PERIODICA POLYTECHNICA SER. CIV. ENG. VOL. 46, NO. 1, PP. 3–15 (2002)

ADDITIONS TO AND IMPORTANT REMARKS ON THE NEW HUNGARIAN ROAD DESIGN STANDARD

Gábor SCHUCHMANN

Department of Highway and Railway Engineering
Budapest University of Technology and Economics
H–1521 Budapest, Hungary

Received: Sept. 5, 2001

Abstract

This article gives a short summary of some latest results and the present standing of the standard-renewal procedure. Our department – as a leader in the scientific side of the field – is generally concerned with the design parameters part, so the chapters of this article deal with the design parameters themselves: radius of horizontal and vertical curves, stopping and overtaking sight distances, transition curves.

Keywords: design parameter limit value, transition curve, horizontal curve, vertical curve, stopping sight distance, overtaking (passing) sight distance.

1. Introduction

The increase in urban and rural speed limits (as it is planned by the new Hungarian road regulation) made rethink the calculation method (and the recalculation) of some design parameters necessary. The whole calculation must be cleared of typical mistakes like rounding inaccuracy of values calculated from each other. Clarifying certain theoretical questions and answers, and making calculations more accurate give us new limit values of design parameters in function of design speed. Comparing the new table of design parameter limit values with the present one, or with the present 'new proposal' it is clear that clarifying theoretical questions and correcting inaccuracy will result in difference between the newest and other values. The difference sometimes means that today there are safety and environmental problems and risks, which both could be cleared up. The newest version has empty columns, too: the highest design speed is 120 km/h, but the new speed limit will be 130 km/h on motorways. This column must be filled.

2. Horizontal Curves

The behaviour of a vehicle in superelevated horizontal curves depends on the curve radius. To get a relation first we have to see the equations (inequalities) in *Fig.1*.

The vehicle must stay on it's original course:

$$G \cdot \sin\alpha + f_S(v) \cdot (G \cdot \cos\alpha + F_r \cdot \sin\alpha) \geq F_r \cdot \cos\alpha.$$

After transforming this equation and taking $\tan\alpha$ as q, and use the equation for $f_L(v)$ measured in Germany [6] (signed [**] below) it is possible to get an explicit algebraic expression including $R_{\min}$:

$$\min R = \frac{v_d^2}{3.6^2 \cdot g \cdot (\max\ f_S \cdot n + q)},$$

where
v_d – design speed (km/h);
f_S – sideways friction factor [*];
f_L – longways friction factor [**];
n – efficient degree of sidewise friction factor;
q – degree of superelevation (%).

[*] $\max\ f_S = 0.925 \cdot \max\ f_L$
[**] $\max\ f_L = 0.241 \cdot \left(\frac{v_d}{100}\right) - 0.721 \cdot \left(\frac{v_d}{100}\right) + 0.708$

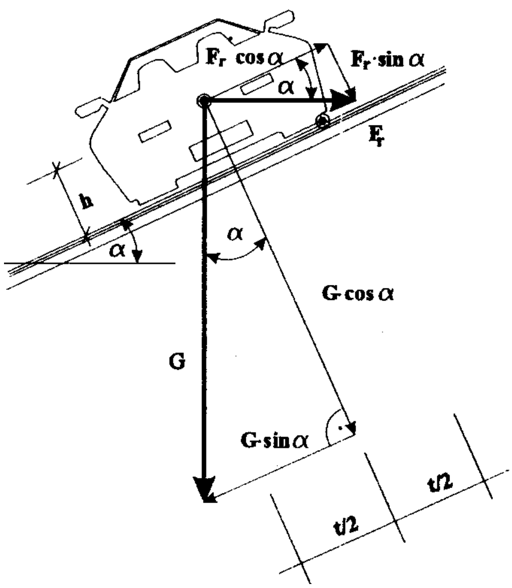

Fig. 1. A vehicle in a superelevated horizontal curve

Table 1 contains calculated values of f_S and f_L at different design speed values.

