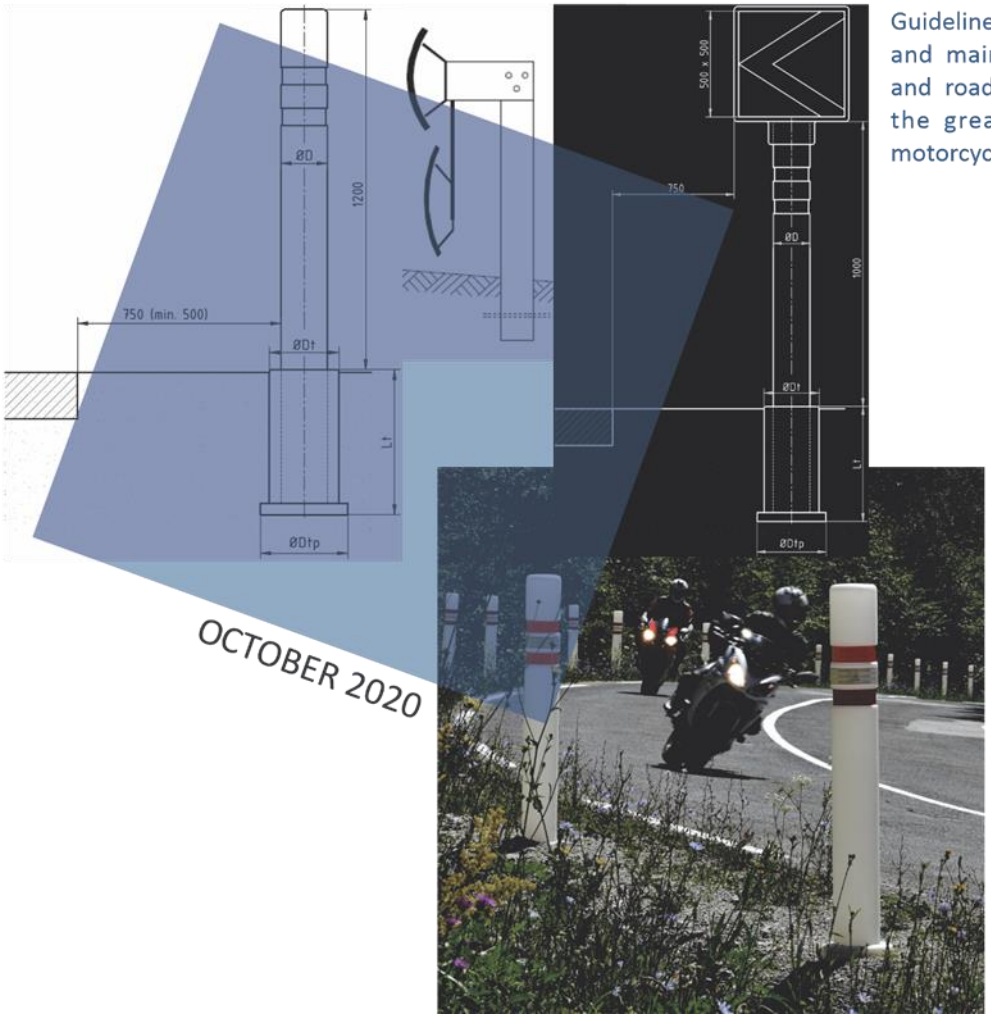
REPUBLIC OF SLOVENIA
MINISTRY OF INFRASTRUCTURE
SLOVENIAN INFRASTRUCTURE AGENCY

University of Maribor
Faculty of Civil Engineering, Transportation Engineering and Architecture

University of Ljubljana
Faculty of Mechanical Engineering

DRI

GUIDELINES FOR MOTORCYCLIST SAFETY



Guidelines for equipping and maintaining roads and roadside areas for the greater safety of motorcyclists.

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EXPLANATION OF TASK

Motorcyclists or those driving “powered two-wheelers (PTW)” fall within the group of vulnerable road users for several reasons:

- they are not surrounded by a “shield”;
- the dynamic of driving a two-track vehicle is different from that of a single-track vehicle (two-track: steering wheel, single-track: handlebar and leaning);
- the small mass relative to other types of motorised road users coming from the other direction;
- the small transverse profile relative to other types of motorised road users (harder to identify);
- measures to ensure passive safety are generally suited to two-track vehicles and can signify a danger for single-track vehicles;
- motorcycles have a greater kW/kg ratio than two-track vehicles.

This has also been recognised by the European Commission, so in the amended version of Directive 2008/96 (Directive 2019/1936) motorcyclists are expressly classed in the group of vulnerable participants:

- *special attention should be paid to the safety of pedestrians, cyclists and motorcyclists (“... in all stages... projects should be checked for all groups of vulnerable road users...”) – new Article 6b;*
- *vulnerable road users are defined precisely in the new Article 2 (10);*
- *Annex II: new requirements (n and h) are included specifically for powered two-wheelers.*

The popularity of motorcycles is growing continuously in Slovenia. According to the latest data from the MZI, in Slovenia the number of driving licences issued both for category A and category B is approximately 195,000. The number of registered motorcycles is increasing, and along with the growth in the number of motorcyclists on the roads, there is an increasing probability of their involvement in traffic accidents.

There were a total of 130,935 motorcycles and powered bicycles registered in Slovenia at the end of 2018. Although in recent years the total number of traffic accidents has been falling in Slovenia, the number of accidents involving motorcyclists has been growing. As a proportion of the total number of injuries and fatalities in traffic accidents, the number of seriously injured and dead motorcyclists is significantly higher relative to their number in the breakdown of road users.

In the past, DRSI alone or in cooperation with other competent Slovenian institutions carried out a range of activities in the area of improving traffic safety for motorcyclists: through preventive actions and education, through additional traffic signalling and improved traffic safety conditions on and along roads. But the majority of these activities were curative.

The present guidelines place Slovenia alongside certain countries (Austria, Germany, Norway, Portugal, the UK, France and Spain) that already have in place regulations in the area of designing, equipping and maintaining roads for the greater safety of motorcyclists, and these have a preventive significance. The guidelines embody findings and suggestions from countries that have been grappling with ensuring motorcycle traffic safety for a long time. It is a summary of best practices in countries with the highest level of traffic safety for motorcyclists, and serves as an additional contribution to ensuring safety for motorcyclists in Slovenia.

1. IDENTIFYING EXPOSED SECTIONS OF ROADS FOR MOTORCYCLISTS

Eliminating deficiencies and faults on the road infrastructure contributes significantly to ensuring greater safety for motorcyclists. Here account should be taken of measures to identify key sections where a systemic approach is being undertaken to effect traffic safety improvements and measures for greater motorcyclist safety.

In identifying road sections that are more exposed in terms of motorcyclist safety, the following needs to be considered:

- the number of motorcyclists on a specific section in the period from June to September,
- the number of traffic accidents involving a motorcyclist on a specific section in the period of the last three years.

In this light it is possible to identify exposed road sections in terms of motorcyclist safety, where the provisions of these guidelines need to be implemented and heeded along the entire section of the individual road. This therefore applies to what are termed motorcycle sections, where there are prominent numbers of motorcyclists and accidents involving motorcycles.

- In order to identify exposed sections where additional measures are to be implemented along the entire section of road, it needs to be factored in that the average daily traffic (ADT) expressed as the number of motorcyclists for the period from June to September is greater than or equal to 200: $m \geq 200$ and the total number of traffic accidents involving motorcyclists in the last three years is greater than or equal to 4: $n \geq 4$.

  - ✓ **Measures on the entire section (motorcycle section): $n \geq 4$ and $m \geq 200$.**

- On road sections where there are prominent data only about the ADT expressed as the number of motorcyclists ($m \geq 200$) or traffic accidents involving motorcyclists ($n \geq 4$), measures are implemented for the greater safety of motorcyclists at dangerous points, in other words not along the entire section.

  - ✓ **Measures on exposed sections: $n \geq 4$ or $m \geq 200$.**

Eliminating irregularities and faults on the road infrastructure or exposed places is also carried out as part of the methodology of the accident black spot, where traffic accidents are concentrated on public road subsections or junctions at which in each of the three years in succession there has been at least one accident, irrespective of the type of injury. In the same way, elimination of irregularities on the national road infrastructure is pursued through research on the factors causing traffic accidents performed by licensed road safety assessors, which serves to define urgently needed measures to improve safety on already established infrastructure. In both cases traffic accidents also involve motorcyclists.

The list of motorcycle sections where additional measures are implemented for greater motorcyclist safety along an entire road section or just in dangerous places is an integral part of the guidelines (annex), and is updated and published regularly as an annex on the website of the Slovenian Infrastructure Directorate.

2. GENERAL CONDITIONS AND METHOD OF SETTING UP SAFETY EQUIPMENT[1] FOR MOTORCYCLISTS

Additional protection and elements for guiding motorcyclists are set up on roads outside settlements:

- on curves with a radius smaller than the minimum for a given calculated speed on the section;
- on curves without a transverse (banking) incline or with a transverse incline less than that prescribed;
- on small-radius curves on major longitudinal inclines (≥ 6%);
- on compound curves ("O-bend" – two arcs connected by a common tangent), where the radius of one of the curves is smaller than or equal to the minimum;
- on reverse curves ("S-curves" or serpentines), where the inflection point on the crown of the convex vertical curvature is of minimum diameter or smaller;
- on curves at the end of a deceleration stretch on motorway or fast highway exit slip roads, where no runaway vehicle ramp is in place;
- on curves where there is a danger of skidding or icing even outside the winter period;
- on isolated curves with a radius of ≤ 250 m;
- on isolated serpentines or on the first of several successive serpentines.

