

An Overview of International Best Practices on Hill Roads

Presented by

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General observation about alignment design policy and practice worldwide:

Speed Consideration

Canada, South Africa and USA	Design speed used as specified by AASHTO for establishing super elevation, Sight Distance (SD), Radius of Vertical Curve
Australia, France, Germany, Switzerland, UK	Operating Speed*

** Operating Speed is the 85th percentile of the Free Flow speed*

Super Elevation

Australia, France, Germany, Switzerland, UK and others	Super elevation vs Radius of curve (Linear)
USA, South Africa and Canada	Super elevation vs Radius of curve (Parabolic)
Sweden	Only Three Super elevation rates

Source: Krammes R.A. and Garnham M.A., "Worldwide Review of Alignment Design Policy"

Alignment Design criteria considered for Hilly Terrains around the World:

Country	Parameters
Australia	❖ Max. Super elevation 10 percent (exception to 12 %)
	❖ Super elevation on a sharper curve adjusted to decrease frictional demand at design speed is not more than 20 - 25 percent on the flatter curve.
	❖ Policy encourages use of Transition curve except where lateral shift between extended tangent line and extended circular arc is less than 250 mm.
	❖ Minimum length of Crest vertical curve depends on sight distance ❖ Minimum length of S.ag vertical curve depends on comfort condition

*Alignment Design criteria considered for
Hilly Terrains around the World (Contd...)*

Maximum Grades followed on Australian Roads (%)

Target Speed (km/h)	Terrain					
	Flat	Rolling	Mountainous			
			<2000 AADT	2000-5000 AADT (See Note 1)	5000-10000 AADT (See Note 2)	>10000 AADT (See Note 3)
50	6-8	8-10	12	10	-	-
60	6-8	7-9	10	9	9	-
80	4-6	5-7	9	8	7	7
100	4	4-6	-	-	6	6
120	3	3-5	-	-	-	5

Road Planning and Design Manual – Chapter 12 (Australia)

Alignment Design criteria considered for Hilly Terrains around the World (Contd...)

Country	Parameters
Belgium	❖ Safe speed is the design speed at Horizontal and Vertical curves
	❖ Clothoid spiral transitions used at changing radii locations (Based on Aesthetics, comfort and super elevation application)
	❖ Vertical alignment consists of uniform gradient joined by parabolic curves ❖ Maximum longitudinal gradient 8percent at 60kmph

Alignment Design criteria considered for Hilly Terrains around the World (Contd...)

Country	Parameters
Canada	❖ Clothoid transition curve is used
	❖ Compound curves are joined by transition curve unless ratio of the longer to shorter radius is less than 1.5
	❖ Both concave and convex vertical curve controlled by stopping sight distance

Alignment Design criteria considered for Hilly Terrains around the World (Contd...)

Country	Parameters
France	❖ Effect of super elevation on Operating speed is not established
	❖ Super elevation is a function of inverse of radius
	❖ French design policy uses transition curve on all horizontal curves except where super elevation is not needed.
	❖ New guidelines specify use of higher variation in sharp curve than for mild curve i.e. Transition curve length increases with increasing final radius.

Alignment Design criteria considered for Hilly Terrains around the World (Contd...)

Country	Parameters
Sweden	❖ For horizontal curve, super elevation is selected from 5.5, 4 or 2.5 percent.
	❖ Vertical alignment guideline constraints use of longitudinal gradient to 6 percent and 8 percent in case of exception.
	❖ Convex curve based on SSD and concave is based on Head light sight distance.

Typical Forgiving Safety Features provided essentially in Hilly Roads around the world

❑ **Climbing Lanes**

- *Extra lane used for short distances in certain areas to improve safety, ease congestion and prevent delays*
- *Help facilitate the passing of trucks and slow moving vehicles whose speed drops because of the sustained steep grades.*



A climbing lane on **SR 87 USA**

(Source: <https://www.azdot.gov/media/blog/posts/2013/01/29/transportation-defined-climbing-lanes>)

❑ **Gabion Safety Barriers**

- *A wall of 1 meter high by 1 meter wide made out of gabions (stone-filled steel mesh cages) wired together*
- *Over 3 years the Safety Unit installed gabion safety barriers at many accident sites on the busiest road out of the Kathmandu Valley*

Advantages:

- *Easy to build if stones availability is affordable*
- *Repairs are simple*
- *Use of light colored stones makes the barrier more visible at night and helps drivers recognize how the road is aligned.*



❑ **Runaway Truck ramp/Truck arrester Bed**

- Traffic device that enables vehicles which are having braking problems to safely stop
- Typically a long, sand- or gravel-filled lane connected to a steep downhill grade section of a main road, designed to accommodate trucks or buses.
- Ramp allows a moving vehicle's kinetic energy to be dissipated gradually in a controlled and relatively harmless way
- Usually located on steep, sustained grades, as in mountainous areas.



