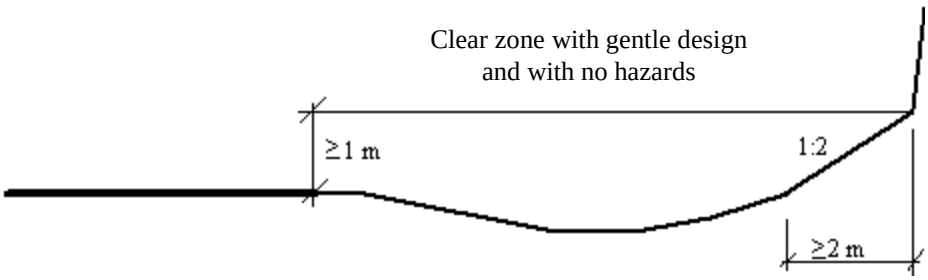
HIGHWAY DESIGN REPORT

Appendix 3

Proposed Design Principles for Road Side Areas and Guardrails



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SWEROAD

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1 Introduction

1.1 Purpose

The purpose of this report is to present a proposal for amendments and changes in the existing Turkish guidelines for the design of road side areas and the use of guardrails.

The objective should be to incorporate the proposal in new comprehensive Turkish design guidelines. Awaiting new guidelines, it is suggested that the proposed changes, after revision and adaptation to Turkish conditions, are used as interim guidelines for the design of new roads.

The proposal is focused on the main safety requirements. In addition, there are a number of safety details and other technical issues that must be included in the future guidelines.

1.2 The road side safety problem

In a Swedish study in 1997 it was found that one out of four drivers and passengers was killed in road accidents in which the vehicle hit a road side obstacle. The obstacles hit were:

- 50 % trees
- 20 % guardrails
- 10 % lighting columns
- 10 % other posts
- 10 % other objects

About two thirds of the objects (trees, some of the posts and other objects) were objects that should not have been close to the roads. Those objects should have been removed from the road side.

About one third (guardrails, lighting columns and some other posts) was road equipment needed for the traffic and the safe operation of the road. Road lighting, for example, is supposed to save three to four times as many lives as persons killed in collisions with lighting columns. However, those objects could probably have been placed or designed safer.

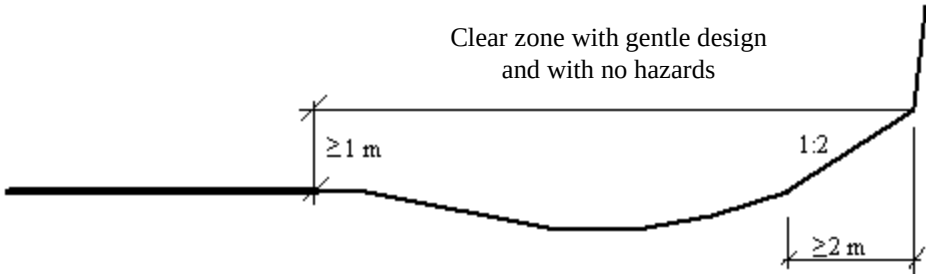
This experience from Sweden is not directly valid for Turkey. But the fact that poor road side conditions are responsible for many serious traffic injuries is probably as valid in Turkey as in Sweden. Consequently, the design of the road side area and road side objects is one of the most important safety issues in road design.

1.3 General design principles

1.3.1 Clear zone

Along every road there should always be a recovery area, a clear zone, permitting the driver to regain control of a vehicle which for some reason has left the roadway. The recovery area should have a gentle design with flat slopes to prevent the vehicle from rolling over. It should also be clear from hazardous objects which can inflict injuries to the driver or passengers.

No hazardous objects should be allowed within the clear zone. Examples of hazardous objects are bridge piers, sign posts, rigid lighting columns, drainage structures, rocks with diameters > 0,2 m and trees with diameters > 0,10 m. Some hazards should be removed (e.g. rocks and trees) and others moved outside the clear zone (e.g. drainage structures).



Typical design of the clear zone

1.3.2 Alternatives to a clear zone

If the hazards (e.g. sign posts and lighting columns) cannot be taken away or moved, the alternatives are:

- to replace them with a non-hazardous equipment,
- to protect them with guardrails or crash cushions.

1.4 Turkish guidelines

1.4.1 Existing guidelines

The proposal is based on the following information of existing Turkish guidelines concerning road side areas and guardrails.

For the design of the road side area, there are old guidelines from 1965 and a revision from 1989. These guidelines are mainly based on construction requirements and safety issues are not considered. The stipulated side slopes are generally too steep for the road side to work as a recovery area. There is, however, a proposal for revision of the guidelines with flatter slopes, but the concept of a clear zone is not included.

For guardrails (and crash cushions) there is a translation of German guidelines from 1997 (Otokorkuluk notları). This is not an official guideline and the extent to which the rules and recommendations are followed in practice is uncertain. However, it seems that it is primarily used by KGM central administration in Ankara.

There are no guidelines for the use of non-hazardous, yielding, breakaway or slip-base supports for signs and lighting.

1.4.2 The need for changes

From a safety point of view, the following actions regarding existing guidelines concerning the road side area should to be taken:

- revised guidelines should be prepared for the design of the road side area considering the need for a recovery area, a clear zone,
- the Otokorkuluk notları on guardrails etc. should be revised and adopted as official guidelines,
- rules for the use of yielding signs and lighting supports should prepared.