Table 2 contains the suggested values of R_{min} and other two values taking into account different pairs of q and n. The contents of *Table 3* are the present values of R_{min}. Comparing them with the new results rounding seems to be the only difference between the new and the present version.

Table 1. Calculated values of f_S and f_L

v_d (km/h)	f_S	f_L
30	0.4749	0.5134
40	0.4238	0.4582
50	0.3772	0.4078
60	0.3350	0.3622
70	0.2973	0.3214
80	0.2640	0.2854
90	0.2375	0.2567
100	0.2109	0.2280
110	0.1910	0.2065
120	0.1756	0.1898
130	0.1646	0.1780
140	0.1581	0.1710
150	0.1561	0.1688

Table 2. Suggested values of R_{min}

v_d	($q = 0.07$; $n = 0.5$)		($q = 0.025$; $n = 0.1$)		($q = -0.025$; $n = 0.3$)	
(km/h)	R_{min} (m)	$n \cdot \max f_S$	R_{min} (m)	$n \cdot \max f_S$	R_{min} (m)	$n \cdot \max f_S$
30	25	0.24	100	0.05	65	0.13
40	45	0.21	190	0.04	125	0.12
50	75	0.19	315	0.04	225	0.11
60	120	0.17	485	0.03	375	0.10
70	175	0.15	705	0.03	600	0.09
80	250	0.13	980	0.03	930	0.08
90	340	0.12	1315	0.02	1420	0.07
100	450	0.11	1710	0.02	2100	0.06
110	575	0.10	2130	0.02	3000	0.06
120	720	0.09	2660	0.02	4100	0.05
130	880	0.09	3200	0.02	5450	0.05
140	1040	0.08	3780	0.02	6870	0.05
150	1200	0.08	4360	0.02	8100	0.05

Table 3. The present values of $R_{\min}$

v_d (km/h)	$R_{\min}$ (m)	q (%)	$n \cdot \max f_S$
50	100	6	0.14
60	150	5	0.14
70	200	5	0.14
80	300	5	0.12
90	–	–	–
100	500	5	0.11
110	–	–	–
120	750	4.5	0.10

3. Transition Curves

There were no theoretical problems with transition curves (linear radius-transition), but in special cases, for example very low speed values or under urban conditions there are no acceptable reasons to use transition curves. The basic equations to calculate minimum transition curve are seen below:

$$p_{\min} = \frac{R}{3}, \qquad L = \frac{p^2}{R}, \qquad \Delta R = \frac{L^2}{24 \cdot R},$$

where

$p_{\min}$ – minimum parameter of the transition curve;
R – radius of the connecting curve;
L – length of the transition curve;
ΔR – shift of the curve.

Table 4. Transition curve parameters

V_d (km/h)	30	40	50	60	70	80	90	100	110	120	130	140	150
$R_{\min}$ (m)	25	45	80	120	180	250	340	450	575	720	880	1040	1200
$p_{\min}$ (m)	15*	25*	30	40	60	80	110	150	200	240	290	345	400
$L_{\min}$ (m)	9.00	13.9	11.3	13.3	20.0	25.6	34.5	50.0	69.0	80.0	100.0	115.0	133.0
ΔR (m)*	0.13	0.18	0.07	0.06	0.09	0.11	0.14	0.23	0.34	0.37	0.45	0.53	0.61

* Superelevation-runoff must be in the transition curve. This is why these lengths are longer than as it would have come from the calculation above.

Table 4 shows the results.

4. Stopping Sight Distance

By definition we have to find the shortest distance from which an object (which is h meters high) lying on the road surface can be perceptible for the driver (whose eye level height is d), in order to be able to stop the vehicle before reaching the object (*Fig. 2*). To calculate the minimum stopping sight distance we must add two distances that are: the distance ran during reaction time, and the distance ran during braking. The equation is:

$$S_s = \frac{v_d}{3.6} \cdot t_R + \frac{1}{3.6^2 \cdot g} \int_0^{v_d} \frac{v}{f_L(v) + \frac{e}{100} + \frac{W_L}{G}} \, \mathrm{d}v,$$

where

S_s – stopping sight distance (m);
v_d – design speed (km/h);
t_R – reaction time (2 s);
f_L – longway friction factor [*];
W_L – longway windage of the vehicle (N) [**];
G – weight of the vehicle (N) [**];
e – signed longway gradient of the road axis (%).