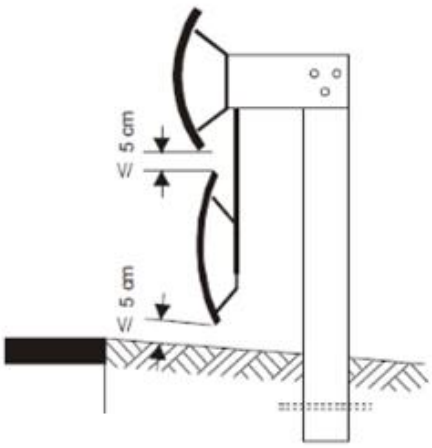
3. MOTORCYCLIST BARRIER ON GUARD RAILS AS AN ADDITIONAL PROTECTION

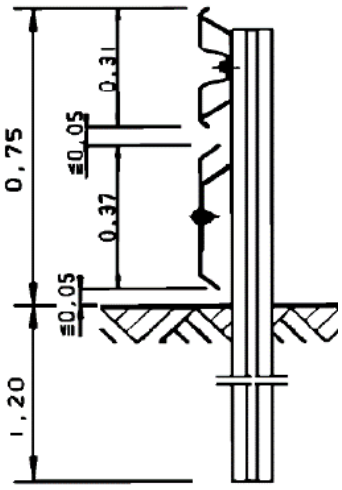
3.1 Conditions for installing motorcyclist guard rails

Motorcyclist guard rails are installed on existing guard rails in sections of dangerous barriers along the road and close to adjacent traffic surfaces (see chapters TSC Guard Rails – designs and method of installation 4.8 and 4.9).

3.2 Method of installation

In all the above-listed cases, the motorcyclist guard rail is set up on the outside of the curve.





Figures 1 and 2: Proper installation of additional protection for motorcyclists: left according to Slovenian [1], and right according to German regulations [2].

[1] *Safety equipment for motorcyclists: motorcycle protection guard rail, impact pads, passive safety poles.*

Additional protection for motorcyclists is installed:

- along the entire length of the arc of a curve and adjoining transition curves;
- if no transition curves have been provided, at least along a length of R/10 at the beginning and R/10 at the end of the curve, where the individual length may not be less than 10 m.

Additional protection for motorcyclists is generally installed when the width of the gap between the arranged verge and lower edge of the additional protection for motorcyclists and between the upper edge of the additional motorcyclist protection and the lower edge of the steel or wood guard rail barrier are less than 5 cm, which prevents a motorcyclist's leg or arm entering the gap.

Figure 3: Proper installation of additional protection for motorcyclists on steel guard rail (source: T. Tollazzi).

Figure 4: Proper installation of additional protection for motorcyclists on wood guard rail (source: Eurorail BV - www.eurorail.nl).

Irrespective of whether the additional motorcyclist protection has been installed with an added motorcyclist rail or impact buffer, the upright poles of any traffic signs must be located behind the guard rail, at a suitable distance, depending on the operational width of the guard rail.

4. MOTORCYCLIST IMPACT PADDING TO SHIELD GUARD RAIL POSTS

4.1. Conditions of installation

Motorcyclist impact padding (MIP) is installed on the upright posts of guard rails, which can represent a major hazard for motorcyclists who fall and slide, in the form of serious point trauma upon impacting the head, neck, torso and other parts of the body.

MIP is installed:

- on existing or new guard rails if they meet the conditions stated in chapter 2 of these guidelines, on curves where due to the geometric elements of the road it is not possible to develop greater speeds (sharp curves and serpentines);
- in front of or behind the motorcyclist protection rails, where they cannot be installed in their full length due to the end elements, and it is not possible here to protect the supporting post in front of the beginning of the motorcyclist barrier.

In terms of their method of operation, MIP is a point (and not linear) element of motorcyclist protection. For this reason, it is a significantly less effective means of ensuring an adequate level of traffic safety for motorcyclist.

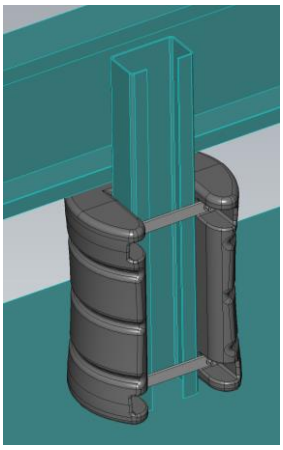
The shape, size and material properties of motorcyclist impact padding (MIP), including its elasticity and flexibility, provides a larger surface of contact with the motorcyclist's body and a physical barrier (in this case for the guard rail post), and in this way reduced pressure or force being exercised on the motorcyclist's body upon impact with the MIP.

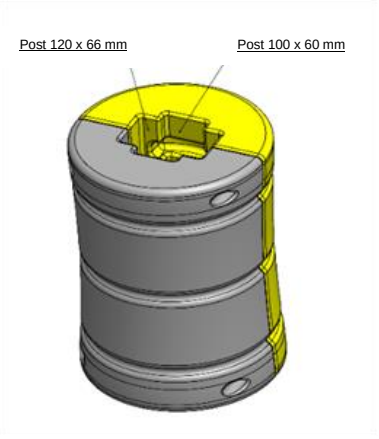
Its effect is achieved through the following properties:

- the material and the structural design ensure less rigidity than metal, and thereby greater elasticity and also plastic crumpling of the MIP upon impact;
- it has no sharp external edges and the largest possible radii of curvature within the geometric constraints dictated by the guard rail, and in relation to parts of the human body;
- MIP does not break apart upon impact (no hard or sharp edges);
- it can also be designed as a shell structure or vessel filled with air or liquid which, upon impact, is released in a controlled manner from the vessel via appropriate valves.

MIP is most commonly installed on the posts of steel guard rails (SGR).

MIP is placed on already installed or newly envisaged guard rails, if they meet the conditions stated in chapter 2 of these guidelines, and if for justified reasons it is not possible to install motorcyclist protection barriers.





Figures 5, 6 and 7: Protection of steel guard rail post with MIP, single-section (left) and two-section (right); [3, 4].

The basic vertical profile of the MIP (Table 1) is an undulating design with the typical size of the outside diameter (*D*), total length (*L*) and a hole in the axis of the external roll. It must be engineered so that it can be installed on the guard rail (GR) posts without interfering with already installed devices.

Table 1: Typical dimensions of MIP

Description	***Designation***	***Size***	***Note***
Outside diameter	*D* [mm]	250 to 300	*several types or diameters possible*
Length (height)	*L* [mm]	360 to 400	*several types or lengths possible*
Cross-section of SGR posts	*a* x *b* [mm]	120 x 66 100 x 60	*the hole in the MIP should not be smaller*

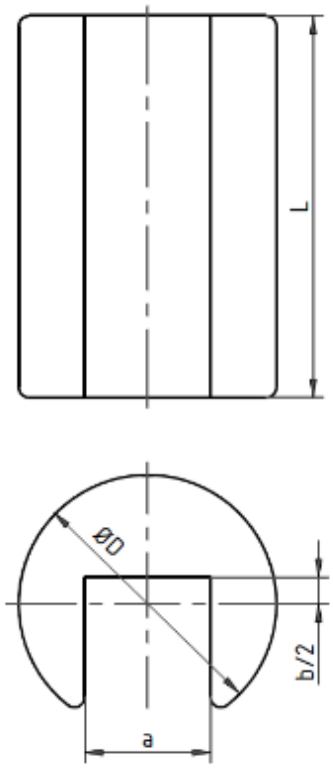


Figure 8: Vertical shape and dimensions of MIP for SGR posts

MIP should have an outside diameter of at least 250 mm, and its height must stretch from the arranged verge to the lower edge of the rail shield. In order to prevent the possibility of contact between human extremities and the SGR post, the gap between the arranged verge and lower edge of the MIP and between the lower edge of the SGR shield and the upper edge of the MIP should be no more than 40 mm.

The MIP can be single-section or two-section or even multi-section (divided). If fastening elements are used in installation, they must be hidden below the external surface of the MIP, so that they do not injure the motorcyclist upon impact and crumpling.

The manufacturer will specify the method of installing and maintaining the MIP.

4.2. Method of installation and maintenance

Before installing the MIP, the verge must be arranged in line with the prescribed maintenance conditions. All vegetation must be removed from the verge and a shoulder line drawn out, if the carriageway width suffices.

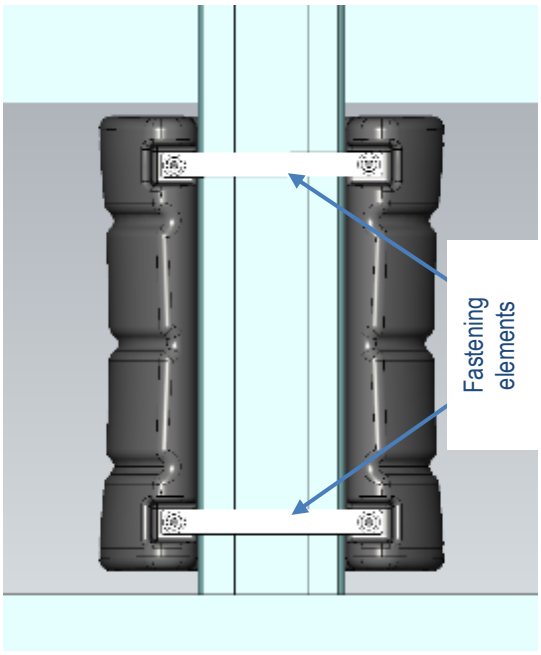
Figure 9: Properly installed MIP on a SGR post (source: B. Matko and U. Brumec).

