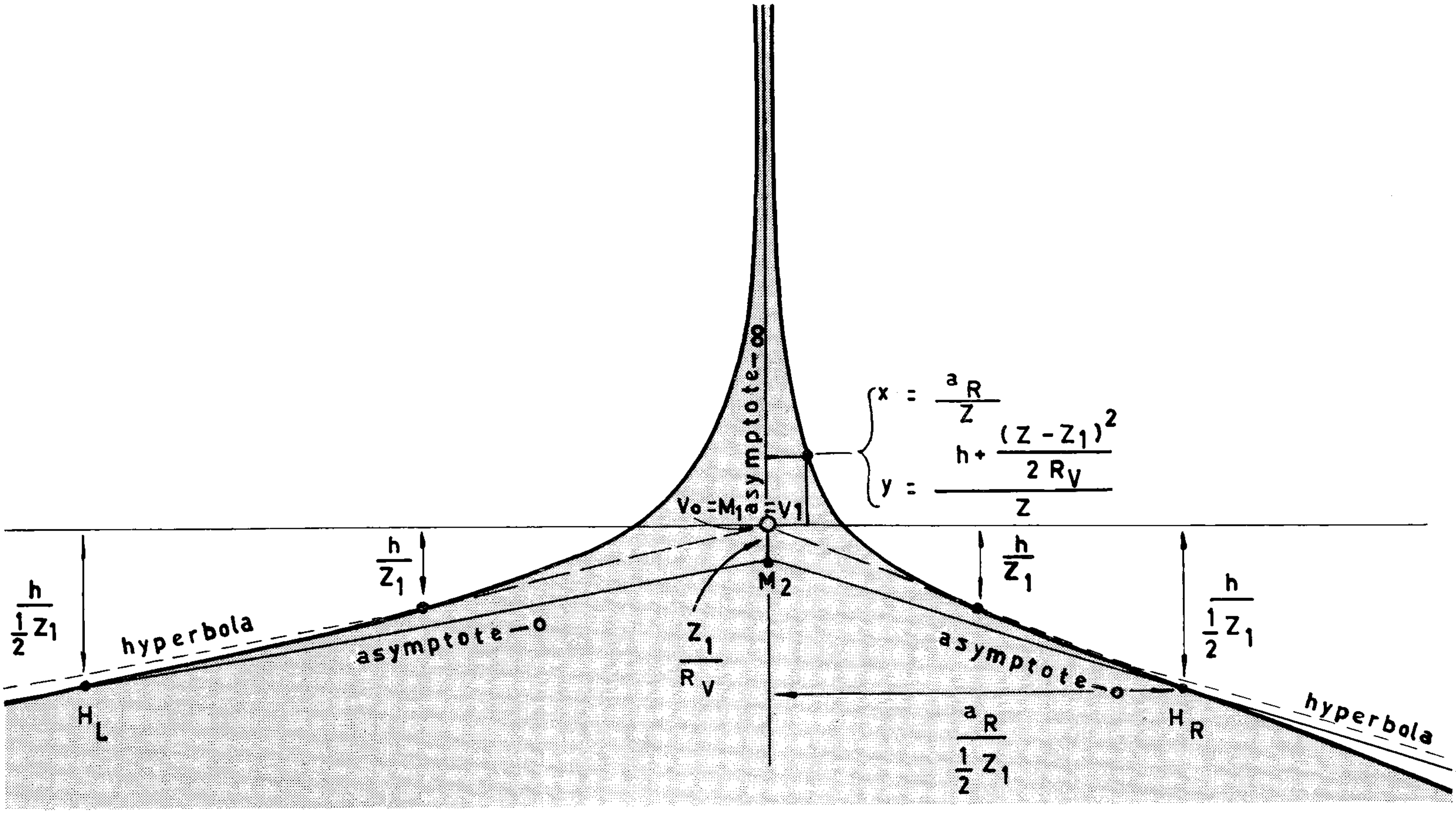


Figure 5.2 Vertical curve, observed from a distance Z_1 in front of its beginning.

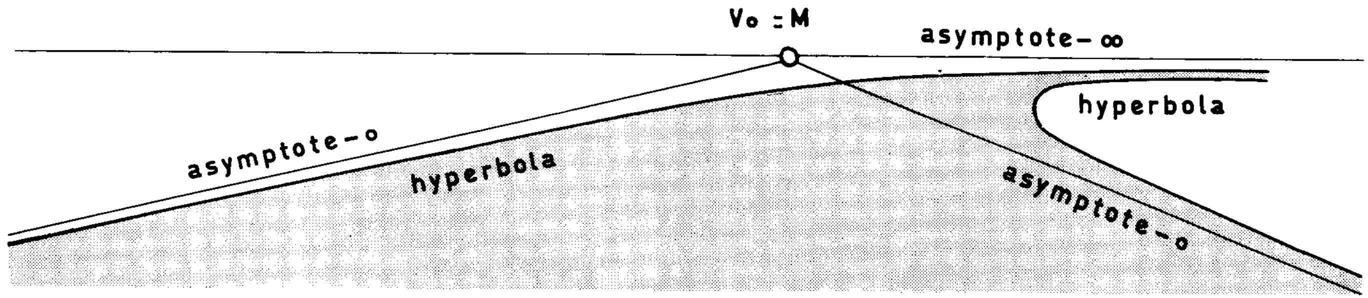


Figure 5.3 Picture when driving in a horizontal curve.

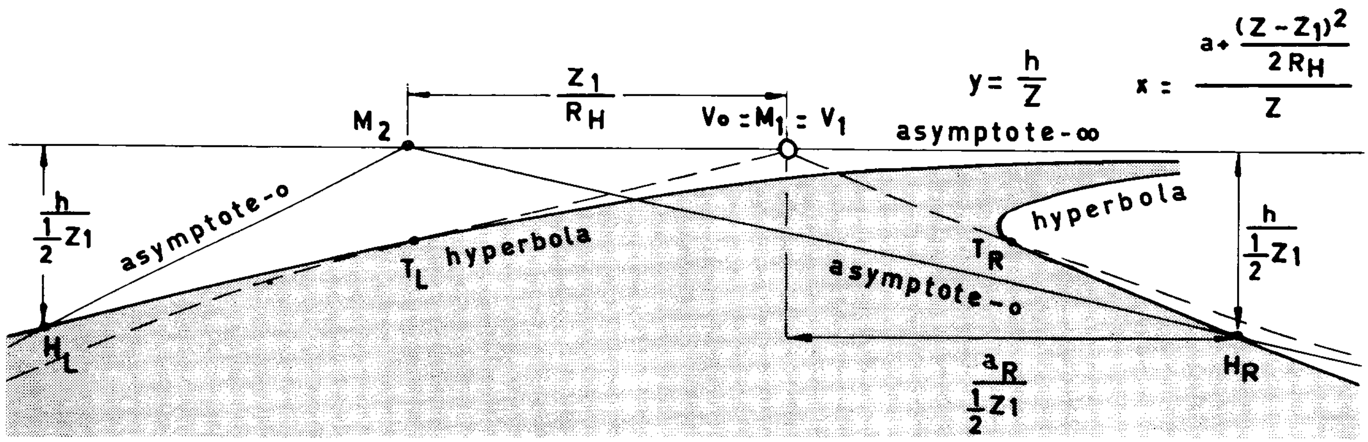


Figure 5.4 Horizontal curve, observed from a distance Z_1 in front of its beginning.

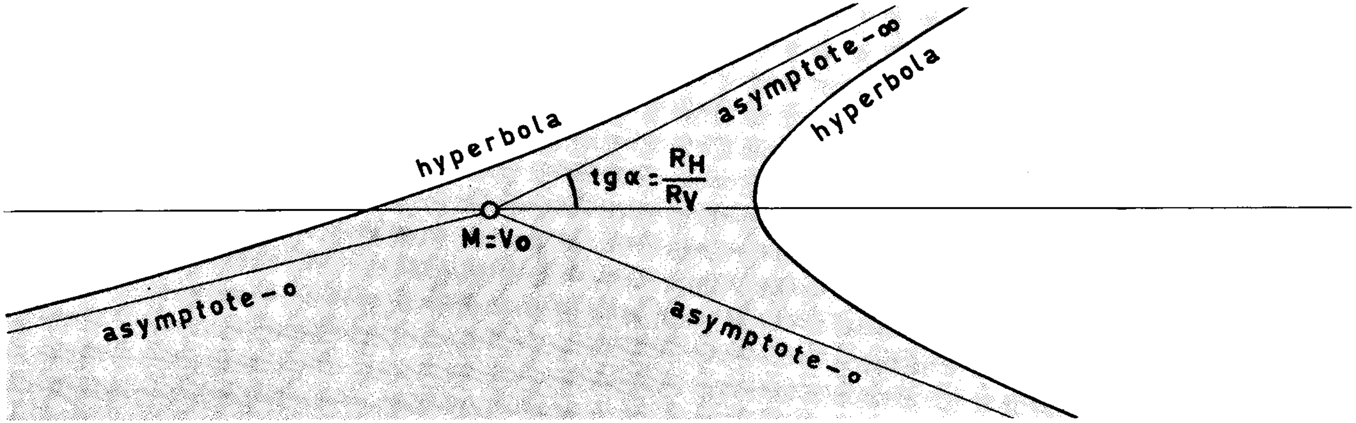


Figure 5.5 Picture when driving in a composite curve; the vertical component dominates.

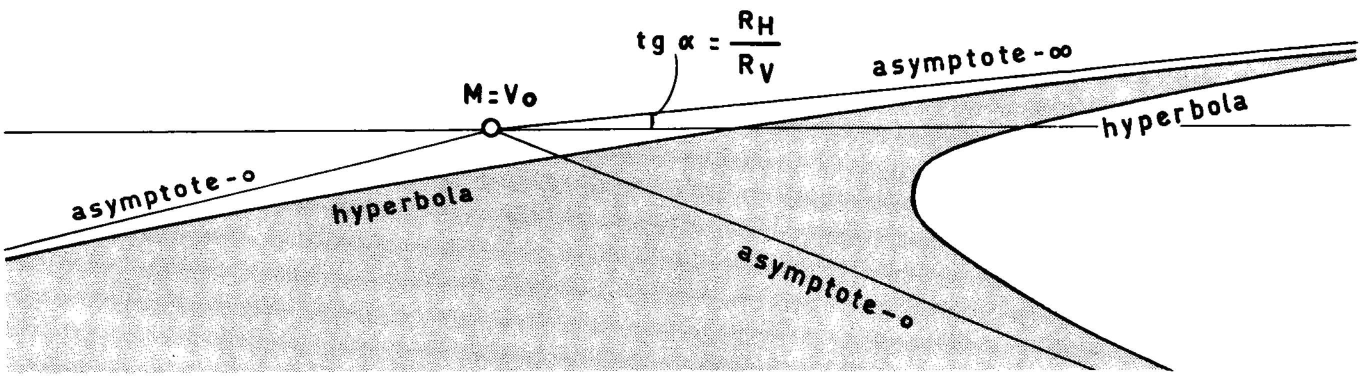


Figure 5.6 Picture when driving in a composite curve; the horizontal component dominates.

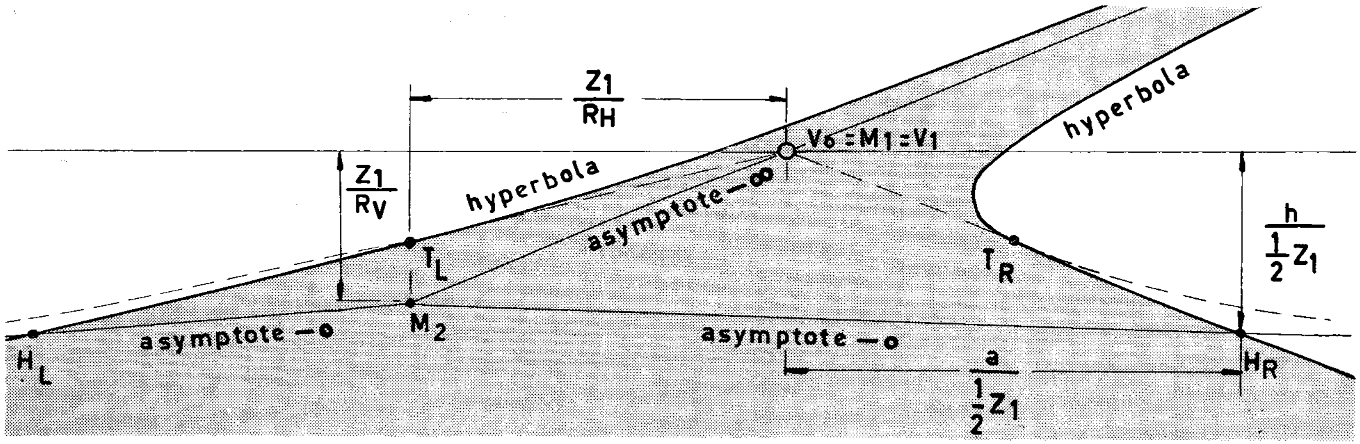


Figure 5.7 Composite curve with dominating vertical component, observed from a distance Z_1 in front of its beginning.

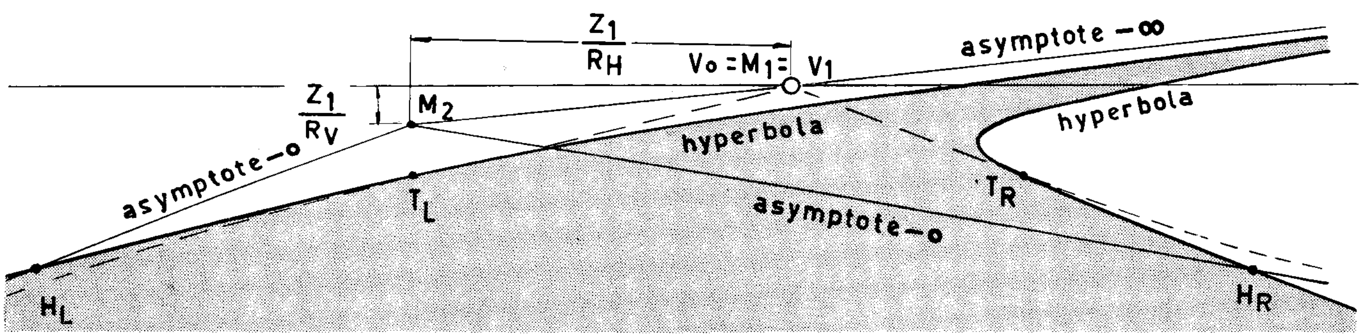


Figure 5.8 Composite curve with dominating horizontal component, observed from a distance Z_1 in front of its beginning.

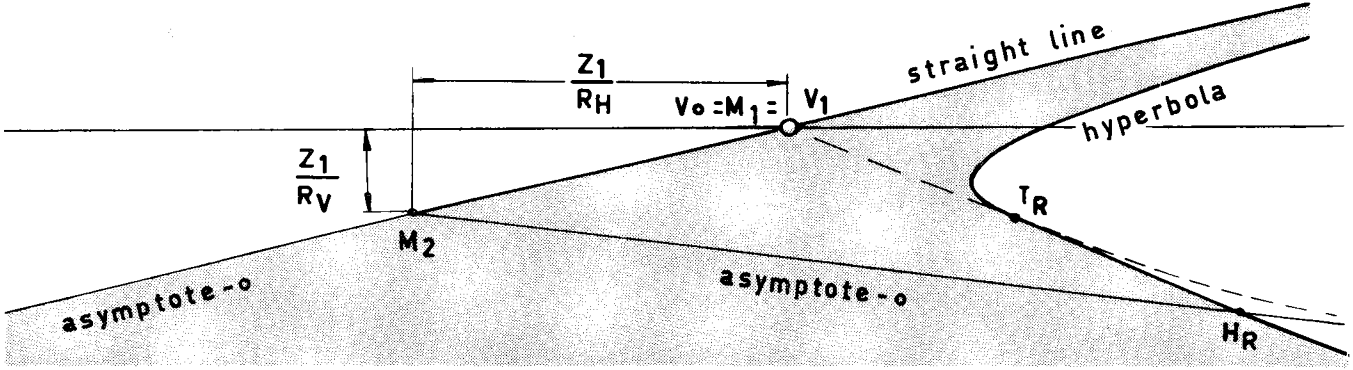


Figure 5.9 Transition between figure 5.7 en 5.8. The outer edge is seen as a straight line.

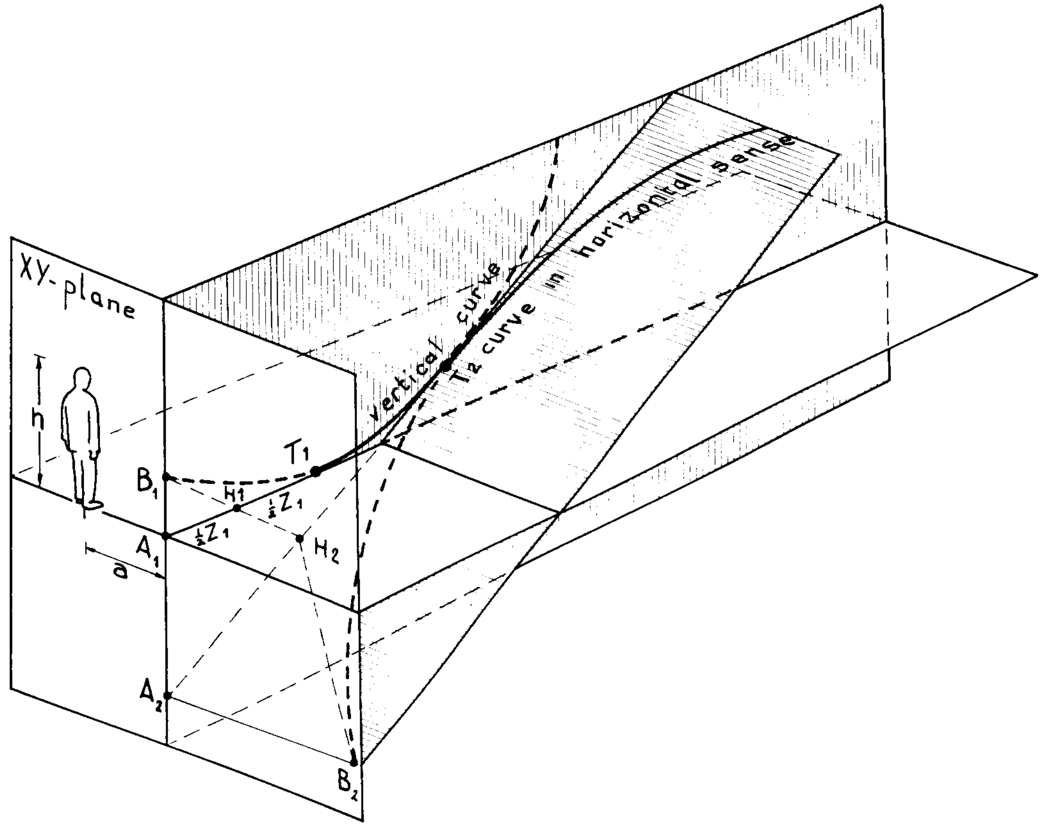


Figure 5.10 Two elements in succesion. Both asymptotes-0 and the tangent in the transition-point intersect in one point.

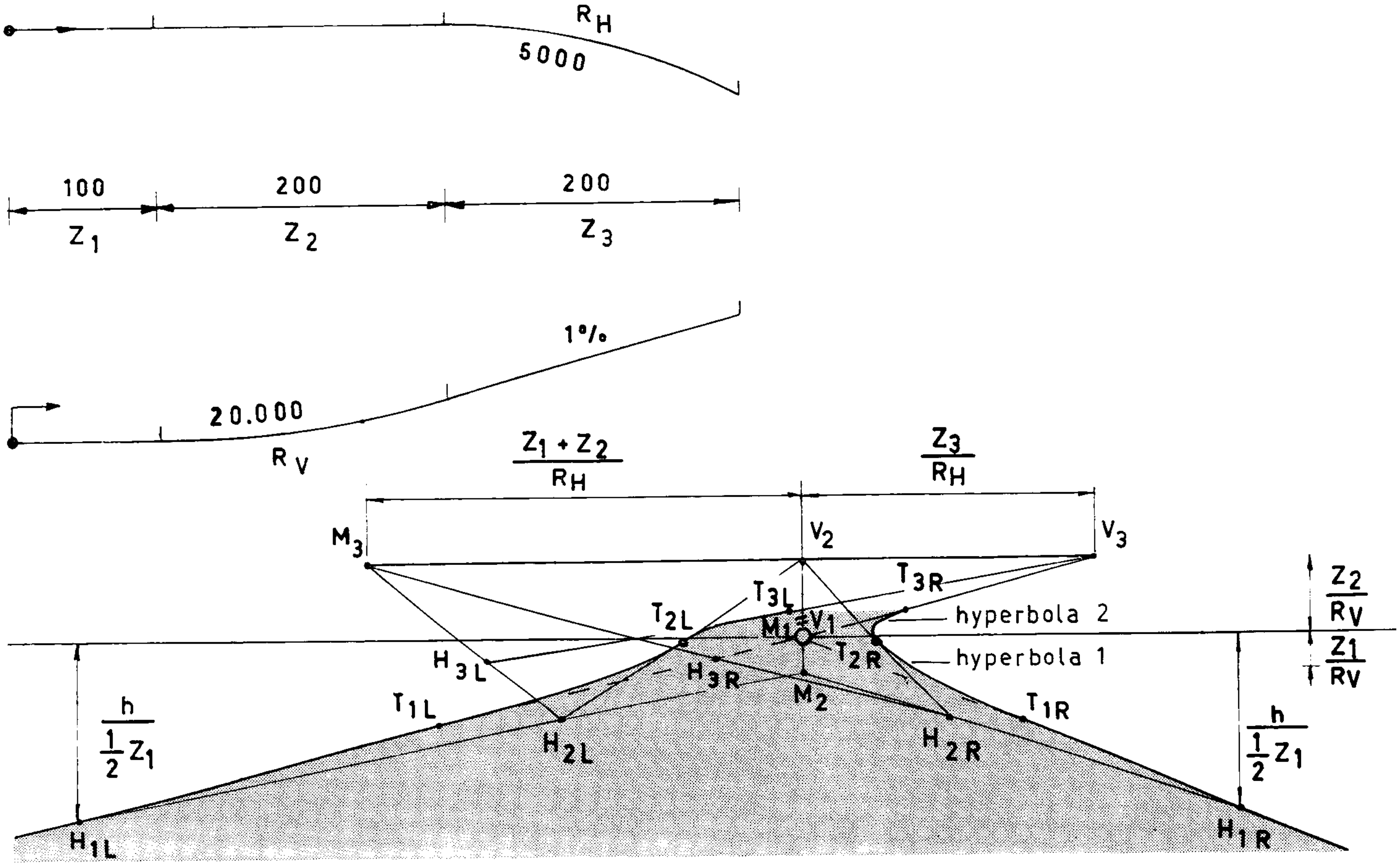


Figure 5.11 Perspective of a situation as represented in figure 5.10.

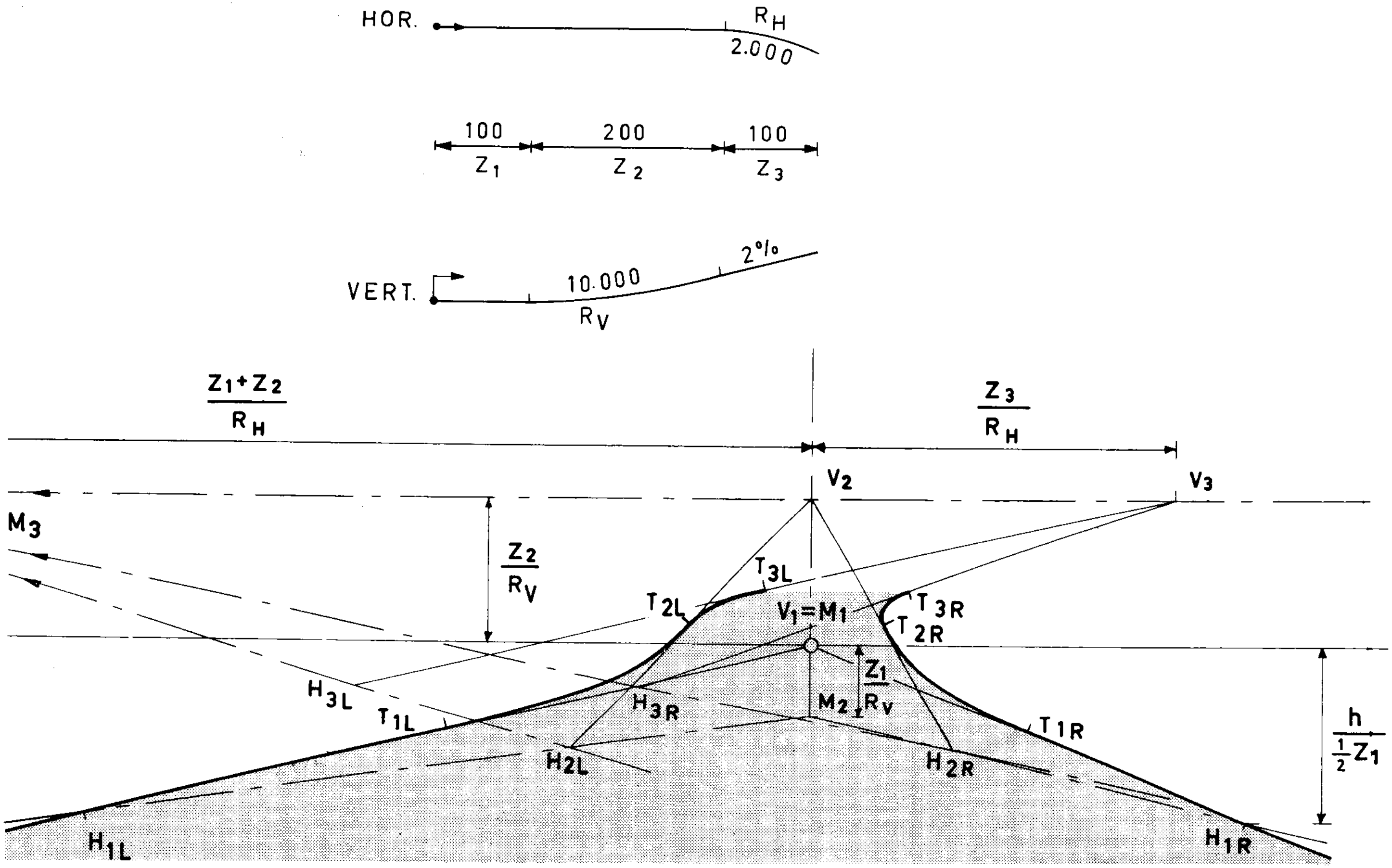


Figure 5.12 A similar case as in figure 5.11, but with different radii.

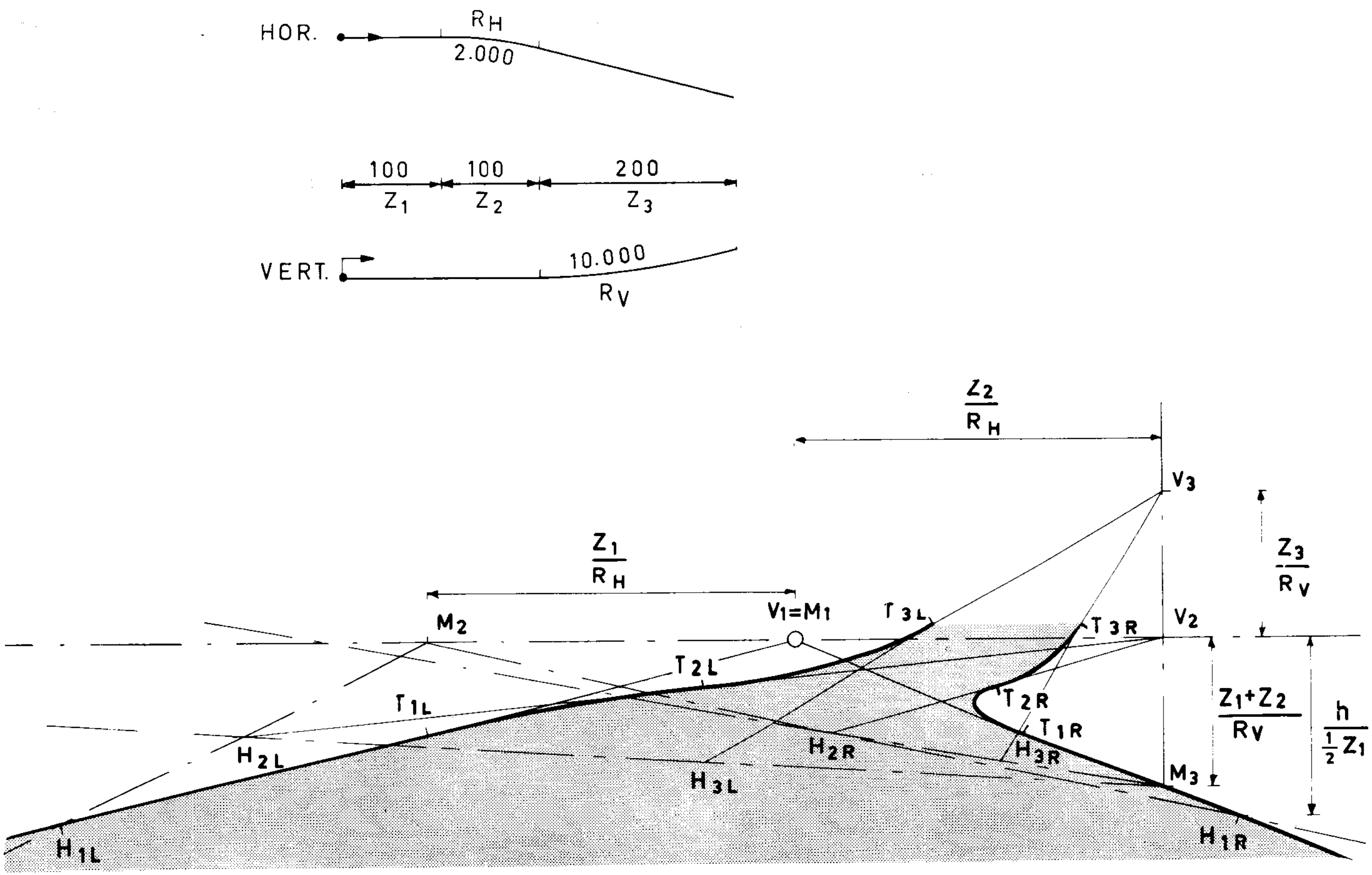


Figure 5.13 Horizontal curve, in front of an elevation.

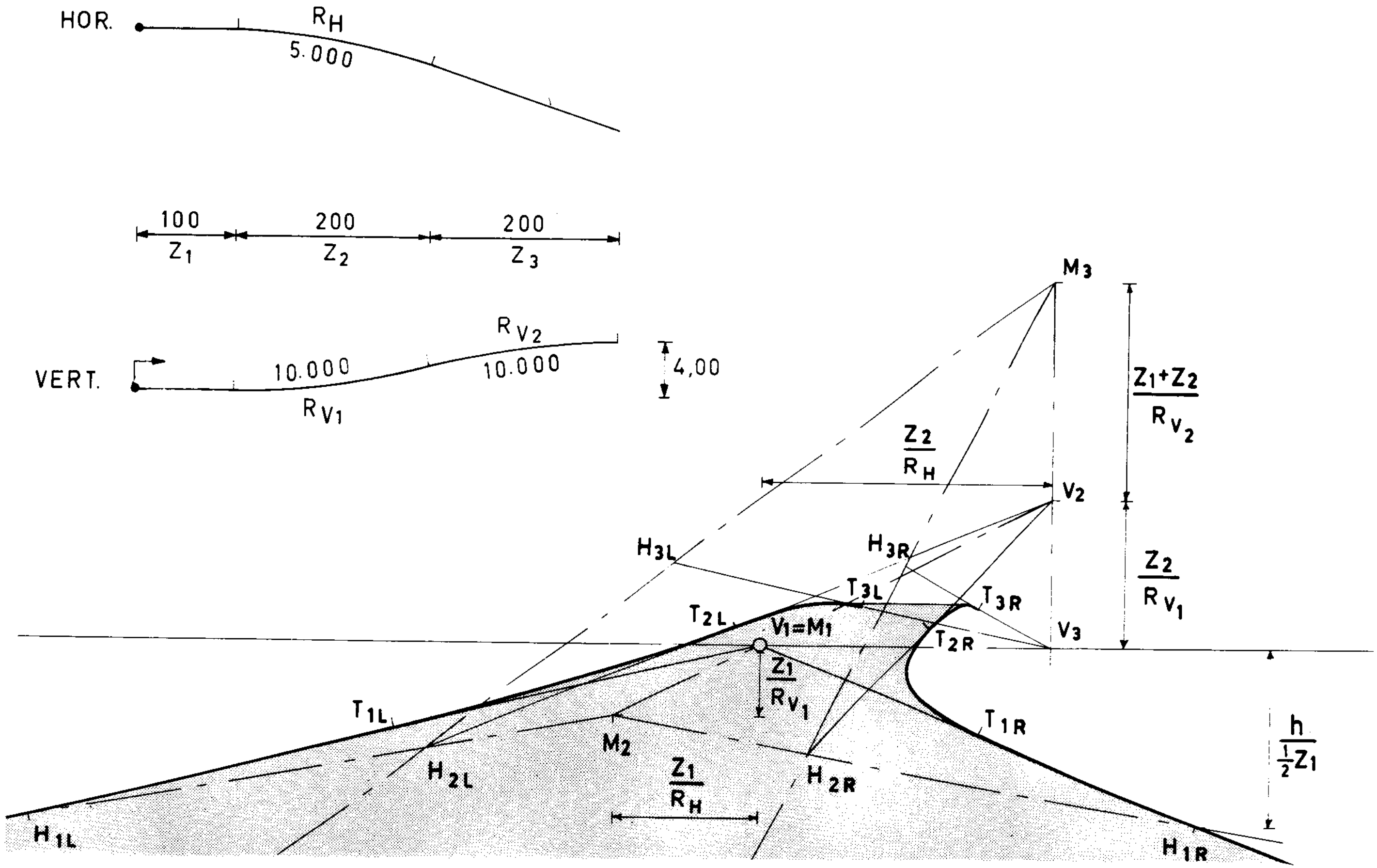


Figure 5.14 Composite curve, in front of a straight convex curve.

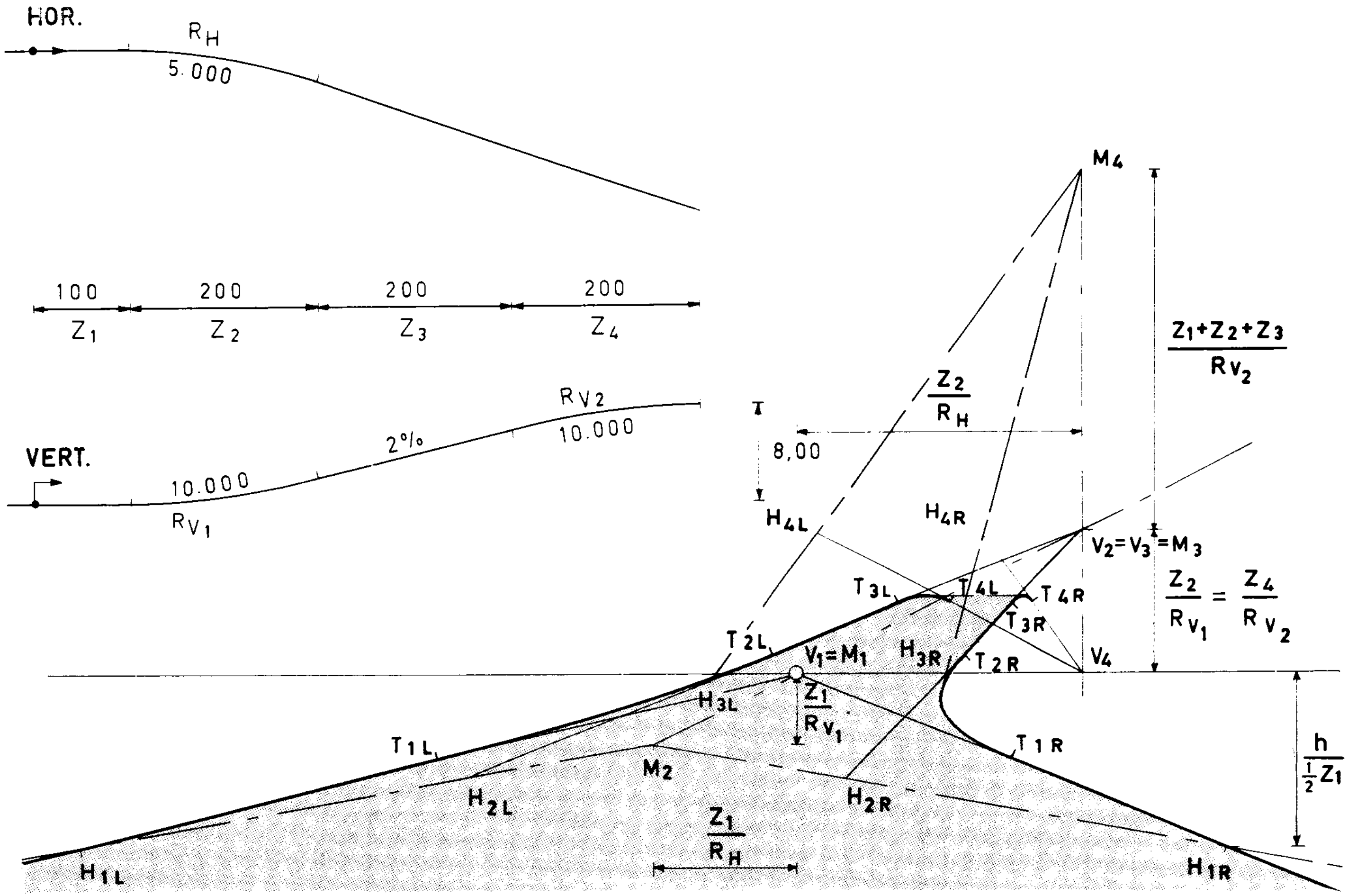


Figure 5.15 A similar case as in figure 5.14, but with a straight section in the slope.