2 Proposed design principles

2.1 Contents

The following actions are suggested:

- Elaboration of a set of **road side types** to be used for different planning conditions.
- Introduction of a requirement for a road side safety area, a **clear zone.**
- Preparation of a policy for the use of **yielding signs and lighting supports.**
- Review of the **guardrail** guidelines.

As a basis for the proposed actions principles and examples are given in this report for:

- Design of the road side area.
- Requirements for a clear zone.
- Policy for yielding sign and lighting supports.
- The use of guardrails.

2.2 Design of the road side area

2.2.1 Road side types

At high speeds a vehicle leaving the roadway travels a longer distance before stopping and the risk to roll over is higher than at low speeds. The main design criterion for the road side area should therefore be the design speed.

However, the possibilities to provide a recovery area that meets the safety requirements are limited, for example, by the terrain and right of way restrictions. In mountainous areas and

for roads with low traffic volumes, the costs to provide an ideal recovery area can be too high compared to the safety benefits. For roads in flat areas, the costs are usually lower and for roads with high traffic volumes higher construction costs are often motivated by the safety returns.

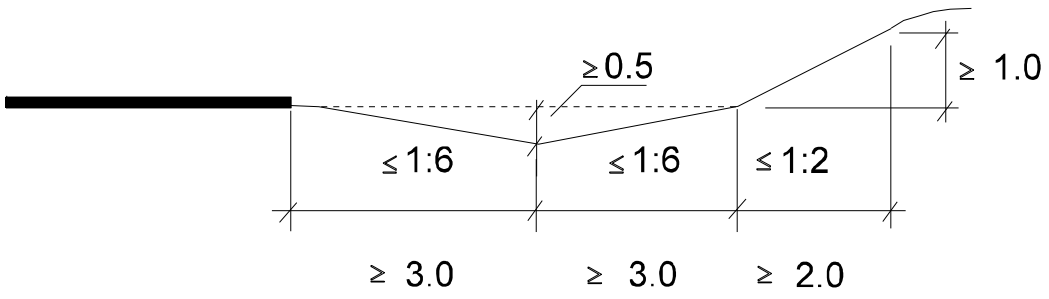
Consequently, construction costs and traffic volumes must also be considered when designing the road side area. Requirements for the road side area should be defined as a set of **road side types** to be used for different planning conditions. In Sweden, for example, the following road side types are used:

Road side type	**Typical design**	**Performance**
A	Gentle slopes, 1:6 or flatter.	*The risk to roll over is **very low*** for a vehicle leaving the road.
B	Gentle slopes, 1:4 or flatter	*The risk to roll over is **low*** for a vehicle leaving the road.
C	Normal slopes, 1:3 or steeper	*There is **some** risk to roll* over for a vehicle leaving the road.

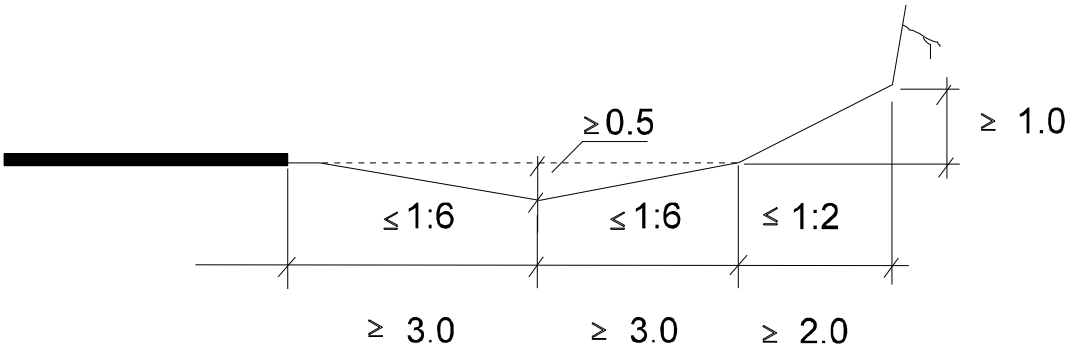
2.2.2 Design of the road side types

Road side type A
Road side type A is suggested to be used on State roads with speed limit 90 km/h or more, and on provincial roads with high traffic volumes (see section 2.2.3).

Cut
Normal cuts are designed with the side front slope 1:6 or flatter and a 0,5 meter deep ditch for road surface water. For the superstructure drainage, pipes have to be used. The back slope should have the slope 1:6 or flatter for at least 3 meters and then 1:2 to a height of at least 1 meter above the road surface.