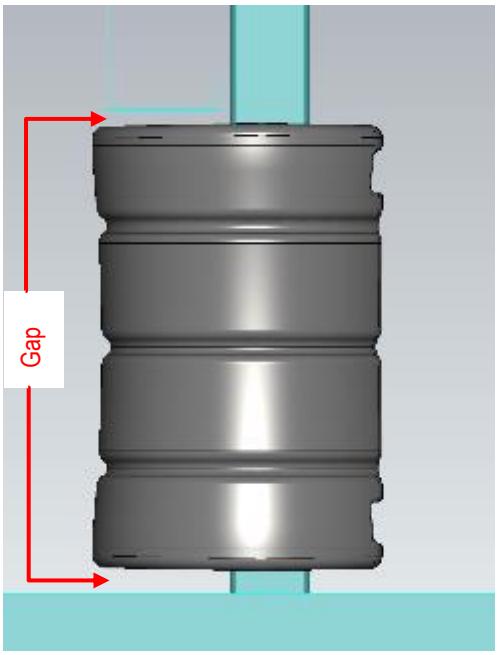
Figure 10: Properly installed MIP on a SGR post (source: B. Matko and U. Brumec).

Single-section MIP is installed on an existing SGR post and the manufacturer secures it with the prescribed fastening elements (bindings, bolts, nuts, washers, protective covering) that

prevent rotation on the post and parts or the entire MIP from falling off. Here checks should be conducted to ensure that fastening elements do not protrude from the external surface of the MIP and that upon impact they cannot cause any additional injury to the motorcyclist.

During installation it is essential to prevent the possibility of human extremities coming into contact with the SGR post. For this reason, the gap between the verge and lower edge of the MIP and between the lower edge of the SGR shield and the upper edge of the MIP should be no more than 40 mm. Since the length of the MIP is shorter than the length between the verge and lower edge of the SGR shielding, the larger gap should be at the top.





Figures 11 and 12: Installation of single-section MIP made of HDPE on a SGR post; [3, 4].

On installation it should be checked whether the fasteners have been used in accordance with the manufacturer's instructions and whether all the constituent parts have been shielded underneath the outer shell of the MIP.

The MIP must be included in regular inspections and maintenance of the road infrastructure. Here it is essential to check:

- the degree of deformation and damage to MIP resulting from mechanical effects (impacts);
- the degree of ageing, which can contribute to possible deformation and the appearance of tears and cracks in the MIP.

MIP should be removed and replaced with new padding when it is observed that:

- upon crumpling, major damage and open cracks have appeared in the MIP, presenting new sharp edges on the MIP;
- fastening elements are damaged or fallen off and they cannot be replaced with new ones.

5. PASSIVE SAFETY POLES TO INDICATE CURVE DIRECTION AND JUNCTIONS

5.1. Conditions of installation

Passive safety poles (PSP) are installed where:

- in the event of impact with a motorcyclist the installation of guard rails would cause greater harm than if there were no guard rail;
- in the event of impact with a motorcyclist the installation of traffic signs 3312 and 3312-2 with or without a guard rail would cause greater harm than if they had not been installed;
- the carriageway has a large-radius blind curve;
- junctions are not easily visible.

PSP are set up on the shoulder or verge of the carriageway to indicate the flow of the road and/or draw attention to possible danger. They are set up on the outer side of the curve at regular intervals depending on the radius of the curve (Table 2) and are white.

Table 2: Intervals between PSP

Radius of curve R [m]	20	30	40	50	60	70	80	90	100	200	300	400
Intervals between poles [m]	4	4	4	4	4	8	8	8	8	12	12	16

Passive safety poles (PSP) are manufactured from appropriate materials, and are of the appropriate shape and size, offering less rigidity of the pole, a greater area of contact between the PSP and the motorcyclist's body parts and, in this way, they offer reduced pressure or local force being exerted on parts of the motorcyclist's body upon impact.

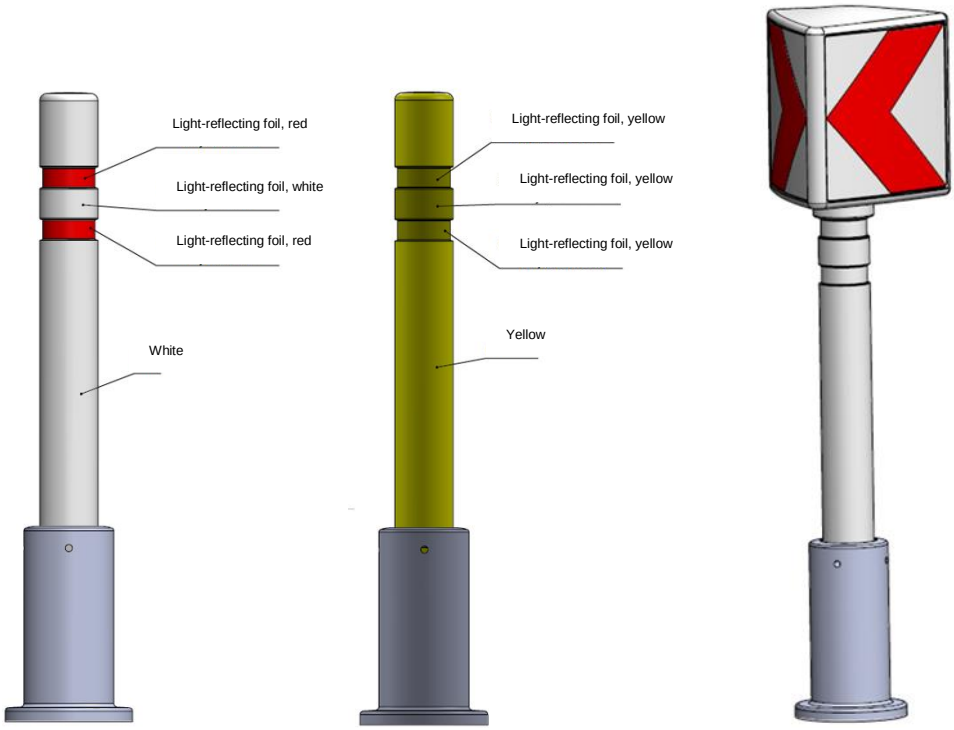


Figure 13: Passive safety poles (PSP) made of HDPE intended for insertion into the ground using a base for easier replacement of the PSP; [5].

PSP are effective due to the following properties:

- they are made of materials and designed structurally so that they have less rigidity than metal and thereby offer greater elasticity (temporarily) and also plastic deformation upon impact;
- they are designed so that above the line of the ground they have no sharp external edges and their surfaces have the largest possible radii of curvature within the geometric constraints and in relation to parts of the human body;
- upon impact they do not break or become damaged leaving hard, sharp edges.

PSP must meet the requirements of standard SIST EN 12899-3 Delineator posts and retroreflectors [6], they must be clearly visible in daytime (design and colour) and must enable the installation of specific additional traffic signs and equipment (reflectors and signs). The dimensions and the tolerances of the dimensions, as well as the colours of the poles and reflectors depend on the contracting authority's requirements. The light-reflecting surface of PSP must fulfil the properties of class RA2.

Since each PSP represents a potential major point trauma if a motorcyclist falls or slides, they must be installed so as to minimise the danger as much as possible or below a certain critical level, in accordance with the technical specification SIST TS 17342 Road restraint systems - Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers. This is achieved by having poles of the appropriate diameter (as big as possible) and made of material that offers greater elasticity (temporarily) and plastic (permanent) deformation in the event of impact, meaning less rigidity of the poles. At the same time the PSP must withstand normal environmental exposure (wind, snow being ploughed, temperature changes and so forth) without any major permanent deformation.

PSP may conform to the following types:

- single-section PSP, made as the shell of a hollow structure from polymers (HDPE – High Density Polyethylene);
- other types of PSP made of related materials using appropriate technology with similar material and functional properties.

The basic vertical profile of the PSP (Table 3) is a roll or tube shape with a typical dimension of the outside diameter (*D*), total length (*L*) and appropriate thickness of the pole wall (*s*), which ensure adequate rigidity and flexibility upon impact in terms of mechanical hardness and other mechanical parameters of the pole material (HDPE or other polymer material).

The pole is closed at the top. On the bottom it is suitable for installation in the base, which is embedded in the earth. The PSP manufacturer prescribes the method of installation and maintenance.

PSP are made of HDPE and must have an outside diameter of 160 mm and length of 1700 mm. They must extend vertically from the ground or from the verge 1,200 mm in height, or with an additional traffic sign for directing traffic flow, 1,500 mm in height.

Table 3: Typical dimensions of PSP in Slovenia

Description	***Designation***	***Size (mm)***
Outside diameter	*D*	160
Length of pole	*L*	1,700
Height of pole above carriageway	*H*	1,200
Total height above carriageway with additional traffic sign for directing traffic flow	*H1*	1,500

Figure 14: Passive safety poles on a curve (source: T. Tollazzi).