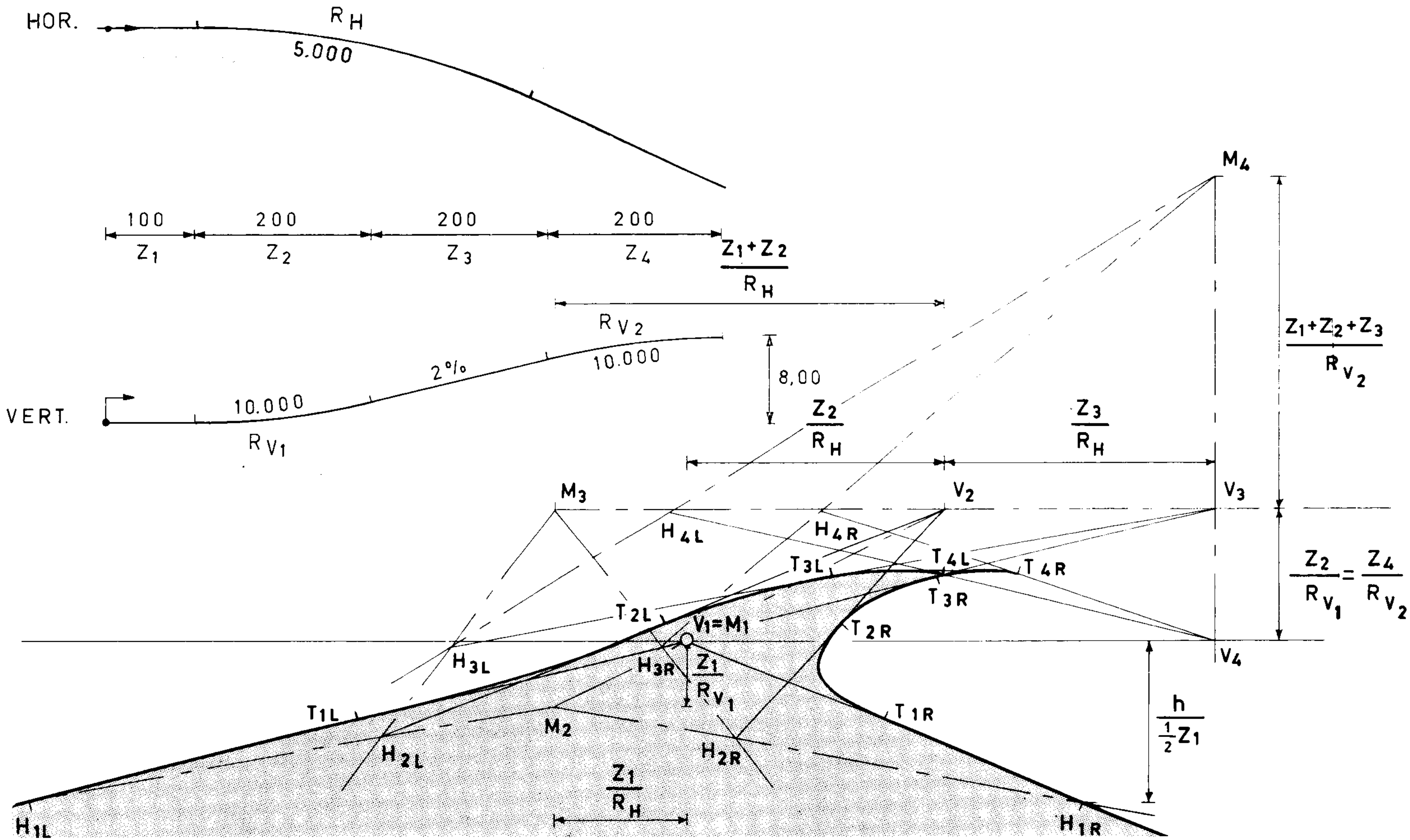


Figure 5.16 Long horizontal curve at the beginning of an elevation.

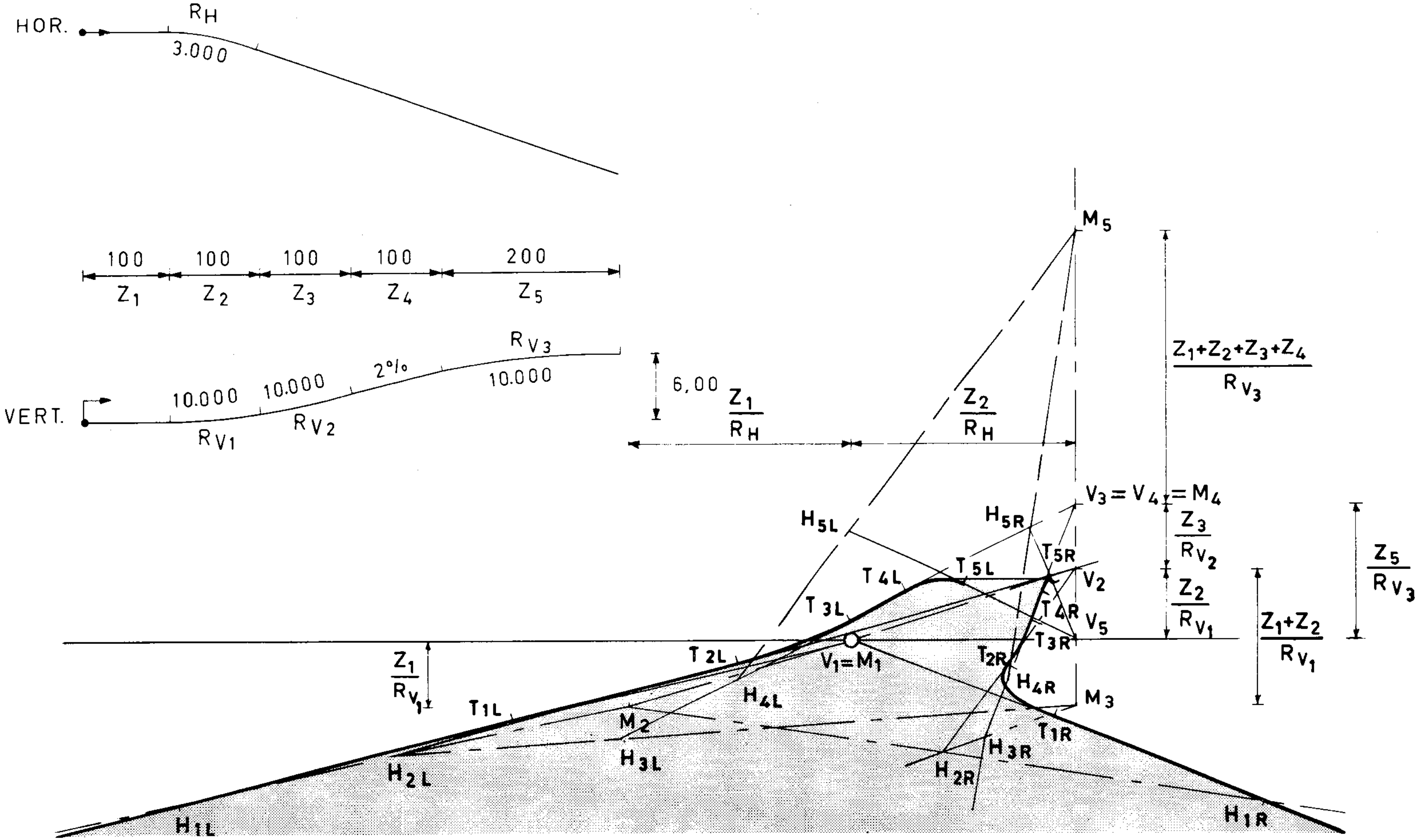


Figure 5.17 Short horizontal curve at the beginning of an elevation.

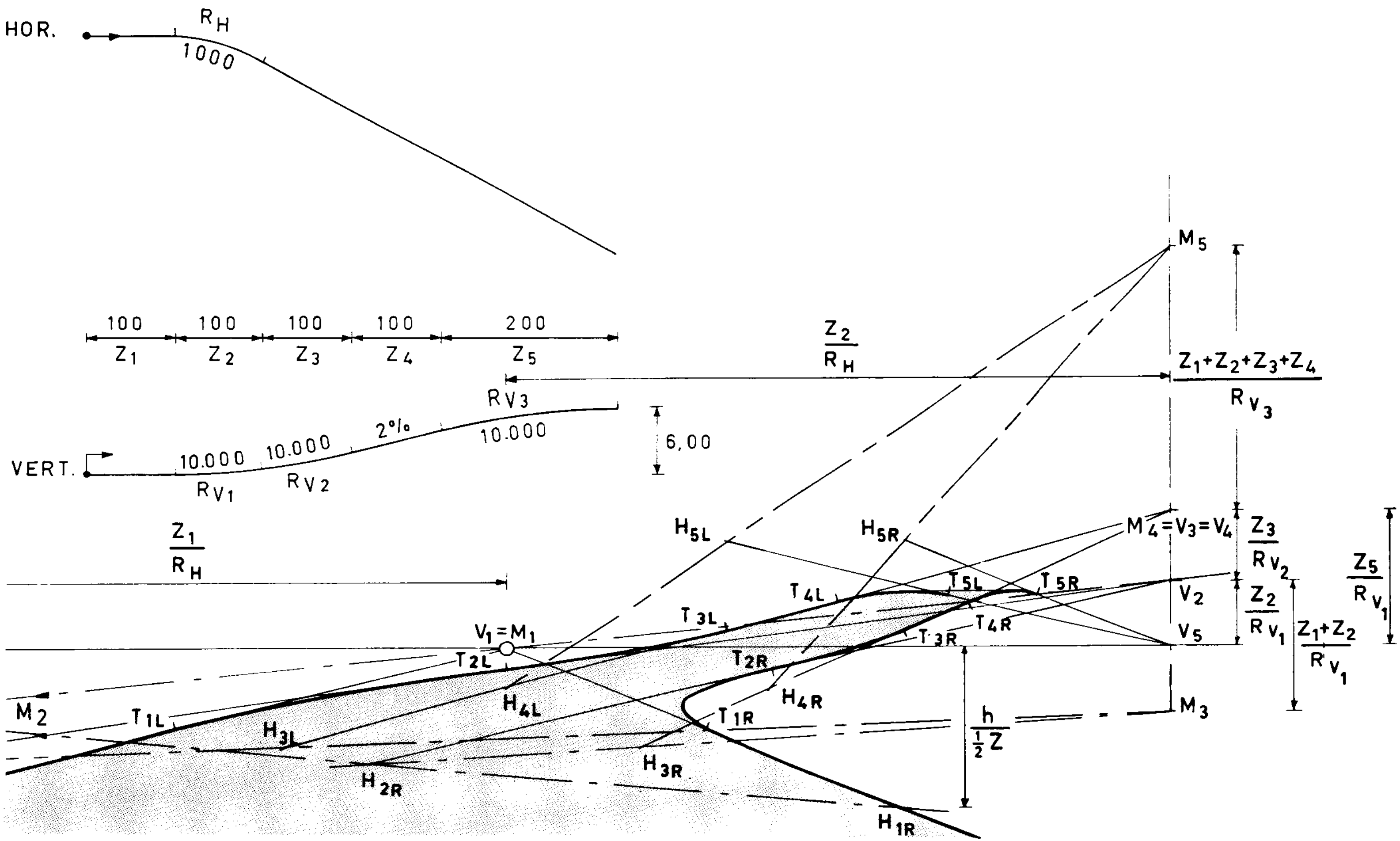


Figure 5.18 A similar situation as in figure 5.17, but with a smaller horizontal radius.

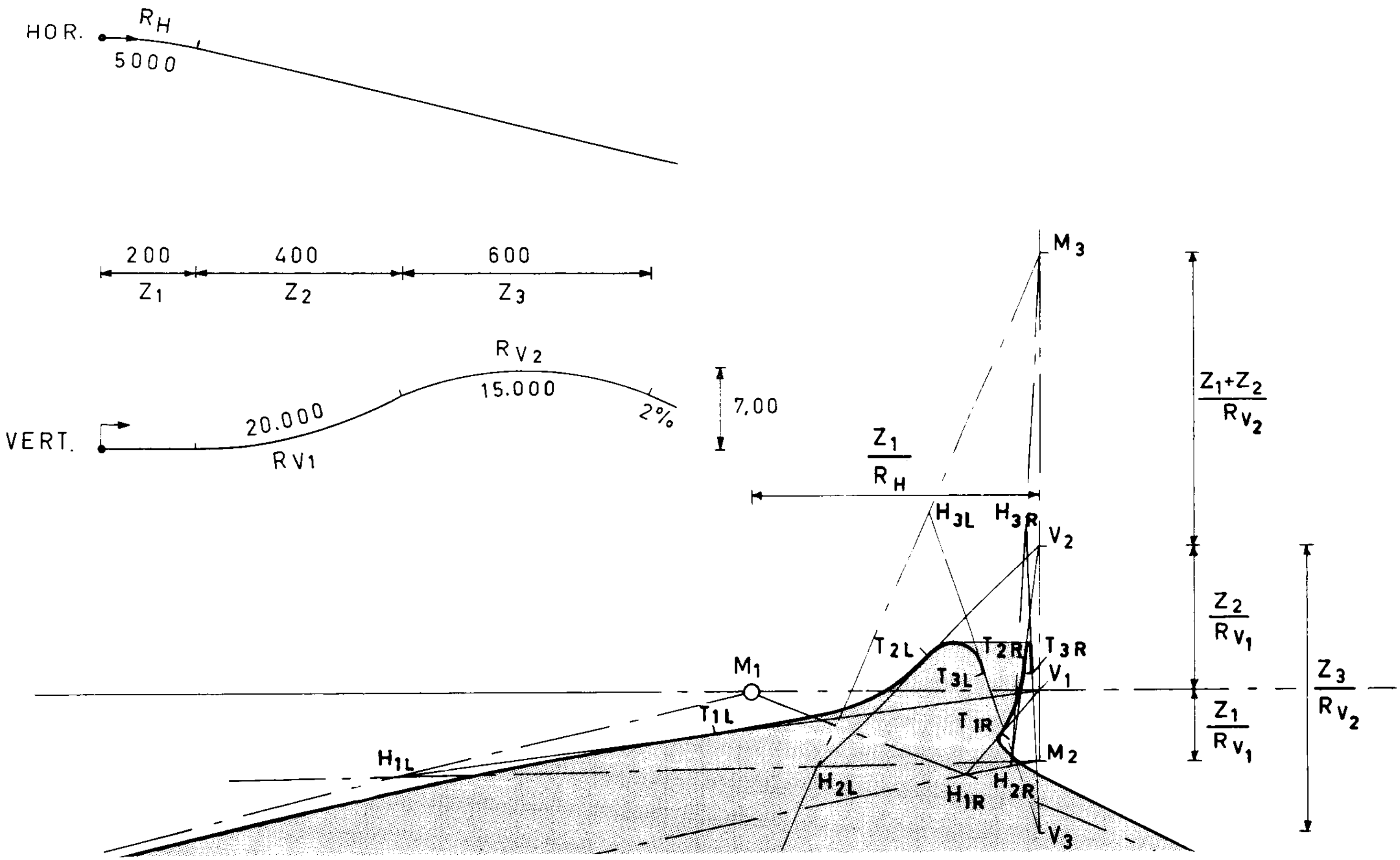


Figure 5.19 Short horizontal curve in front of a straight approach.

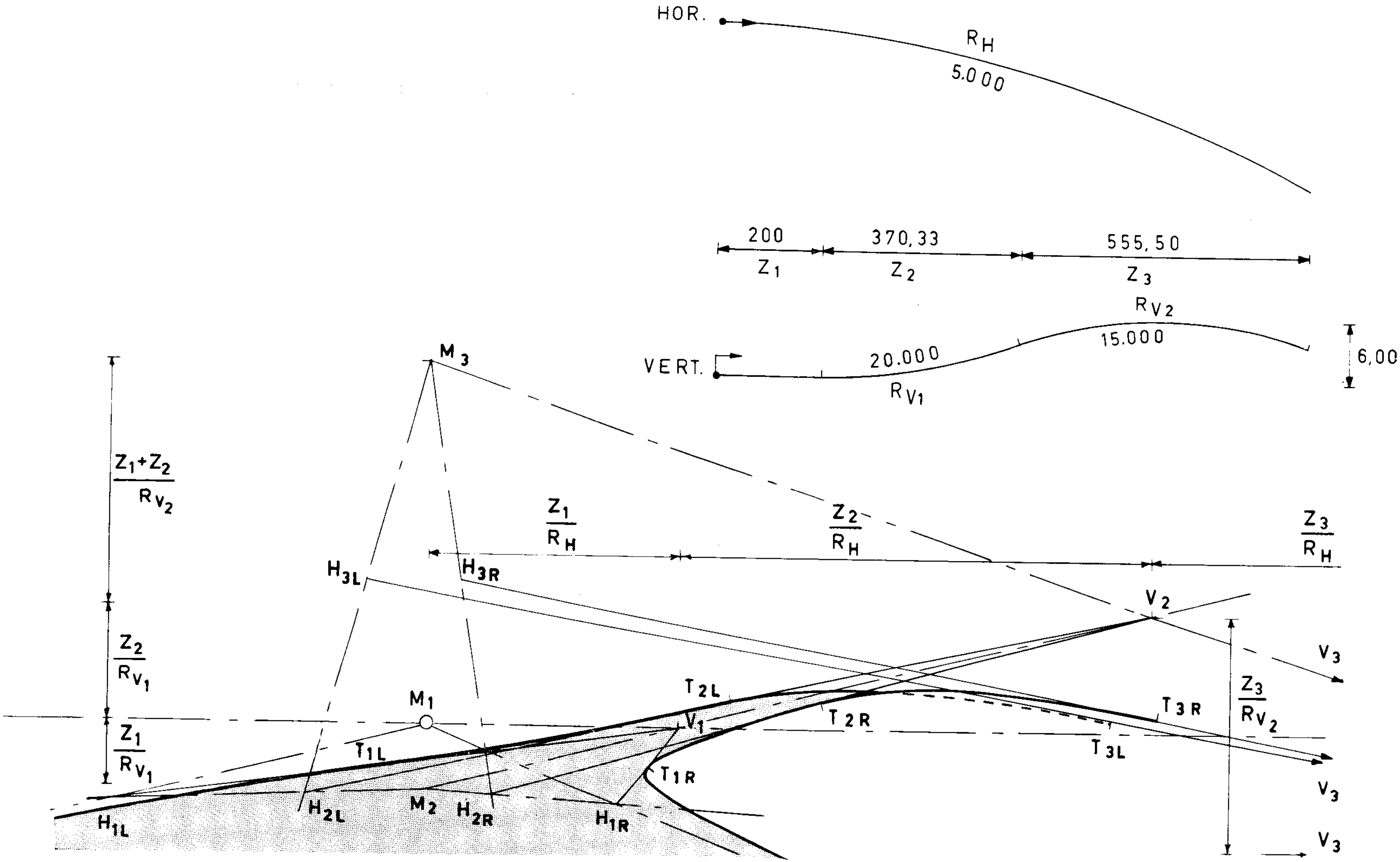


Figure 5.20 Elevation in a horizontal curve.

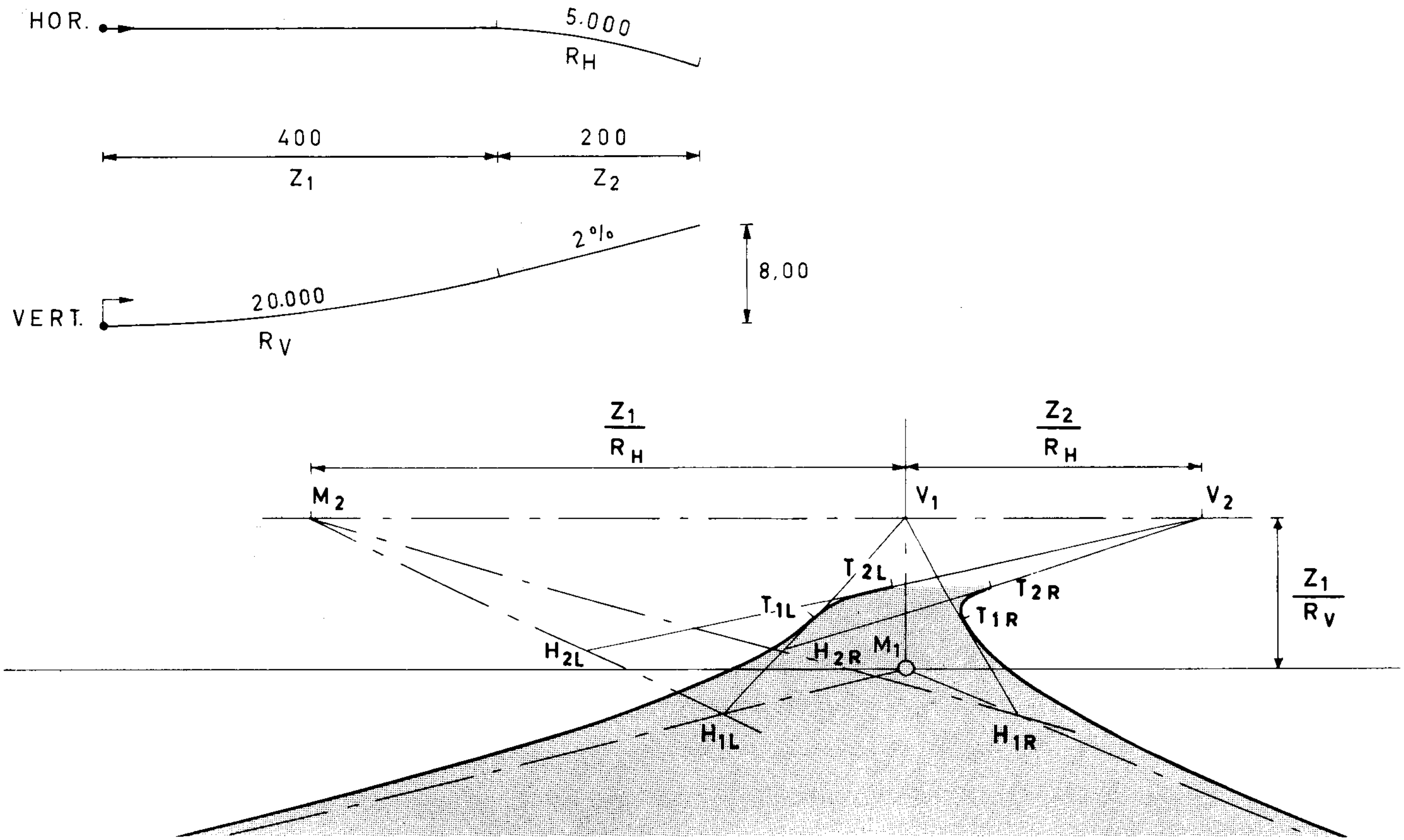


Figure 5.21 Vertical curve in front of a curve in horizontal sense.

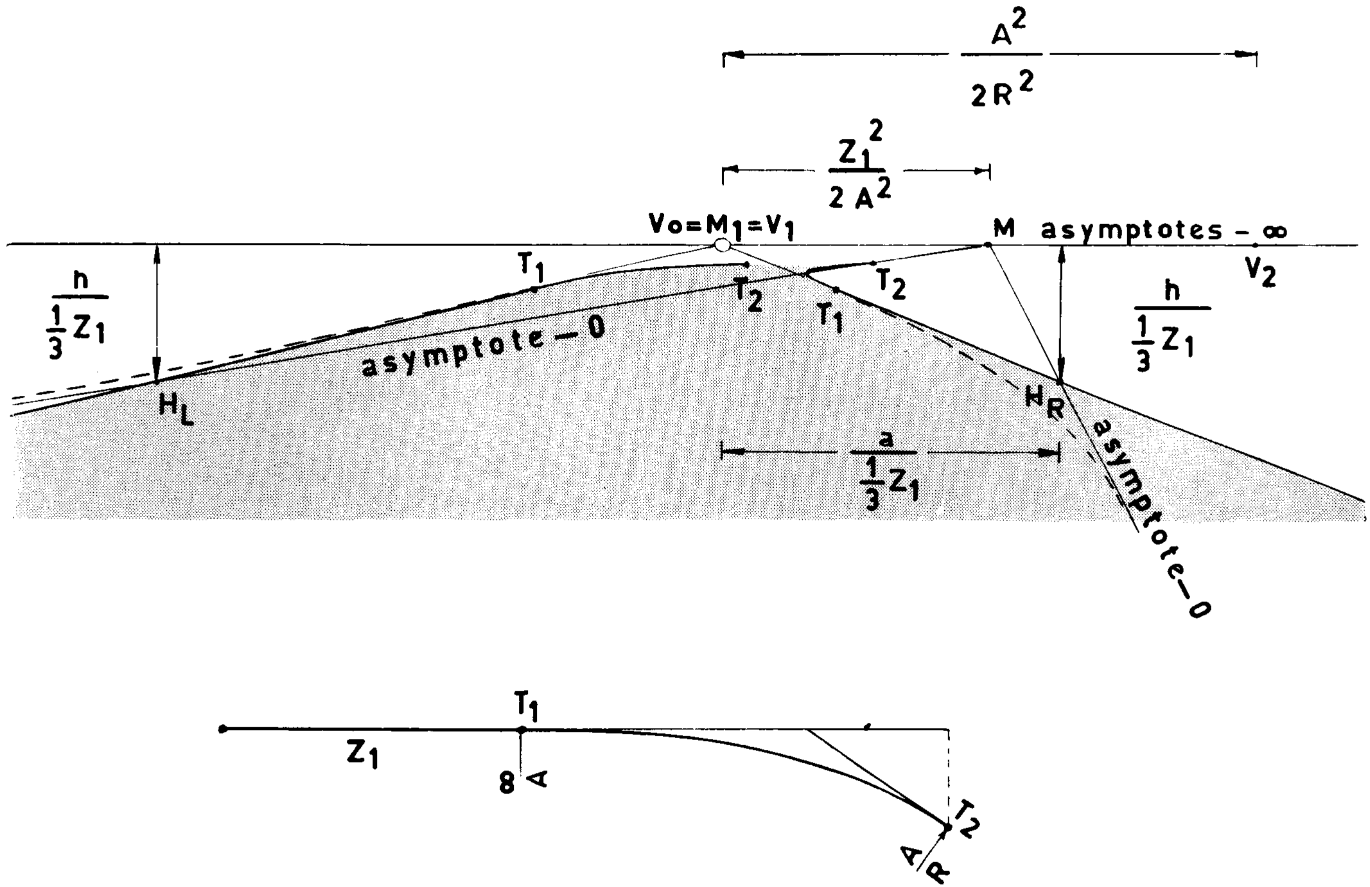


Figure 5.22 Transition-curve, observed from a distance Z_1 in front of its beginning.

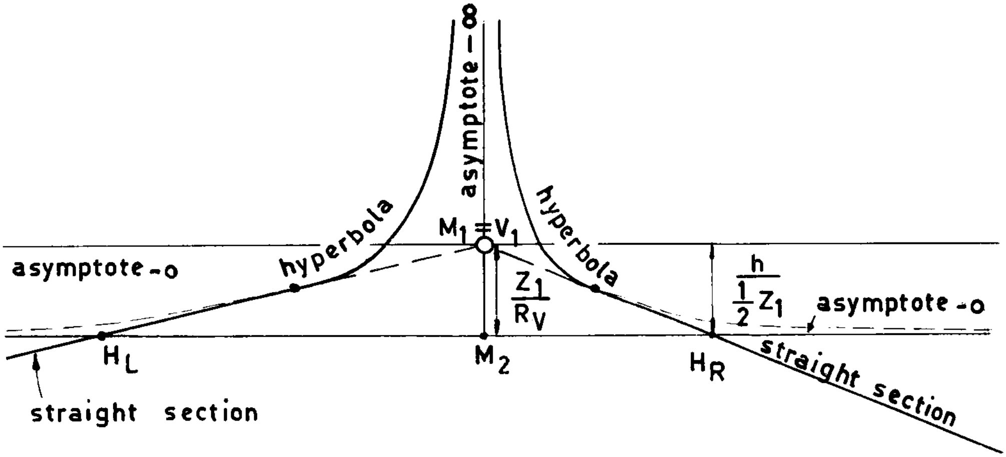


Figure 6.1 A concave curve with a small radius. Abrupt transition from the straight section to a strongly bent curve, impression of a kink.

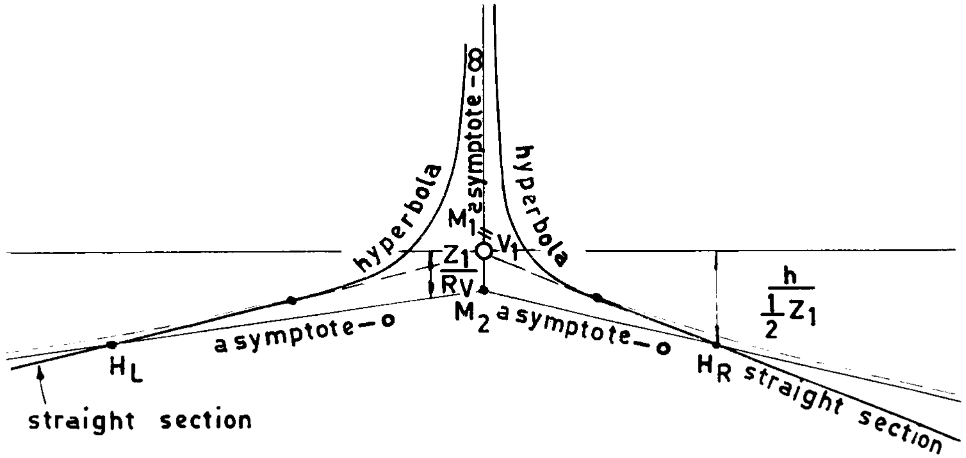


Figure 6.2 A concave curve with a large radius. Fluent transition from the straight section to a less strongly bent curve, no kink.

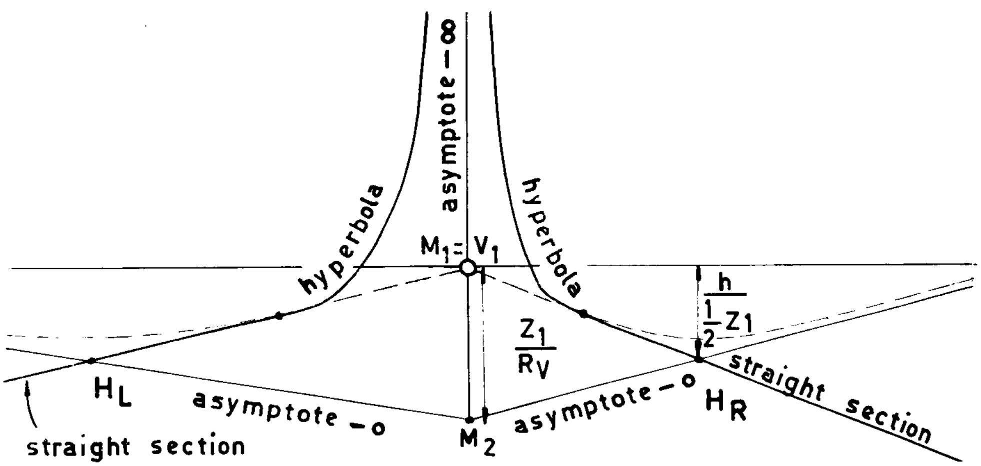


Figure 6.3 Change-over from figure 6.1 to 6.2.

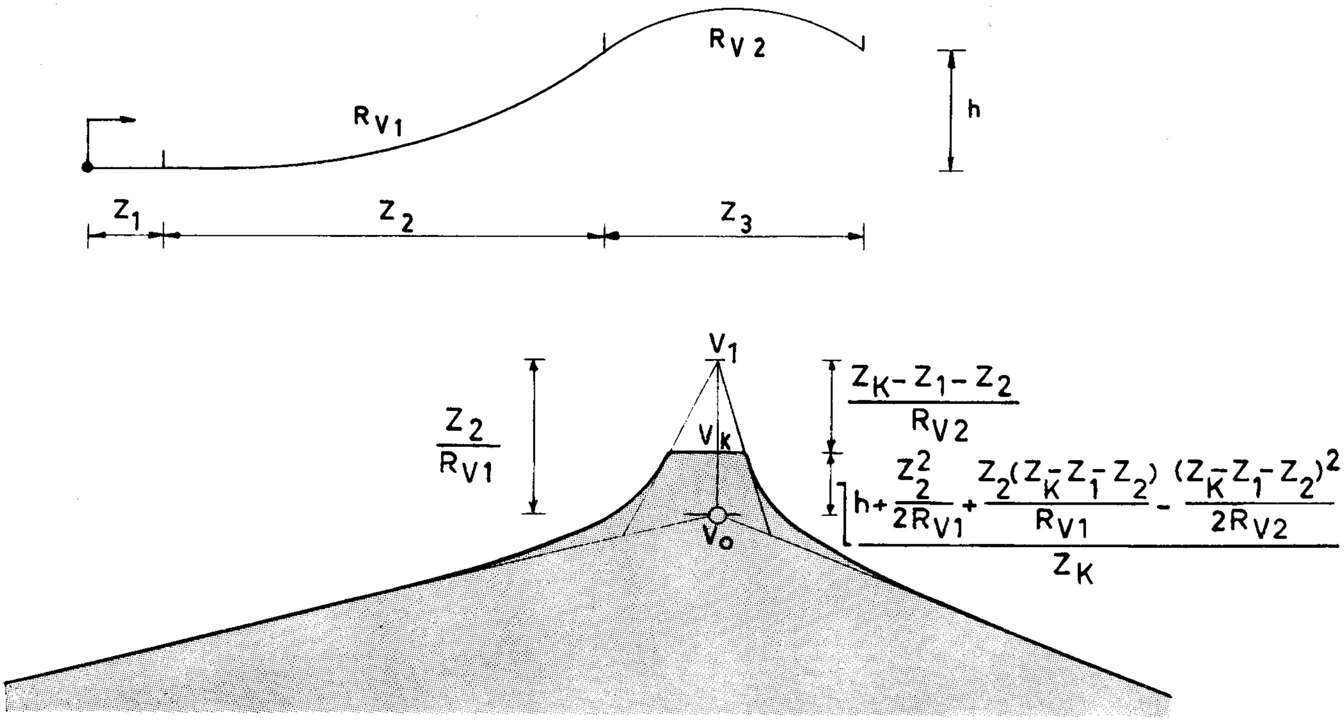


Figure 6.4 Turning point in the convex curve of a straight approach, beginning at a variable distance Z_1, in front of the observer.