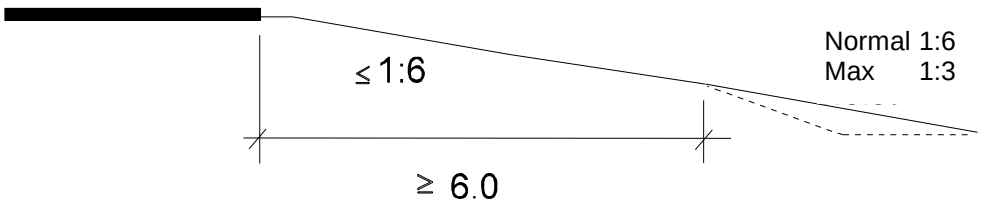


Normal earth cut section for road side type A



Normal rock cut section for road side type A

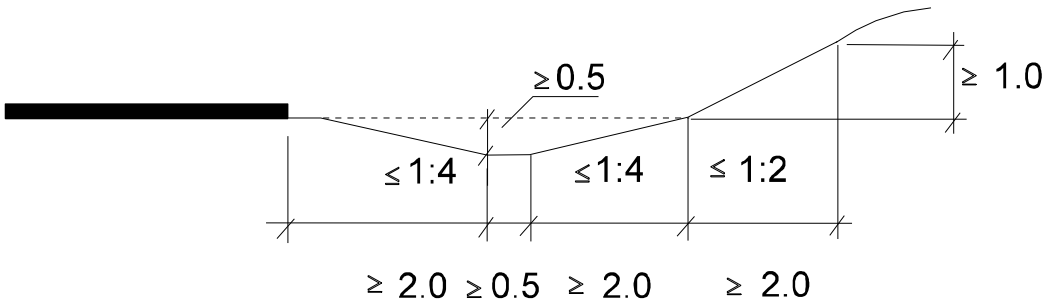
Fill
Normal fills are designed with the side slope 1:6 or flatter on a width of at least 6 meters and then maximum 1:3.



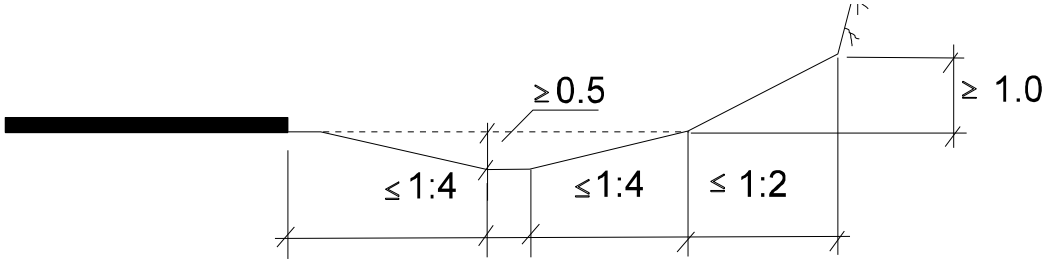
Normal fill section for road side type A

Road side type B
Road side type B is suggested to be used on State roads with speed limit 70 km/h, and on provincial roads with medium traffic volumes (see section 2.2.3).

Cut
Normal cuts are designed with the side front slope 1:4 or flatter and a 0,5 meter deep and 0,5 meter wide ditch for road surface water. For the superstructure drainage, pipes have to be used. The back slope should have the slope 1:4 or flatter for at least 2 meters and then 1:2 to a height at least 1 meter above the road surface.

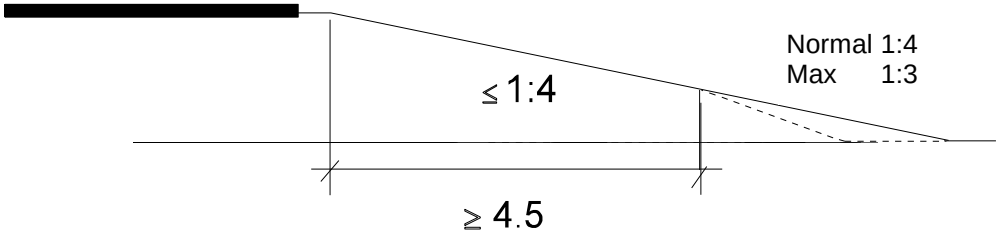


Normal earth cut section for road side type B



Normal rock cut section for road side type B

Fill
Normal fills are designed with the side slope 1:4 or flatter on a width of at least 4,5 meters and then maximum 1:3.

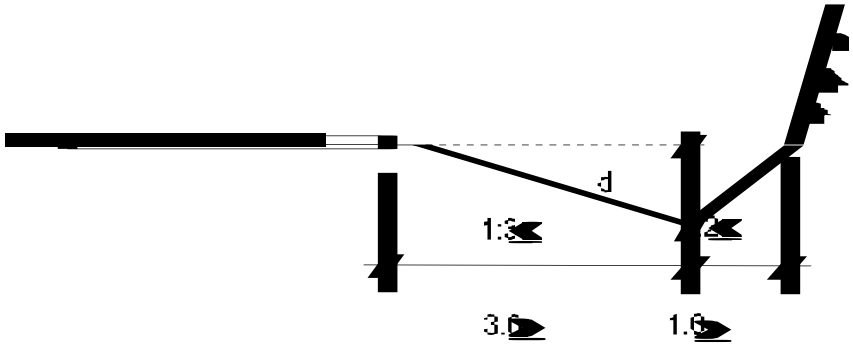


Normal fill section for road side type B

Road side type C
Road side type C is suggested to be used on all roads with speed limit 50 km/h or less, and on provincial roads with low traffic volumes (see section 2.2.3).