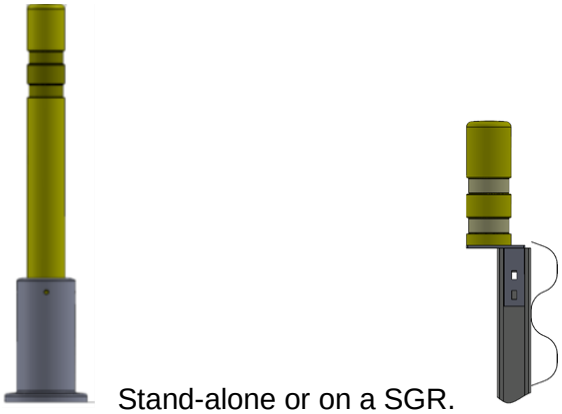
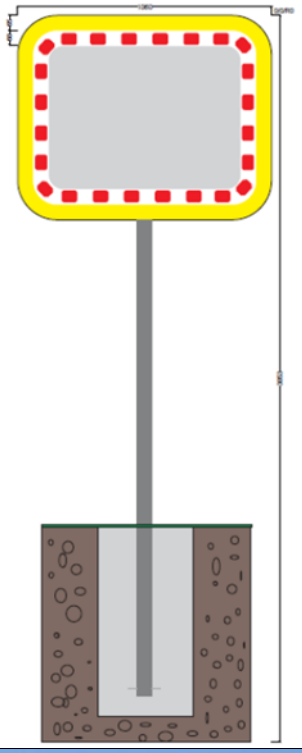
5.2. Conditions of installation at junctions

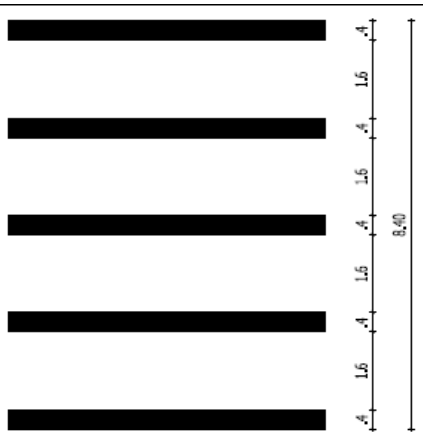
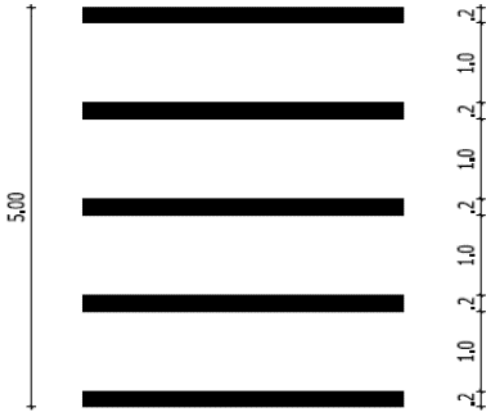
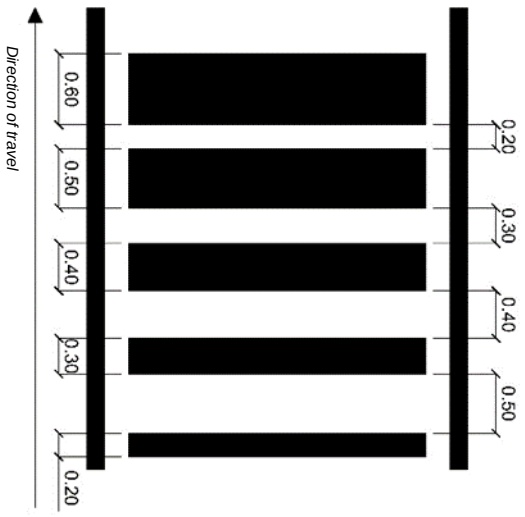
PSP are placed at junctions in cases where the conditions are not met for installing traffic sign 1103 or where the junction is not perceived (junctions not clearly visible).

Passive safety poles at junctions are yellow and conform to the dimensions in Table 3.

Figure 15: Passive safety poles at a junction (source: T. Tollazzi).

Where clear visibility is not guaranteed, one of the sets of possible solutions can be used to indicate an unseen junction.

In the case of a junction that is not clearly visible, it is usually indicated with yellow passive safety poles.	 Stand-alone or on a SGR.
Fluorescent yellow-green border on a traffic mirror, mainly where the traffic mirror cannot be clearly seen from a distance. This serves to increase the visibility of the mirror and junction, and thereby to modify the actions and attention of the motorcyclist.	
Display of junctions on traffic signs (1103-X and 1104-X) and where needed additional fluorescent yellow-green border for greater visibility of the junction.	

Traffic signs 1103-X and 1104-X with additional appropriate ground signage 5601, but not on a curve. To reduce the risk of skidding (smaller skidding surface) the installation of the “danger” symbol in white on the road surface is suggested.	
Optical brakes* (not on a curve)	
Sound brakes* (not on a curve)	
Short version of the optical brake where space is limited, but not on a curve.	

Concentration of direction signs.	According to the principle: 50 – 25 – 12 – 6 – 3 m.
As an ultimate measure there is the possibility of a speed limit: “prohibition and limit sign” in combination with the above measures to make the limit credible. An addition to the speed limit sign 2232-X, appropriate ground signage 5602 is suggested, but not on a curve. To reduce the risk of skidding (smaller skidding surface) the installation of the “prohibition and limit” symbol in white on the road surface is suggested.	

* Where visibility is not guaranteed, optical or sound speed reduction warnings can be installed instead of PSP for greater motorcyclist safety. Optical and sound brakes must always be installed at an appropriate distance from the junction and on a straight section of road or transition curve, but never on a curve.

Where it is not possible to place optical or sound brakes on public roads outside settlements in accordance with TSC 03.800:2009, it is also possible to install a “shortened version of the brake”, with or without extension (Figures 16 and 17), for the purpose of increasing motorcyclist safety.

OPTICAL BRAKE DIAGRAM

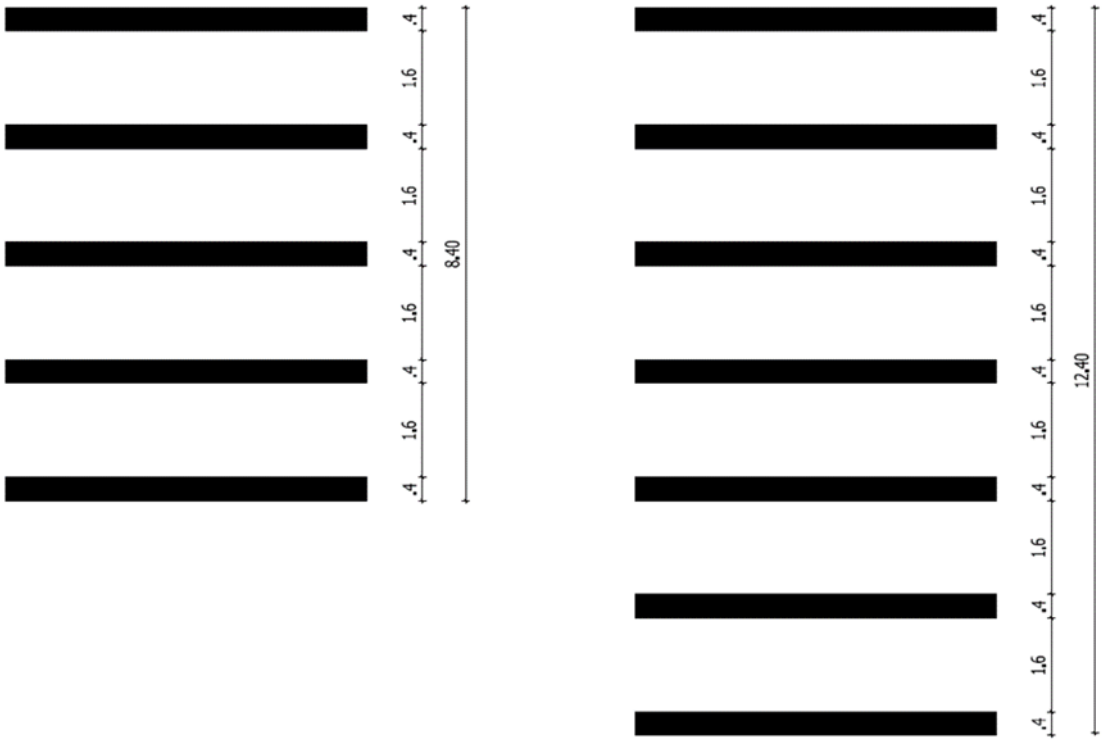


Figure 16: Shortened version of optical brake, left: without extension, right: with extension.

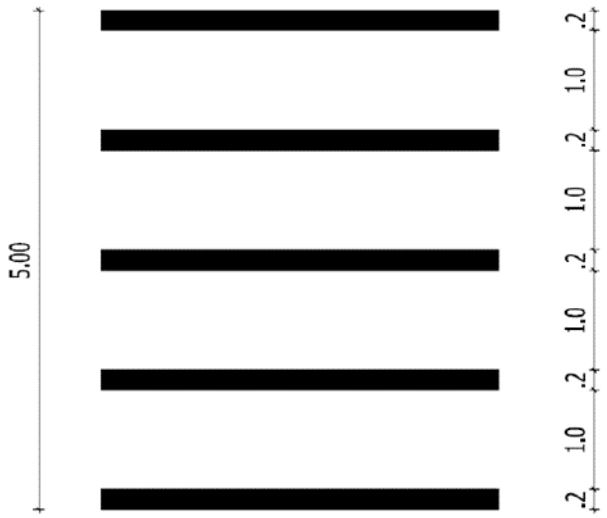


Figure 17: Shortened version of sound brake; where necessary it can also be extended in the same way as for the optical brakes.

5.3. Method of installation and maintenance

Passive safety poles (PSP) of appropriate type and nominal size are set up at the location of road curves under the conditions outlined in the previous chapter.

PSP are set up on the outer side of the curves, or on the side of the route that is the result of vectors of speed of the motorcyclist and the vector of centrifugal speed in the event of a skid.

Before setting up the PSP, the level of the verges is arranged relative to the level of the carriageway, and vegetation is cleared from the direct vicinity of the PSP.

PSP are set up:

- along the entire length of the arc of a curve and adjoining transition curves or
- if no transition curves have been provided, at least along a length of R/10 at the beginning and R/10 at the end of the curve, where the individual length may not be less than 10 m;
- at intervals according to Table 2.

PSP are installed by embedding into the earth of the verge, which must be arranged in advance relative to the carriageway in such a manner that the outer rim of the pole is set 750 mm away from the edge of the carriageway (Figures 18 and 19). In exceptions the distance of the outer rim of the pole from the edge of the carriageway may be 500 mm.