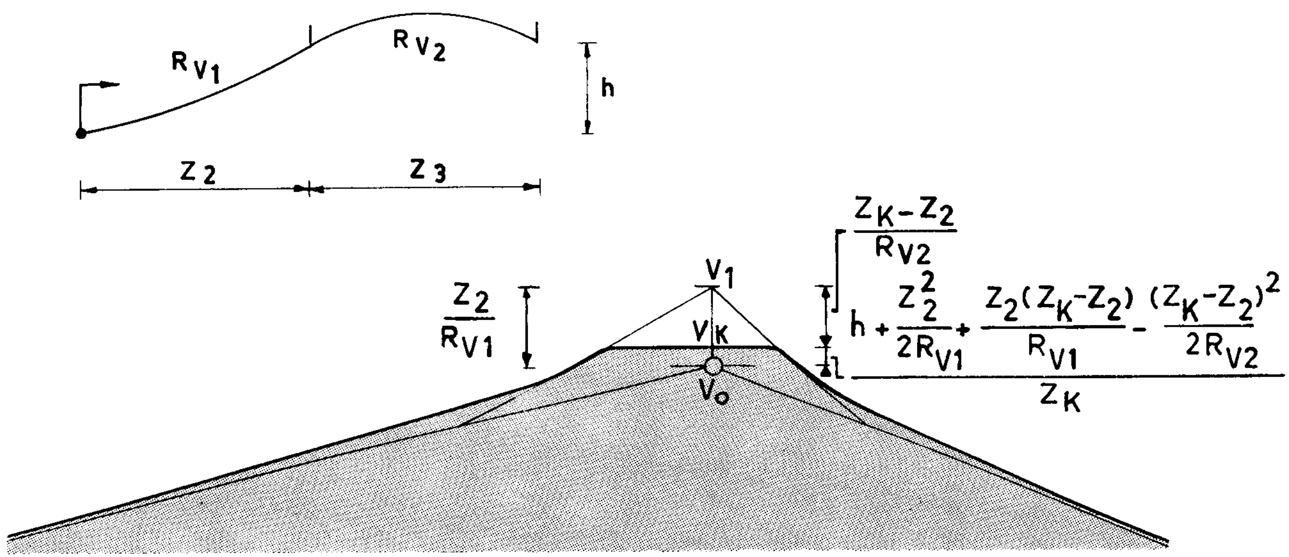
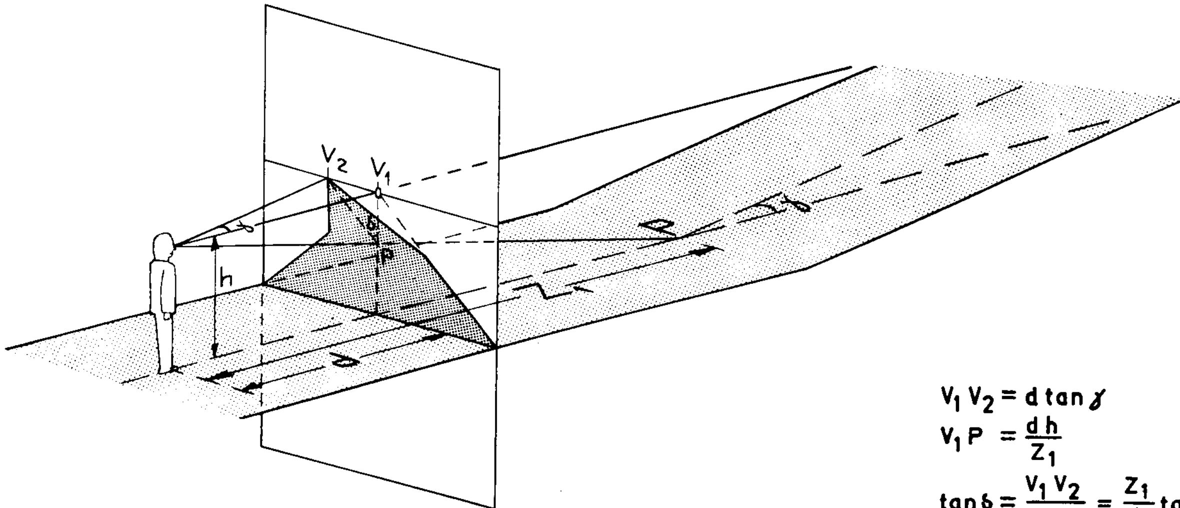


Figure 6.5 Turning point in the convex curve of an approach, when the observer is in the concave curve, at a variable distance Z_2 to its end.



$$V_1 V_2 = d \tan \gamma$$

$$V_1 P = \frac{d\,h}{Z_1}$$

$$\tan \delta = \frac{V_1 V_2}{V_1 P} = \frac{Z_1}{h} \tan \gamma$$

$$\tan \gamma : \tan \delta = h : Z_1$$

Figure 6.6 The relation between the real and the visual change of direction.

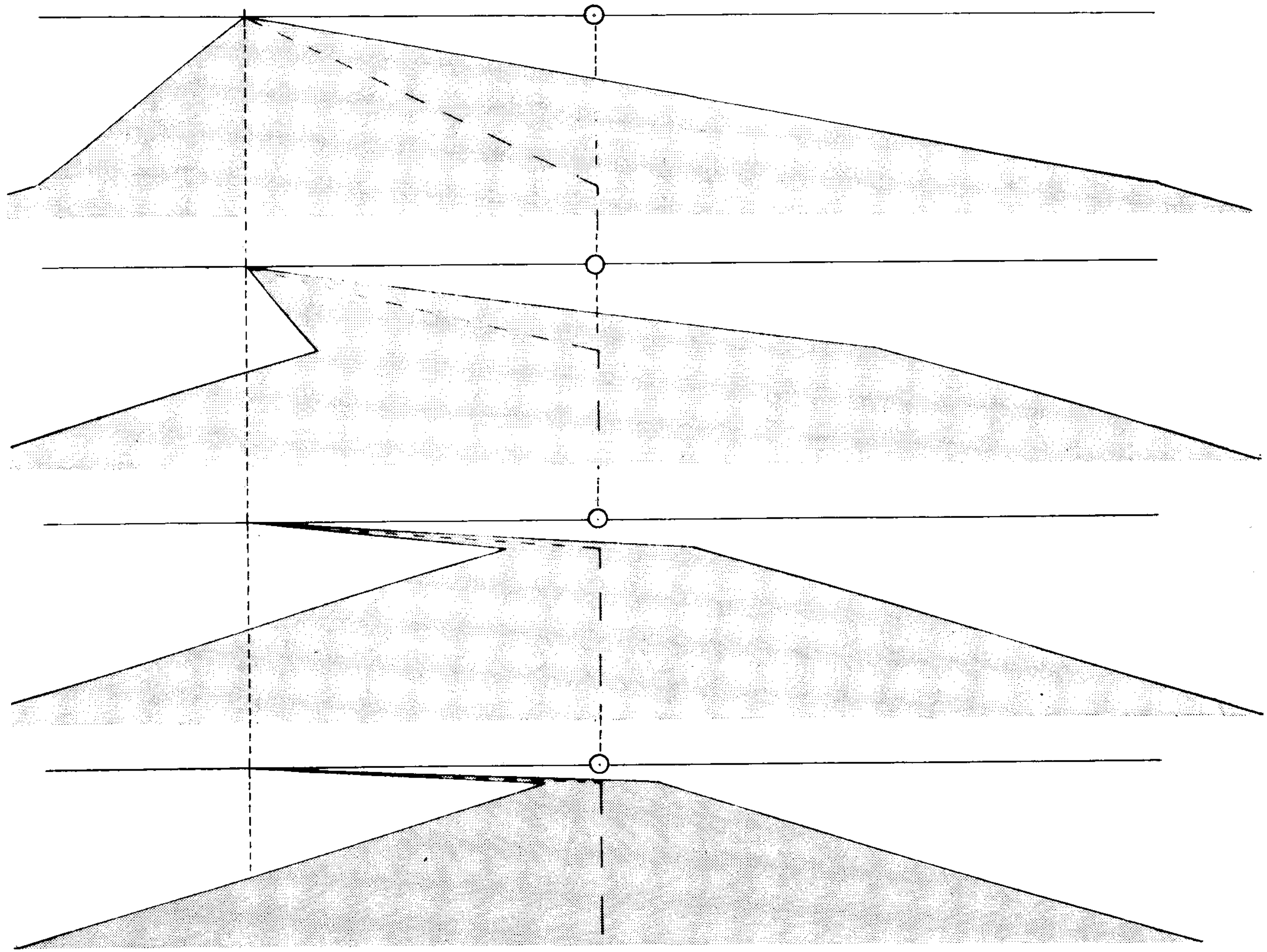


Figure 6.7 Development of the picture on nearing a change of direction.

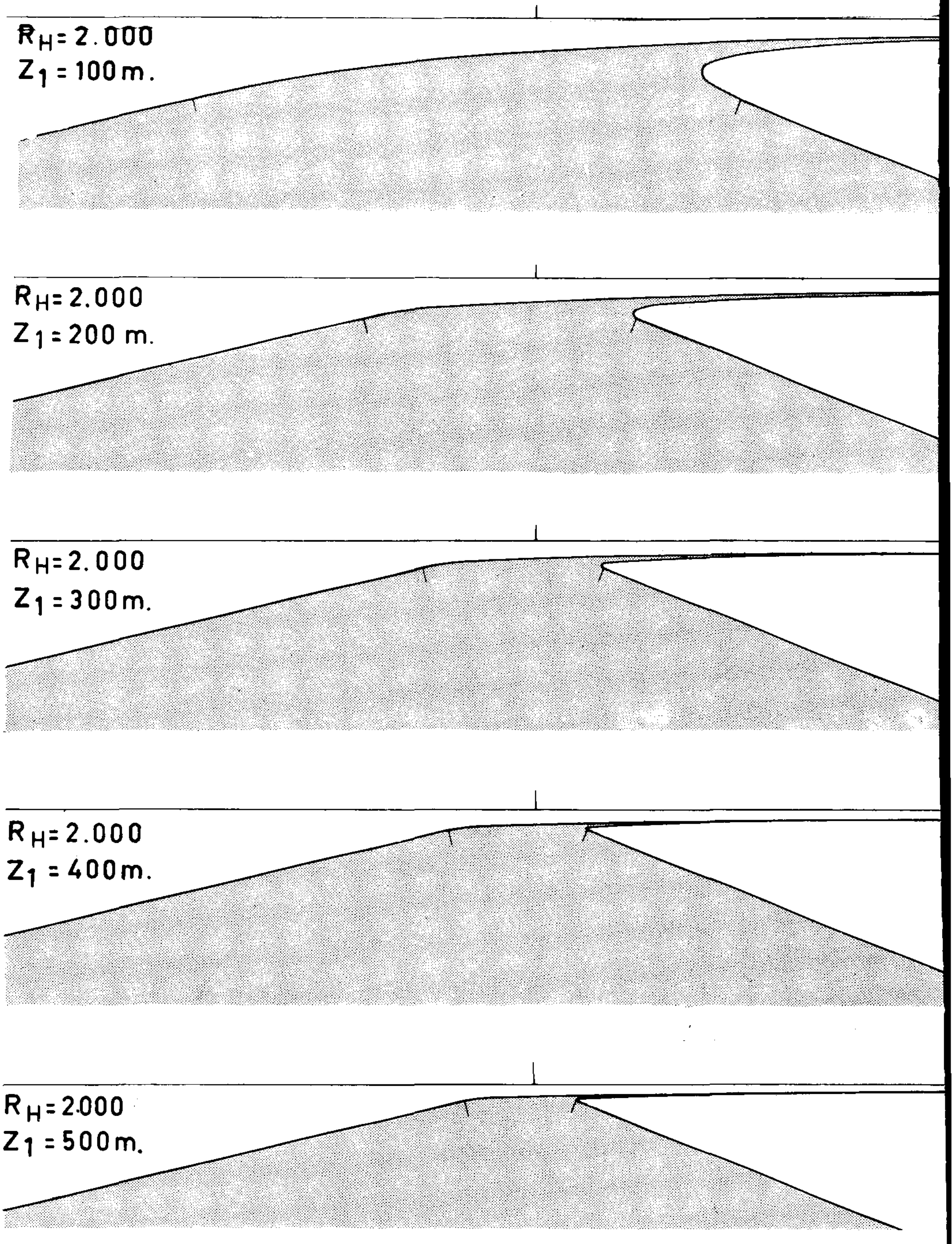


Figure 6.8 A horizontal curve with a radius of 2000 m, seen during the approach.

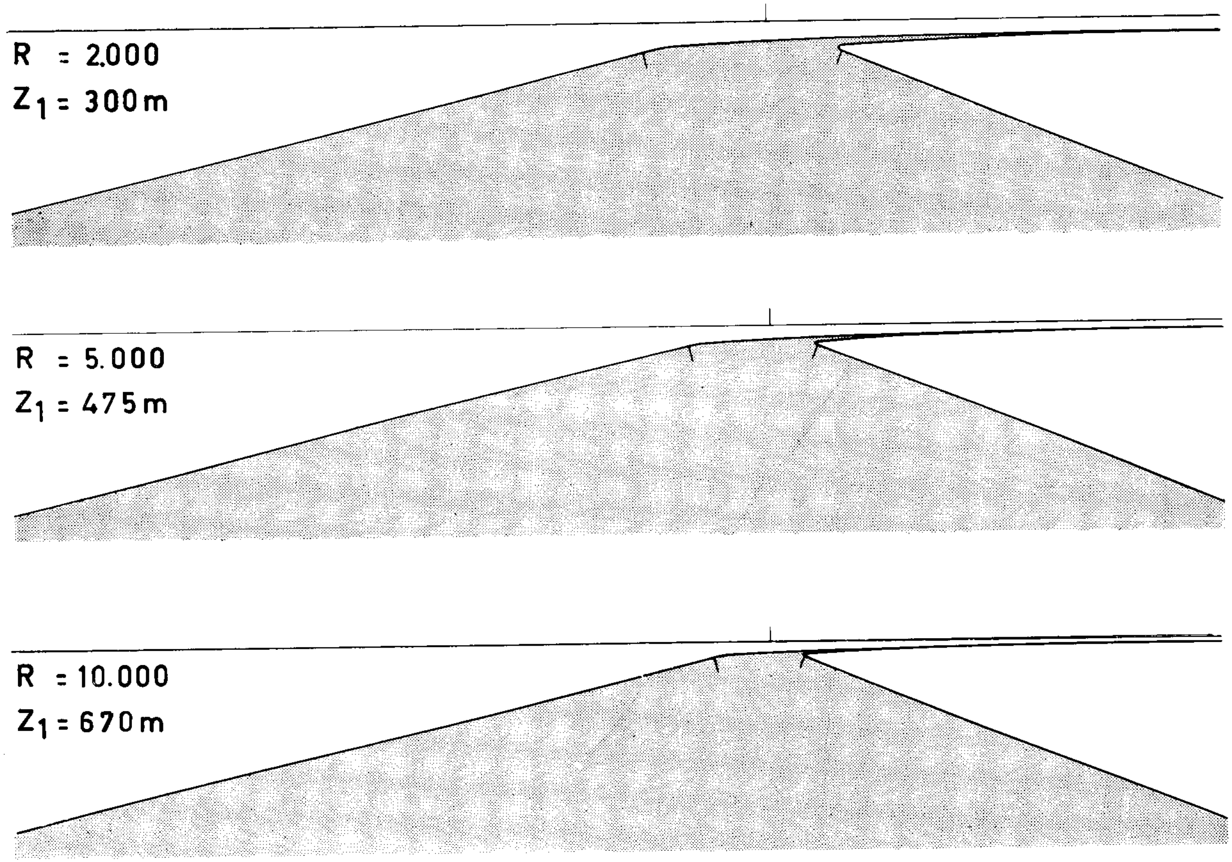


Figure 6.9 Horizontal curves with different radii, observed at the distances giving the same impression.

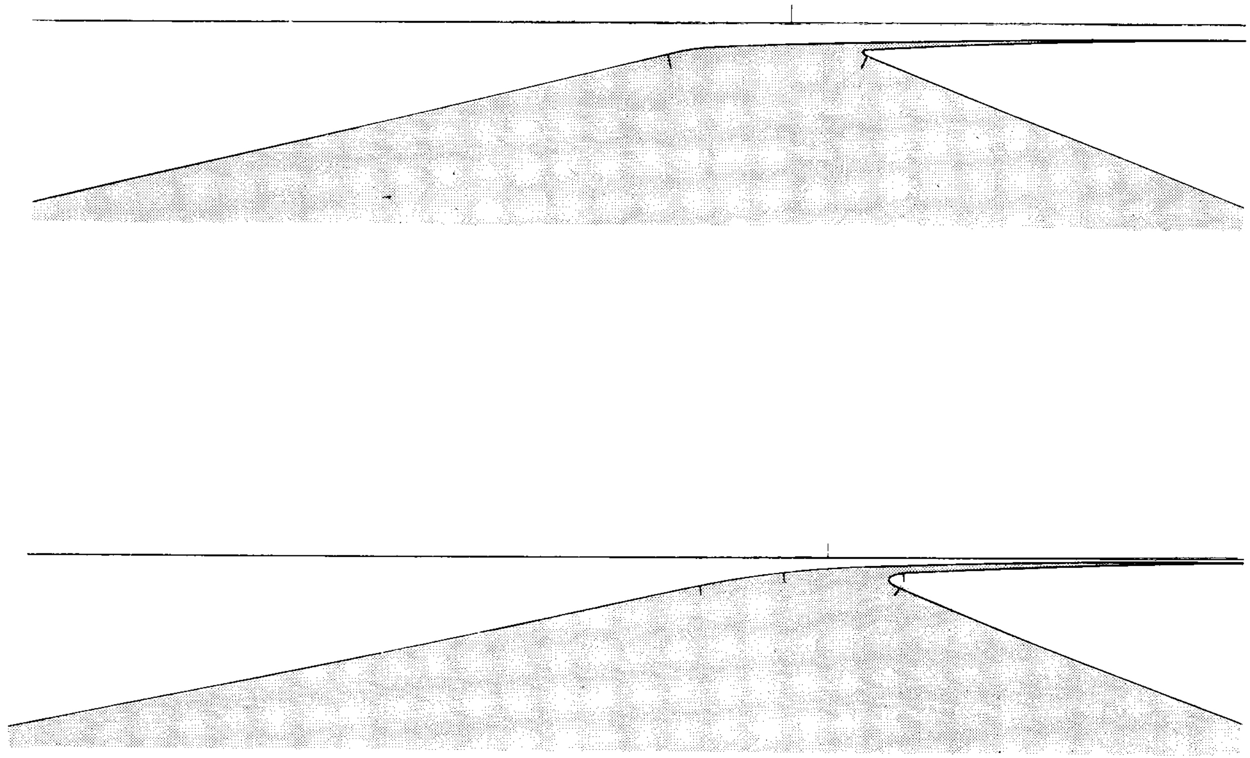
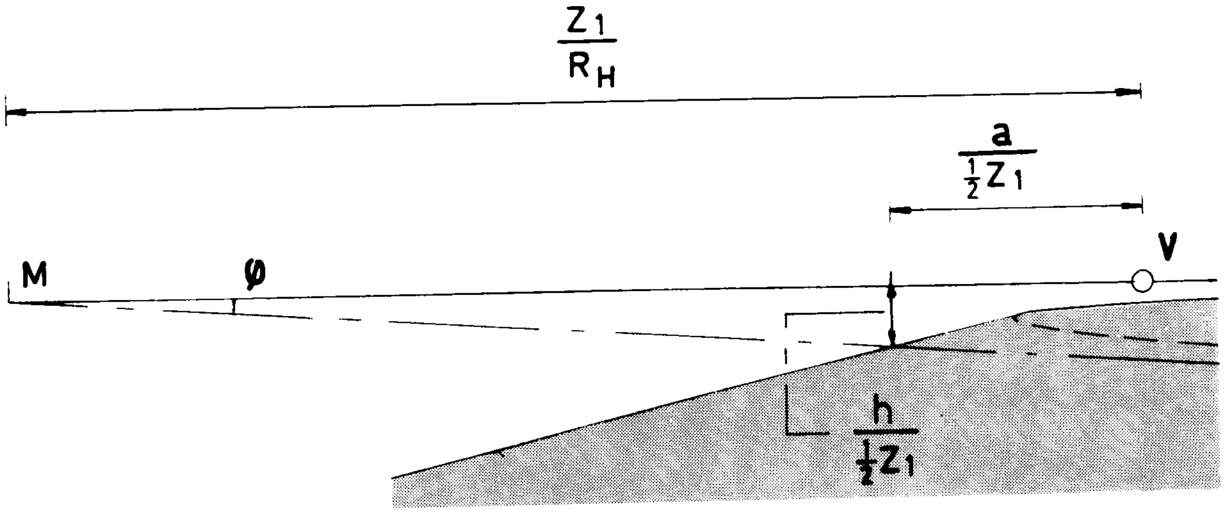


Figure 6.10 The difference in the picture of a horizontal curve with and without a transition-curve.



$R = 2000$

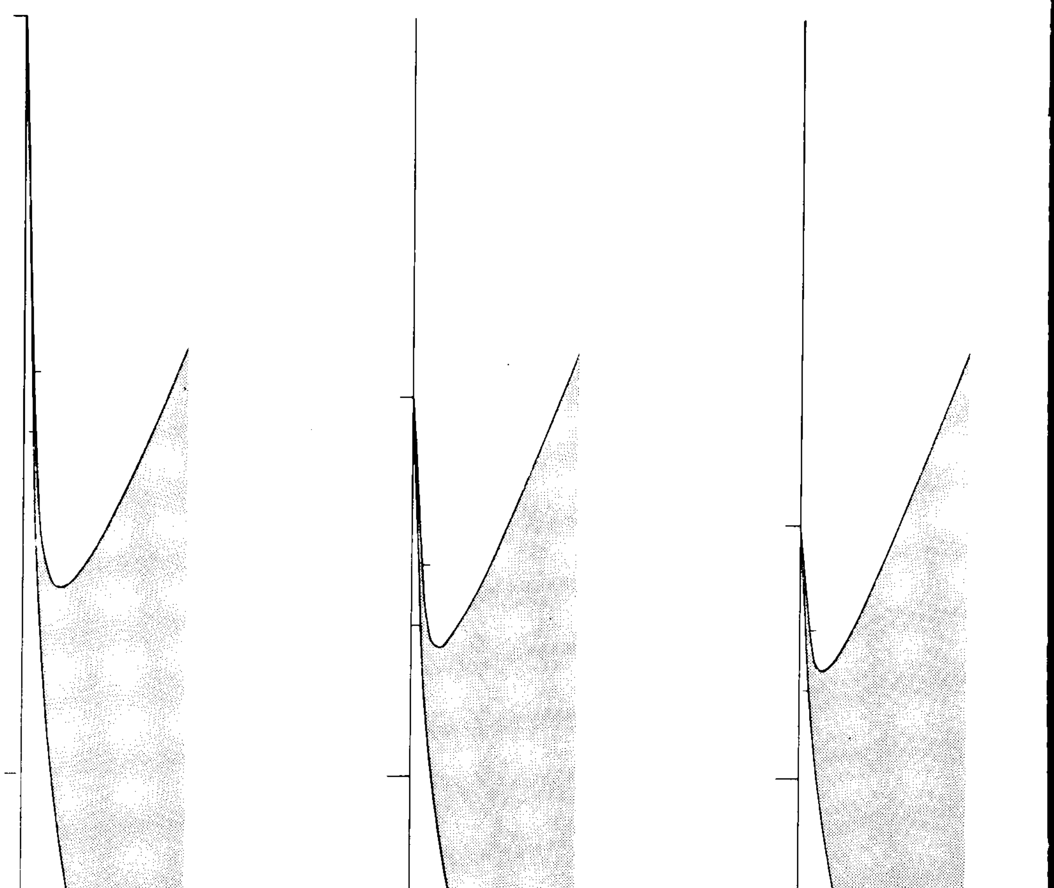
$Z_1 = 300$

$a = -5$

$h = -1,20$

$\tan \varphi = 0,06857 \qquad \varphi = \pm 4°$

Figure 6.11 Angle between the asymptotes of the hyperbola being the picture of a horizontal curve with a radius of 2000 m, observed from a distance of 300 m in front of it.


$R_H = 10.000$ m
$Z_K = 244{,}95$
$R_H = 20.000$ m.
$Z_K = 346{,}41$
$R_H = 30.000$ m.
$Z_K = 424{,}26$

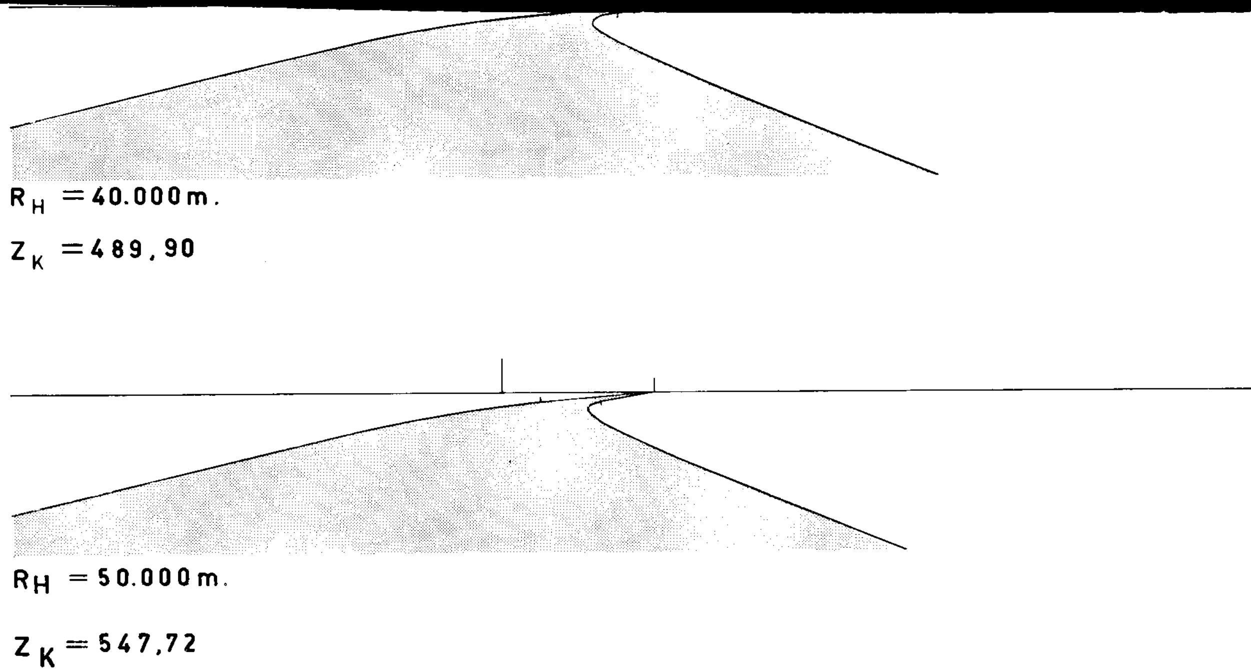


Figure 6.12 Road-sections, 1000 m long, with large radii of different size.

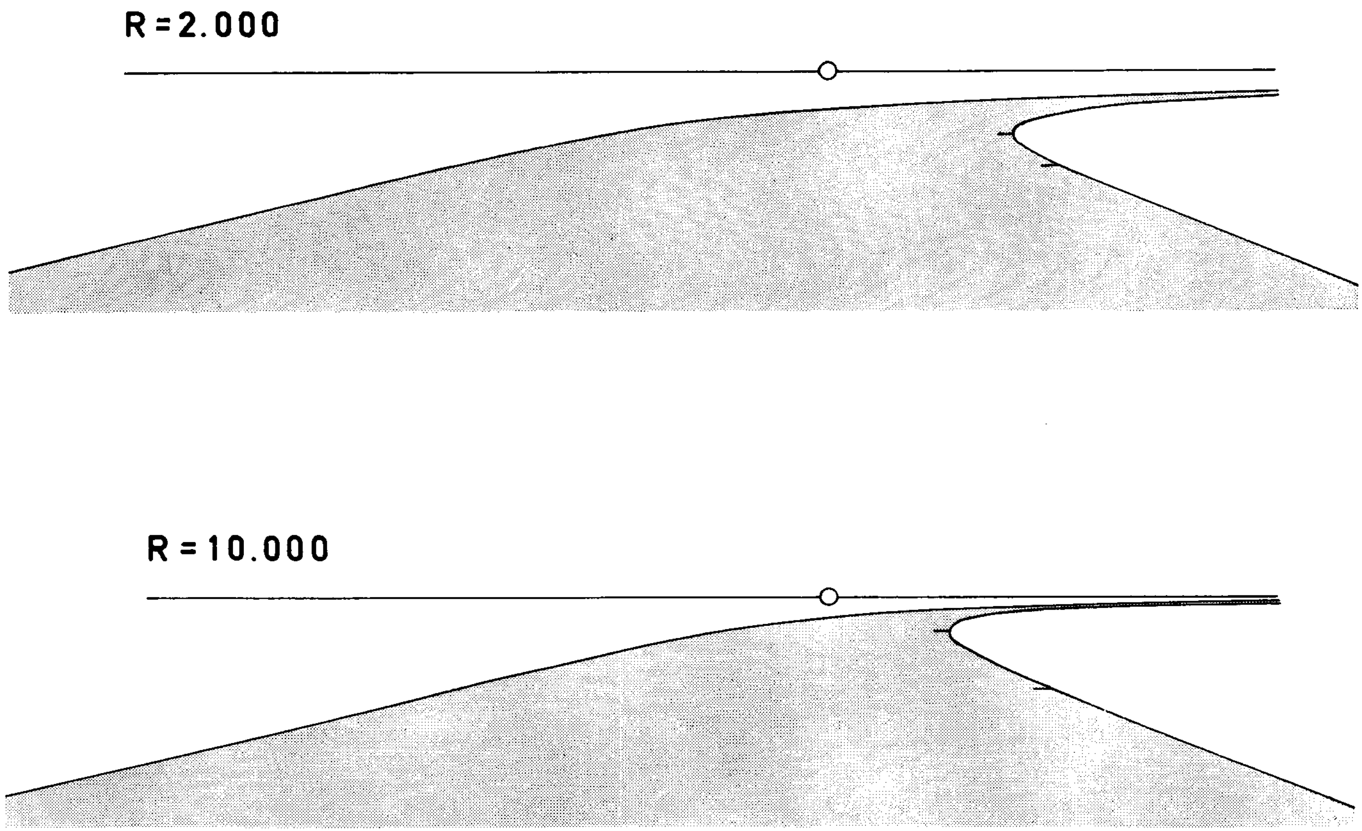


Figure 6.13 Turning point in the inner edge of a curve beginning at 100 m in front of the observer, with a large and a small radius.

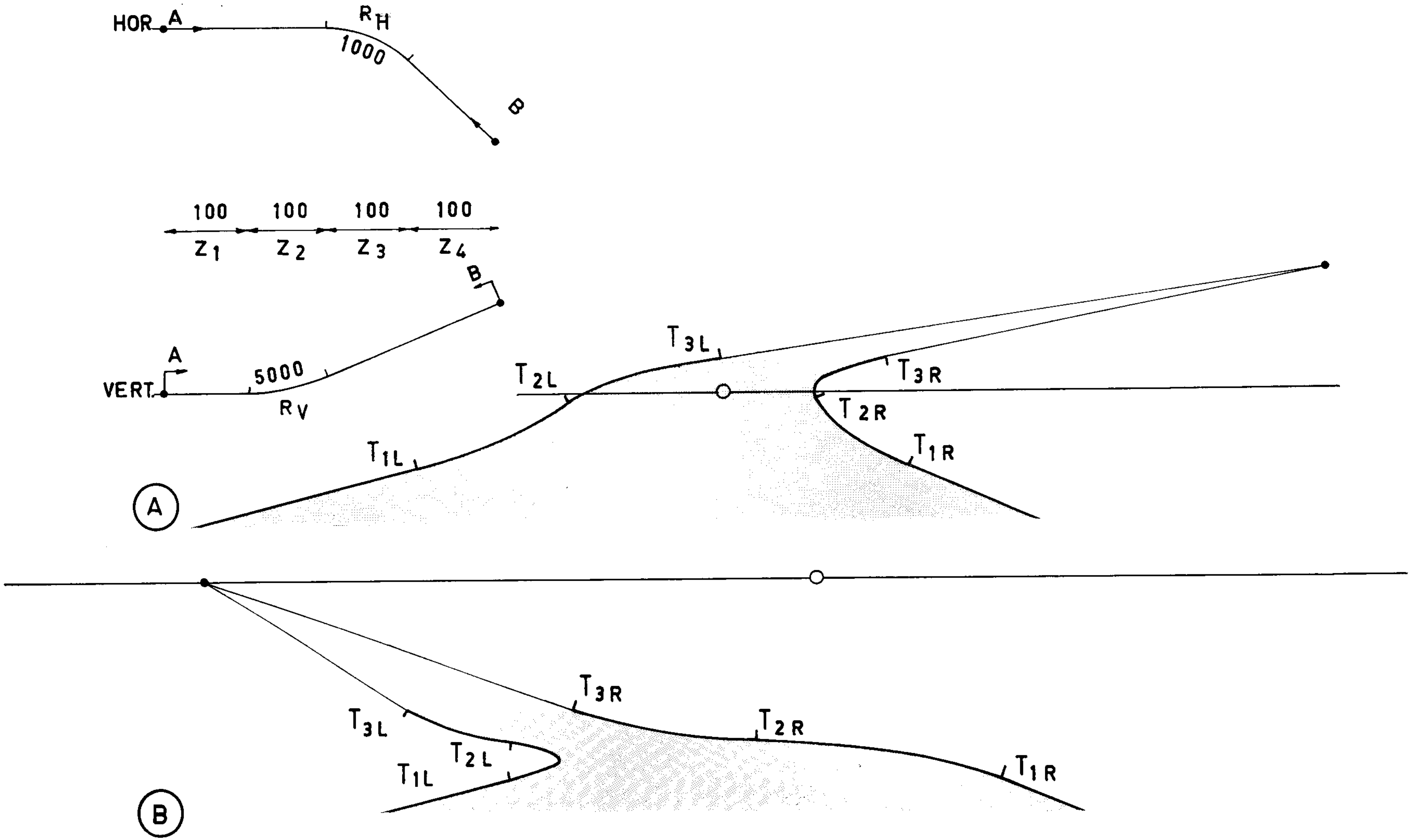


Figure 6.14 Vertical curve and curve in horizontal sense, in succession, observed in both directions.

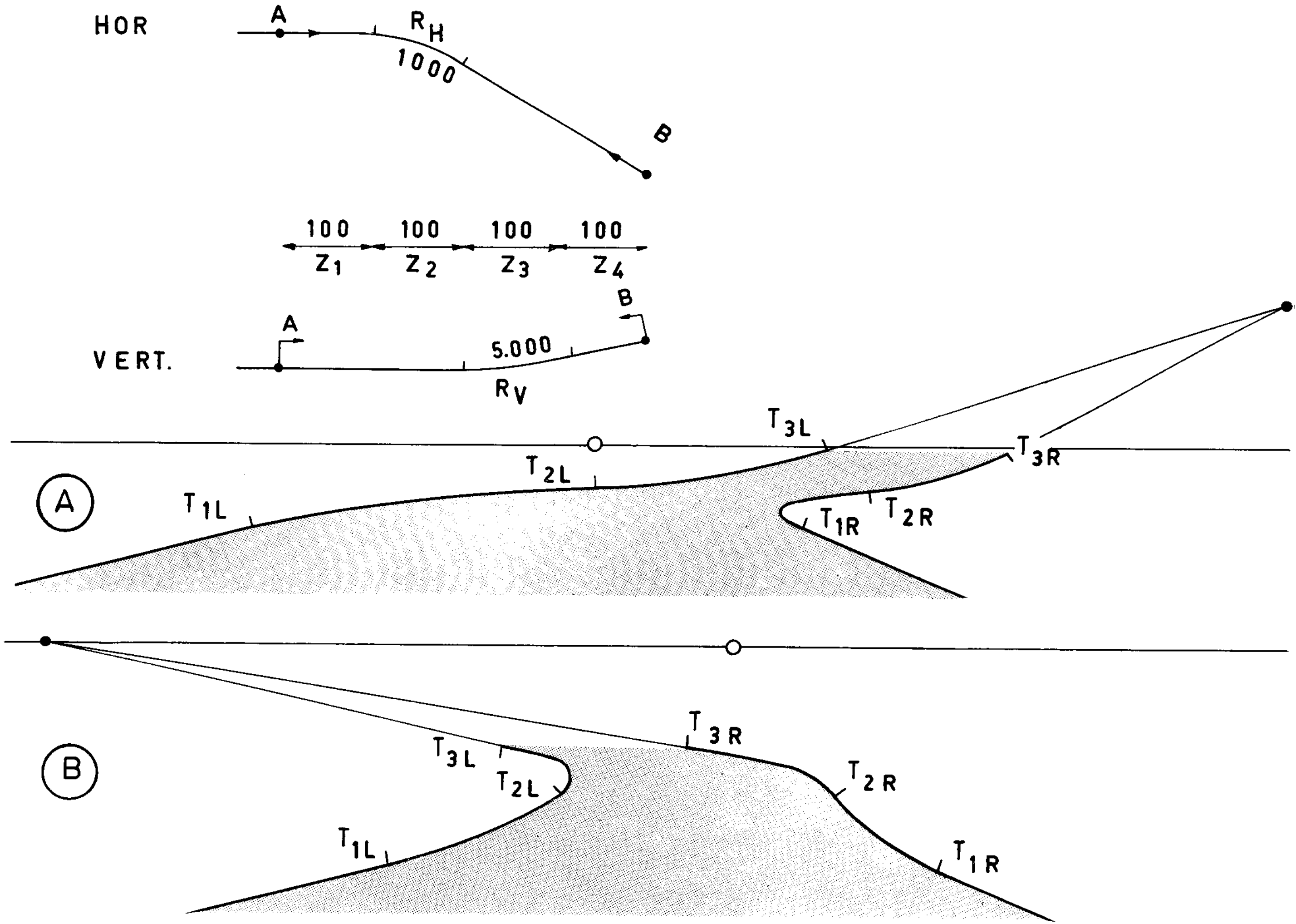


Figure 6.15 Horizontal and vertical curve in succession, observed in both directions. These pictures are nearly identical with those of figure 6.14.