100 meter long gravel escape ramp downhill on the A7 near Amskroud in Morocco

(Source: https://en.wikipedia.org/wiki/Runaway_truck_ramp)

❑ **Optical Speed Bars**

- *Transverse stripes spaced at gradually decreasing distances (Manual on Uniform Traffic Control Devices, USA)*
- *The rationale for using them is to increase drivers' perception of speed and cause them to reduce their speed*
- *As spacing between bars gradually narrows, drivers sense they have increased speed and will slow down to keep the same time between each set of bars*



Virginia Department of Transportation, USA

(Source: https://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/ch7.cfm)

❑ Cable Median Barrier

- Made of three or four steel cables strung on posts***
- When a car hits the barrier, the posts break and the cables flex, absorbing much of a crash's kinetic energy. This redirects the vehicle along the median, preventing a cross-median crash.***
- In addition to the ability to lessen crash severity, the cable barriers cost less than permanent concrete barriers or metal beam crash barriers.***



A cable barrier separating lanes on a 2+1 road in Sweden

Typical Forgiving Safety Features essentially in Hilly Roads around the world (Contd...)

- ❑ Cable barrier is intended for use on slopes with a 1:6 vertical to horizontal

Table 3. Performance of Cable Median Barriers in Various States: Effectiveness

State	Collisions (number)	Penetrations (number)	Effectiveness (%)	References
AR	1,829	152	91.7	Chen 2004
IA	20	0	100.0	KCRG News 2007
NC	71	5	93.0	Hunter et al. 1999
NY	99	4	96.0	Tyrell and Bryden 1989
OH	372	4	98.9	Arnold 2006
OK	400	1	99.8	<i>The Purcell Register</i> 2005
OR	53	2	94.3	Sposito and Johnston 1998
RI	20	0	100.0	RIDOT 2005
SC	3,000	15	99.5	FHWA 2005
UT	18	2	88.9	Laird 2006
WA	774	41	94.7	MacDonald and Batiste 2007

Performance of Cable Median Barriers in various states of USA

- ❖ More than 90% effective in reducing Fatalities

(Source: Ray M. H., M.ASCE1., Silvestri C., Conron C. E. and Mongiardini M., "Experience with Cable Median Barriers in the United States: Design Standards, Policies, and Performance", Journal of Transportation Engineering, ASCE, October 2009, pp - 711-714)

Advantage of cable Median Barriers

- In Sweden (Bergh et al., 2005), as well as in Ireland (NRA, 2007, Gazzini, 2008), cable barriers were chosen***
- Advantages with cable barriers are that they are cheap compared to metal beam barriers***
- Easily repaired when hit and can be dropped / opened rather easily for access in emergency situations***

❑ **2+1 Lane Road**

- *Specific category of three-lane road, consisting of two lanes in one direction and one lane in the other, alternating every few kilometer and separated usually with a steel cable barrier*
- *Traditional roads of at least 13 meters width can be converted to 2+1 roads and reach near-motorway safety levels at a much lower cost than an actual conversion to motorway or dual carriageway*
- *Denmark and Sweden have been building 2+1 roads since the 1990s (Most cost effective than converting 2lane to 4lane roads)*
- *Suited for safe overtaking operation and increase capacity*



2+1 section of B54 near Steinfurt, Germany

(Courtesy Source:

https://commons.wikimedia.org/wiki/File:B_54_be_i_Steinfurt.jpg)

Implementation of 2+1 lane Roads

- Four 2+1 roads of total 15 km length were evaluated in Norway (Saukshaug and Giæver ,2004) and the results showed that all injury crashes have been reduced by about 60 %.*
- In Ireland, the evaluation of the pilots showed reductions of the rates of fatalities and serious injured by 50 – 60%*
- In Finland (Liikennevirasto, 2010), the safety level of 2+1 roads with cable barrier is about the same as for motorways*

❑ ***Sequential Dynamic Curve Warning System***

- *A solar-powered traffic signage system designed to minimize crashes on horizontal curves*
- *Give drivers advanced warning and in-curve guidance with the Dynamic Curve Warning System (used and proven to reduce vehicle speeds and crash rates as reported by the Federal Highway Administration, USA)*





Thank You!
Your Queries are solicited!