The edge of a traffic sign affixed at the top of a PSP must be at a distance of at least 750 mm from the edge of the carriageway (Figures 20 and 21).

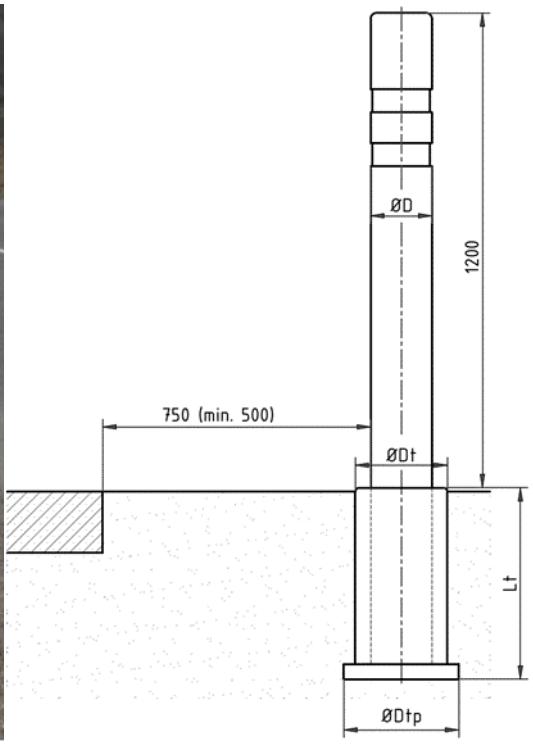
PSP must be included in regular inspections and maintenance of the road infrastructure. Here the following should be checked:

- the degree of deformation and damage to the PSP resulting from mechanical effects (impacts);
- the degree of ageing, which can contribute to possible deformation and the appearance of tears and cracks.

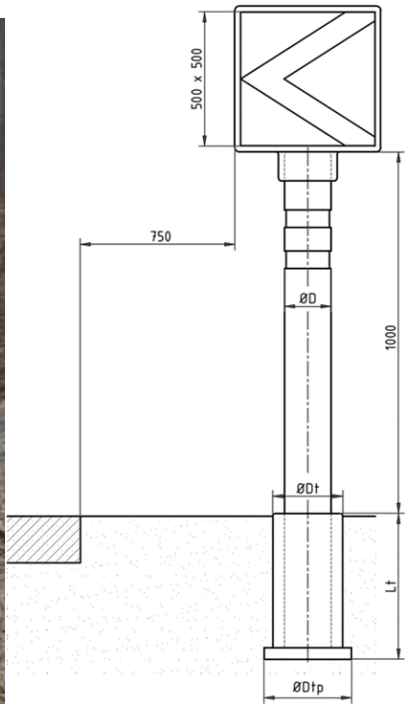
PSP should be removed and replaced with new ones if upon deformation large open cracks or damage to PSP parts have appeared, presenting new sharp edges on the PSP.

Special attention is paid to cleaning the PSP since exhaust gases and detritus on the road can significantly reduce their visibility.

In areas with abundant vegetation, it makes sense also to install weed protection, to prevent grass growing around the PSP.



Figures 18 and 19: Distance of outer rim of PSP from edge of carriageway in the case of PSP without additional traffic sign



Figures 20 and 21: Distance of outer rim of PSP from edge of carriageway with additional traffic sign 3312 (source: R. Strah).

6. GUIDING AND ADDITIONAL INFORMATION FOR MOTORCYCLISTS ON SECTIONS OF OPEN ROAD OUTSIDE SETTLEMENTS USING TRAFFIC SIGNALS AND EQUIPMENT

6.1. Explanation of the need for additional guidance and information for motorcyclists

The results of foreign and domestic research indicate [7–13] that the actions of motorcyclists (i.e. human behaviour) on the road differ from the behaviour of those driving other motor vehicles. The very same person will behave differently (and while driving will fix on different points) when they ride a motorcycle as compared to when they drive a car.

Even the "gaze behaviour" of the motorcyclist (points on which they fix their gaze) differs from that of drivers of other motor vehicles. The average car driver looks at a point on the road that is considerably closer than the point looked at by the average motorcyclist. We say that the driver of a two-track vehicle observes the middle line, while the motorcyclist looks ahead to the next curve or to the most distant point along the road that they can see. For this reason, motorcyclists pay greater attention to the road, and less to their surroundings.

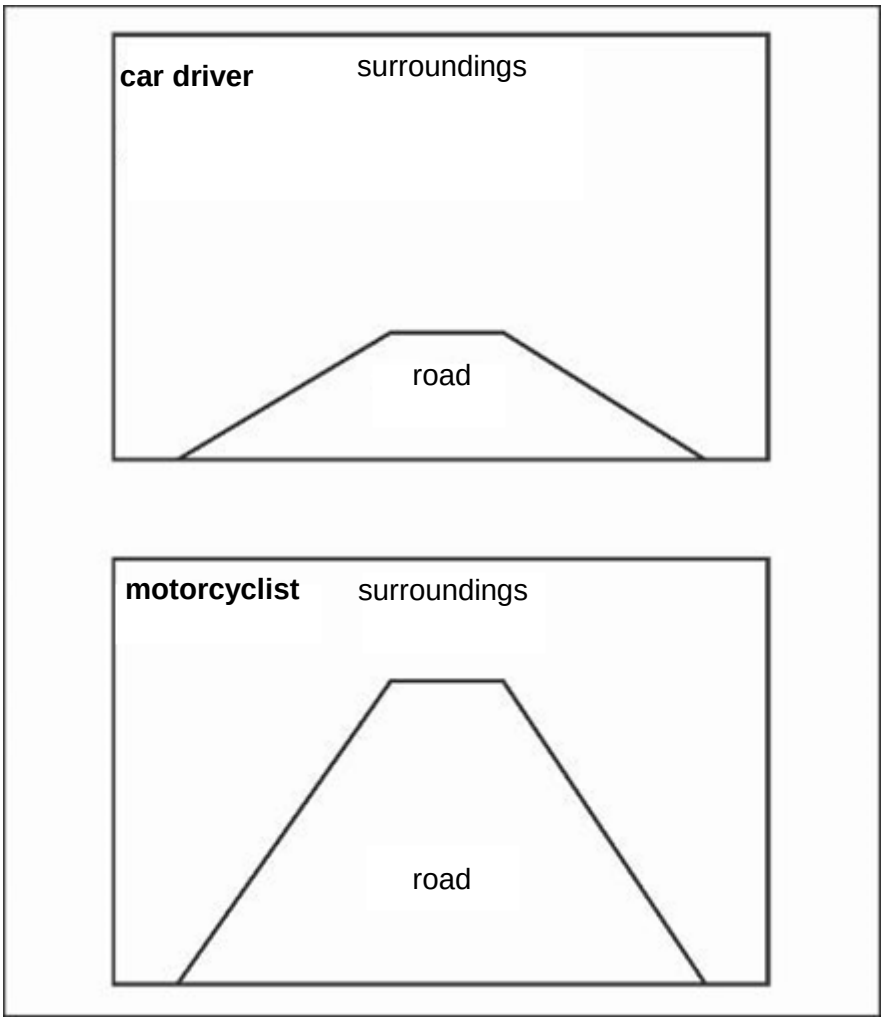


Figure 22: Gaze behaviour of car driver and motorcyclist [2]

The differing gazes of the car driver and motorcyclist are also affected by the type of motorcycle helmet (Fig. 23), but for construction and transport experts in the field of designing, equipping and maintaining roads this is less important, since it involves insignificant differences.

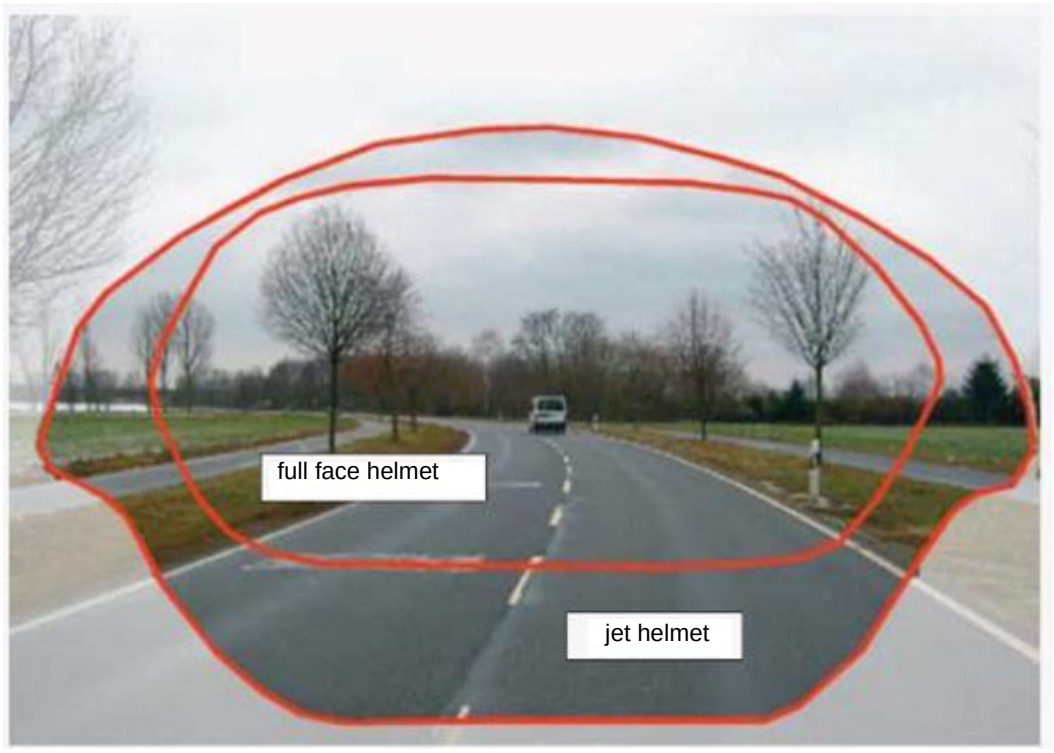


Figure 23: Field of vision of motorcyclist depending on type of helmet; jet helmet – no lower jaw protection, full face helmet – lower jaw protection [2]

The difference in how objects are fixed in the gaze depends on the traffic situation (speed limit, open road without or with tunnel or crossroad with a priority road, crossroad with traffic lights, roundabout). Although motorcyclists fall within the group of vulnerable road users and should therefore pay the greatest attention to traffic flow and other (heavier) motor vehicles, foreign research indicates that motorcyclists pay most attention to the carriageway and roadside.