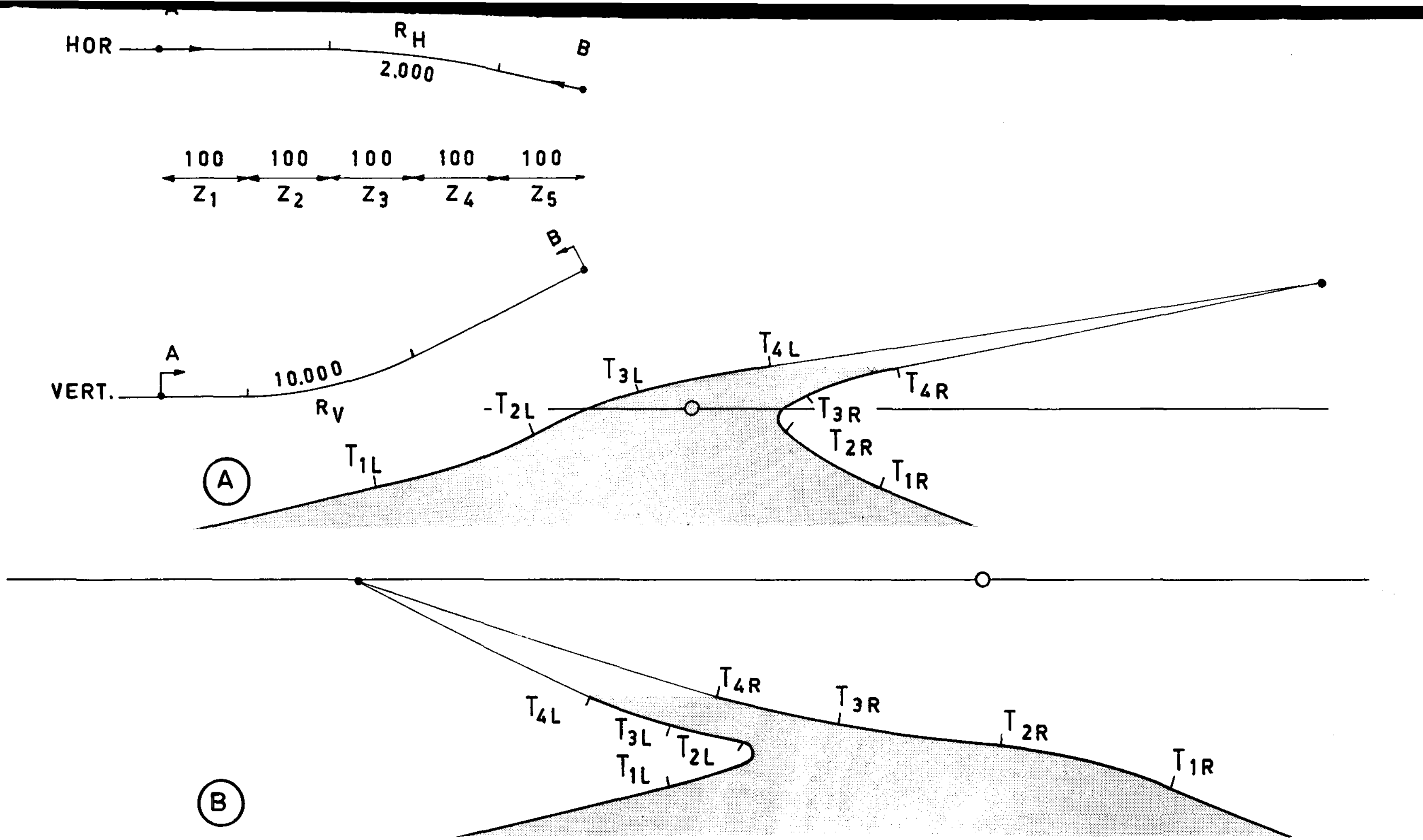


Figure 6.16 Situation as in figure 6.14, but with partly overlapping curves.

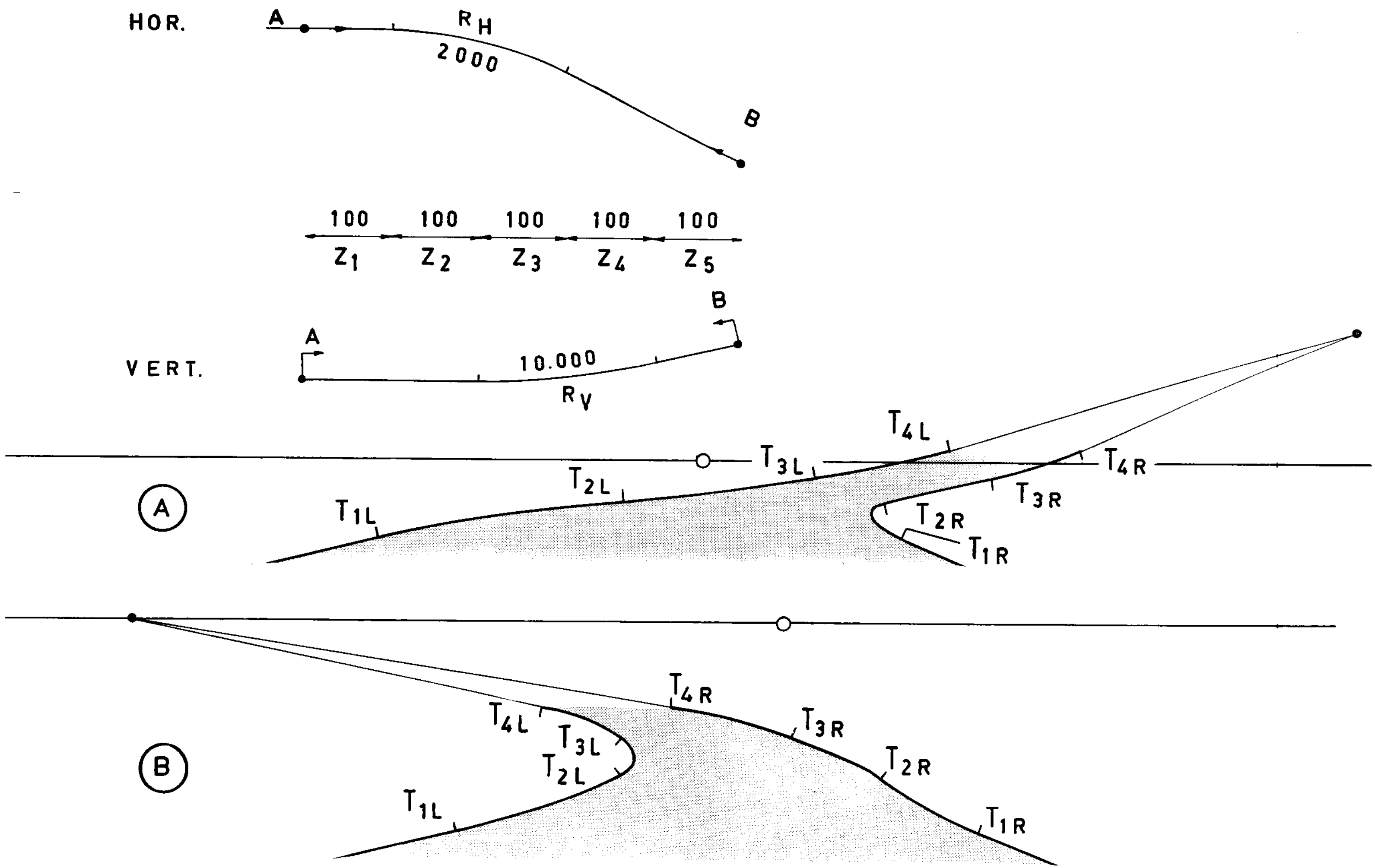


Figure 6.17 Situation as in figure 6.15, but with partly overlapping curves.

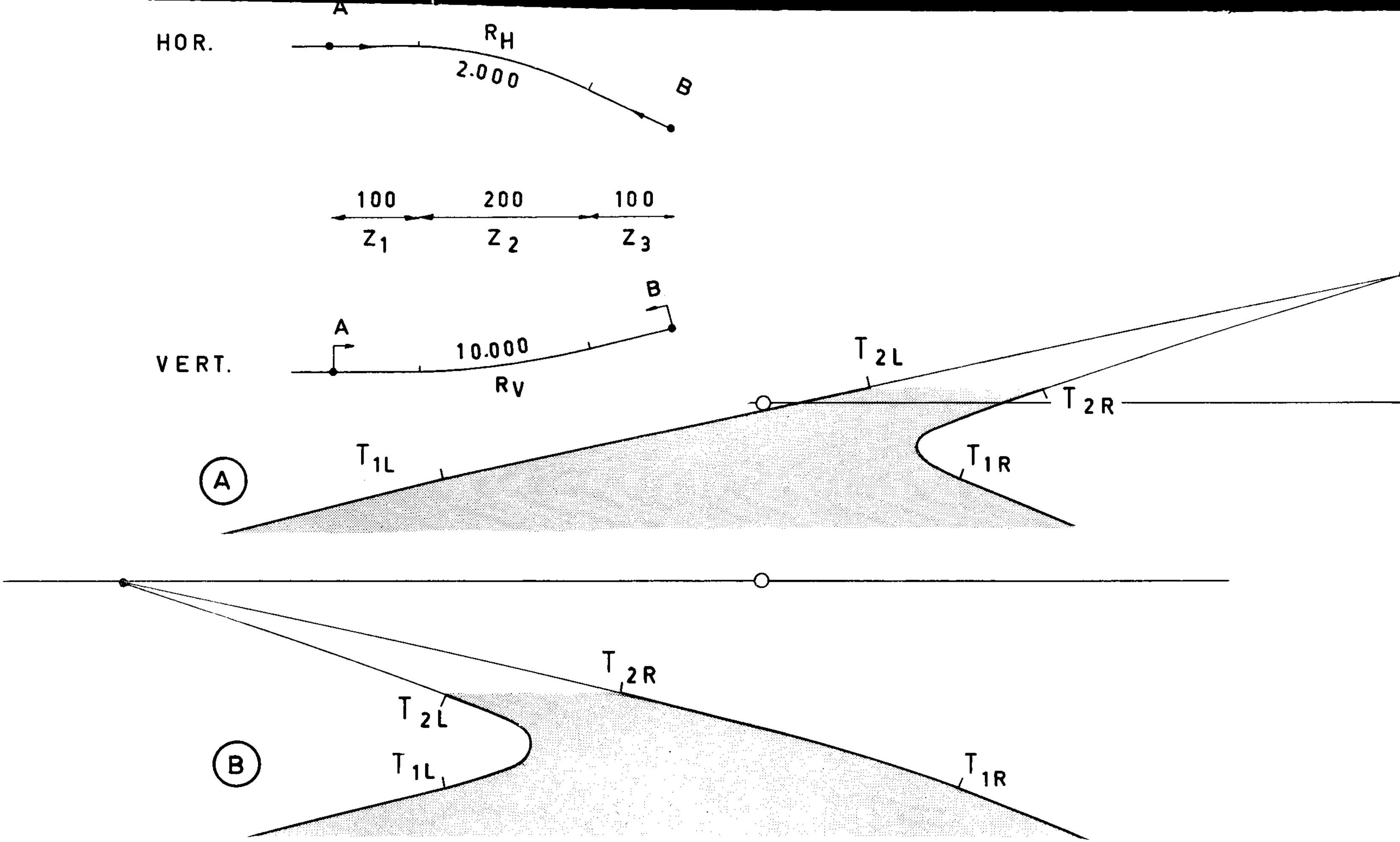


Figure 6.18 The composite curve, being the ideal solution for a change of direction in the horizontal as well as in the vertical sense.

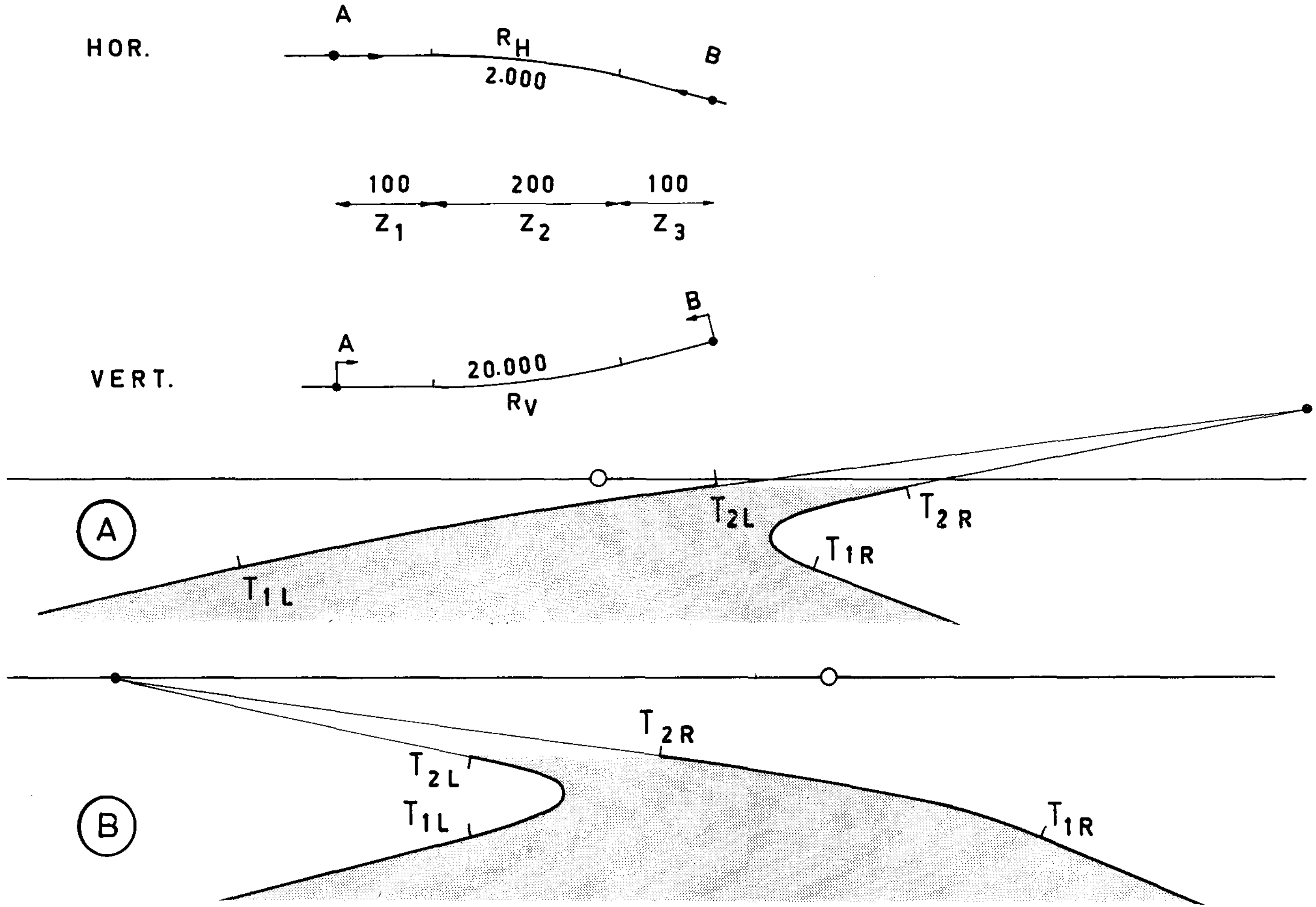


Figure 6.19 Similar situation as in figure 6.18, but with different radii.

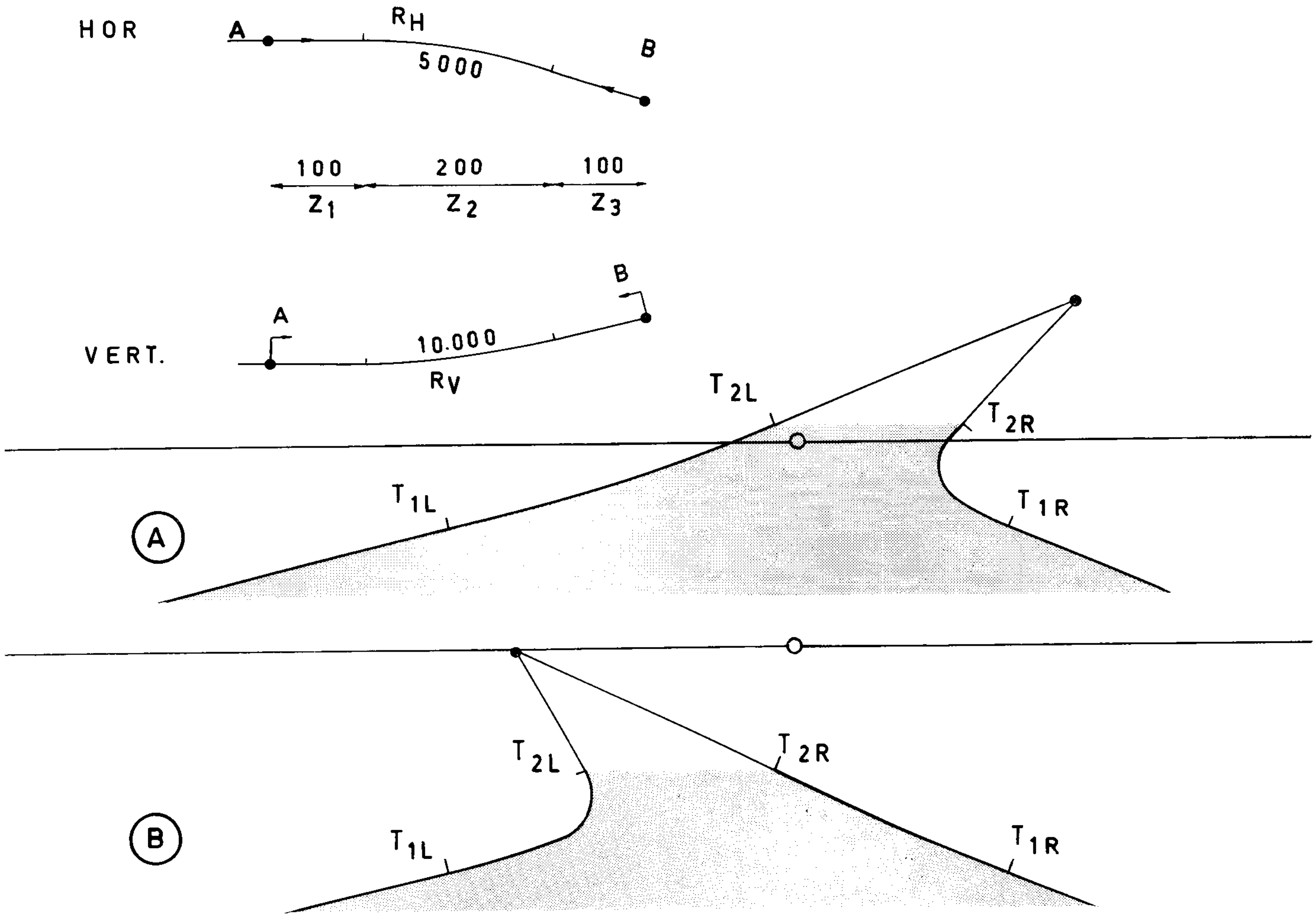


Figure 6.20 Situation as in figure 6.19.

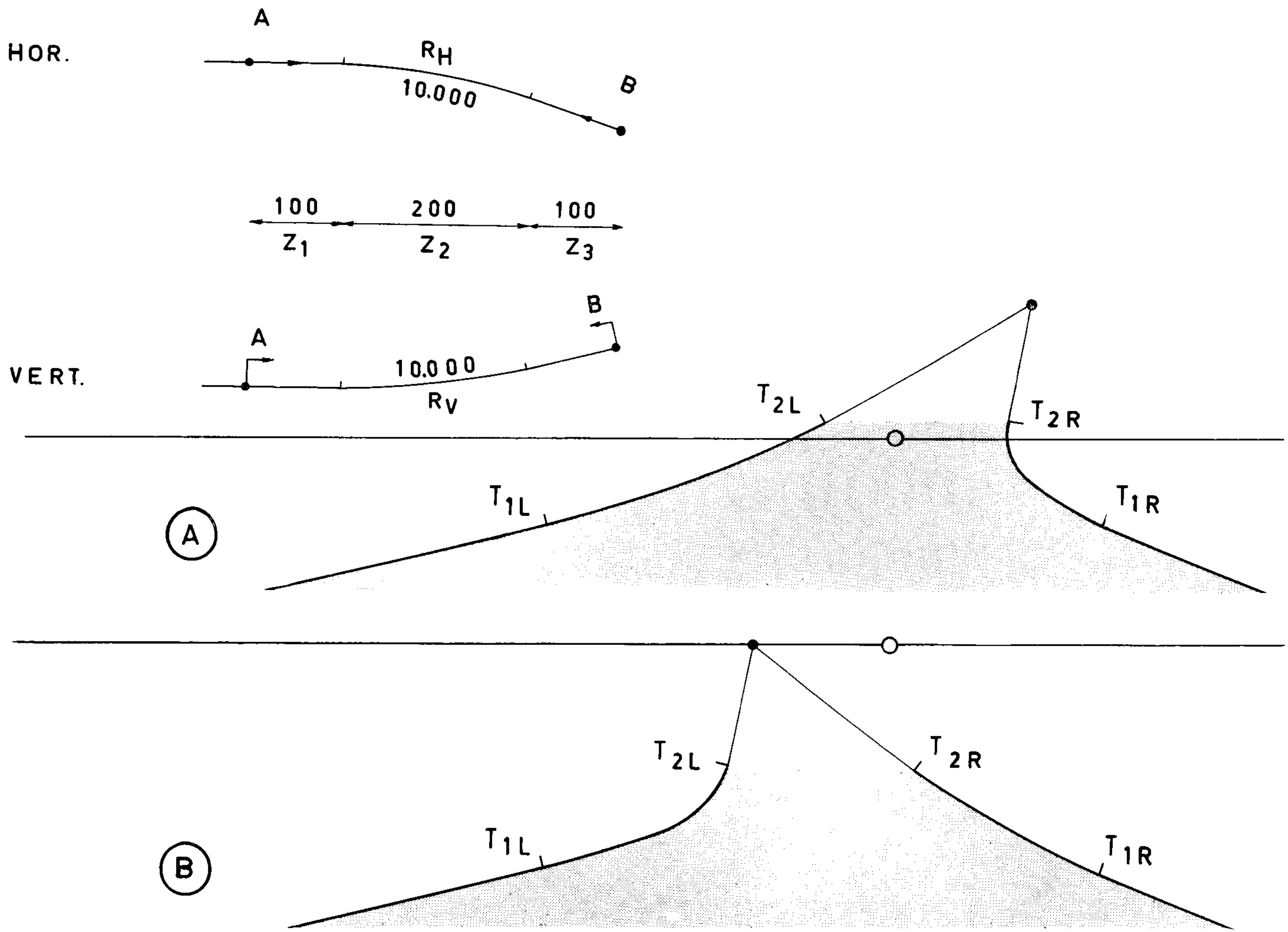


Figure 6.21 Situation as in figure 6.19.

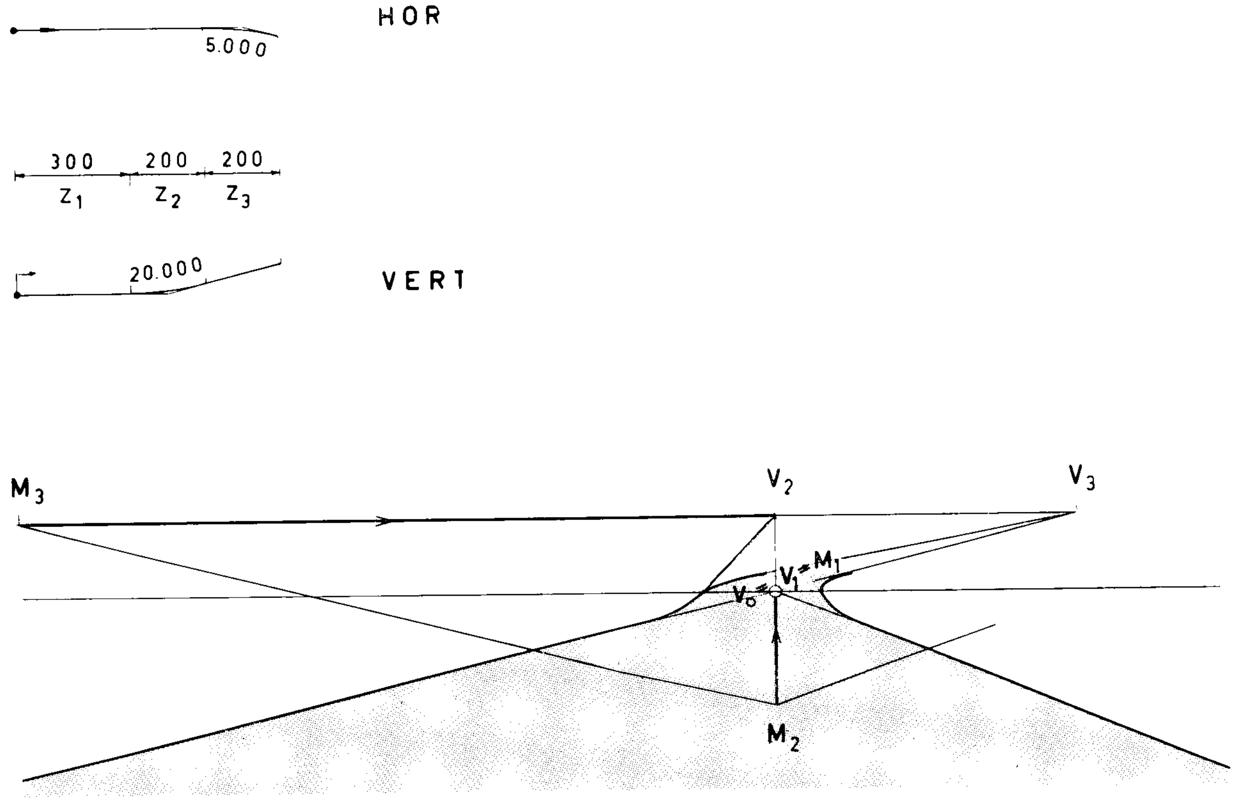


Figure 6.22 Course of the centres, when the shape of the picture does not change during the approach.

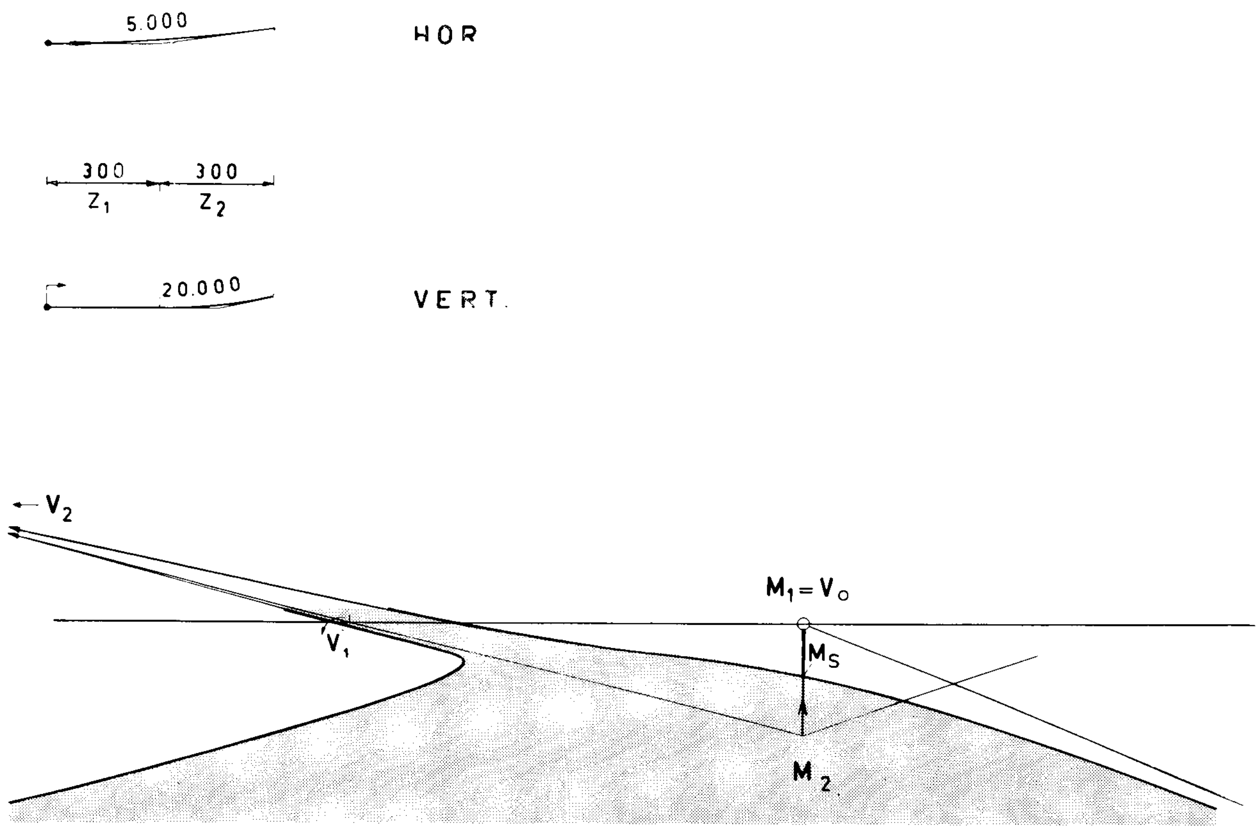


Figure 6.23 Course of the centres, when the shape of the pictures does change during the approach.

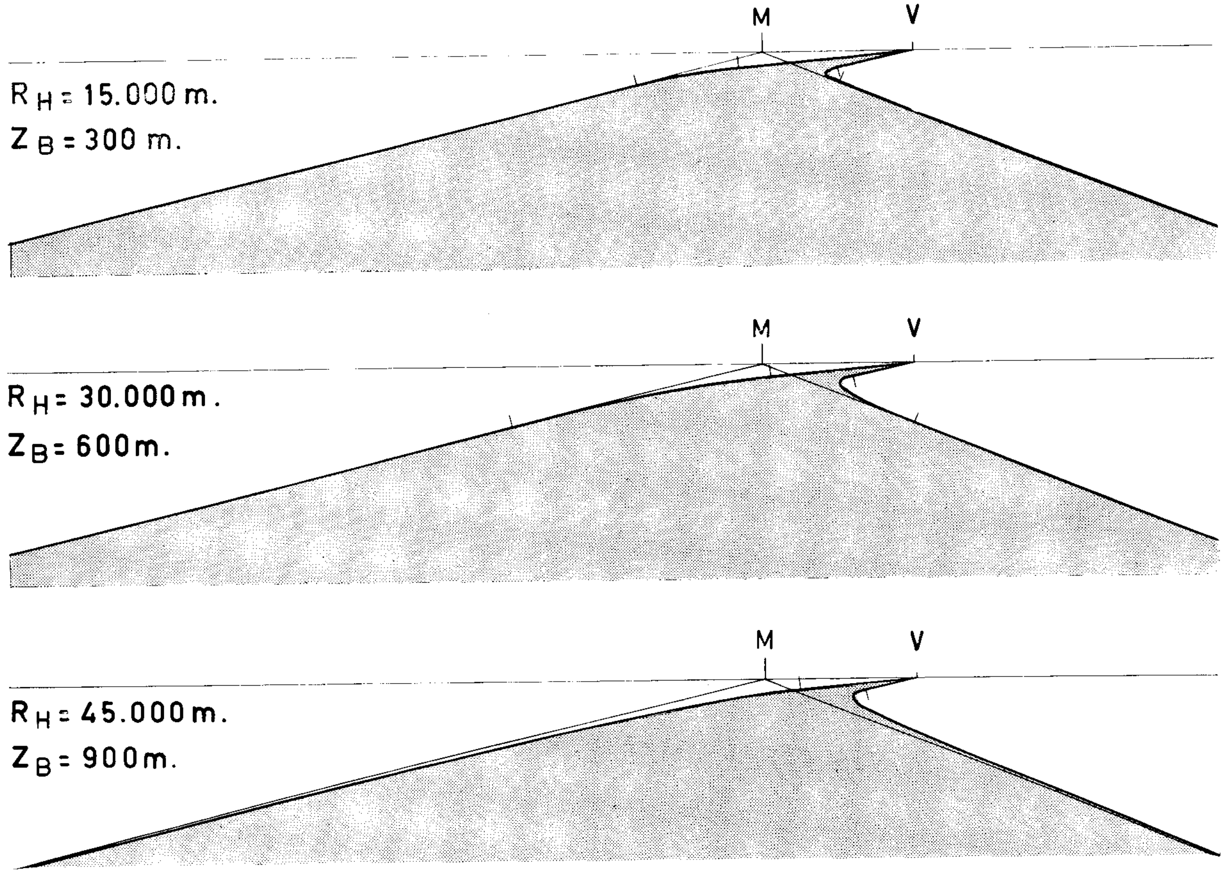


Figure 7.1 Horizontal curves with equal change of direction and different radii, observed from the same distance to their angle-points, here 450 m.