[*] $f_L = 0.241 \cdot \left(\frac{v}{100}\right)^2 - 0.721 \cdot \left(\frac{v}{100}\right) + 0.708$
[**] $\frac{W_L}{G} = 0.327 \cdot 10^{-4} \cdot \left(\frac{v}{3.6}\right)^2$

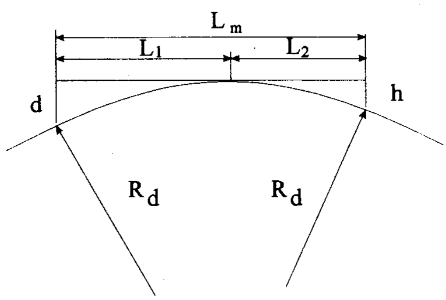

Fig. 2. Definition of stopping sight distance

Fig. 3 shows the results of the calculations, *Table 5* contains the present values of stopping sight distance. Note that reality does not always match with these new results, especially at higher speed values (90–130 km/h) [5]. These differences may give us a reason to believe that the vehicle fleet of Hungary developed faster than standardisation.

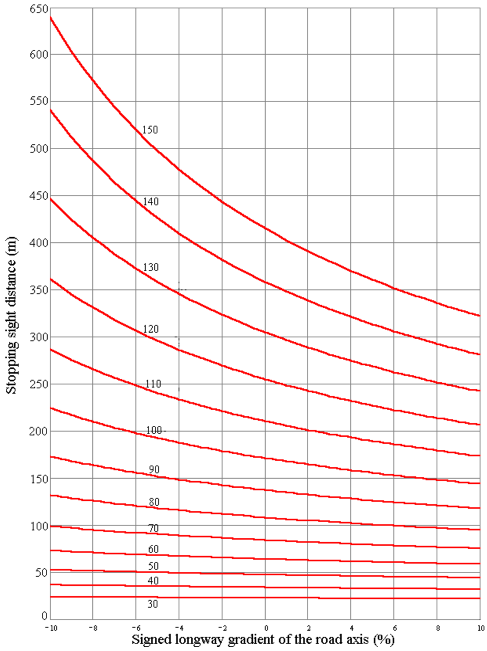

Fig. 3. Calculated values of stopping sight distance

Table 5. Present values of stopping sight distance

V_d (km/h)	S_s (m)
50	50
60	70
70	90
80	120
90	–
100	190
110	–
120	270

5. Overtaking Sight Distance

A common overtaking happens at constant overtaking speed, under the conditions below:

Speed of the vehicle being overtaken:	0.85 v_d
Length of the vehicle being overtaken:	18 m
Speed of the overtaking vehicle:	1.1 v_d
Length of the overtaking vehicle:	5 m

By definition, the overtaking vehicle must be after the overtaking at least a stopping sight distance away from the vehicle coming from the opposite direction (*Fig. 4*). So the equation of overtaking will be

$$0.85 \cdot v_d \cdot t + 2 \cdot k + 5 + 18 = 1.1 \cdot v_d \cdot t,$$

where
k – distance before and after overtaking (15 m)
t – overtaking time:

$$t = \frac{2 \cdot k + 23}{0.25 \cdot v_d} = \frac{8 \cdot k + 92}{v_d}.$$

The whole overtaking sight distance (S_O) is the sum of three different distances (as can be seen in *Fig. 4*):

$$S_O = D_1 + D_2 + D_3.$$

The first distance (D_1) will be the overtaking distance:

$$D_1 = 1.1 \cdot v_d \cdot t = 1.1 \cdot v_d \cdot \frac{8 \cdot k + 92}{v_d} = 8.8 \cdot k + 101.2.$$

