An Overview of International Best Practices on Hill Roads

Presented by

Dr. S. Velmurugan, Senior Principal Scientist, Traffic Engineering and Safety Division, CSIR - Central Road Research Institute (CRRI), New Delhi

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General observation about alignment design policy and practice worldwide:

**Speed Consideration**

<table>
<thead>
<tr>
<th>Country</th>
<th>Super Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada, South Africa and USA</td>
<td>Design speed used as specified by AASHTO for establishing super elevation, Sight Distance (SD), Radius of Vertical Curve</td>
</tr>
<tr>
<td>Australia, France, Germany, Switzerland, UK</td>
<td>Operating Speed*</td>
</tr>
</tbody>
</table>

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

**Super Elevation**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Australia, France, Germany, Switzerland, UK and others</td>
<td>Super elevation vs Radius of curve (Linear)</td>
</tr>
<tr>
<td>USA, South Africa and Canada</td>
<td>Super elevation vs Radius of curve (Parabolic)</td>
</tr>
<tr>
<td>Sweden</td>
<td>Only Three Super elevation rates</td>
</tr>
</tbody>
</table>

## Alignment Design criteria considered for Hilly Terrains around the World:

<table>
<thead>
<tr>
<th>Country</th>
<th>Parameters</th>
</tr>
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</table>
| 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 |

### Maximum Grades followed on Australian Roads (%)

<table>
<thead>
<tr>
<th>Target Speed (km/h)</th>
<th>Flat</th>
<th>Rolling</th>
<th>Terrain</th>
<th>&lt;2000 AADT</th>
<th>2000-5000 AADT (See Note 1)</th>
<th>5000-10000 AADT (See Note 2)</th>
<th>&gt;10000 AADT (See Note 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>6-8</td>
<td>8-10</td>
<td>Flat</td>
<td>12</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>60</td>
<td>6-8</td>
<td>7-9</td>
<td>Rolling</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>80</td>
<td>4-6</td>
<td>5-7</td>
<td>Rolling</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>4-6</td>
<td>Rolling</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>120</td>
<td>3</td>
<td>3-5</td>
<td>Rolling</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
</tbody>
</table>
### Alignment Design criteria considered for Hilly Terrains around the World (Contd...)

<table>
<thead>
<tr>
<th>Country</th>
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</table>
| 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 8 percent at 60kmph |

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<tr>
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<th>Parameters</th>
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<tbody>
<tr>
<td>Canada</td>
<td>❖ Clothoid transition curve is used</td>
</tr>
<tr>
<td></td>
<td>❖ Compound curves are joined by transition curve unless ratio of the longer to shorter radius is less than 1.5</td>
</tr>
<tr>
<td></td>
<td>❖ Both concave and convex vertical curve controlled by stopping sight distance</td>
</tr>
</tbody>
</table>

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<th>Parameters</th>
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<tbody>
<tr>
<td>France</td>
<td>- Effect of super elevation on Operating speed is not established</td>
</tr>
<tr>
<td></td>
<td>- Super elevation is a function of inverse of radius</td>
</tr>
<tr>
<td></td>
<td>- French design policy uses transition curve on all horizontal curves except where super elevation is not needed.</td>
</tr>
<tr>
<td></td>
<td>- New guidelines specify use of higher variation in sharp curve than for mild curve i.e. Transition curve length increases with increasing final radius.</td>
</tr>
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### Alignment Design criteria considered for Hilly Terrains around the World (Contd...)

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| 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](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](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

(Courtesy Source: https://commons.wikimedia.org/wiki/File:E20_2plus1_west_of_Skara.jpg)
Cable barrier is intended for use on slopes with a 1:6 vertical to horizontal ratio.

Performance of Cable Median Barriers in various states of USA:

More than 90% effective in reducing Fatalities.

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 kilometers 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 2 lane to 4 lane 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_bei_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)

Courtesy: Source: http://slideplayer.com/slide/4864723/
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