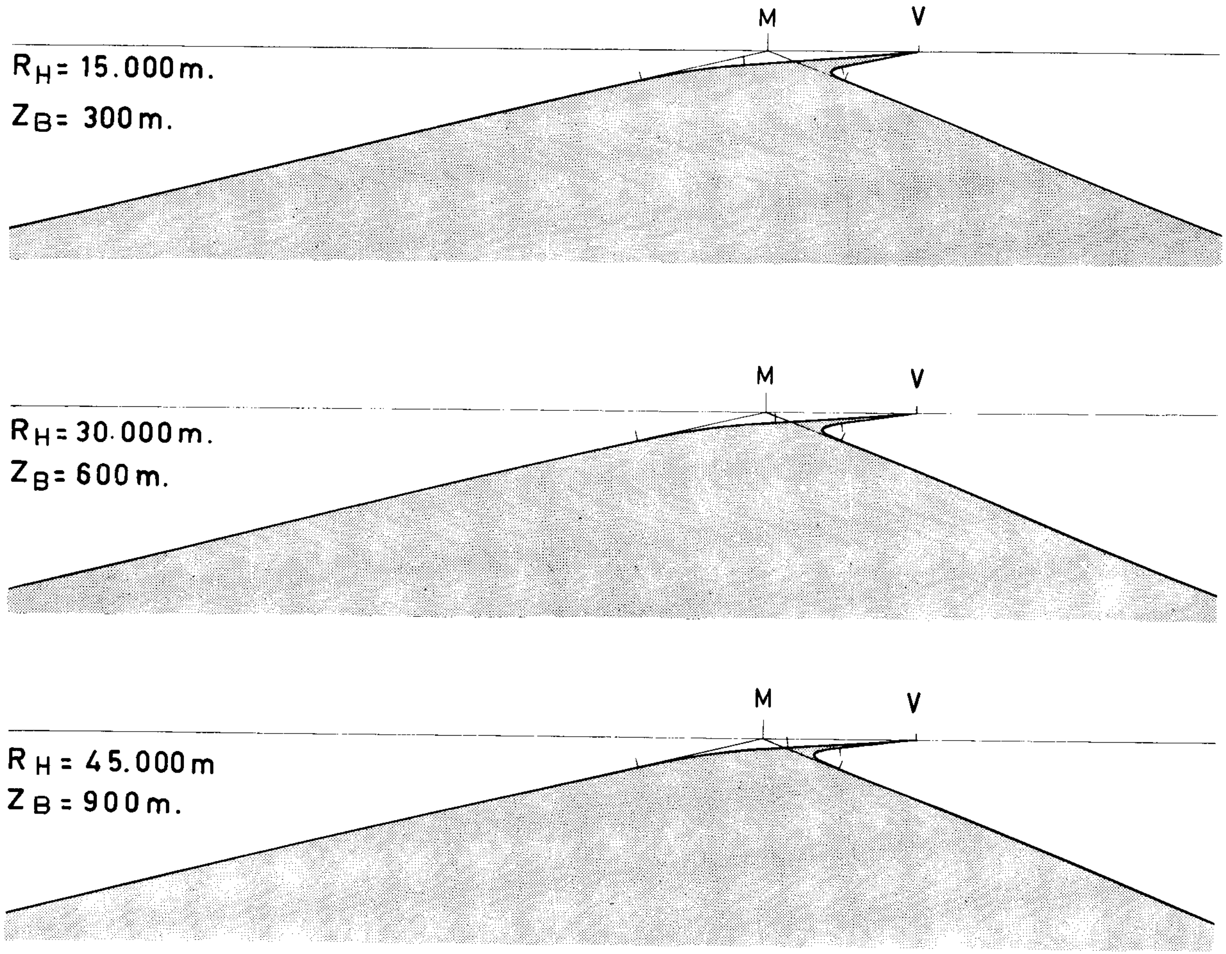


Figure 7.2 Horizontal curves with equal change of direction and different radii, observed from the same distance in front of their beginning, here 300 m.

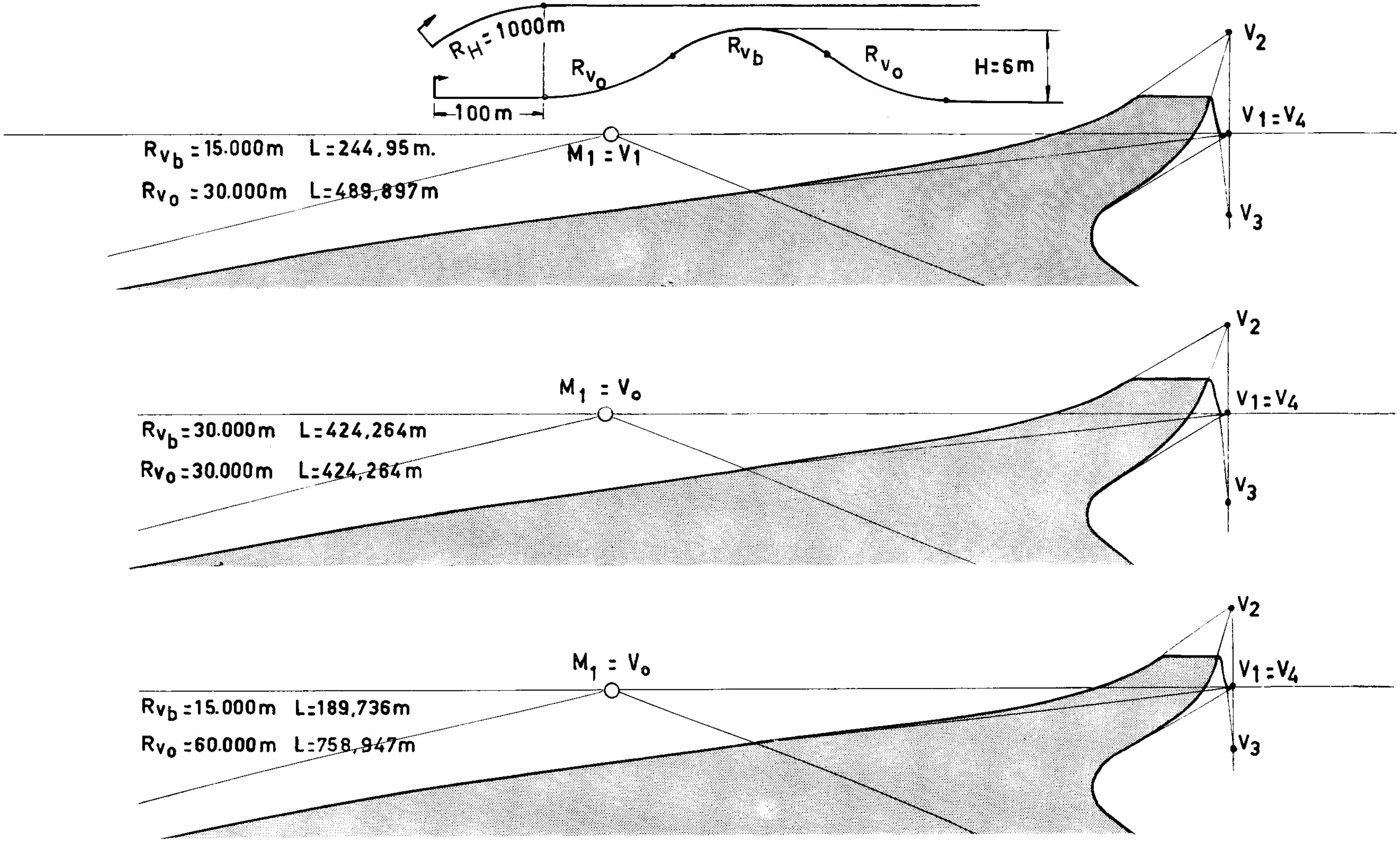


Figure 7.3 A horizontal curve in front of a straight elevation.

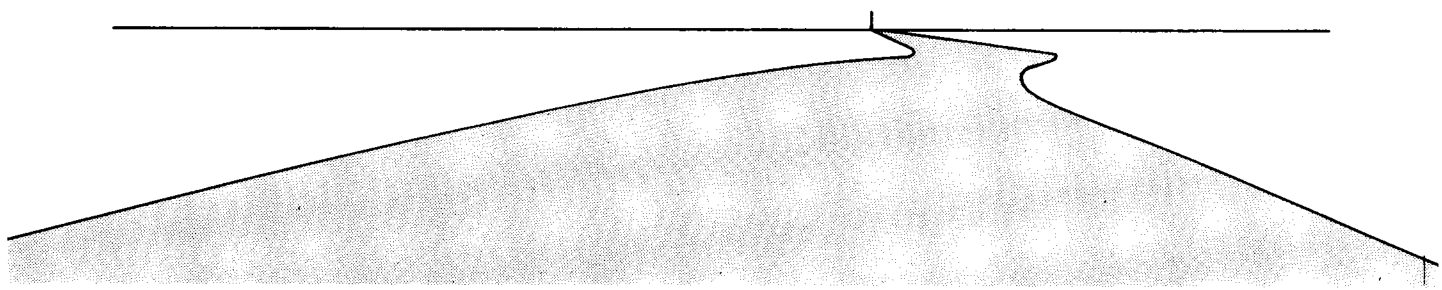


Figure 7.4 A horizontal displacement equal to the road width.

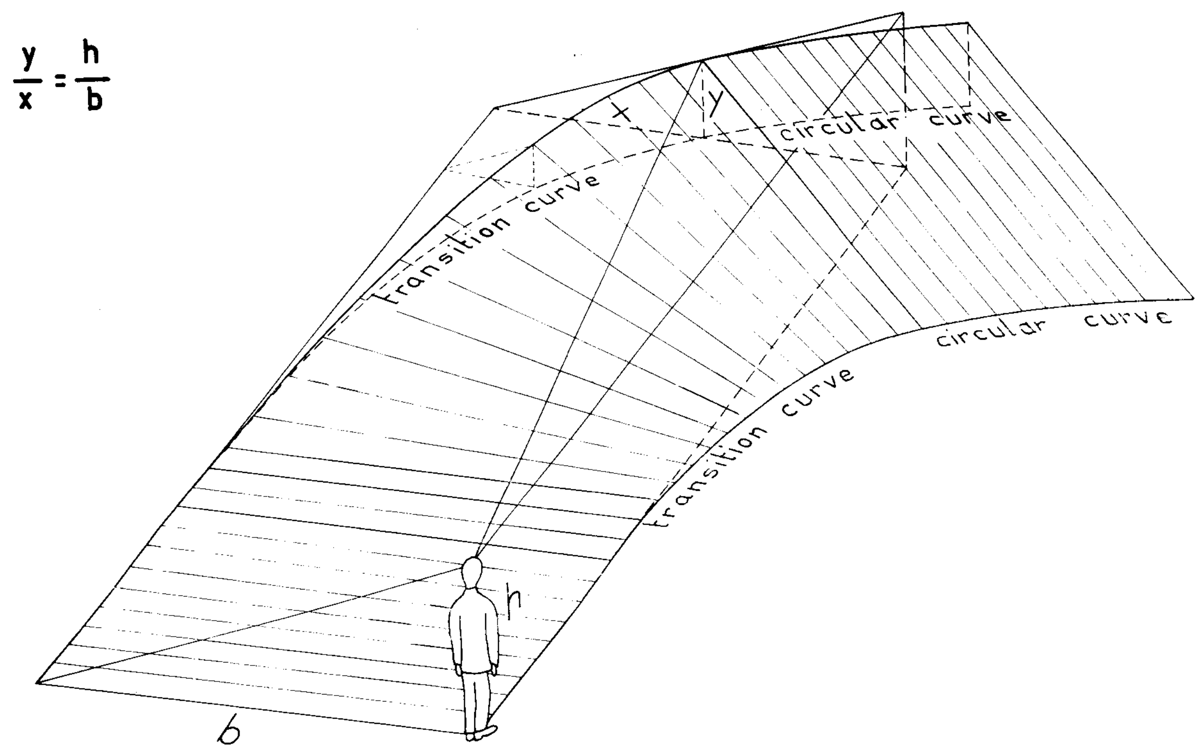


Figure 7.5 The condition for a non-disturbing shape of the transition to the superelevation.

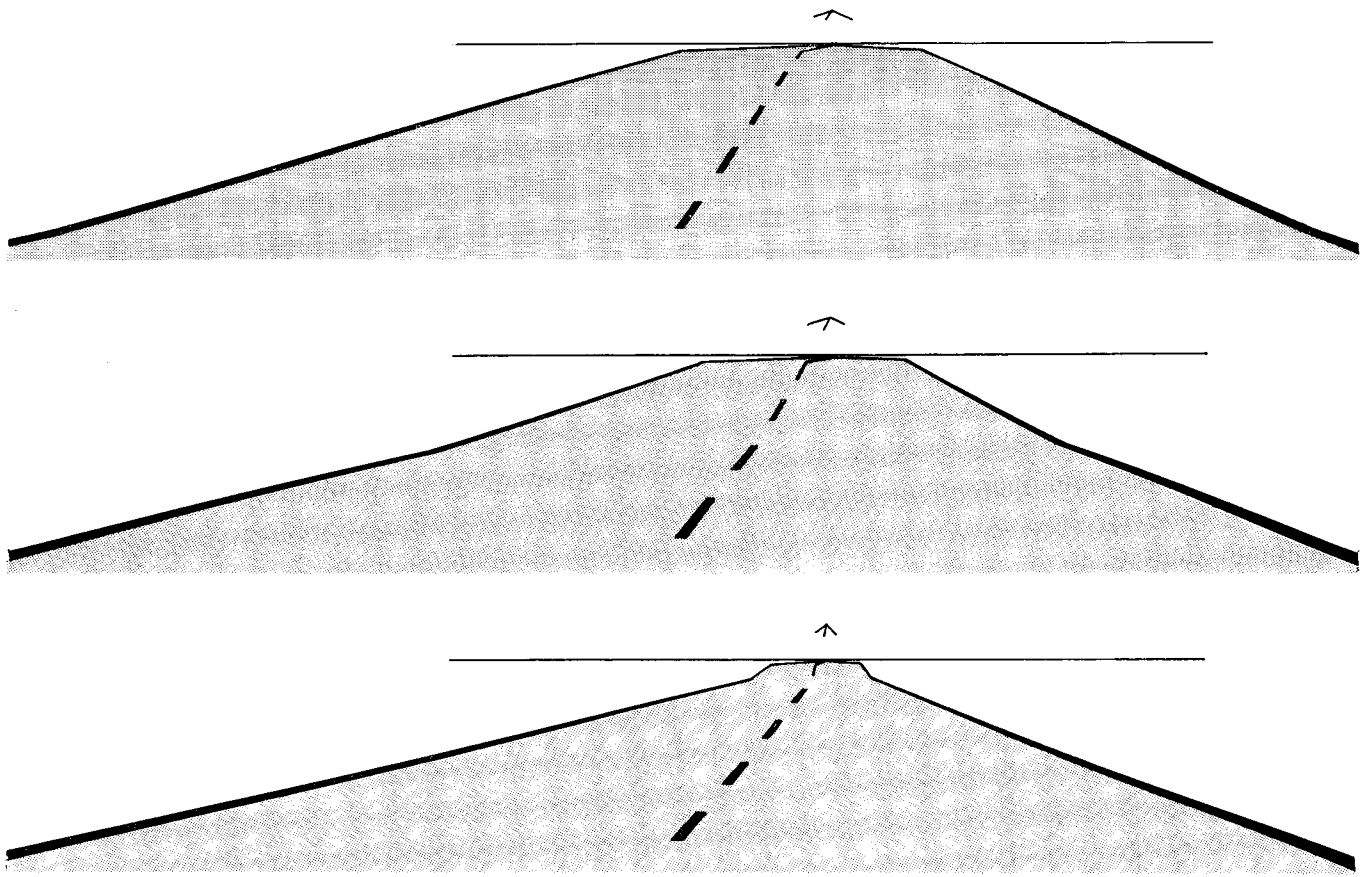


Figure 7.6 Nearing a minor elevation with a slope of 0,5%.

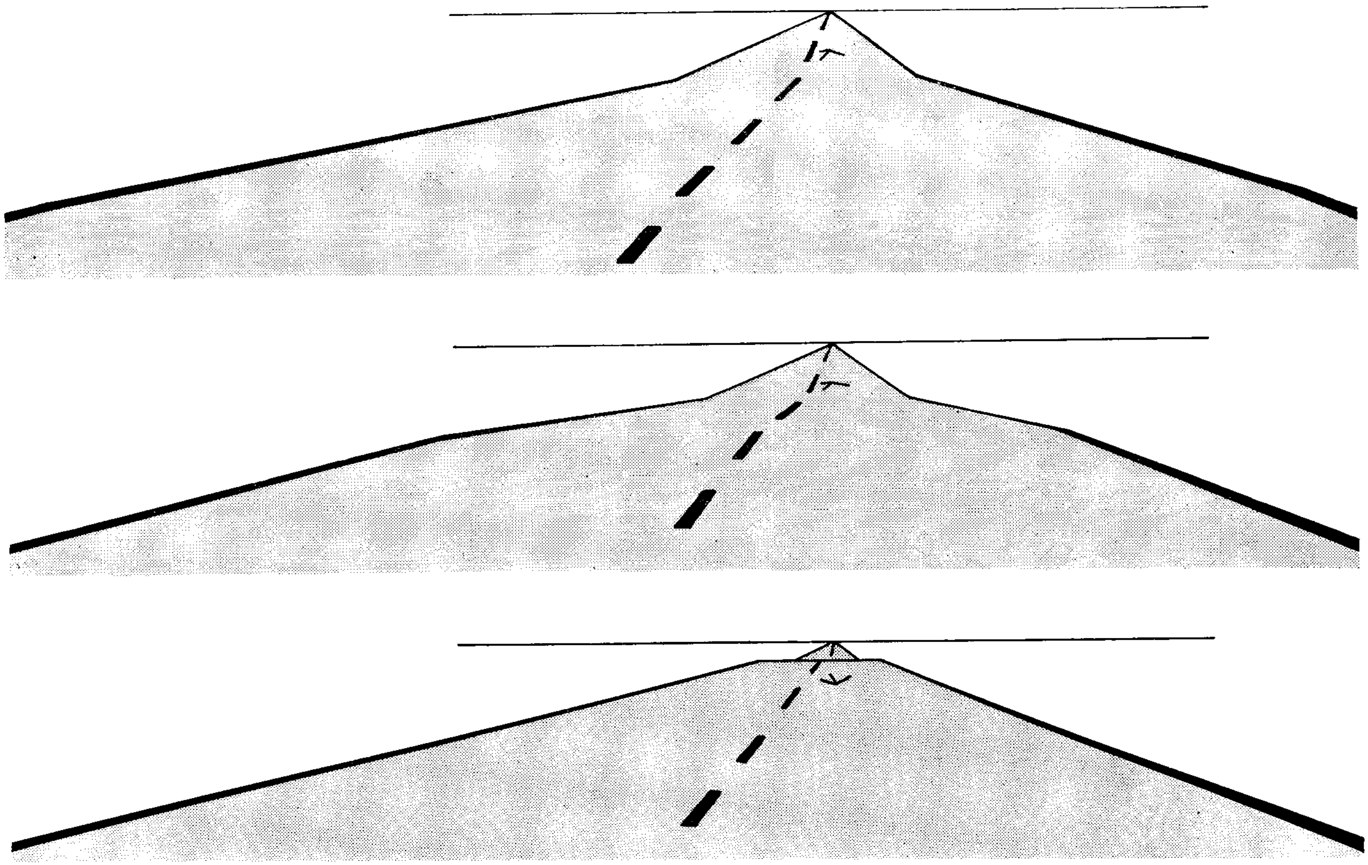


Figure 7.7 Nearing a minor declination with a slope of 0,5%.

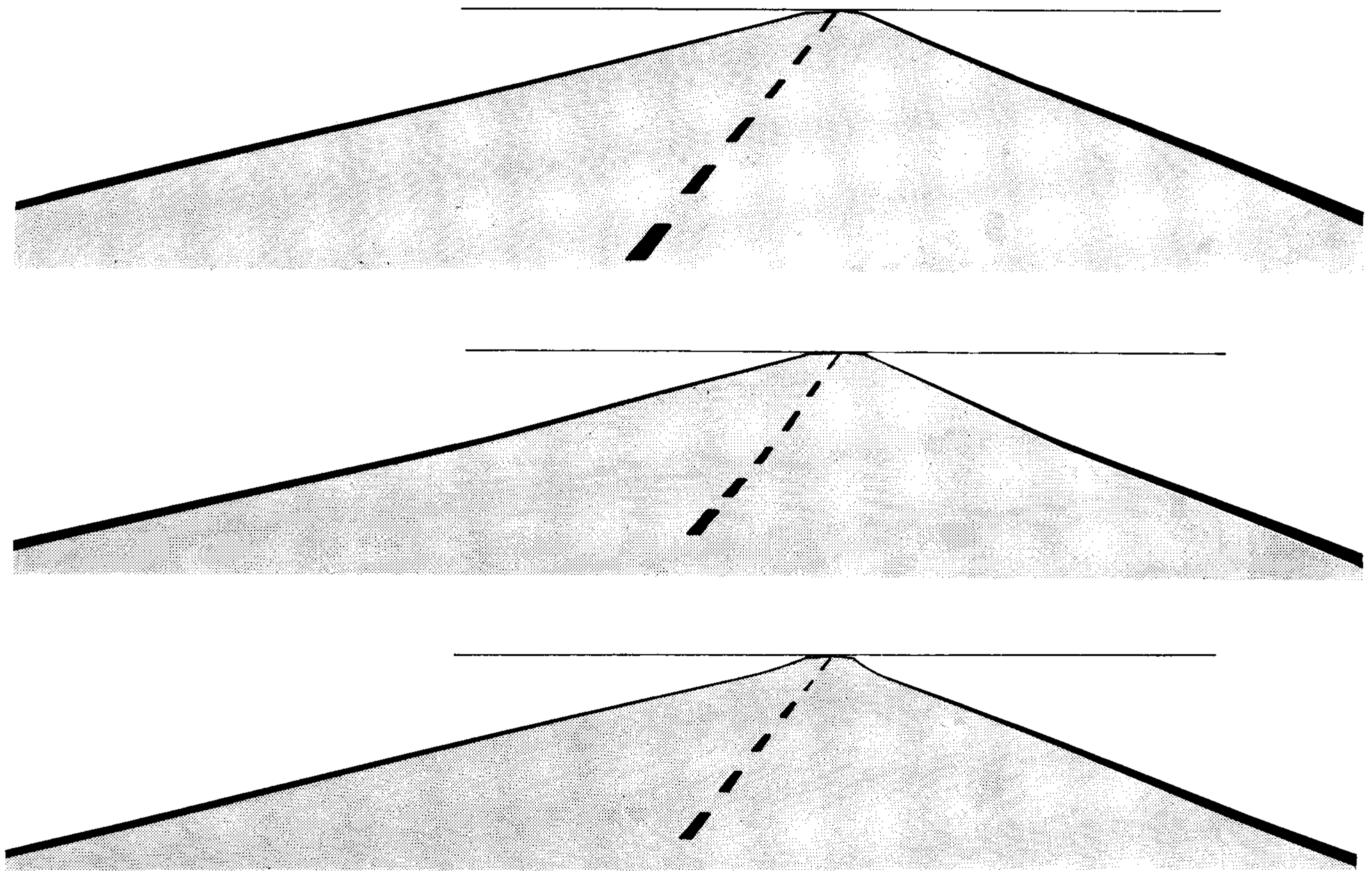


Figure 7.8 Nearing a minor elevation with a slope of 0,1‰.

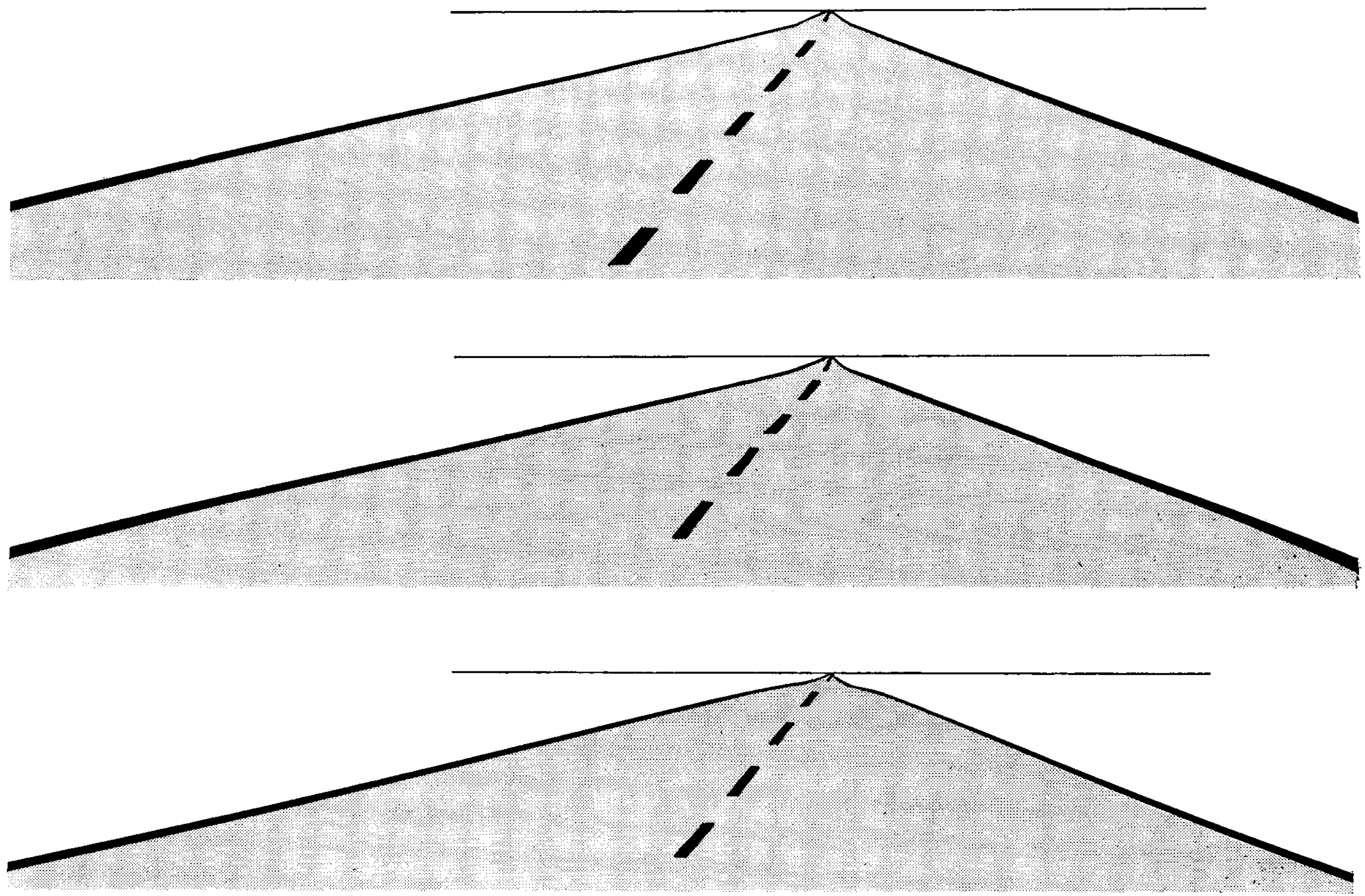


Figure 7.9 Nearing a minor declination with a slope of 0,1%.

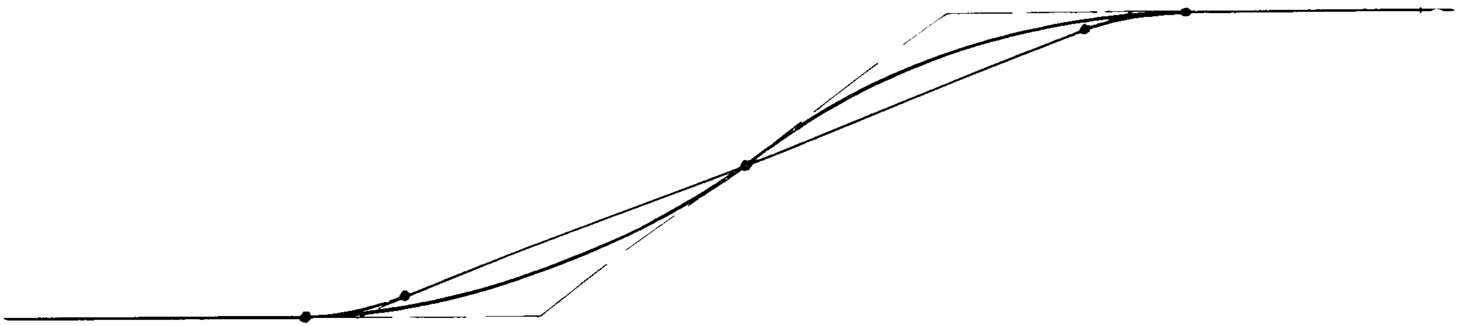


Figure 7.10 Larger radii at the foot and the top over the same length cause a steeper rate of slope.

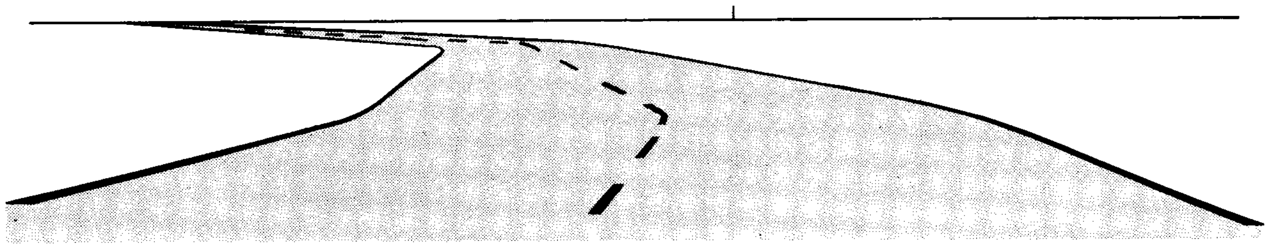


Figure 7.11 Straight section between horizontal curves in the same direction.

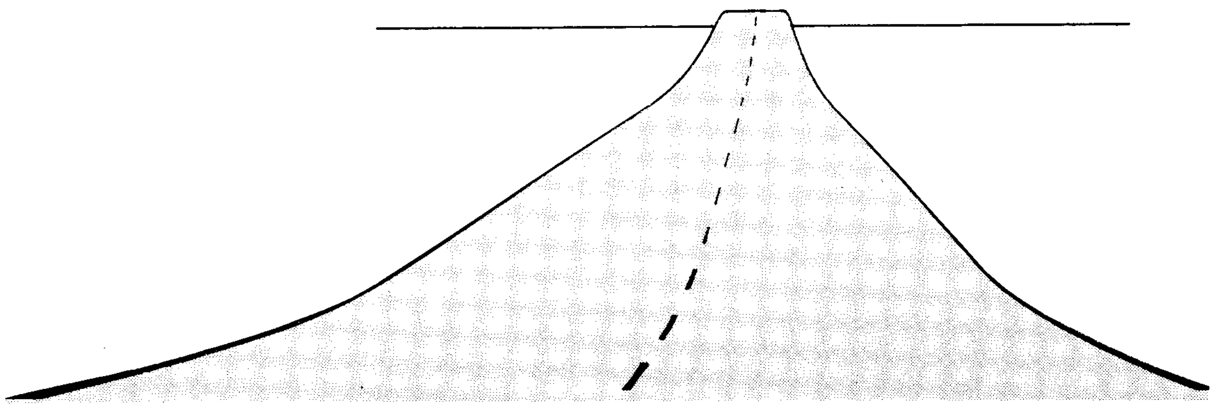


Figure 7.12 Straight section between concave curves.

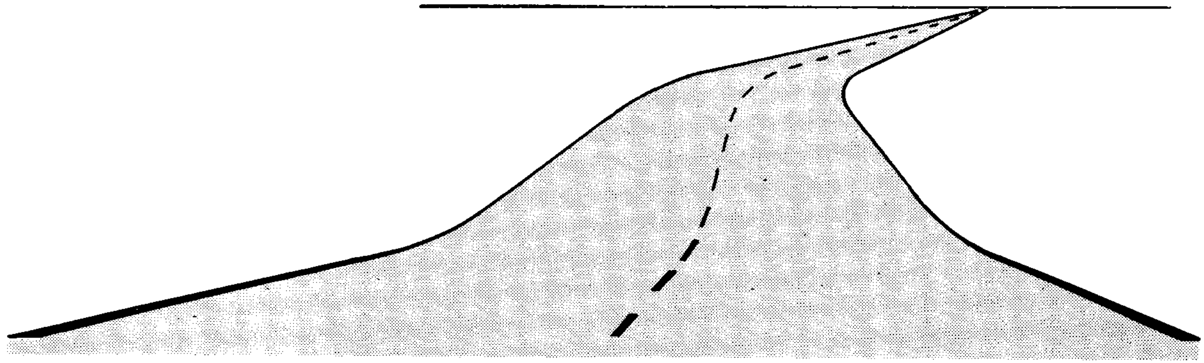


Figure 7.13 Concave curve in front of a straight section and a horizontal curve.

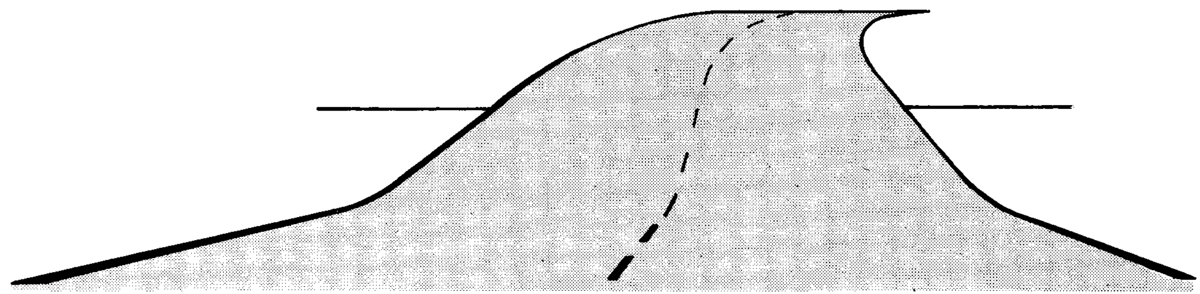


Figure 7.14 Concave curve in front of a straight slope and a horizontally bent top curve.

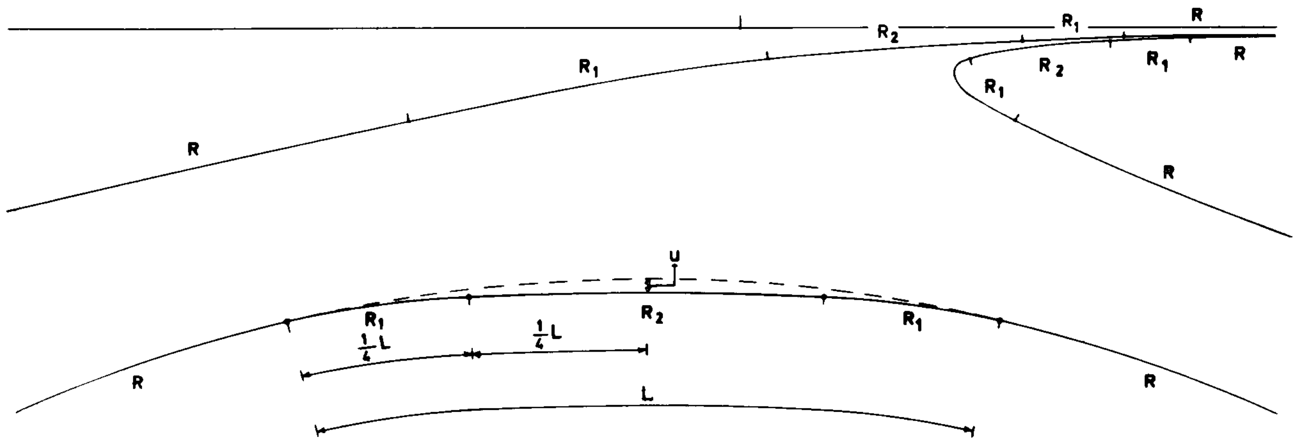


Figure 7.15 Local displacement in a horizontal curve.

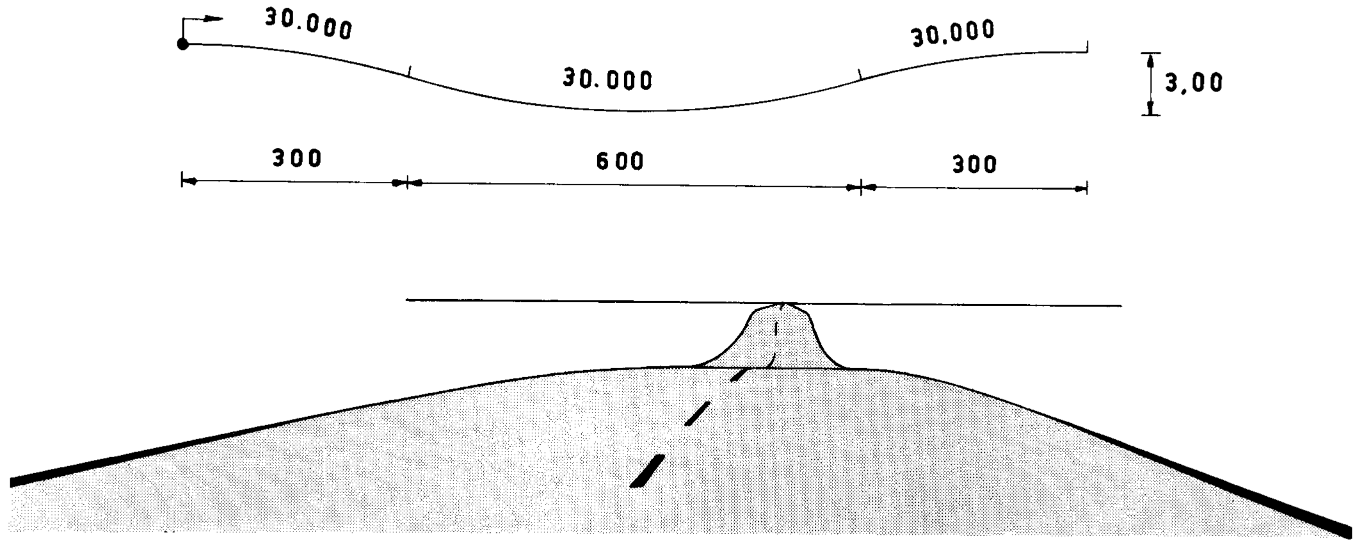


Figure 7.16 Locap dip in a horizontally straight section.