The second is the distance (D_2) run by the vehicle coming from the opposite direction during the time of overtaking:

$$D_2 = v_d \cdot t = v_d \cdot \frac{8 \cdot k + 92}{v_d} = 8 \cdot k + 92.$$

There must be a third safety distance between the overtaking and the other vehicle coming from the opposite direction after the whole manoeuvre (D_3), which will be the stopping sight distance of the vehicle coming from the opposite direction:

$$D_3 = S_3(v_d).$$

So their sum will be

$$S_O = D_1 + D_2 + D_3 = 16.8 \cdot k + 193.2 + D_3.$$

The results for each design speed are contained in *Table 6*, the present values of overtaking sight distance can be seen in *Table 7*. Note that these calculated values of overtaking sight distance are sometimes 40% bigger than real values [5]. It means that at these speed values (30–60 km/h) smaller values are acceptable (as can be seen in [5], p. 41, Table 5).

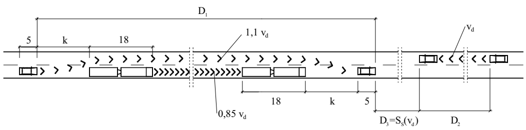

Fig. 4. The overtaking process

Table 6. Calculated values of overtaking sight distance

V_d (km/h)	S_O (m)
30	470
40	480
50	495
60	510
70	530
80	555
90	585
100	615
110	655
120	700*
130	750*
140	805*
150	860*

*These values were calculated and presented just for the special case when traffic uses only one half of a motorway.

Table 7. Present values of overtaking sight distance

V_d (km/h)	S_O (m)
50	300
60	380
70	420
80	480
90	–
100	600
110	660
120	720

6. Convex Vertical Curves

The curve radius needed to ensure stopping (R_{XS}) before an object on the road surface:

$$R_{XS} = \frac{S_S^2}{2(\sqrt{d} + \sqrt{h(v_d)})^2}.$$

The curve radius needed to ensure overtaking (R_{xo}):

$$R_{XO} = \frac{S_O^2}{8 \cdot h},$$

where

R_X – convex curve radius (m)
S_S – stopping sight distance (m)
S_O – overtaking sight distance (m)
d – driver's eye level (1.00 m)
$h(v_d)$ – object height when stopping, see *Table* 8
h – object height when overtaking, constant (1.00 m)

The calculated convex curve radiuses (needed to ensure stopping (R_{XS}, h depends on v_d) and overtaking (R_{XO}, $h = 1.00$)) can be seen in *Table* 9. Present values are contained in *Table* 10.

Table 8. Object heights for convex curve calculations

v_d (km/h)	h (m)
30	0
40	0
50	0
60	0
70	0
80	0.05
90	0.10
100	0.10
110	0.20
120	0.20
130	0.20
140	0.20
150	0.20

Table 9. Calculated values of convex vertical curves

v_d (km/h)	R_{xs} (m)	R_{xo} (m)
30	300	27500
40	600	29000
50	1150	30500
60	2100	32500
70	3600	35000
80	4000	38500
90	5500	42500
100	8500	47500
110	11500	54000
120	16000	61500*
130	22500	70000*
140	31000	81000*
150	41500	93000*

*These values were calculated and presented just for the special case when traffic uses only one half of a motorway.

Table 10. Present values of convex vertical curves

v_d (km/h)	R_{xs} (m)	R_{xo} (m)
50	–	10000
60	1000	15000
70	2000	20000
80	3500	25000
90	–	–
100	7500	40000
110	–	–
120	15000	50000

7. Concave Vertical Curves

In case of a concave vertical curve in the daytime there are no objects to block the driver's sight. So the only necessary condition to ensure the driver to stop the vehicle before any object lying on the road surface is the perceptibility at night. This condition will be met when the headlights of the vehicle overshine a range of the stopping sight distance (as can be seen in *Fig.* 5).
The relation can be read form *Fig.* 5 is

$$h + S_S \cdot \sin\phi = \frac{S_S^2}{2 \cdot R_C},$$

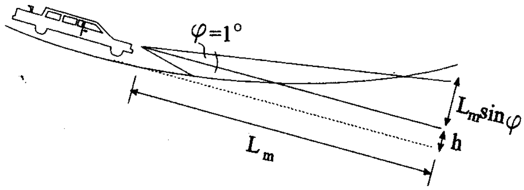

Fig. 5. The definition of minimum concave vertical curve

so the curve radius needed to ensure stopping (R_c) will be

$$R_C = \frac{S_S^2}{2 \cdot (h + S_s \cdot \sin \phi)},$$

where
R_c – concave curve radius (m);
h – headlight level of the vehicle (0.5 m);
ϕ – long-range light angle (1*).
Table 11 contains the results.