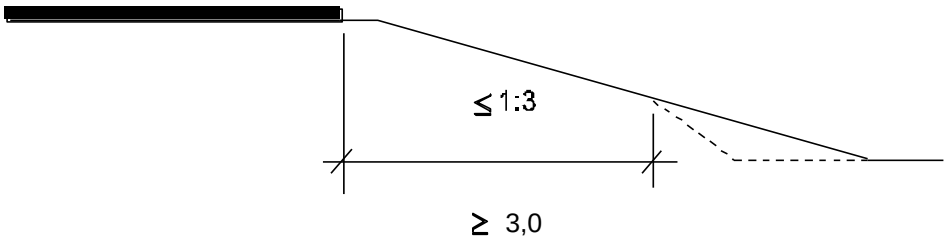
Cut
Normal cuts are designed with the side front slope 1:3 or flatter and an open ditch with a depth determined by the thickness of the superstructure. The back slope should have the slope 1:2 or flatter for at least 1 meter.

Normal earth cut section for road side type C



Normal rock cut section for road side type C

Fill
Normal fills are designed with the side slope 1:3 or flatter on a width of at least 3 meters.



Normal fill section for road side type C

2.2.3 Selection of road side type

The requirements for the recovery area depend mainly on the speed. As mentioned above, a vehicle leaving the road at high speed travels longer before stopping and the risk of overturning is greater at high speed. The main criterion for selecting road side type should therefore be the design speed. For economic reasons the traffic volume must also be considered.

A policy for the selection of road side type for different road classes based on design speed and traffic volume should be developed. The table below shows the selection of road side type according to the Swedish guidelines.

Design speed, km/h	50	70			90			110		
Traffic volume, v/d		<4000	4000 - 7000	>7000	<2000	2000 - 3000	>3000	<1000	1000 - 2000	>2000
State roads	C	B			A			A		
Provincial roads	C	C	B	B	C	B	A	C	B	A

Selection of road side type according to Swedish guidelines

Different terrain conditions can also be considered, for example, by defining different traffic classes for flat, rolling or mountainous terrain. An example of how an adaptation of

the Swedish guidelines to Turkish conditions could be done is shown in the table below. It must however be pointed out that the traffic volumes in the table are chosen only to show the proposed principle.

Design speed, km/h	50	70			90			110		
Traffic volume, v/d:										
- Flat terrain		<3000	3000 - 6000	>6000	<1000	1000 - 2000	>2000	<500	500 - 1500	>1500
- Rolling terrain		<4000	4000 - 7000	>7000	<2000	2000 - 3000	>3000	<1000	1000 - 2000	>2000
- Mountainous terrain		<5000	5000 - 8000	>8000	<3000	3000 - 4000	>4000	<2000	2000 - 3000	>3000
State roads	C	B			A			A		
Provincial roads	C	C	B	B	C	B	A	C	B	A

Example of policy for selection of road side type

2.3 Clear zone

Width

The width of the clear zone should primarily be based on the design speed. However, construction costs and traffic volumes should also be considered. This can be done by defining widths for different standard levels and rules for the selection of standard level based on construction conditions (e.g. terrain conditions) and traffic volumes. An example on how this can be done is shown in the following tables.

Design speed km/h	Standard level		
	High	Fair	Low
50	>3 m	<3 m	-
70	>7 m	>3 m	<3 m
90	>9 m	>4,5 m	<4,5 m
110	>10 m	>6 m	<6 m

Example of required width of the clear zone

Traffic volume	Low	Medium	High
State roads	High		
Provincial roads	Low	Fair	High

Example of policy for selection of standard level for the clear zone

2.4 Yielding sign and lighting supports

2.4.1 Types and classification

A preparation of a policy for the use of yielding sign and lighting supports is proposed.

Depending on performance there are three types of yielding supports:

Energy absorbing	High Energy absorbing,	HE
	Low Energy absorbing,	LE
Non Energy absorbing		NE

Yielding supports are classified into three speed classes and three safety classes. The speed classes are 100, 70 and 50 km/h. The safety classes are 1, 2 and 3, where 3 is the safest.

2.4.2 Draft policy

A policy for the use of yielding support can include the following points:

Requirements for safety class
For example:
Within the clear zone, sign and lighting supports must be yielding supports, safety class 1 or higher.

Requirements for speed class
For example:
1. Supports in speed class 100 can be used on all roads.
2. Supports in speed class 70 can be used on roads with speed limit 70 km/h or less.
3. Supports in speed class 50 can be used on roads with speed limit 50 km/h or less.

Requirements for energy absorption type
For example:
1. HE and LE supports can be used everywhere.
2. HE and LE supports should be used where it is especially important to avoid:
   - secondary collisions with hazardous objects,
   - secondary collisions with other vehicles,
   - that pedestrians are injured.
3. NE supports can be used in other locations.

2.5 Guardrails

2.5.1 Introduction

General
A revision of the preliminary guidelines (Otokorkuluk notları) is proposed.

The purpose should be an adaptation both to Turkish conditions and to new research results and to new international standards (CEN). This is an extensive work, that must be done by guardrail and safety experts in collaboration.

Guidelines for the use of guardrails should be based on socio-economic analyses of the number and severity of accidents for different road side and median design with and without guardrails.

Guardrails can cause damages when hit and also secondary accidents if the vehicle is "bounced back" onto the road and collides with other vehicles. It can also obstruct the sight and be unaesthetic. Consequently, the main principle should be to avoid guardrails and try alternative solutions, such as wider median, removal of obstacles, flatter slopes, lower profile or yielding posts.