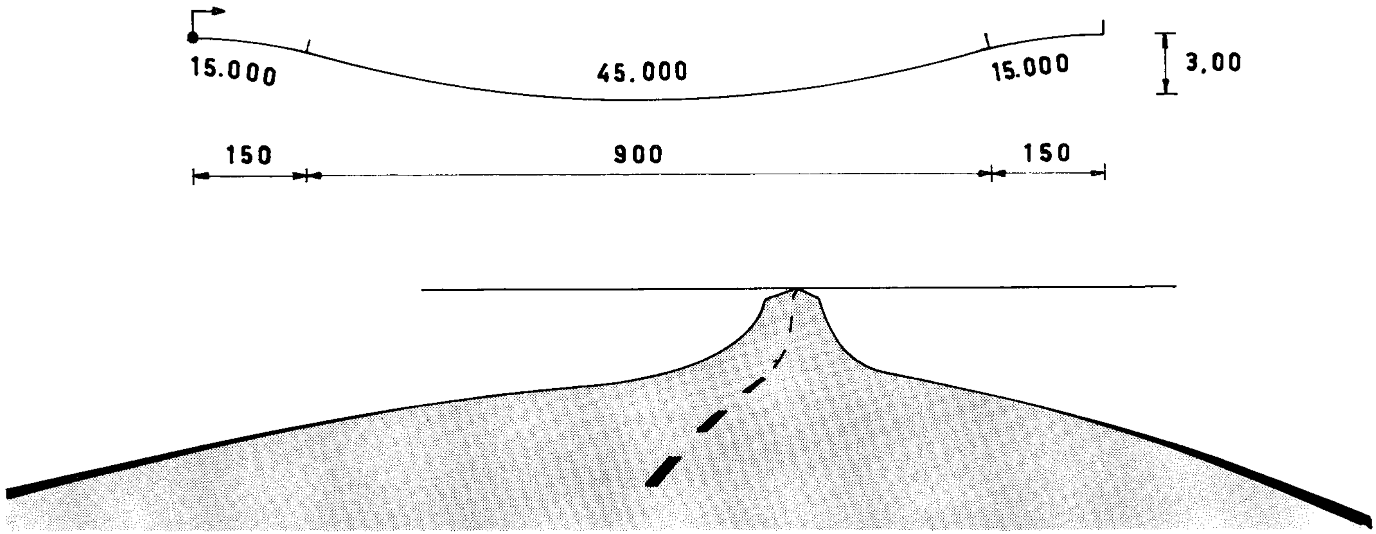


Figure 7.17 As figure 7.16, but with larger radius of the concave curve and smaller ones of the convex curves.

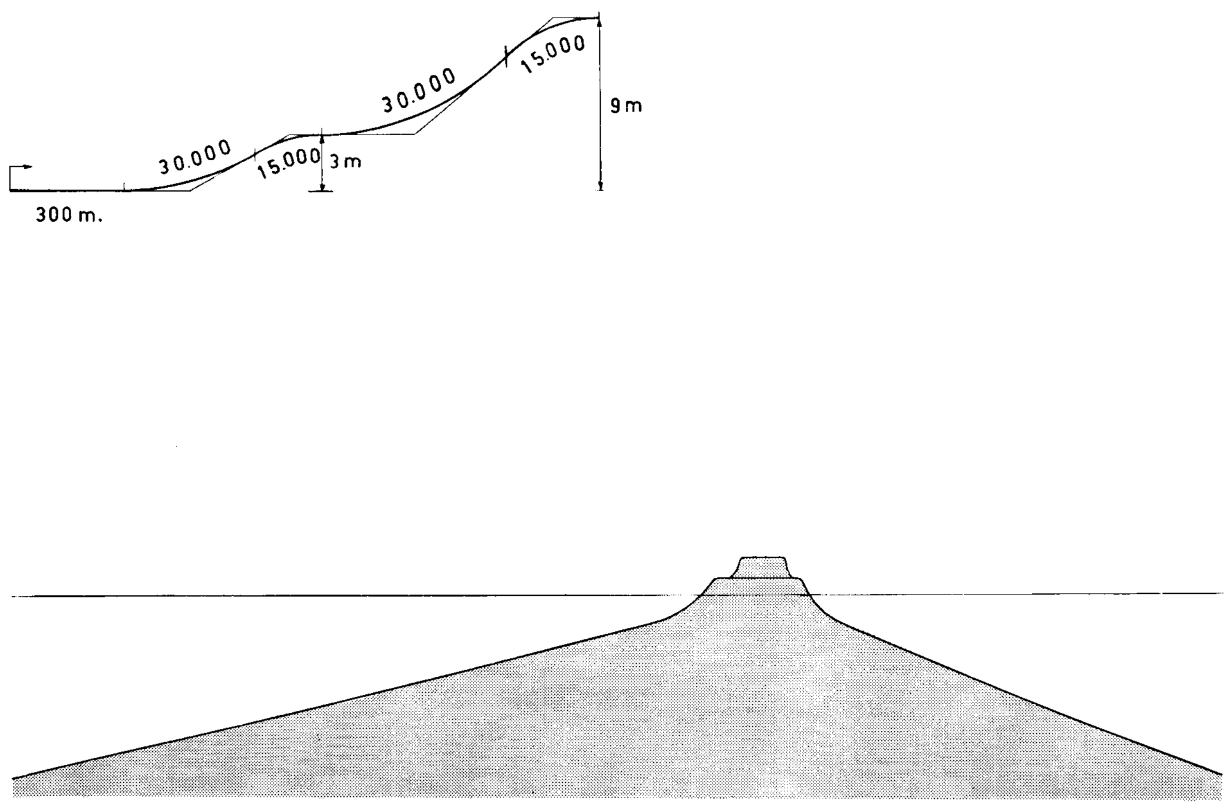


Figure 7.18 A terrace at a low level.

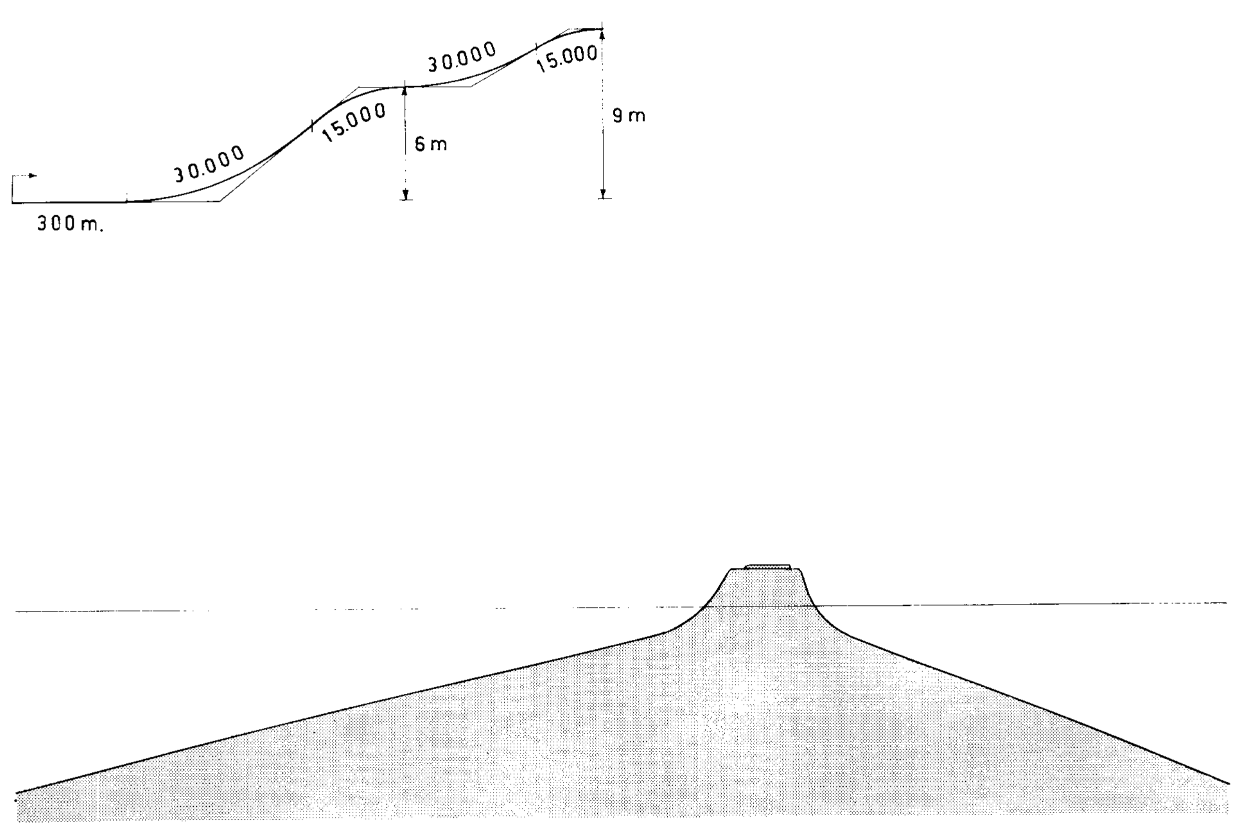


Figure 7.19 A terrace at a high level.

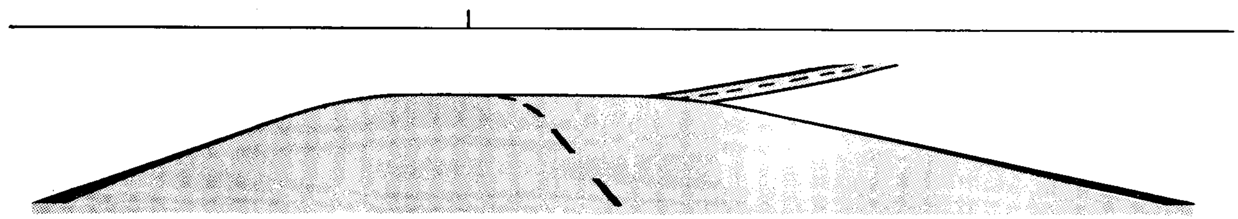


Figure 7.20 An elevation in a horizontal curve, observed from the top. There is a shift in the picture.

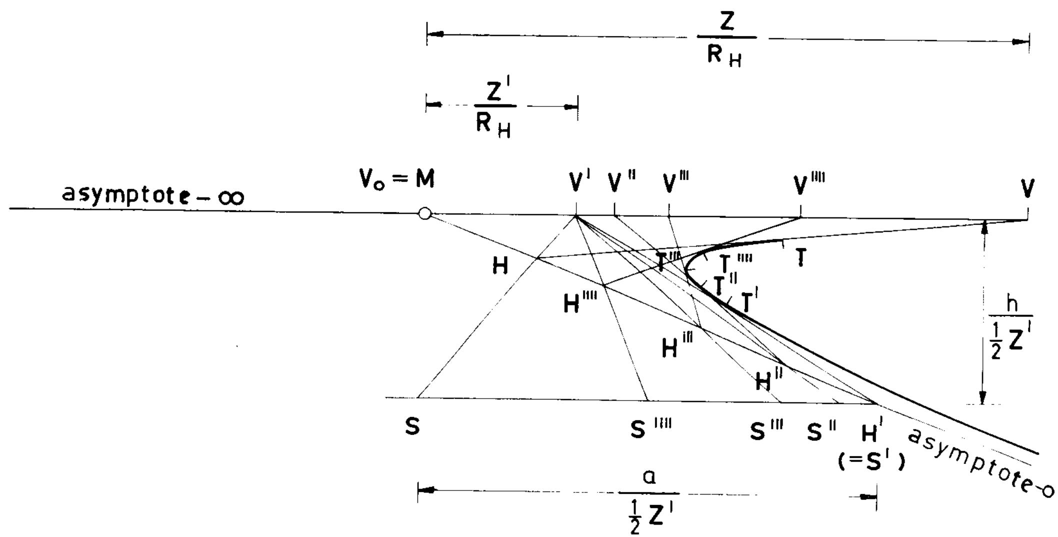


Figure 8.1 Construction of the inner edge of a horizontal curve by means of the tangents method.

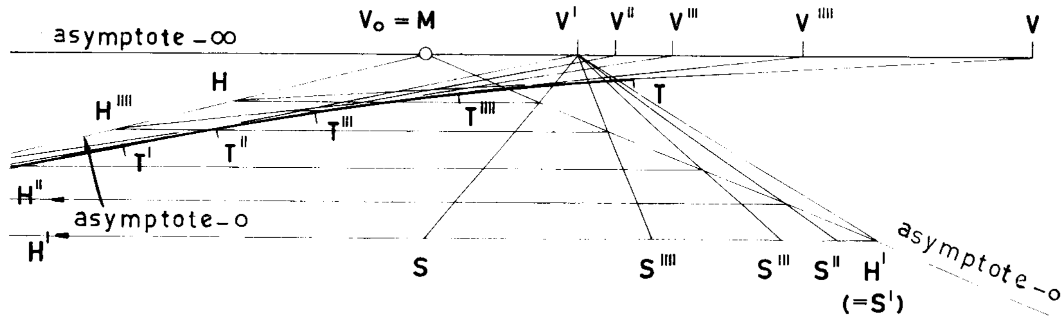


Figure 8.2 Construction of the outer curve.

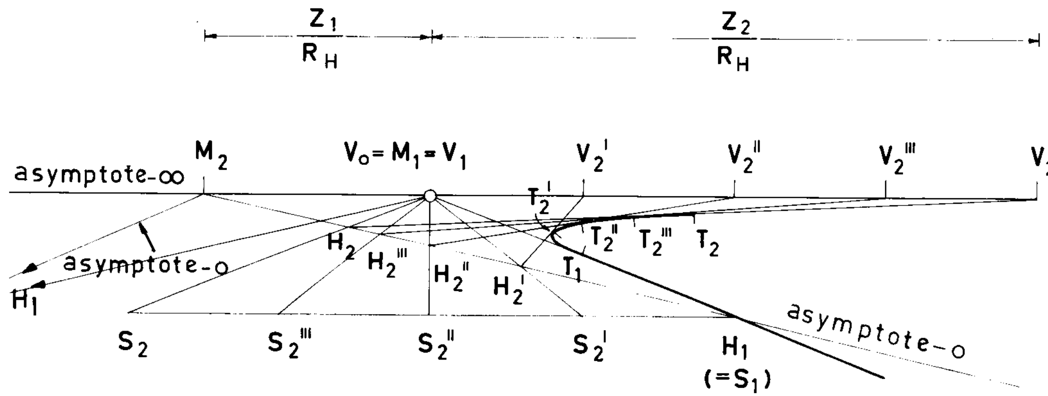


Figure 8.3 Construction of the inner edge when the curve begins at Z_1 in front of the observer.

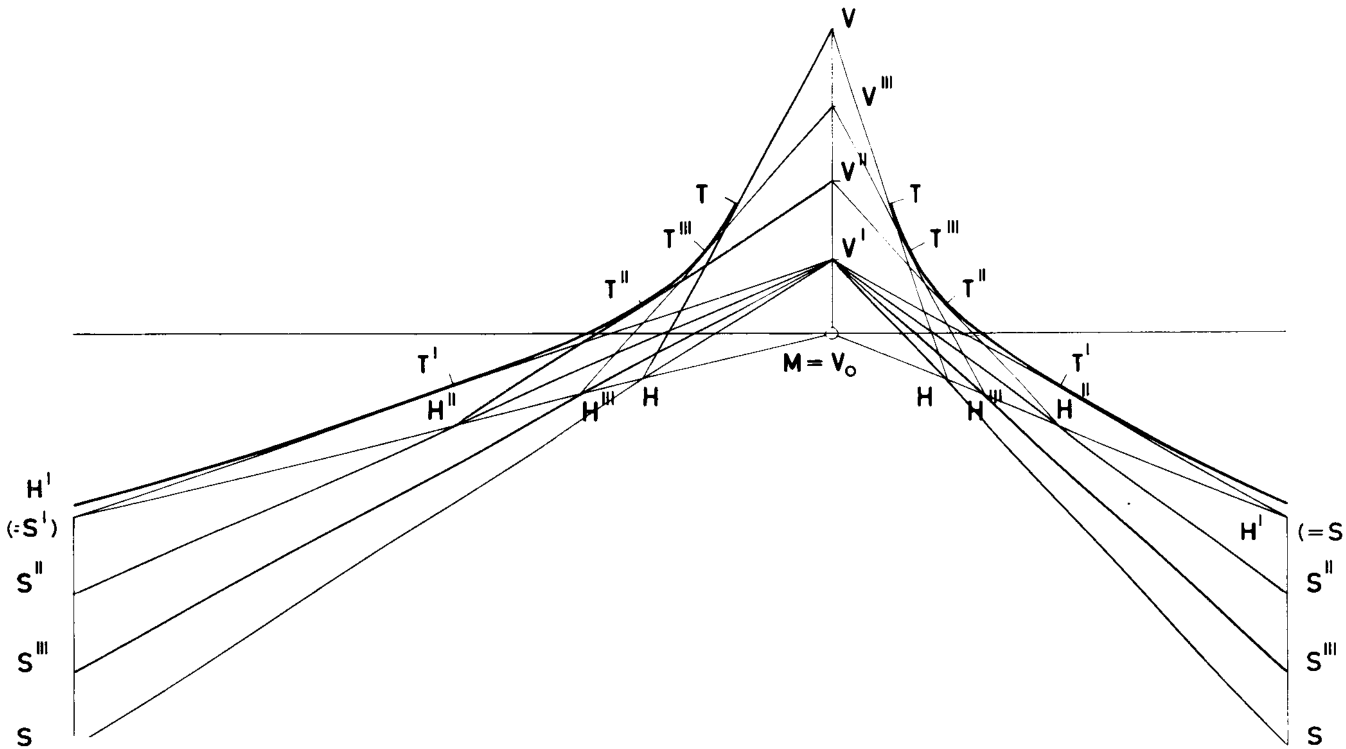


Figure 8.4 Construction of a vertical curve with the tangents method.

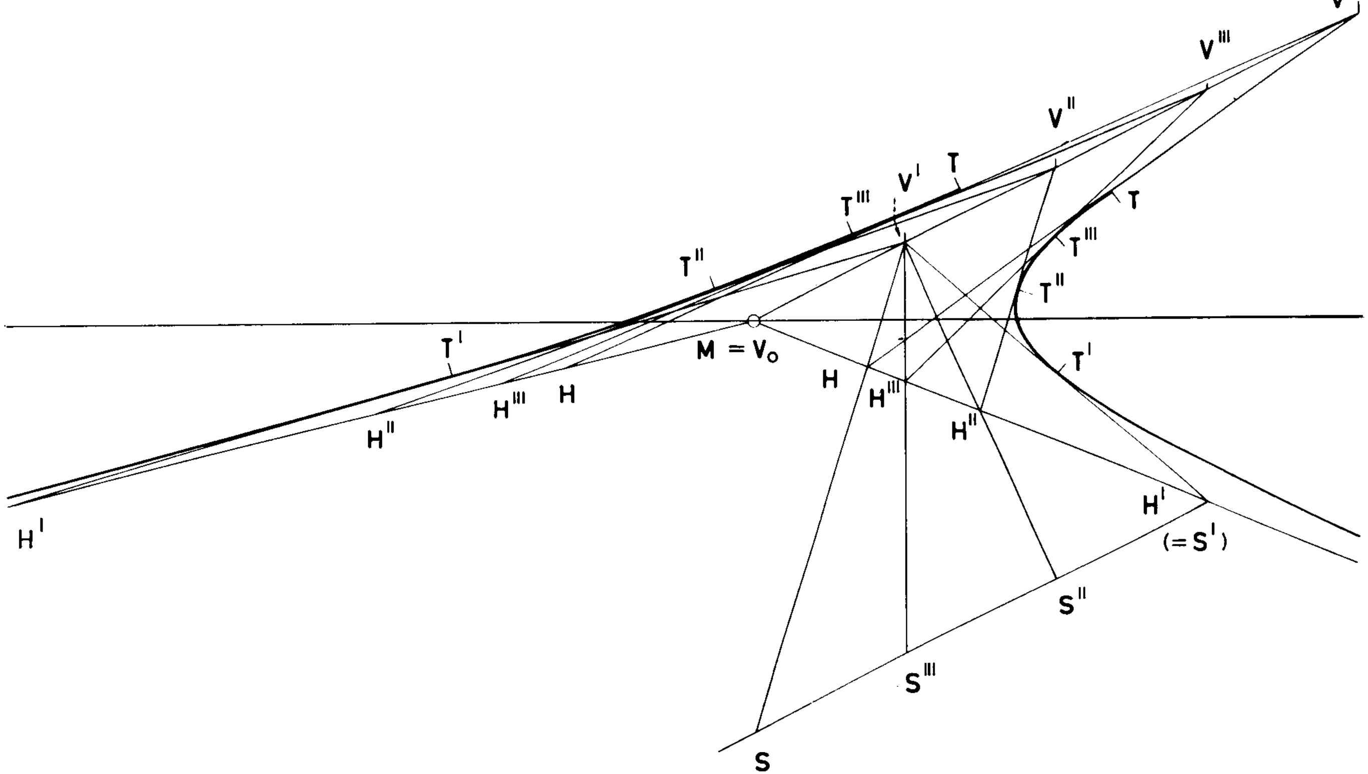


Figure 8.5 Construction of a composite curve with the tangents method.

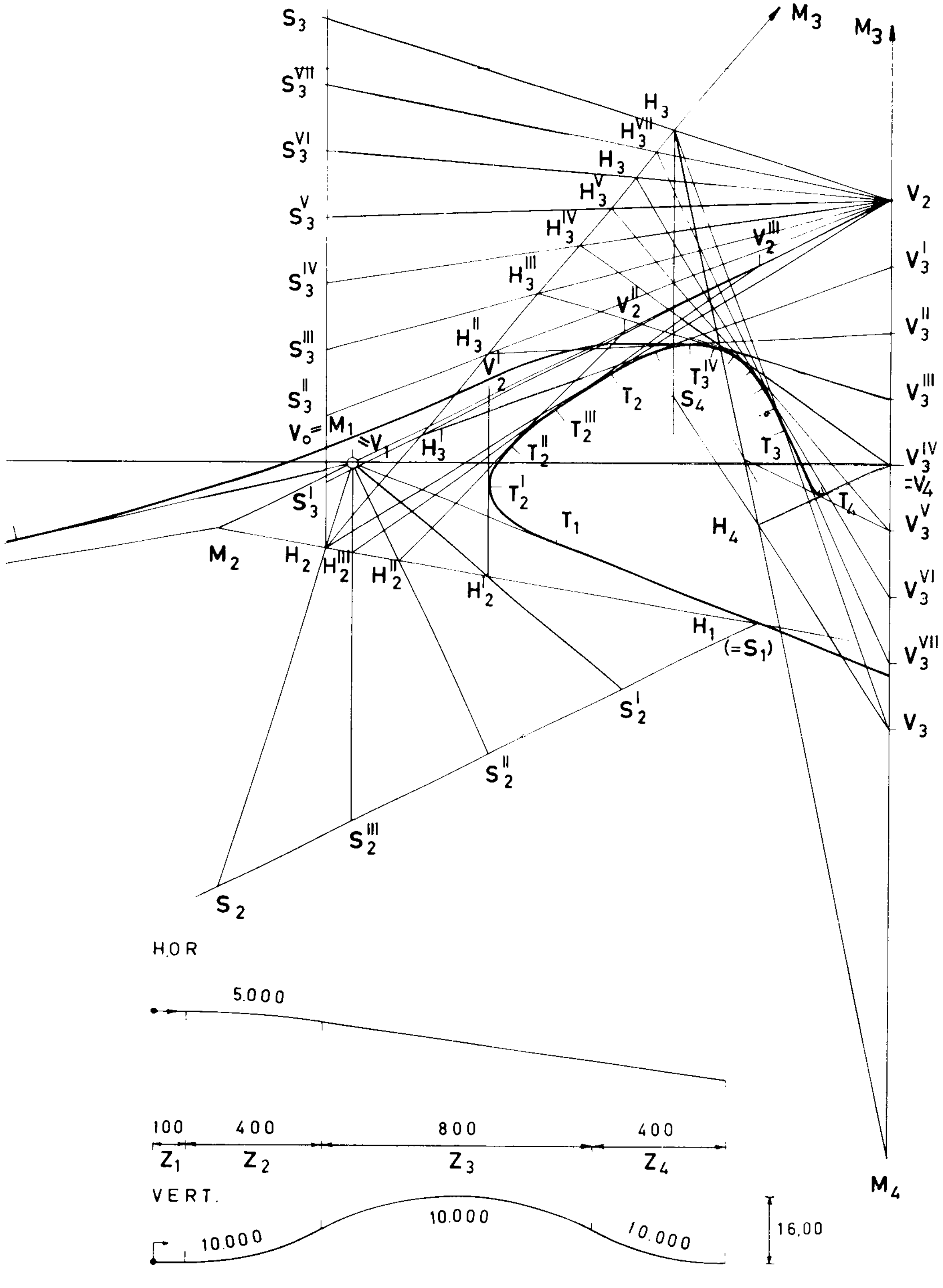


Figure 8.6 Example for the study of the tangents method.

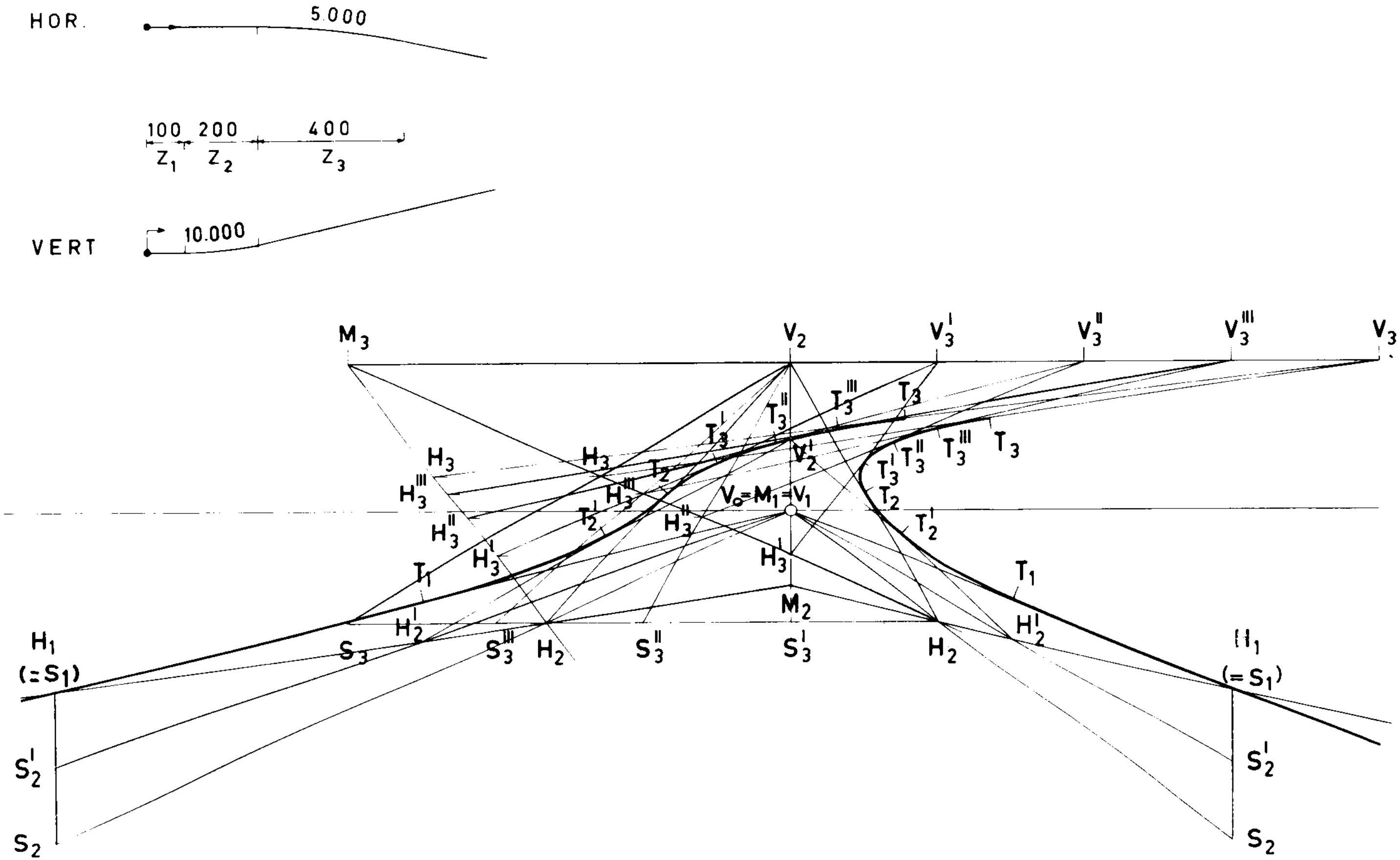


Figure 8.7 Example for the study of the tangents method.

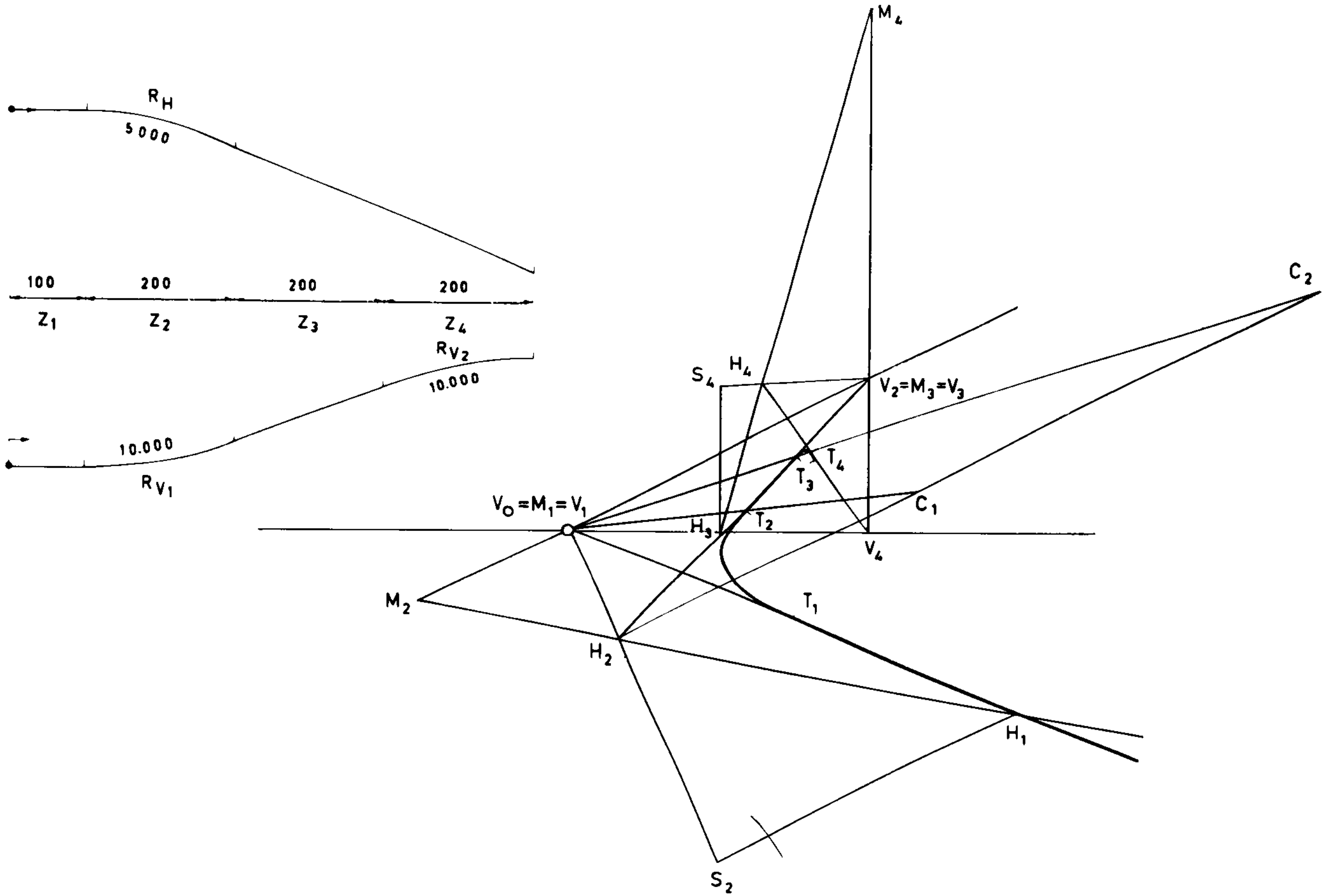


Figure 8.8 Example for the study of the tangents method, with a three-dimensionally straight section.

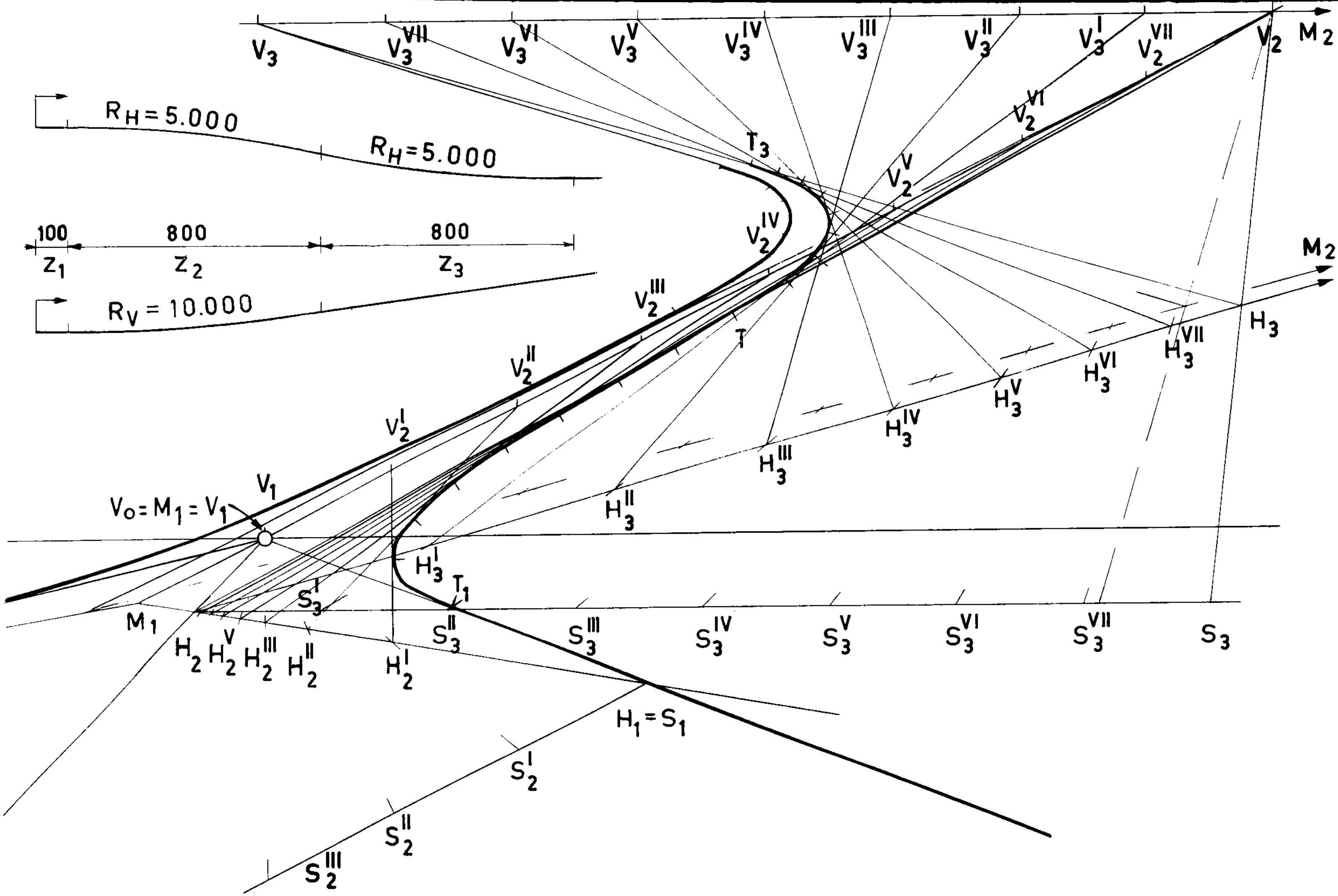
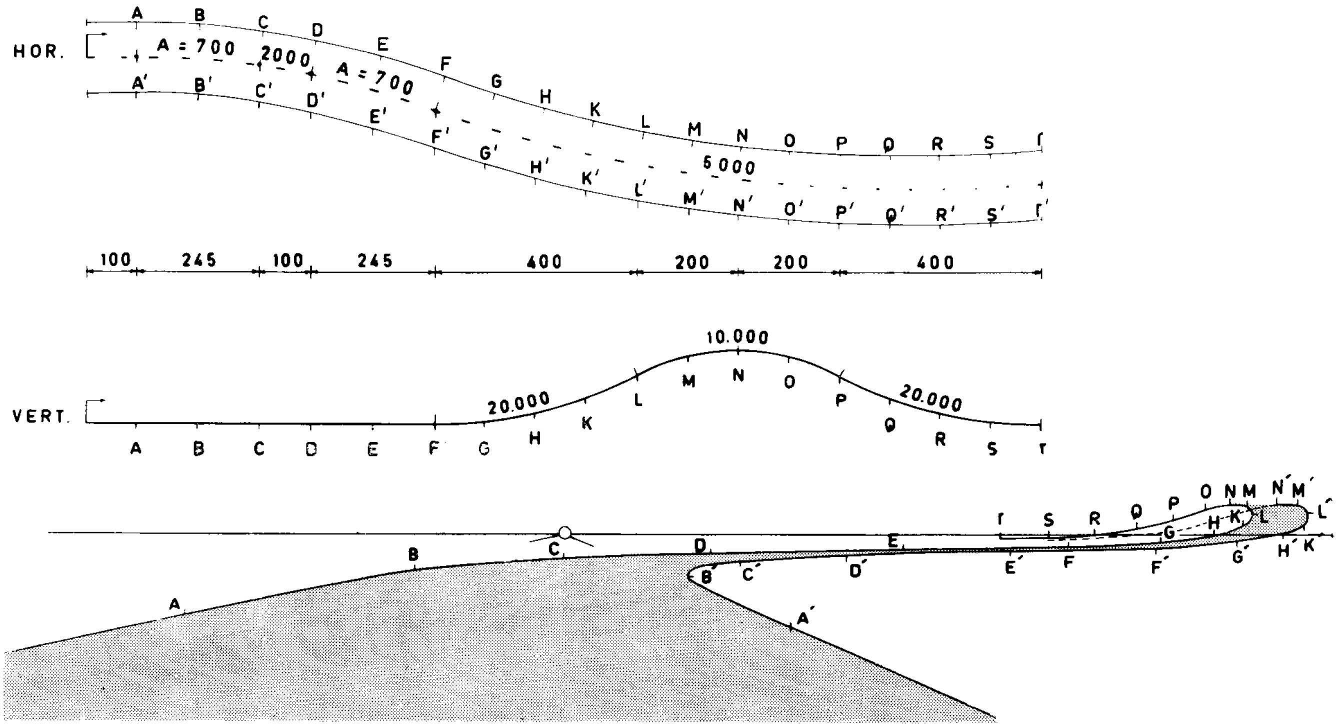


Figure 8.9 Example of a road in a hilly region, constructed with the tangents method.