Table 11. Calculated values of concave vertical curves

v_d (km/h)	R_c (m)
30	300
40	550
50	850
60	1300
70	1800
80	2500
90	3300
100	4300
110	5400
120	6600
130	8000
140	9500
150	11000

8. Summary

This article is primarily trying to clarify the calculation method of road design parameters, and their limit values. On the other hand there are some theoretical questions to get through [1] [2], and practical demonstration projects to compare the new results with [5].

Table 12. Comparison of present and calculated values of design parameters

Design parameters			Design speed												
			30	40	50	60	70	80	90	100	110	120	130	140	150
Horizontal alignment	Horizontal curve radius	min R (m)	25	45	80	120	180	250	340	450	575	720	880	1040	1200
	Transition curve parameter	min p (m)	15	25	30	40	60	80	110	150	200	240	290	345	400
			21	32	48	64	85*	130*	152*	175					
Vertical alignment	Convex vertical curve	from stopping sight distance min R_{xs} (m)	260	600	1200	2000	3500	4000	5500	8500	11000	16000	22500	31000	41500
			160	350	700	1200	2100	3500	5500	8500		16500			
		from overtaking sight distance min R_{xo} (m)	–	–	–	32500	35000	38500	42500	47500	54000	61500	70000	81000	93000
			11000	13500	16500	20000	25000	30000	40000	50000		80000			
	Concave vertical curve	min R_c (m)	300	550	850	1300	1800	2500	3300	4300	5400	6600	8000	9500	11000
			250	500	800	1100	1600	2300	3000	3900		6500			
Sight distance	Stopping sight distance ($e = 0\%$)	min S_s (m)	25	35	50	65	85	110	140	170	210	260	310	360	420
	Overtaking sight distance ($e = 0\%$)	min S_o (m)	470**	480**	495**	510**	530**	555**	585	615	655	700	750	805	860
			300	330	360	400	440	500	560	640		800			

* the present values could only be applied if superelevation length is relevant

** decreasing these values (as can be read in [5]) requires consideration

[white box] – present (or matching) values; [grey box] – new results

Table 12 seems to be the best as a summary, there are all the new (and the compared) results in it, and can be taken as a suggestion to be the new standard.

During the whole recalculation-reconsideration process the main aspect was SAFETY. So the new limit values may lead us to either more (smaller values like transition curve parameter or overtaking sight distance) or less (higher values like vertical curve radiuses) economical, but always safe solutions.

References

[1] Fi, I., *Forgalmi tervezés, technika, menedzsment*, Műegyetemi kiadó, 1997.
[2] Fi,I., *Utak és környezetük tervezése*, Műegyetemi kiadó, 2000.
[3] Közutak Tervezési Szabályzata, bemutató. Szerk. MAÚT szakbizottsága, 2000.
[4] Közutak Tervezése, Útügyi Műszaki Előírás ME 07-3713/1994.
[5] Balogh, I. – Schuchmann, G. – Somogyvári, Zs. – Styevola, I., Új kutatási eredmények a szükséges megállási és előzési látótávolságok meghatározására irányuló vizsgálatoknál, *Közúti és Mélyépítési Szemle*, **51** No. 1. (2001), pp. 36–41.
[6] Richtlinien für die Anlage von Straßen, Linienführung (RAS-L), 1995. Forschungsgesellschaft für Straßen- und Verkehrswesen.
[7] Richtlinien für die Anlage von Straßen, Linienführung (RAS-L), 1984. Forschungsgesellschaft für Straßen- und Verkehrswesen.