Guardrails are used for two typical situations:

- for hazards along the road – road side guardrails
- to prevent vehicles to run over the median to the opposite directed roadway – median guardrails

Road side guardrails
Road side guardrails should be used for single obstacles inside the clear zone and for continuous hazards along the road, such as rock cuts, high and steep side slopes, vertical drops and water areas.

Median Guardrails
Median guardrails are used for:

- obstacles in the median,
- to prevent an errant vehicle to enter the opposite directed roadway.

2.5.2 Road side guardrails

Fixed Objects
The requirements for road side guardrails can be divided into two different situations:

- **single fixed objects** in the road side area like e.g. a bridge pillar
- **long hazards** with many fixed objects in a row like e.g. a forest or a row of lighting posts

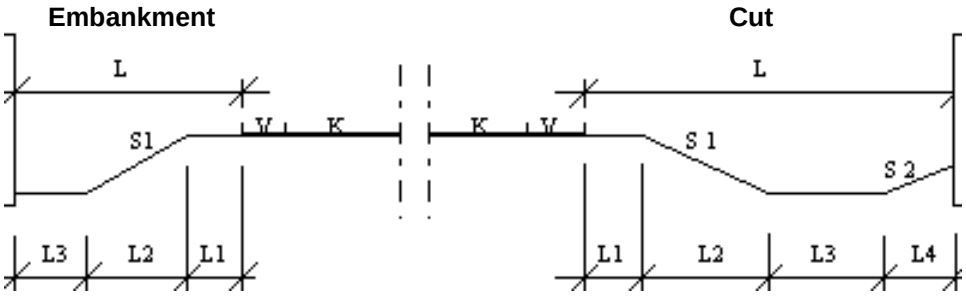
Fixed objects are, for example:

- Bridge piers
- Concrete foundations
- Lighting posts with a diameter > 0,1 m
- Rocks higher than 0.2 m
- Trees with a diameter > 0,1 m (1,5 m over the ground)

At 70 km/h or more, guardrails should be used if the fixed object is closer to the road than the distance **L** according to the tables below. Note that sections with a side slope steeper than 1:3 shall not be included in L. On the outside of curves, with a radius less than $1,5*R_{min}$ 1,0 m shall be added to the distance **L**.

Minimum distance **L** to fixed objects without guardrail						
	Single fixed objects			Long hazards		
ADT, v/d	70 km/h	90 km/h	110 km/h	70 km/h	90 km/h	110 km/h
0-1000	2 m	3 m	4 m	3 m	5 m [1)]	7 m [2)]
1000-3000	2 m	3 m	5 m [1)]	5 m	7 m [1) 3)]	8 m [2)]
3000-5000	3 m	4 m	6 m [1)]	6 m	8 m [1) 3)]	9 m [2)]
5000	4 m	4 m	6 m [1)]	7 m [1) 3)]	9 m [1) 3)]	10 m [2)]

1) For objects more than 4 m from embankment guardrail is not needed.
2) For objects more than 6 m from embankment guardrail is not needed.



Side slope (S1):	Steeper than 1:3	1:3 or flatter
Embankment:	L=L1+L3	L=L1+L2+L3
Cut:	L=L1+L3+L4	L=L1+L2+L3+L4

The use of guardrails at fixed objects

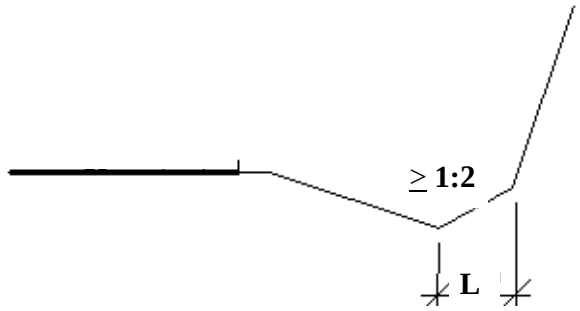
Rock cuts
Guardrail is not needed for road side type A and B.

For road side type C, or similar design, guardrails should be used in rock cuts if the distance from the bottom of the ditch to the rock cut is shorter than **L** according to the table below.

Note that sections with a side slope flatter than 1:2 shall not be included in L. Outside curves with a radius less than $1,5*R_{min}$, the distance **L** shall be increased with 1,0 m.

Minimum distance **L** in rock cuts with road side type C without guardrail			
ADT, v/d	70 km/h	90 km/h	110 km/h
0-1000	0 m	1,5 m	2,5 m [1)]
1000-3000	0,5 m	3 m	4,5 m [1)]
3000-5000	1 m	4 m	5,5 m [1)]
5000	1,5 m	4,5 m [1)]	6 m [1)]

1) If the rock cut begins 1 m or more over the road surface guardrail is not needed.

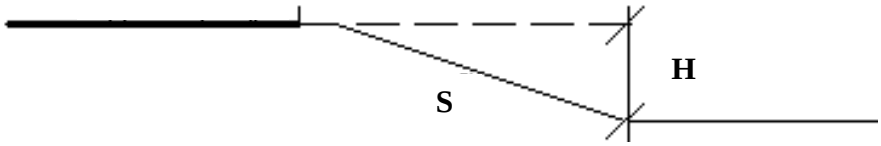


The use of guardrails in rock cuts

Embankments
Guardrails should be used for the side slopes 1:4 or steeper and fill heights according to the table and figure below.