Such prevalent focus is completely understandable, since the greatest danger for motorcyclists lies right there in the carriageway and on the narrow shoulder of the roadside.

The reasons or dangers in the increased focus of motorcyclists on the carriageway lie in the mutual influence of motorcyclists on each other and with other motorised road users, the evenness of the carriageway, grip of the road surface, potholes, cracks on the surface, dust and sand, ruts in the road, sediments, objects that have fallen off vehicles and other obstacles, animals on the road, liquid spills, aquaplaning, unexpected changes in the quality of the carriageway, sub-standard patching and similar.

The causes or dangers of increased focus of motorcyclists on the roadside are tied to the existence of roadsides without safety barriers, poorly maintained verges, dangerous elements for longitudinal drainage, the possibility of collision with a dangerous object on the roadside, impacts with unprotected safety barriers and other.

In view of the above it is quite obvious that guiding or providing information for motorcyclists through traffic signalling (especially with ground markings) and traffic equipment are extremely important for ensuring their safety in traffic on open roads outside settlements.

6.2. Some possible methods of guiding and additional information through traffic signalling and equipment

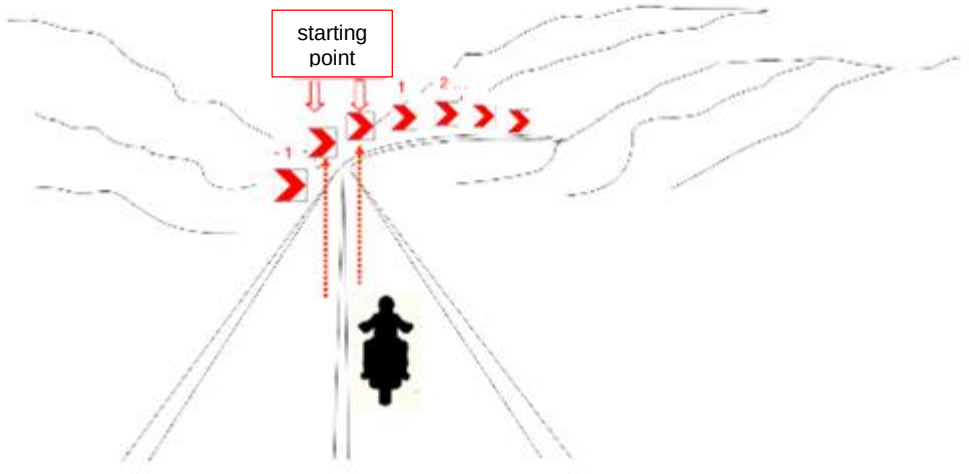


Figure 24: Concept of setting up traffic signs 3312 for guiding traffic on bends (Source: DRI, d.o.o.)

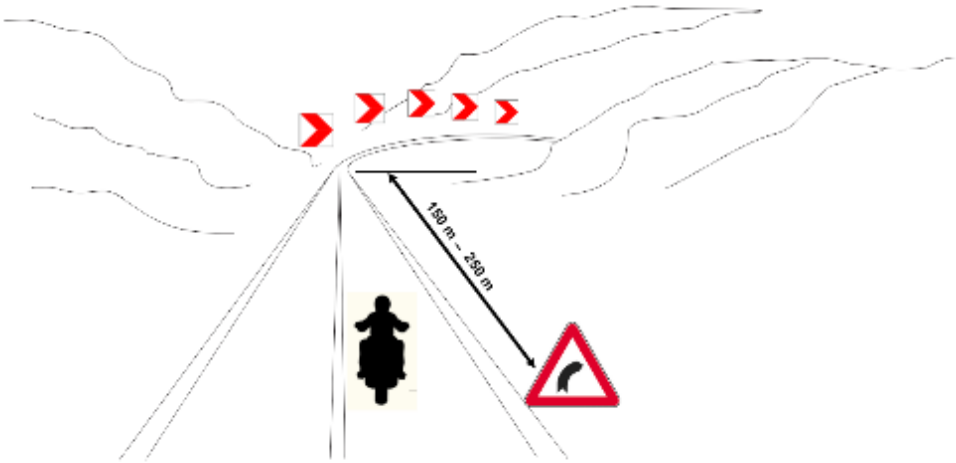


Figure 25: Concept of setting up traffic signs for guiding traffic on bends (Source: DRI, d.o.o.)

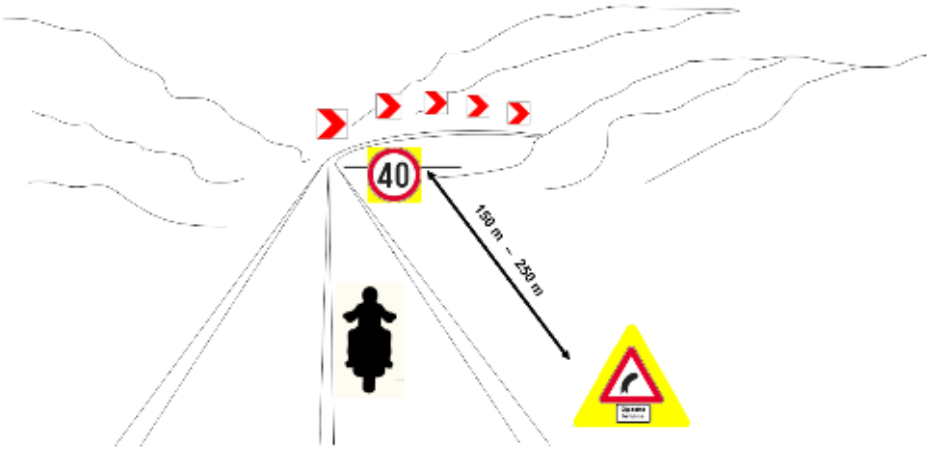


Figure 26: Concept of setting up traffic signs for guiding traffic on bends (Source: DRI, d.o.o.)

Figures 27 and 28: Increased visibility of bend at night: red-white strips for guiding on bends in combination with SGR with additional motorcyclist protection and double-sided 3312 signs for guiding traffic on bends (Source: U. Brumec)

Figure 29: Execution of embankment along a curve with green cover, aimed at better guidance of motorcyclists through the curve (Source: World Road Association – PIARC: Road Safety Manual)

6.3. Some examples of combinations of elements for guiding traffic in curves with road equipment

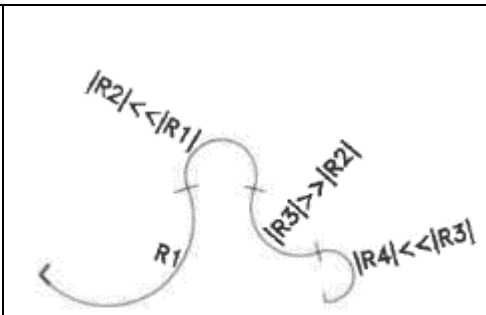
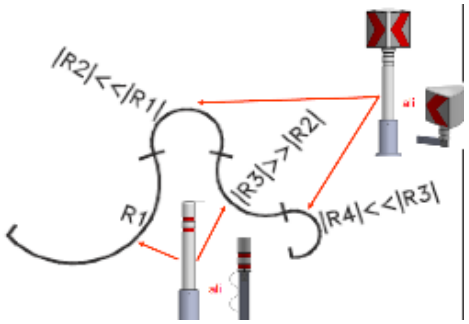
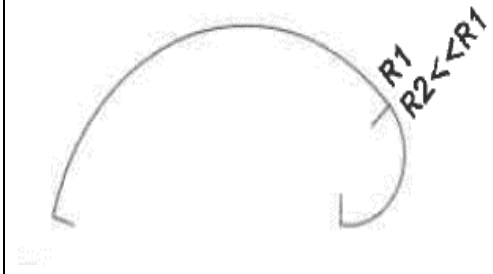
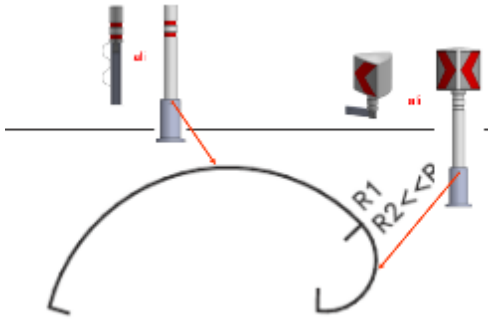
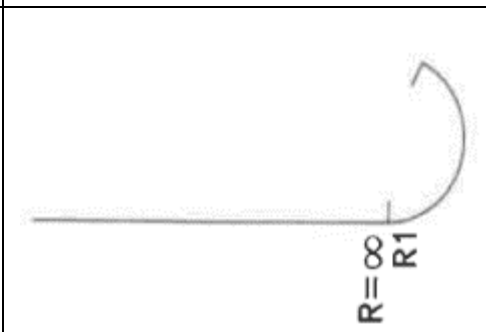
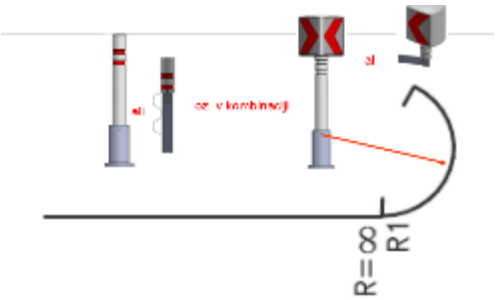
sequence of curves of differing radii		
compound curve		
curve after long straight stretch		