HOR.
A = 700
2000
A = 700
5000
100
245
100
245
400
200
200
400
VERT.
10.000
20.000
20.000

Point	Z in m	X_L in m.	X_R in m.	x_L in cm.	x_R in cm.	Y_L in m.	Y_R in m.	y_L in cm.	y_R in cm.
	0	—5,000	3,000			—1,10	—1,26		
A	100	—5,000	3,000	—5,000	3,000	—1,10	—1,26	—1,100	—1,260
B	222,5	—4,375	3,625	—1,966	1,629	—1,10	—1,26	—0,494	—0,566
C	345	0,000	8,000	0,000	2,319	—1,10	—1,26	—0,319	—0,365
D	445	8,627	16,627	1,938	3,736	—1,10	—1,26	—0,247	—0,283
E	567,5	25,363	33,363	4,469	5,879	—1,10	—1,26	—0,194	—0,222
F	690	45,856	53,856	6,646	7,805	—1,10	—1,26	—0,159	—0,185
G	790	62,095	70,095	7,860	8,872	—0,85	—0,69	—0,108	—0,087
H	890	76,334	84,334	8,577	9,476	—0,10	—0,06	—0,011	—0,007
K	990	88,573	96,573	8,947	9,755	1,15	1,31	0,116	0,132
L	1090	98,812	106,812	9,065	9,799	2,90	3,06	0,266	0,281
M	1190	107,05	115,05	9,000	9,688	4,40	4,56	0,369	0,383
N	1290	113,29	121,29	8,782	9,400	4,90	5,06	0,380	0,392
O	1390	117,53	125,53	8,455	9,030	4,40	4,56	0,316	0,328
P	1490	119,77	127,77	8,050	8,575	2,90	3,06	0,195	0,208
Q	1590	120,01	128,01	7,550	8,080	1,15	1,31	0,070	0,082
R	1690	118,25	126,25	7,003	7,470	—0,10	0,06	—0,006	—0,004
S	1790	114,48	122,48	6,476	6,843	—0,85	—0,69	—0,047	—0,038
T	1890	108,72	116,72	5,753	6,176	—1,10	—0,94	—0,058	—0,05

Figure 8.10 A picture calculated with the coordinates method.

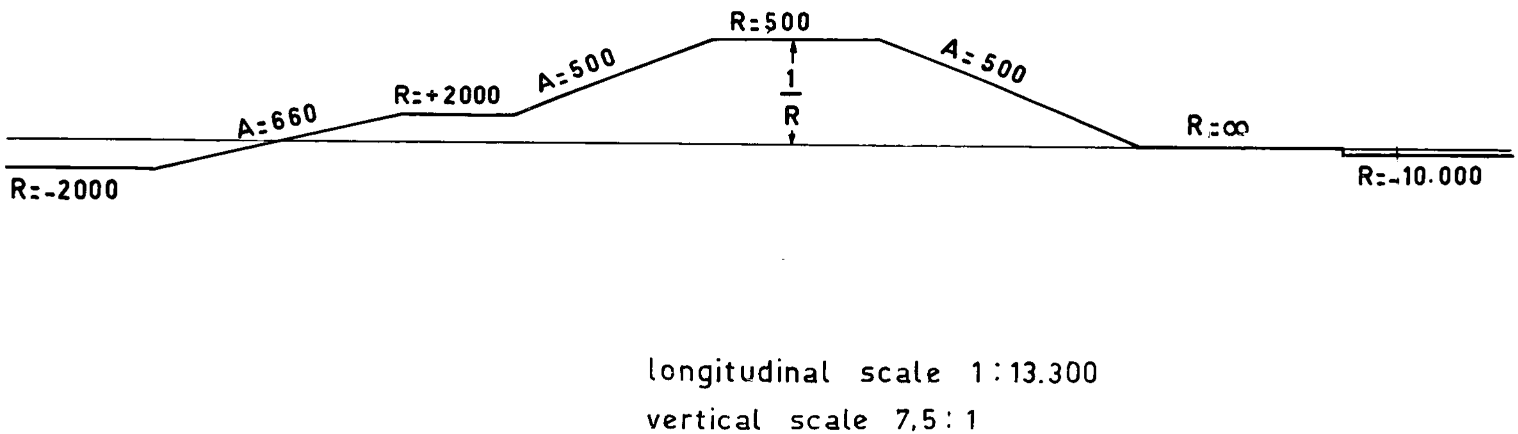


Figure 8.11 Example of a curvature diagram.

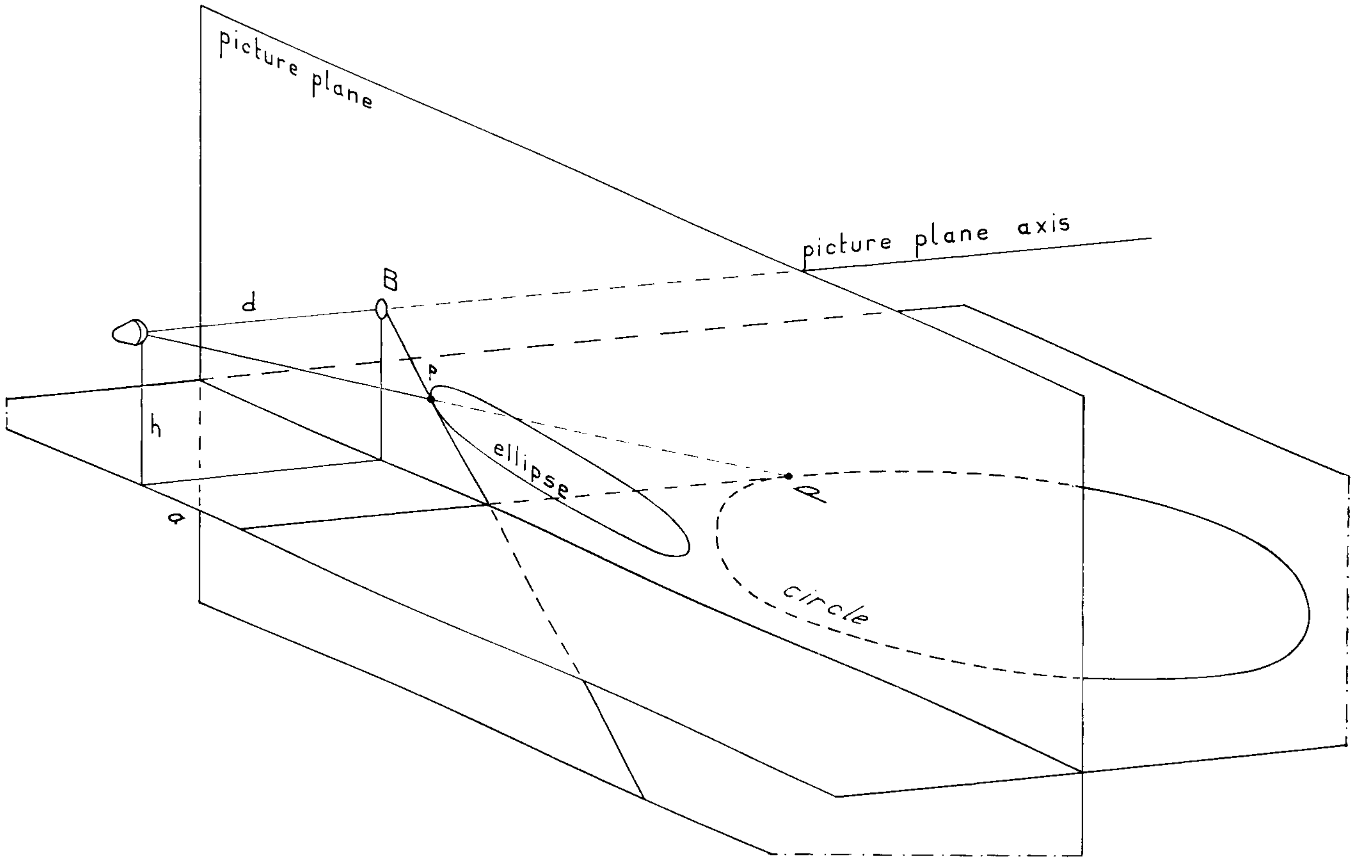


Figure 9.1 The picture of a circle lying in front of the vanishing plane is an ellipse.

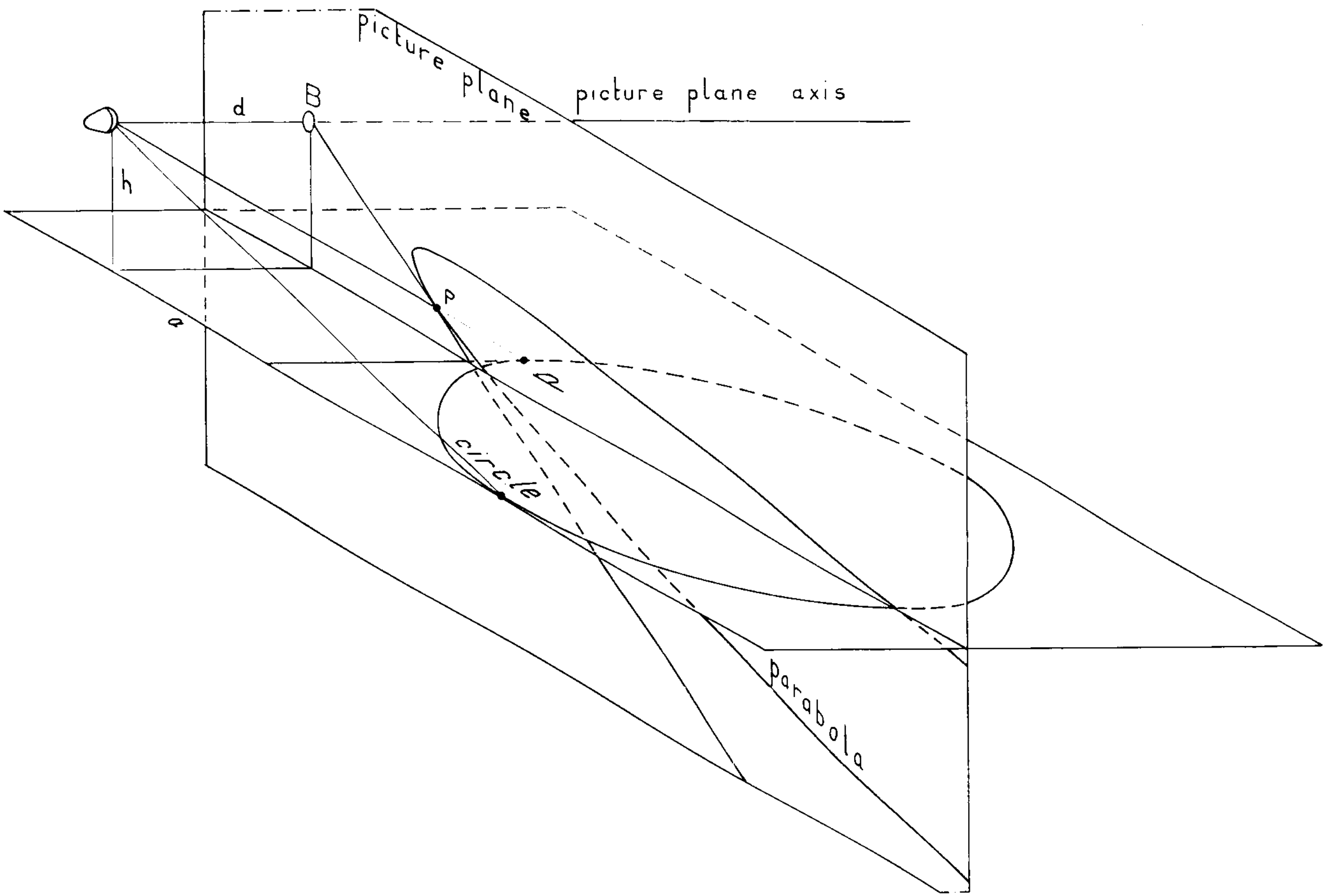


Figure 9.2 The picture of a circle contacting the vanishing plane is a parabola.

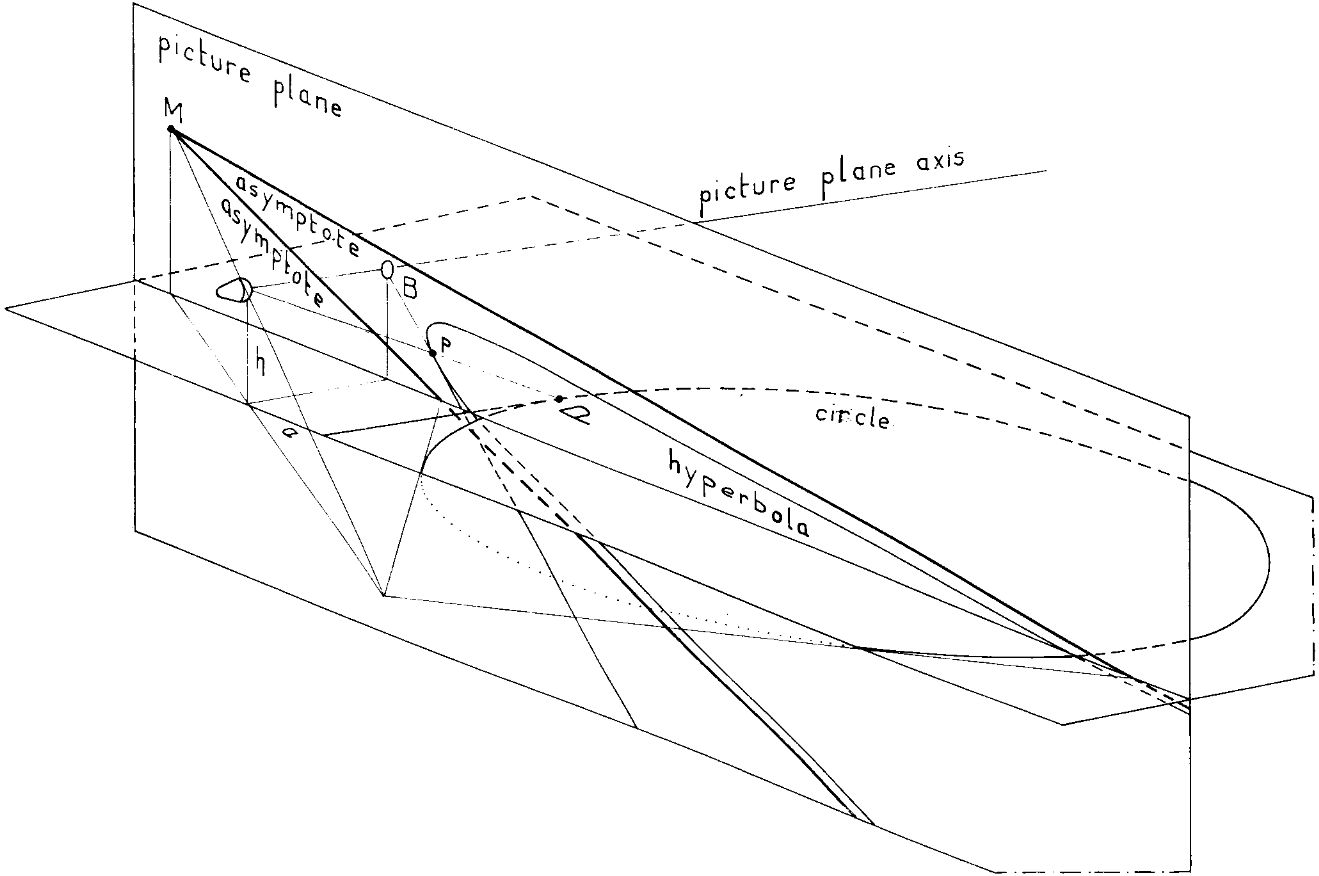


Figure 9.3 The picture of a circle intersecting the vanishing plane is a hyperbola.

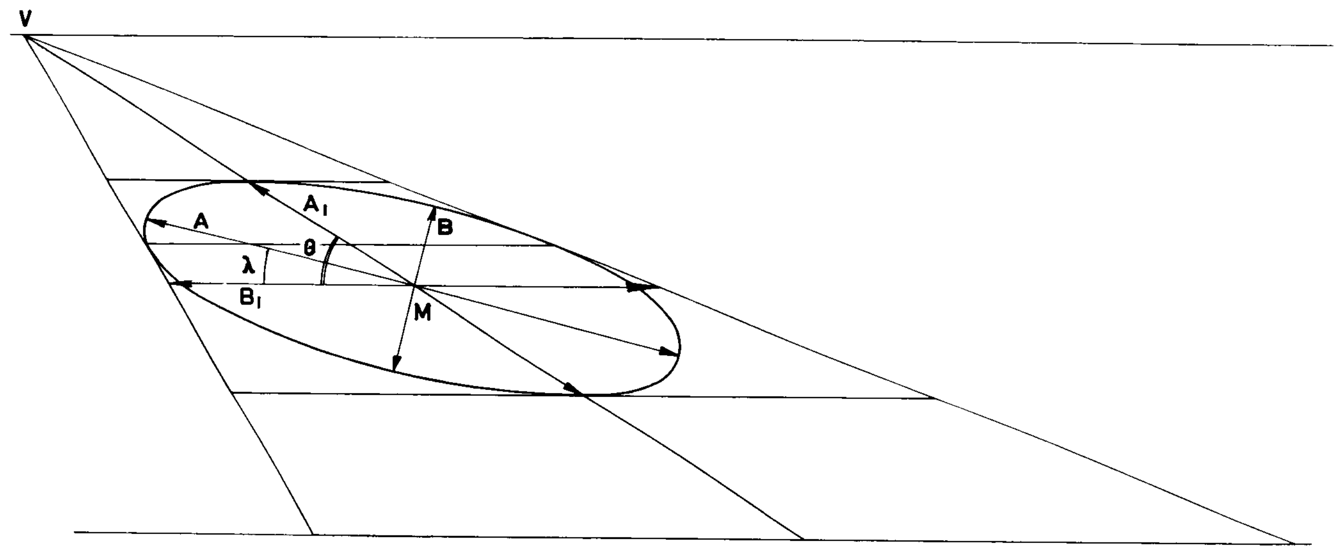


Figure 9.4 The circle represented by an ellipse.

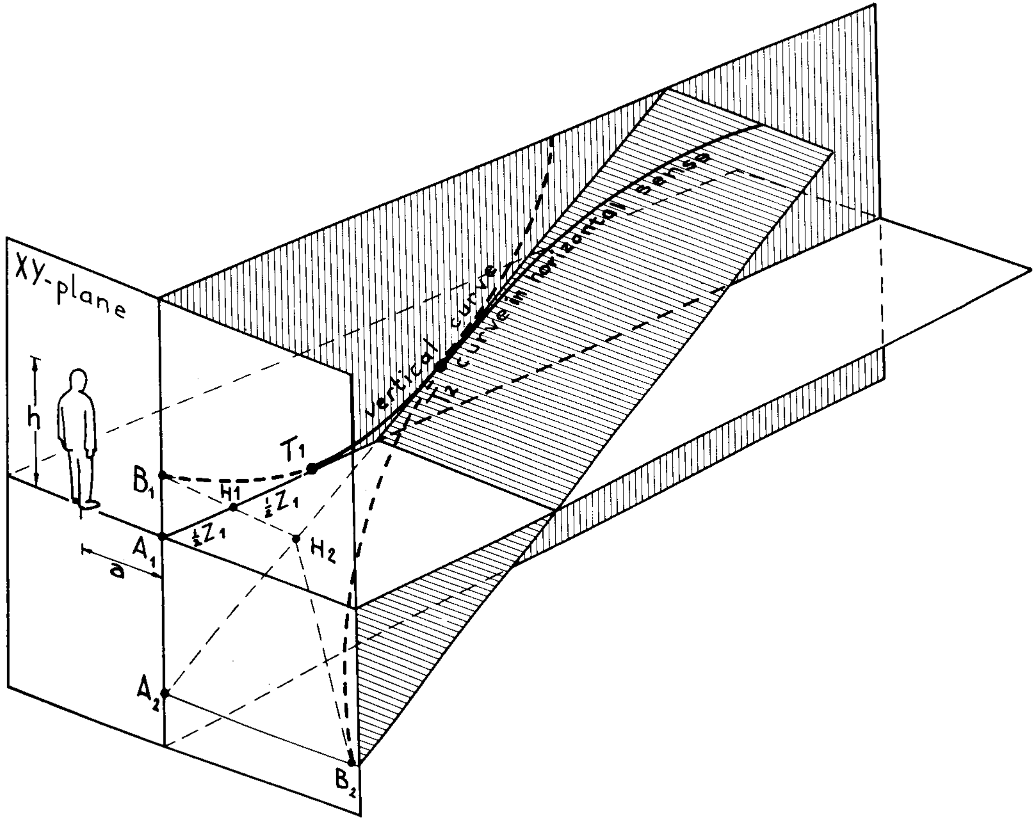


Figure 9.5 Three-dimensional picture explaining the properties of successive elements.

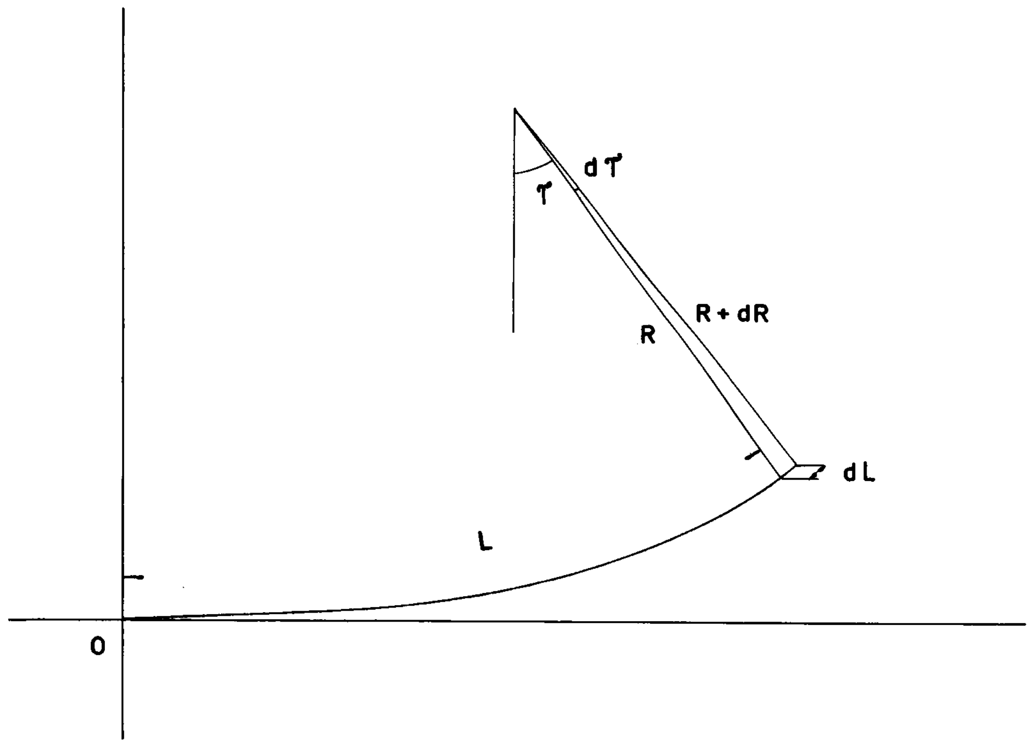


Figure 9.6 The clothoid as transition-curve.

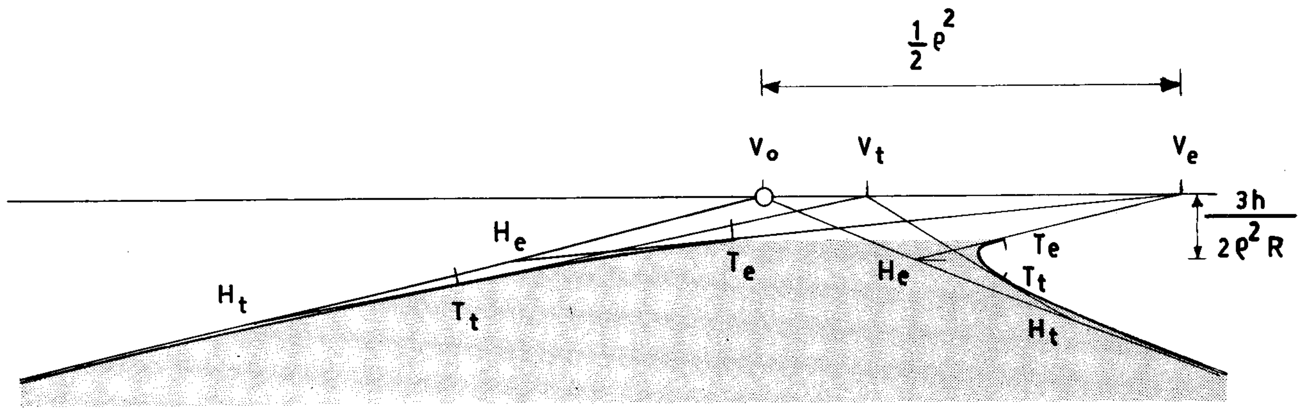


Figure 9.7 A transition-curve with parameter A = ρR, observed from its beginning.

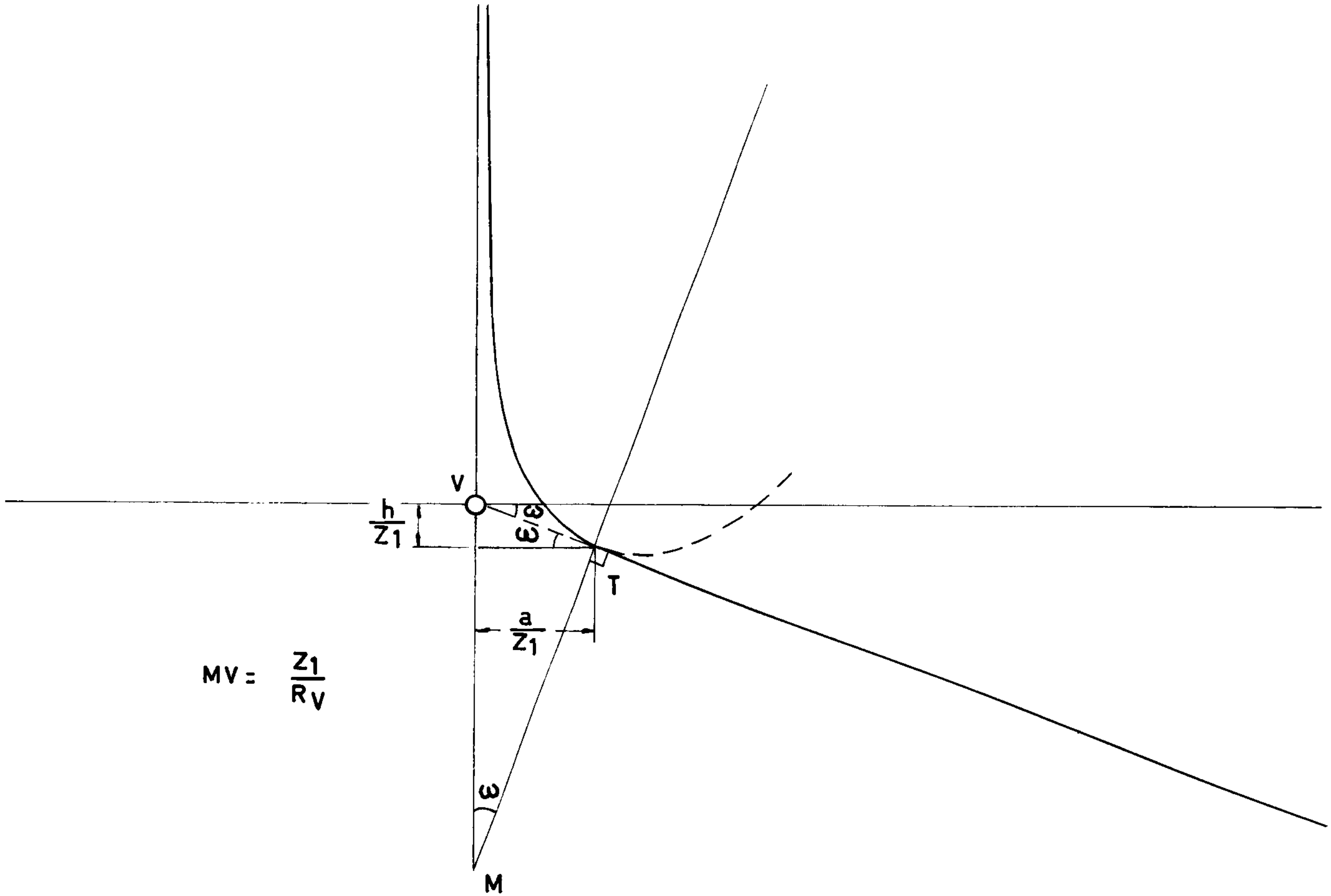


Figure 9.8 A concave curve in the picture beginning at the top of the hyperbola.

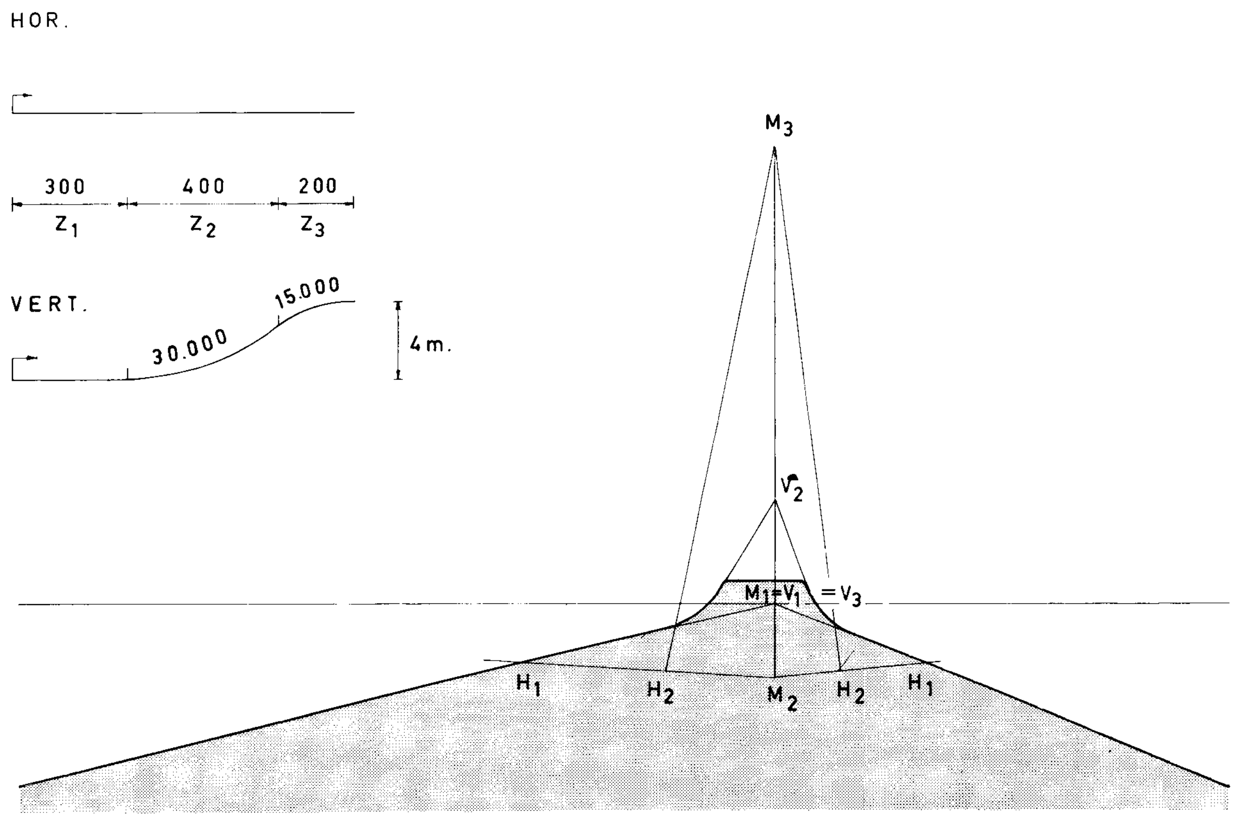


Figure 9.9 Straight section in front of an approach.