Outside curves with a radius less than $1,5*R_{min}$, the height **H** shall be increased with 1,0 m for side slope 1:2 and 2,0 m for side slopes 1:3.

Maximum fill height **H** without guardrail				
Side slope S=1:2				
ADT, v/d	50 km/h	70 km/h	90 km/h	110 km/h
0-1000	20 m	4 m	1,5 m	x
1000-3000	18 m	3 m	x	x
3000-5000	12 m	2 m	x	x
5000	9 m	1 m	x	x
Side slope S=1:3				
ADT, v/d	50 km/h	70 km/h	90 km/h	110 km/h
0-1000	25 m	12 m	6 m	3 m
1000-3000	20 m	10 m	4 m	2 m
3000-5000	18 m	8 m	3,5 m	2 m
5000	15 m	7 m	3 m	2 m
Side slope S=1:4				
ADT, v/d	50 km/h	70 km/h	90 km/h	110 km/h
0-1000	30 m	15 m	8 m	5 m
1000-3000	25 m	13 m	7 m	4 m
3000-5000	20 m	11 m	6 m	3 m
5000	20 m	10 m	6 m	3 m



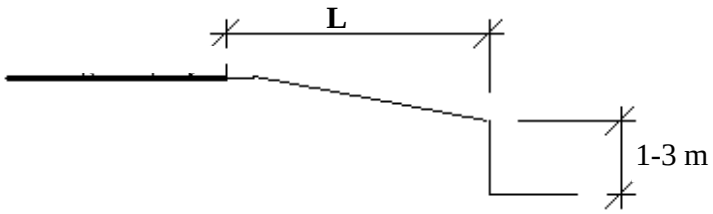
The use of guardrails on embankments

Vertical drops

Guardrails should be used at vertical drops, for example, retaining walls, between 1,5 and 3,0 m according to the table and figure below. At vertical drops higher than 3.0 m inside the clear zone, guardrails should always be used.

Sections steeper than 1:3 should not be included in the distance **L**. Outside curves with a radius less than $1,5*R_{min}$, the distance **L** shall be increased with 1,0 m.

Maximum distance **L** to vertical drops without guardrail				
ADT, v/d	50 km/h	70 km/h	90 km/h	110 km/h
0-1000	2 m	3 m	5 m	7 m
1000-3000	4 m	5 m	7 m	8 m
3000-5000	5 m	6 m	8 m	9 m
5000	6 m	7 m	9 m	10 m



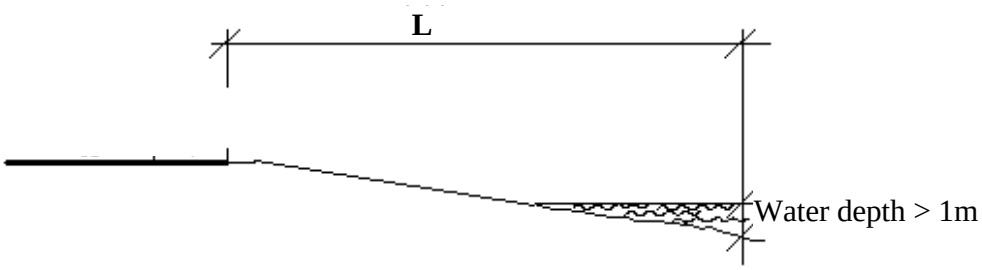
The use of guardrails at vertical drops

Water Areas

Guardrails should be used at water areas (rivers, lakes, etc.) along the road according to the following table if the water depth is more than 1 m.

Sections steeper than 1:3 should not be included in the distance **L**. Outside curves with a radius less than 1,5*R_{min}, the distance **L** shall be increased with 1,0 m.

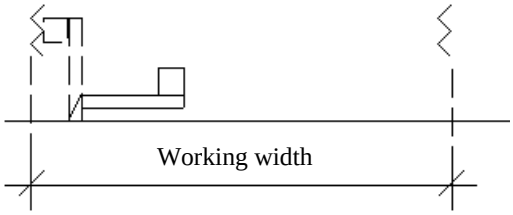
Maximum distance L to water areas without guardrail				
ADT, v/d	50 km/h	70 km/h	90 km/h	110 km/h
0-1000	2 m	3 m	5 m	7 m
1000-3000	4 m	5 m	7 m	8 m
3000-5000	5 m	6 m	8 m	9 m
5000	6 m	7 m	9 m	10 m



The use of guardrails at water areas

Guardrail position
The distance between the guardrail and the hazard (e.g. slope crest or other obstacle) must be greater then the working width (W) for the guardrail.

The working width is the maximum deflection of the guardrail at impacts according to the European standard (EN 1317-2) and to the figure below.