Figure 30: Examples of combinations for guiding through curves. The combination depends on visibility into the curve and on features of the curve (potential "surprises" awaiting the motorcyclist). Where there is no need to install SGR, only directional passive safety poles are installed and/or double-sided signs for guiding traffic in bends on passive safety poles (Source: U. Brumec)

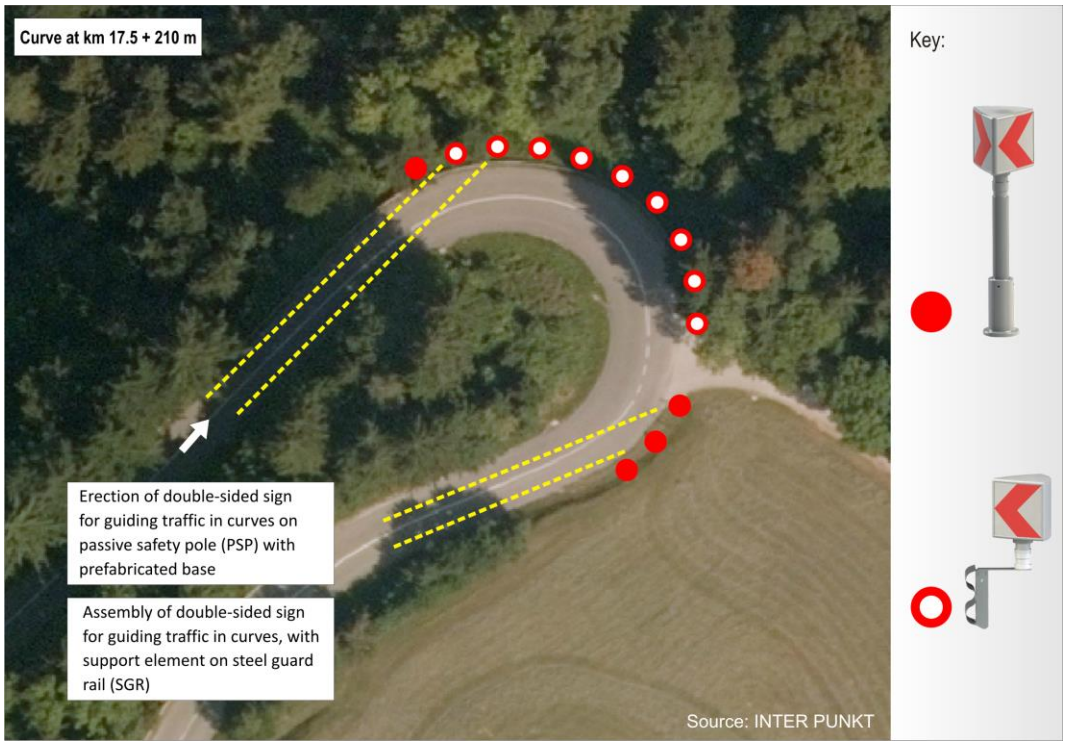


Figure 31: Example of determining the location of double-sided signs for guiding traffic in curves on passive safety poles (PSP) with prefabricated bases, and double-sided signs for guiding traffic in curves with support elements for assembly on steel guard rail (Source: INTER PUNKT d.o.o.).

Figure 32: Example of determining the locations of white directional passive safety poles (PSP) with prefabricated bases, and of white directional poles with support elements for assembly on steel guard rail (Source: INTER PUNKT d.o.o.).

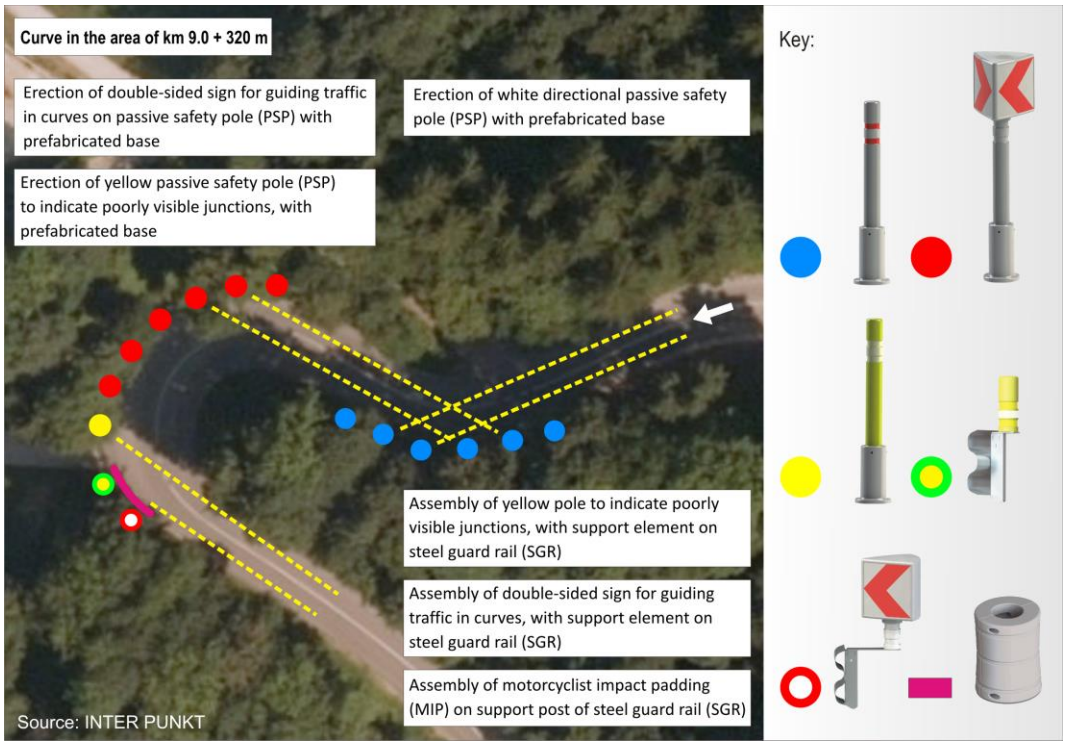


Figure 33: Example of determining the location of white directional passive safety poles (PSP) with prefabricated bases, double-sided signs for guiding traffic in curves on passive safety poles (PSP) with prefabricated bases, yellow passive safety pole (PSP) with prefabricated base to indicate poorly visible junction and yellow pole to indicate poorly visible junction with support element for assembly on steel guard rail, double-sided sign for guiding traffic in curves with support element for assembly on steel guard rail and motorcyclist impact padding on steel guard rail support post (Source: INTER PUNKT d.o.o.).

7. EXAMPLES OF BEST AND BAD PRACTICES DURING EQUIPPING AND MAINTENANCE

This chapter does not intend to, nor can it, present all the situations and arrangements that might exist in an actual setting. The arrangement is indeed often determined by the roadside conditions, the available space, ownership of the surrounding land, configuration of the terrain, the type of earth along the roadside, the incline and length of excavated and embanked slopes, the distance of dangerous fixed objects, rivers and streams, the existence of individual junctions and forest tracks and by the funds available to the road manager.

The roadside area is especially important for the safety of motorcyclists, since it affects the seriousness of the consequences when a motorcyclist leaves the carriageway. The general approach is shown in the table below:

IDENTIFICATION OF DANGER			
REMOVE DANGER	MOVE DANGER	PROTECT FROM DANGER	INDICATE DANGER

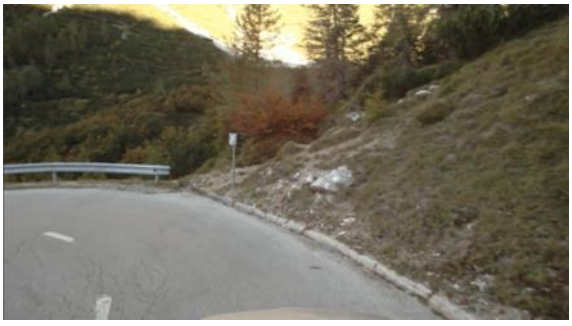
First, we need to identify the danger or the dangerous roadside element. The best thing is to remove it, but often this is not feasible. If the removal of a dangerous element is not possible, we check to see whether the element can be moved or shifted away from the roadside. If that too is not possible, we protect the dangerous element, to prevent a motorcyclist colliding with a rigid physical obstacle. If none of the above are feasible, the dangerous element is additionally indicated.

Regardless of the fact that this chapter cannot show all the situations and arrangements that might exist in an actual setting, we set out below some of the most common and most obvious examples as defined by the results of foreign research and practices in Slovenia and abroad.

Figure 33: Example of best practice with appropriate indication of curve and junction with other safety elements for motorcyclists (source: R. Strah).

7.1. Installation stage

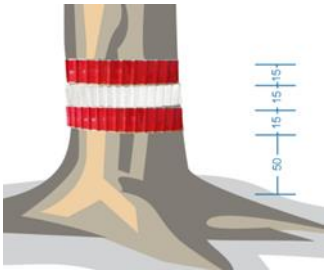
The selection of appropriate elements for equipping roads is vitally important in ensuring safety for motorcyclists on the road. Road equipment elements are generally adapted to the needs of cars and other two-track vehicles, while certain equipment elements can in fact be dangerous for motorcyclists.