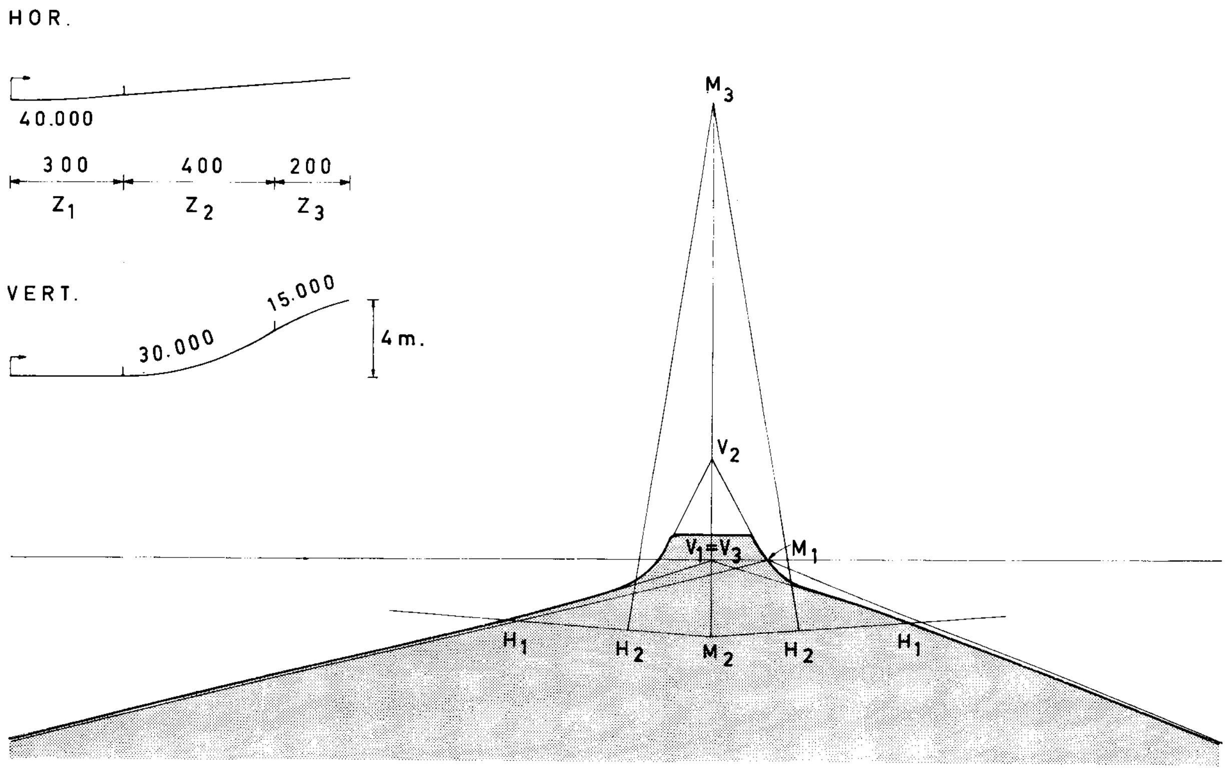


Figure 9.10 Almost straight section in front of an approach.

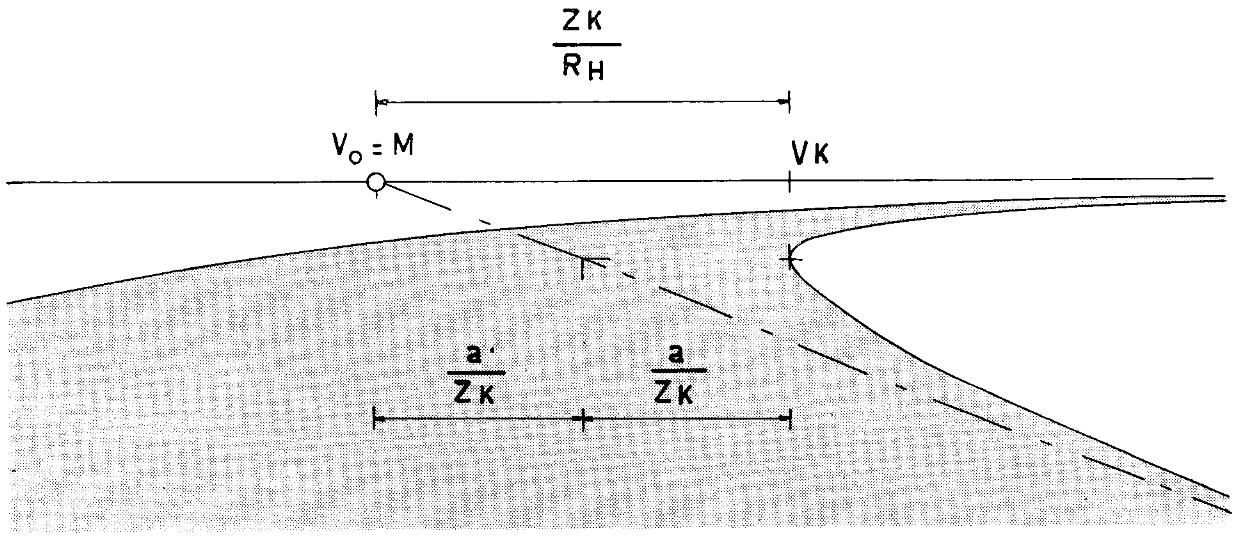


Figure 9.11 The turning point in the inner curve.

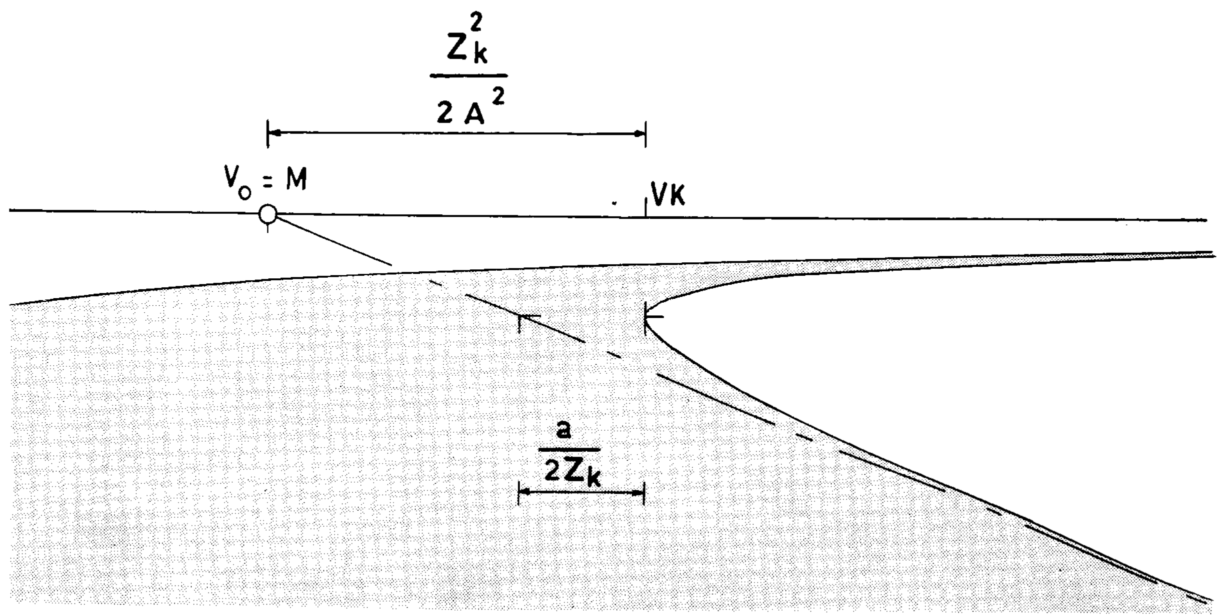


Figure 9.12 The turning point in the transition-curve.

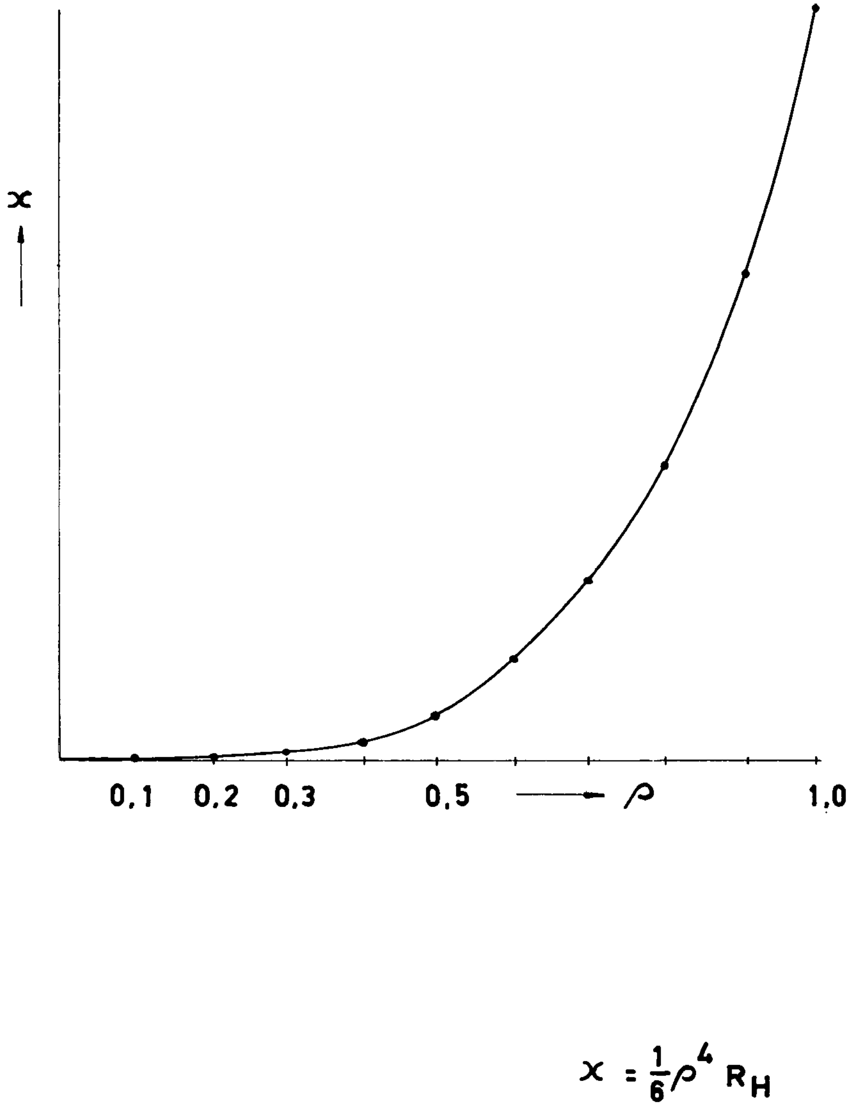


Figure 9.13 The deviation at the end of the transition-curve, in proportion to $\rho \left(\frac{A}{R} \right)$.

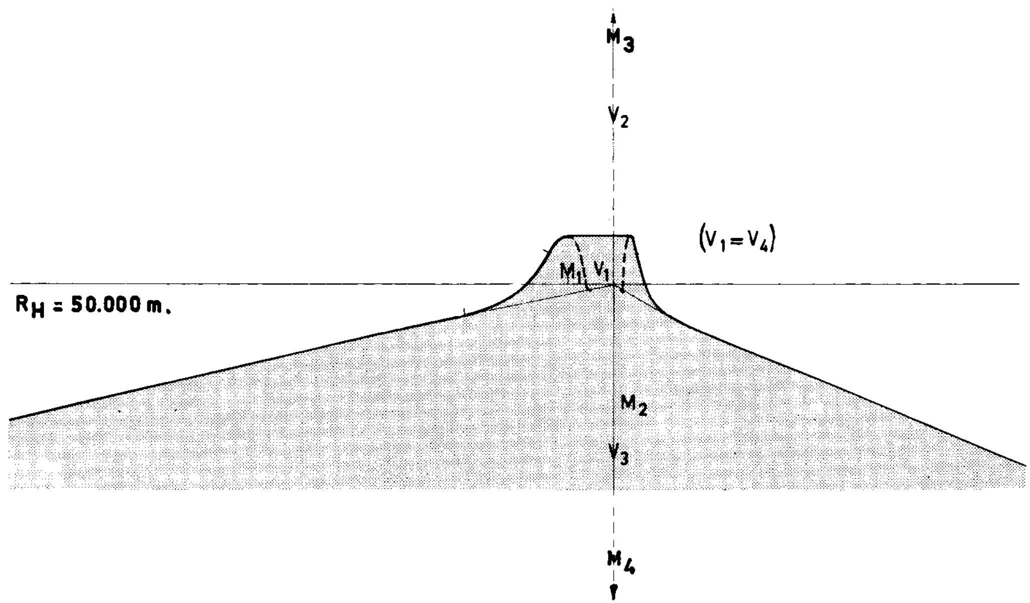


Figure 9.14 The course of the centre of successive curves is situated between the edges of the road.

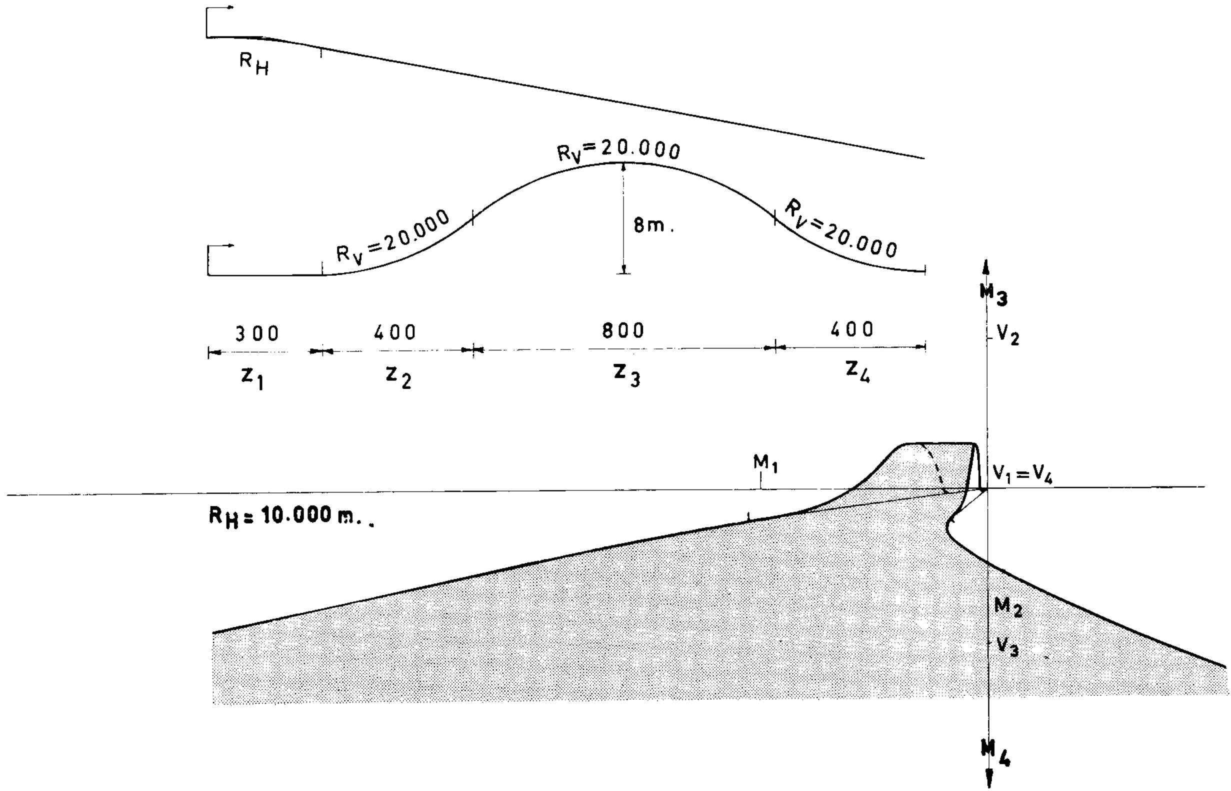
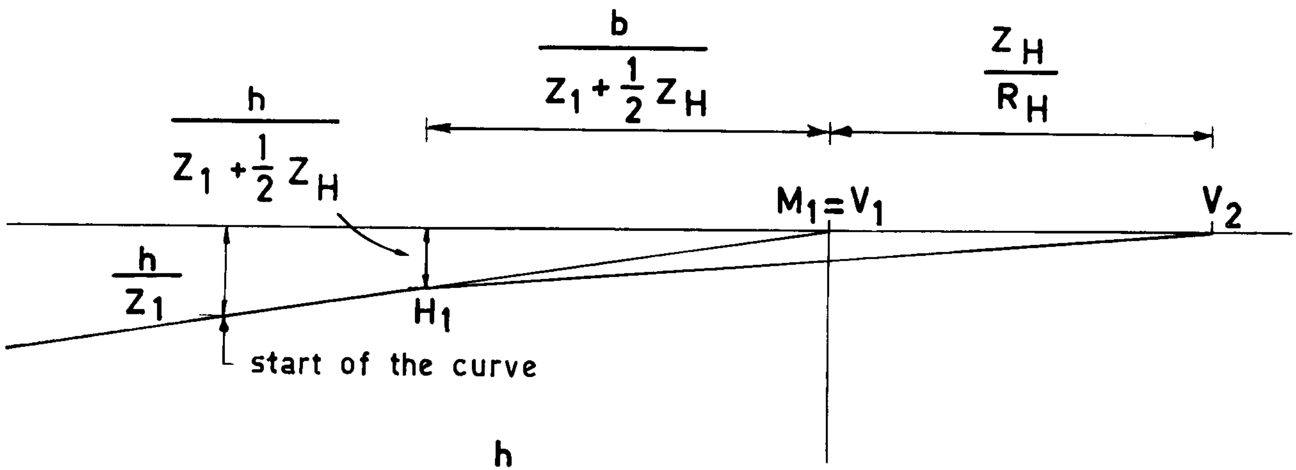


Figure 9.15 The course of the centres of successive curves intersect the road edges.



$$\frac{R_H}{R_V} < \frac{\dfrac{h}{Z_1 + \frac{1}{2} Z_H}}{\dfrac{b}{Z_1 + \frac{1}{2} Z_H} + \dfrac{Z_H}{R_H}}$$

$$R_V > \frac{b\, R_H + Z_H (Z_1 + \frac{1}{2} Z_H)}{h}$$

Figure 9.16 Elevation in a horizontal curve, observed from a distance Z_1 in front of the beginning of this horizontal curve.

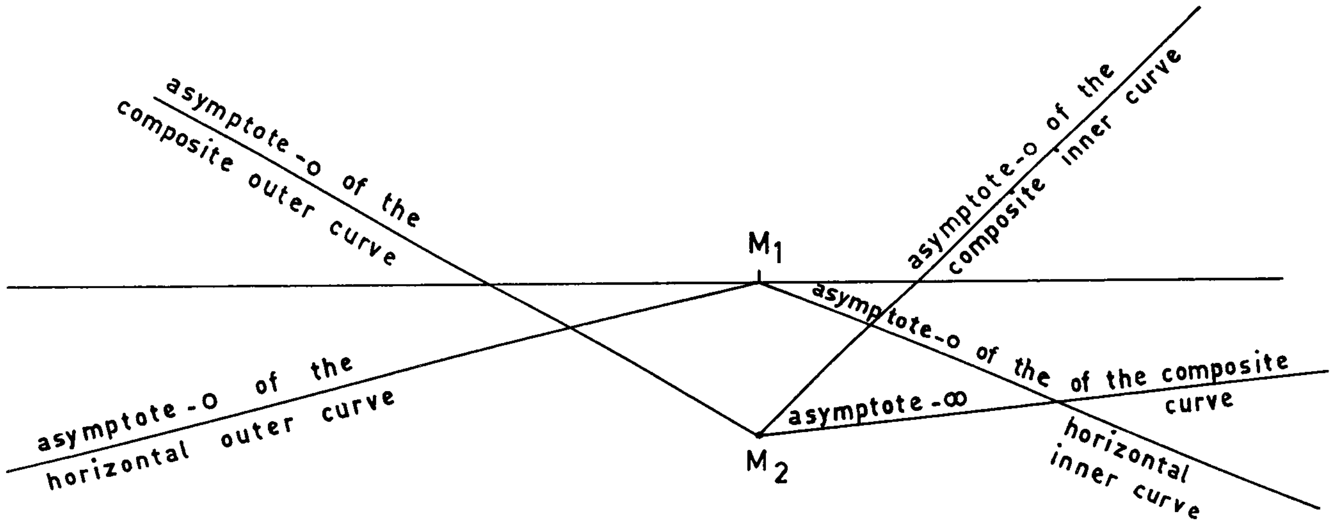


Figure 9.17 Approaching an elevation unto 400 m.

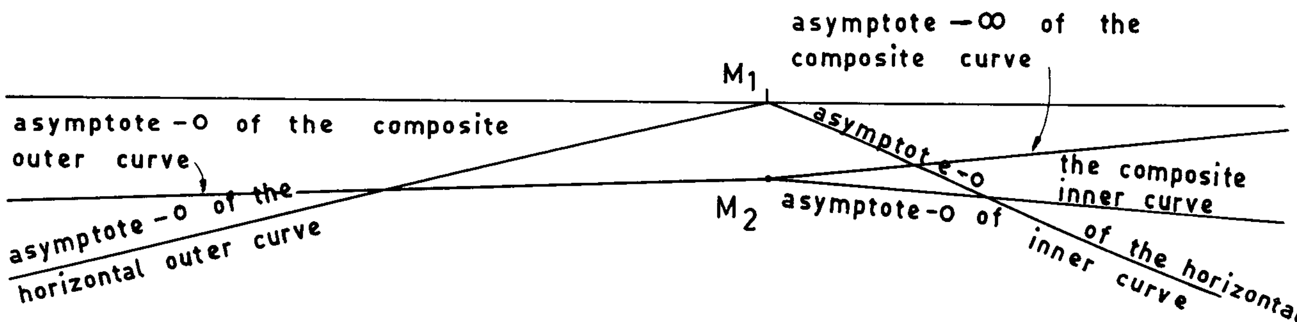


Figure 9.18 Approaching an elevation unto 200 m.

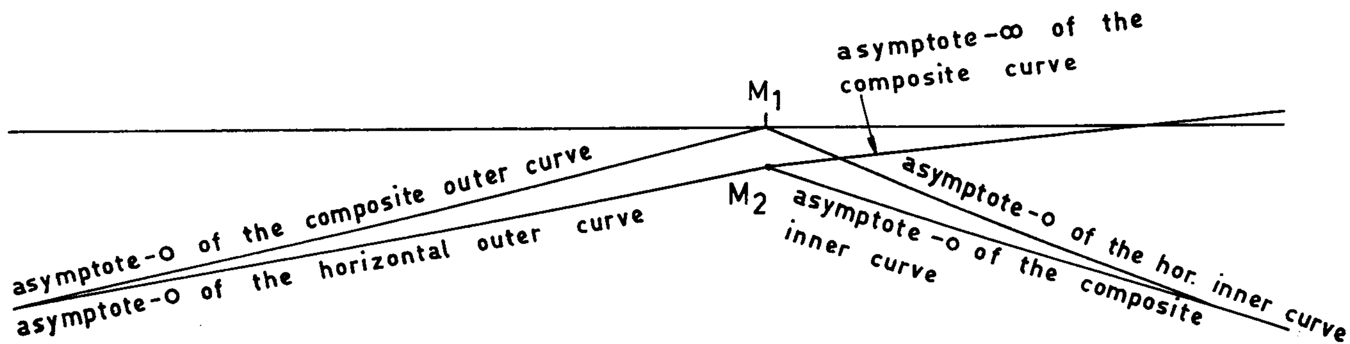
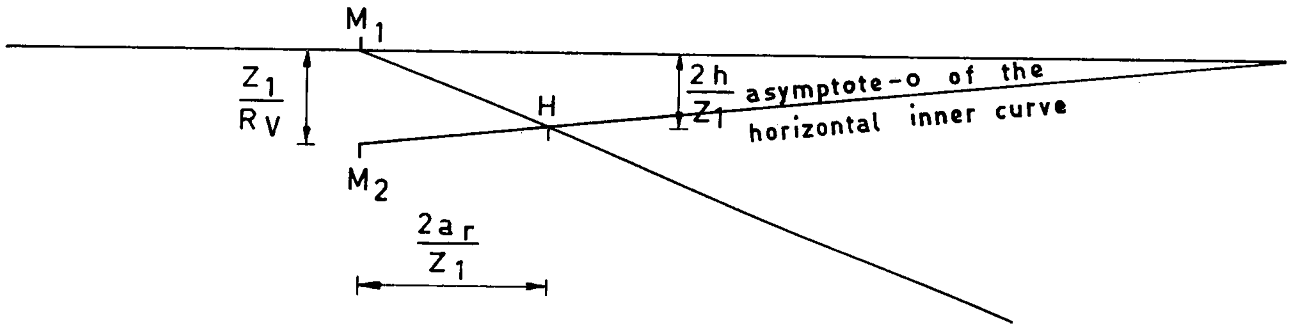


Figure 9.19 Approaching an elevation unto 100 m.

INNER CURVE



$$\frac{\frac{Z_1}{R_V} - \frac{2h}{Z_1}}{\frac{2a_r}{Z_1}} = \frac{R_H}{R_V}$$

$$\frac{Z_1^2}{R_V} - 2h = \frac{2a_r R_H}{R_V}$$

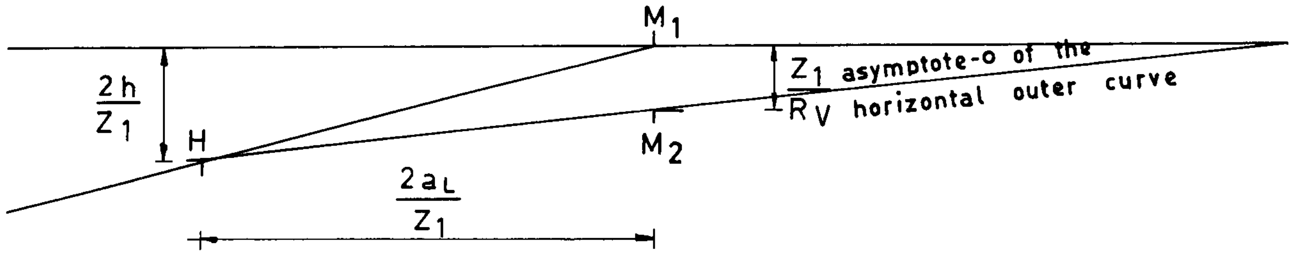
$$Z_1^2 - 2hR_V = 2a_r R_H$$

$$Z_1^2 = 2hR_V + 2a_r R_H$$

$$Z_1 = \sqrt{2hR_V + 2a_r R_H}$$

Figure 9.20 Limit for an S-shape in the inner curve.

OUTER CURVE



$$\frac{\frac{2h}{Z_1} - \frac{Z_1}{R_V}}{\frac{2a_L}{Z_1}} = \frac{R_H}{R_V}$$

$$2hR_V = 2a_LR_H + Z_1^2$$

$$2h - \frac{Z_1^2}{R_V} = \frac{2a_LR_H}{R_V}$$

$$Z_1^2 = 2hR_V - 2a_LR_H$$

$$Z_1 = \sqrt{2hR_V - 2a_LR_H}$$

Figure 9.21 Limit for an S-shape in the outer curve.

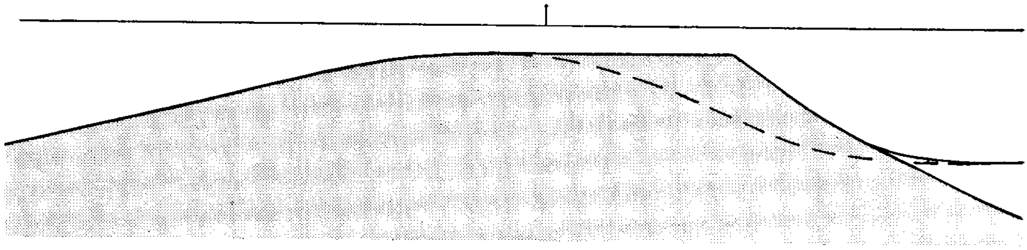


Figure 9.22 When nearing the concave curve, its inner edge at one moment is a seemingly straight line.

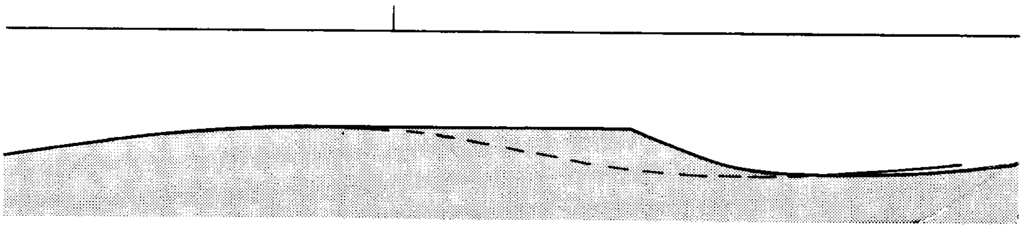


Figure 9.23 When driving in the concave curve, its inner edge for some time is a seemingly straight line.

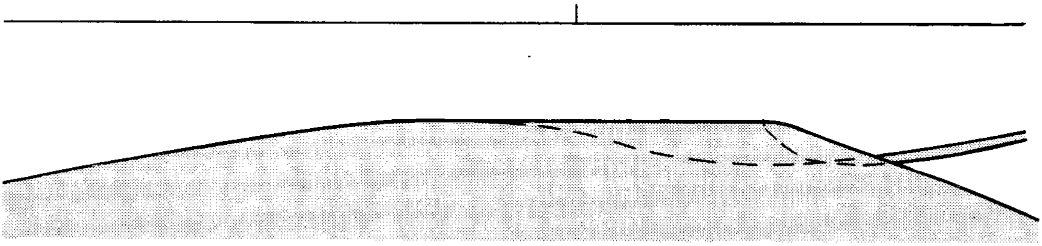


Figure 9.24 The (invisible) loop in the inner edge.

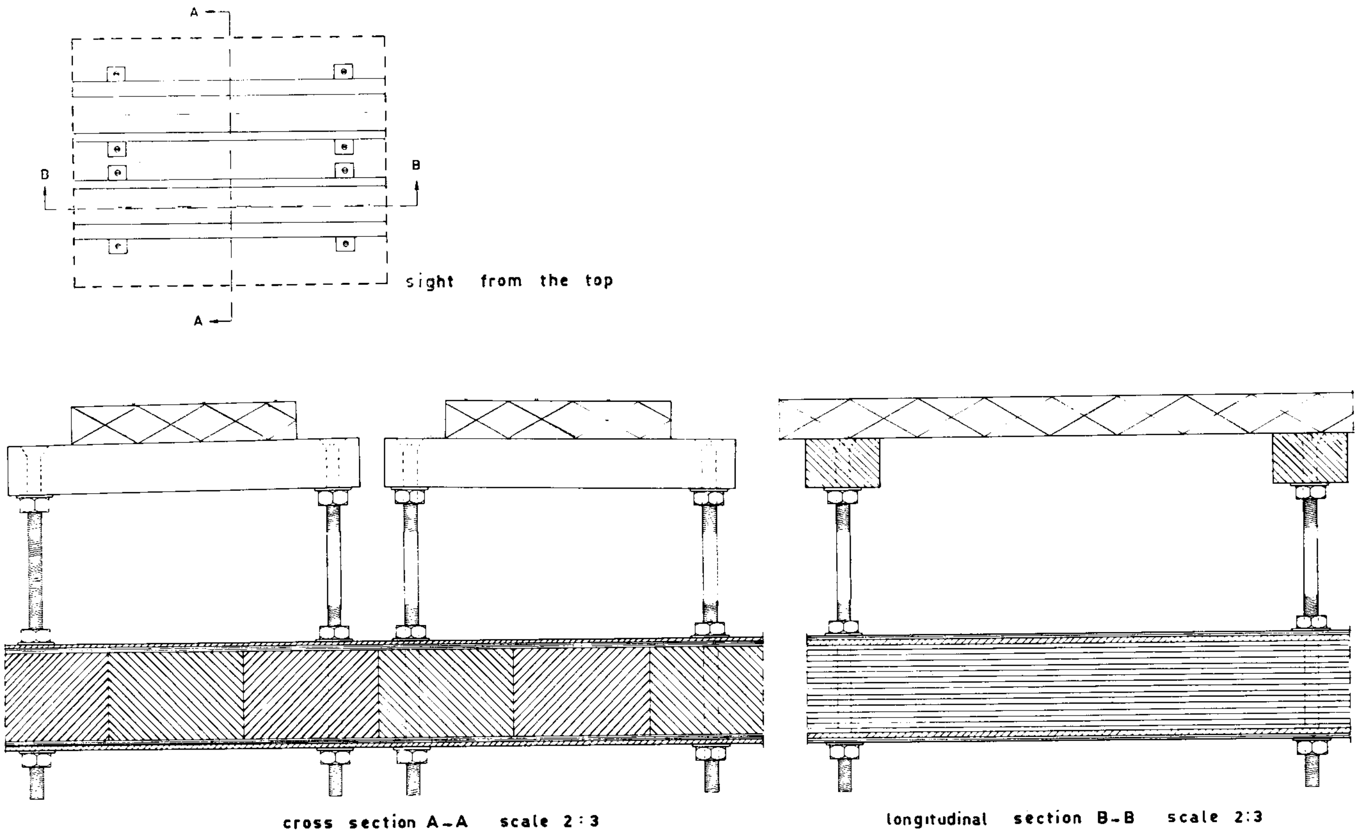


Figure 9.25 Construction of model of carriage-ways.

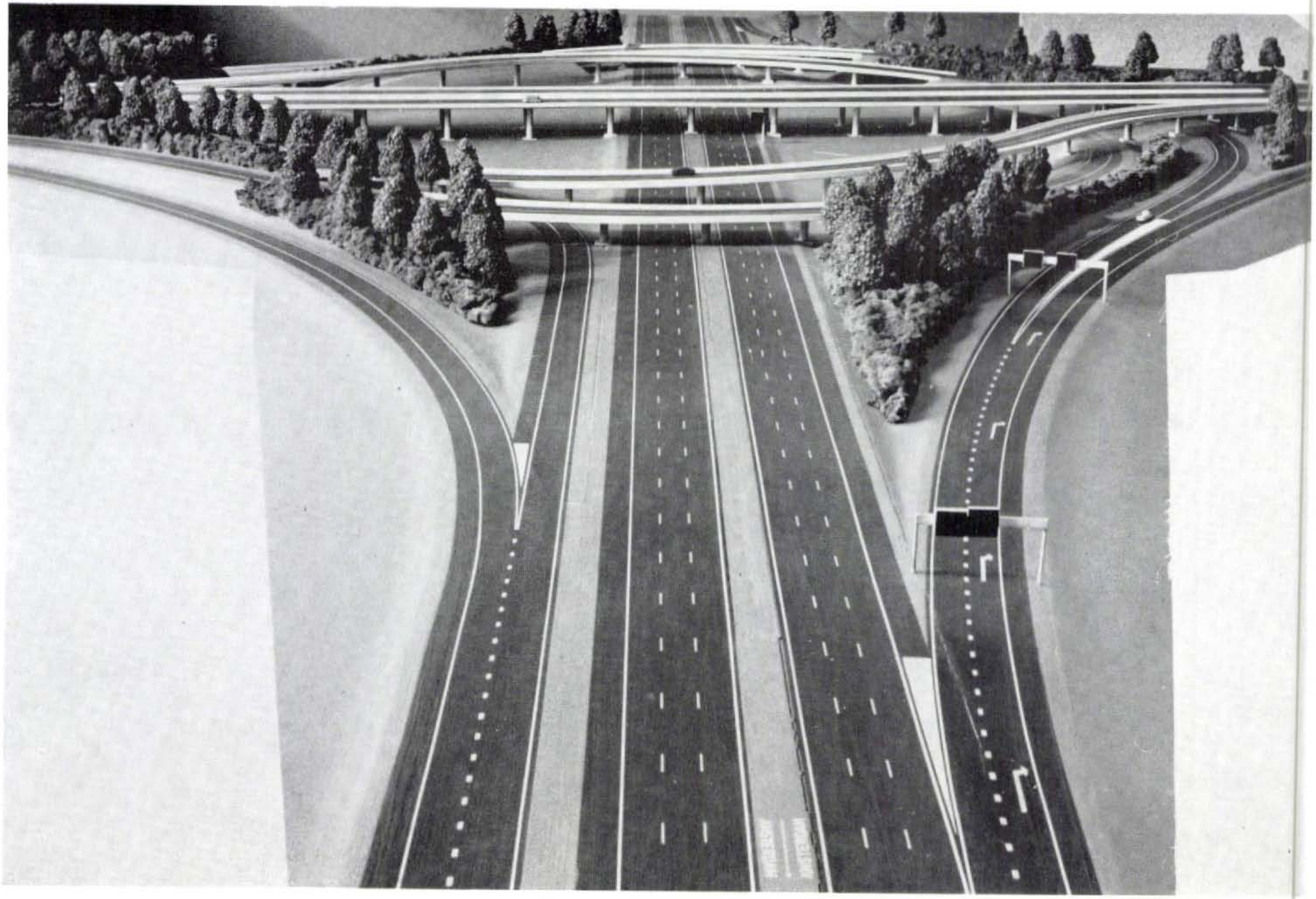


Figure 9.26 Example of a complete model.

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