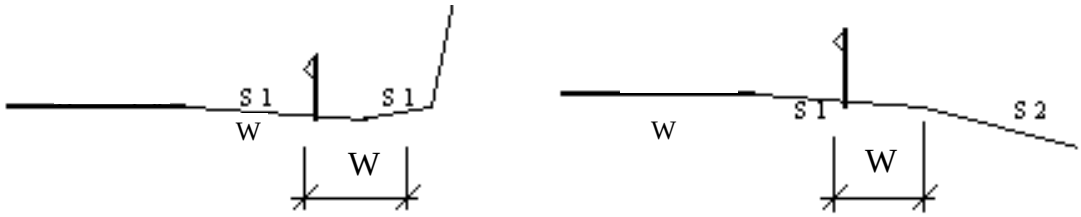


The guardrail can be located either close to the roadway (Alternative 1) or at a distance from the roadway (Alternative 2). At connections to bridges the guardrail should be placed according to Alternative 1.

Alternative 1. Close to the roadway

Examples of guardrail location close to the roadway

Alternative 2. At a distance from the roadway



Examples of guardrail location at a distance from the roadway

When placed at a distance from the roadway the design of the road side area between the road and the guardrail must meet the requirements for road side type A. See section 2.2.2.

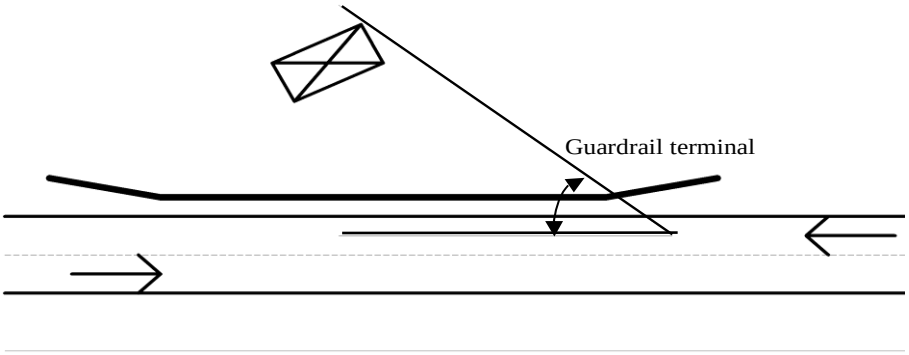
The advantages and disadvantages with a location at a distance from the road are:

- The possibility to avoid to hit the guardrail is increased.
- If hit the impact can be higher and at a greater angle causing worse damages.
- Shorter guardrails can be used.

Guardrail length

The guardrail should with the normal height (terminals excluded) cover the obstacle for different exit angles according to the table and figure below.

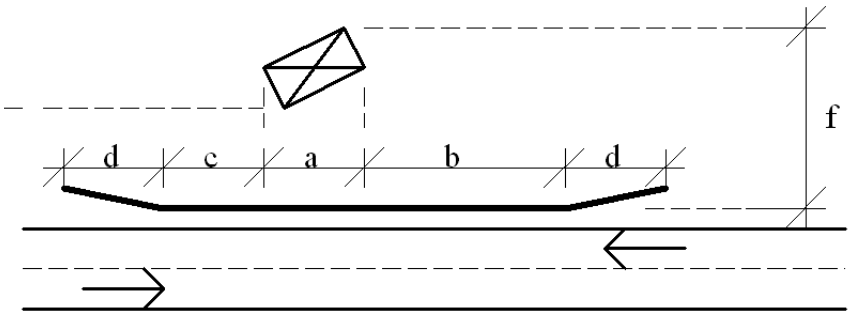
Design speed km/h	Standard level	
	High	Fair
50	12 °	14 °
70	10 °	12 °
90	8 °	10 °
110	6 °	8 °



Basic requirement for guardrail length

The guardrail can be divided into sections according to the figure below where:

- Section **a** is the length of the obstacle along parallel to the road
- Section **b** and **c** are the needed lengths according to the principle above for the two traffic directions
- Sections **d** are the guardrail terminals

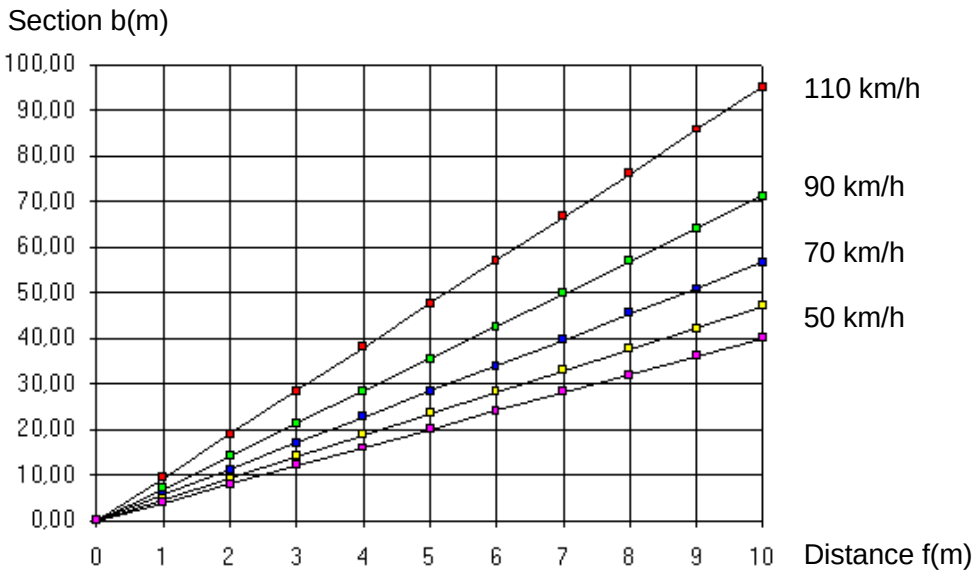


Guardrail sections

The effective length of the guardrail is **a+b+c** and the total length is **a+b+c+2d**.

Calculation of guardrail length

1) The section **a** is decided by the hazard.
   E.g. for a bridge pillar **a** can be 2 meters.
2) The sections **b** is determined by the diagram below.
   E.g. for a 2 m wide bridge pillar 3 m from the road (edge of roadway), the distance f is 4 m if the guardrail is placed 1 m from the road (2+3-1=4).
   With the design speed 90 km/h the length of section **b** is a little less than 40 meters.
3) Section **c** = b/2.
   For the example above section **c** will be 20 meters.
4) Section **d** is generally 12 meters. If the available space is limited, **d** can be 4,6 meters.



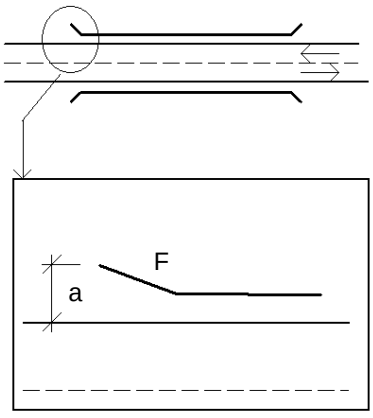
Terminals
Terminals should be designed as either flared or energy absorbing.

Flared terminals

Flared terminals are generally turned down (anchored in the ground) and can be twisted or not twisted.

In Sweden flared terminals are generally anchored but not twisted, 12 m long and designed according to the figure to the right.

To reduce the risk for too big impact angles, the flare of the terminal should not exceed the following values.



Design of flared guardrail terminals

	≤70 km/h	90 km/h	110 km/h
Distance, D	≥ 1,0 m	≥ 1,5 m	≥ 2,0 m
Flare, F	1:10	1:15	1:20

Maximum flare for guardrail terminals

Energy absorbing terminals
Energy absorbing guardrail terminals have been used in USA and other countries for many years, but have just recently been introduced in Sweden.

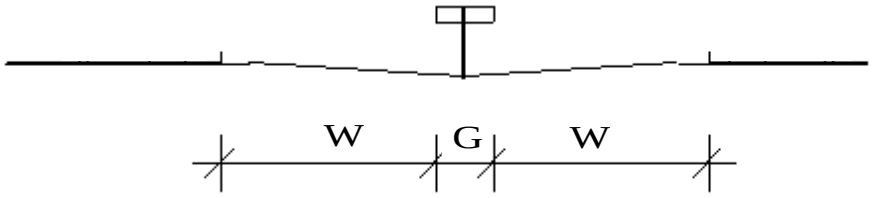
Connection of guardrails
Regardless of the design, guardrail terminals are always safety hazards. If the distance between two guardrails is too short, the guardrails should be connected.

50 km/h	70 km/h	90 km/h	110 km/h
20 m	50 m	80 m	100 m

Minimum distance between two guardrails without connection

2.5.3 Median Guardrails

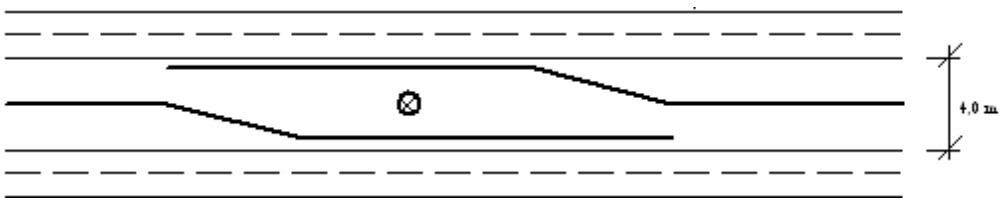
Required median width
Required median width is shown in the figure below. Wider medians can be required, for example, for snow storage, drainage, lighting and maintenance.



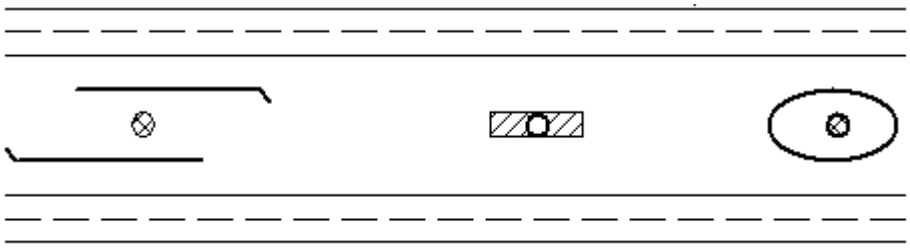
W = Working width
G = Guardrail width

Required median width

Design at obstacles
Examples on normal and alternative designs at obstacles, for example, bridge pillars are given in the figures below.



Example of normal design at obstacles



To the left	Two road side guardrails
In the middle	Crash cushion
To the right	"Bullnose attenuator". Egg-shaped, often steel beam guardrail, around a fixed obstacle.

Alternative designs past obstacles