➢ **Ensuring adequate visibility** is vitally important for safe motorcycle riding through a curve, since motorcyclists cannot brake hard on a curve.	 A berm offering adequate visibility must be ensured at the design stage, especially on sharp and isolated curves. The same is true of already installed road infrastructure. If this is not feasible, a curve with poor visibility should be appropriately indicated and protected in accordance with the guidelines for motorcyclist safety.
➢ **A lack of additional protection for motorcyclists on SGR on sharp and isolated curves** is a major danger for motorcyclists in the event of them losing control of the motorcycle and skidding out of the curve.	 In such cases the roadside is dangerous, so additional protection for motorcyclists needs to be installed on the SGR in accordance with the guidelines for motorcyclist safety.
➢ **Providing guard rails with an adequate level of maintenance and appropriate length and end treatment** – guard rails that are too short and “windows” in barriers or walls are very dangerous for motorcyclists.	

	  In such cases the barriers should be appropriately extended, and “windows” closed with SGR featuring additional motorcyclist protection.
➢ **SGR end treatments are not installed under the principle of passivity and safety** and represent a danger to motorcyclists.	  The SGR end treatment elements must be curved and must have safety features.

- **Dangerous elements of longitudinal drainage** pose a great danger to motorcyclists if they lose control of their motorcycle.

Solutions for demonstrated dangerous places:
– between junctions, concrete pipes are installed in the channels and covered with gravel up to the level of the verge;
– at the ends grates are installed in an incline of H : L = 1 : 5.

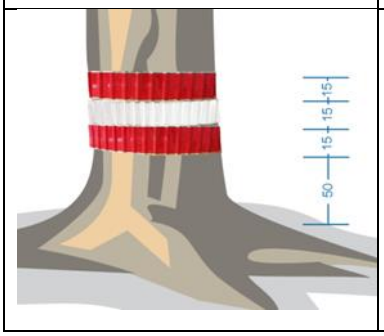
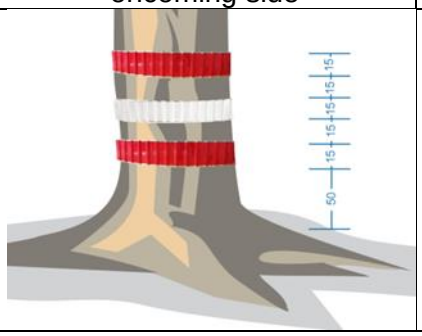
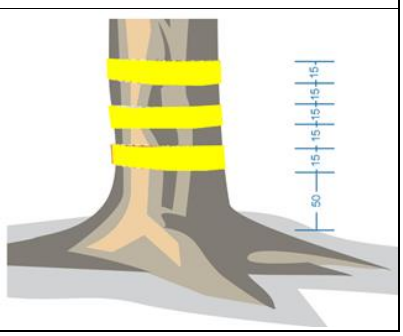
	 Distance between grates is ≤ 5 cm.
➢ **Dangerous elements along the roadside** pose a great danger to motorcyclists.	 If dangerous elements on the side of the road cannot be removed, moved or protected, they should be visibly marked. The marking of trees lining a road is shown in detail at the end of the table (Figures 33 and 34).
➢ **Stand-alone traffic signs 3312 and 3312-2** without SGR and additional motorcyclist protection in front of signposts are a major danger for motorcyclists in the event of skidding on a bend.	 Along a dangerous roadside, SGR with additional protection for motorcyclists is installed. Double-sided 3312 traffic signs for directing traffic on bends are installed on SGR or on special poles at an adequate distance from the SGR, as determined by the operational width of the SGR.

If the carriageway is secured with a guard rail, the horizontal distance between the rail and the closest point of the traffic sign must be the same as the width of the guard rail (Article 9 of the Rules on traffic signalling and traffic equipment on roads).

Along a safe roadside there is no need to install a guard rail. It is sufficient to install PSP with or without double-sided traffic signs 3312 for guiding traffic on bends.

Detailed explanation of concept of marking lines of trees and protected trees

Lines of trees and protected tree along the side of a road are among the dangerous elements which as a rule cannot be removed, moved or protected. For this reason, they should be additionally and visibly marked in a way that does not damage the tree.

on open section of road	in area of junction on the oncoming side	at a junction
		

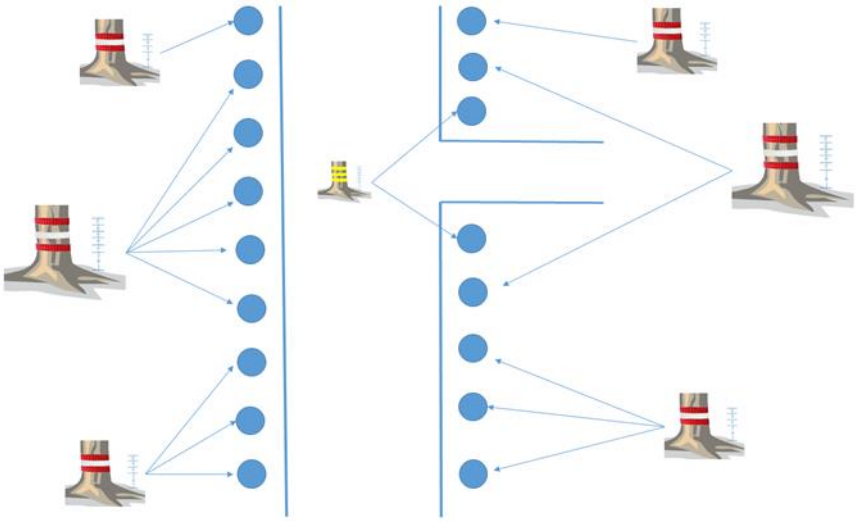


Figure 33: Method of marking line of trees and junction (Source: U. Brumec)

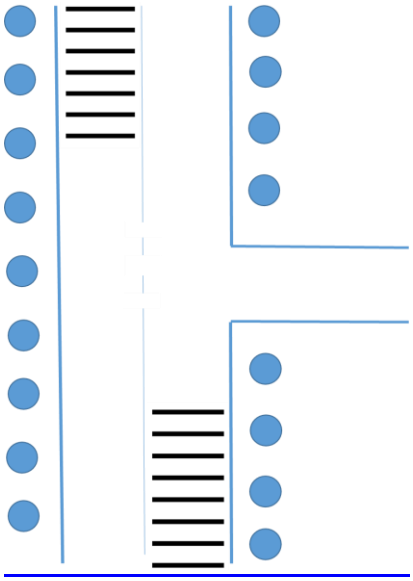


Figure 34: Method of marking line of trees with additional optical brakes for warning of non-visible junction (Source: U. Brumec)

7.2. Maintenance stage

Regular maintenance of roads is vital for motorcyclist safety. Despite the fact that a road has been properly designed and road equipment elements have been carefully selected, with use of the road certain danger spots can arise for motorcyclists.

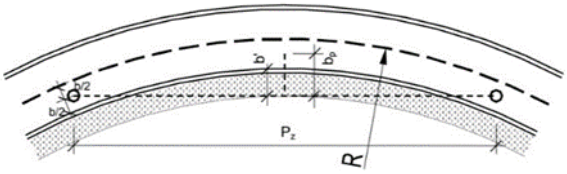
- **Reduced visibility** (due to vegetation)

We must aim to ensure visibility, despite the fact that this often encroaches on private land.

The Rules on the regular maintenance of public roads (Official Gazette of the Republic of Slovenia, No. 38/16) provide that regular maintenance works include regular control of vegetation, and that the visibility service must ensure the cutting and trimming of plant matter to ensure the visibility of traffic signs in the strip along the carriageway intended for the installation of traffic signs and in the field of visibility and visibility berms.

Horizontal visibility is defined in the Rules on road design (Official Gazette of the Republic of Slovenia, Nos. 91/05, 26/06, 109/10 – ZCes-1 and 36/18). This derives from the minimum stopping distance, defined as a function of the design speed and the incline of the road gradient.

The width of visibility berms along the right side of the carriageway is determined by the line of unobstructed view from the eye-view of a driver in the middle of the driving lane at a height of 1.0 m above the carriageway for the length of the stopping distance.



$$b_p = \frac{P_z^2}{8 \cdot R}$$

$$b' = b_p - \frac{b}{2}$$

In areas with high vegetation and where there is forest right by the road, additional expansion of visibility berms is envisaged by at least 1.0 m.

- **Improper repair of cracks** does not pose any danger for two-track vehicles, but represents a danger for motorcyclists if the repairs are done on a curve. This is a very dangerous and unexpected situation for the motorcyclist, since bituminised lines of cracks offer significantly less grip than the road surface. Bituminised lines of cracks are especially dangerous with a wet road surface.

Bituminising of lines of cracks must immediately be followed by spreading of crushed quartz (fractions of 0.3-1.2 mm) and not rock dust, since the latter does not ensure adequate grip.

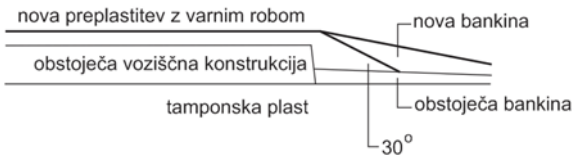
- **Improper patching of carriageway (constant changes to the state of the road surface)** represents a major danger for motorcyclists due to the changing grip on curves.

(Source: J. Cezar)

Patches must be rectangular in shape and with sides parallel and rectangular to the axis of the road and at the same level as the non-repaired road surface.

Equally it is desirable for patches to be made across the entire carriageway, since otherwise the grip under the left and right wheels of two-track vehicles differs.

➢ **The edge of resurfacing in the middle of a curve** is extremely dangerous for motorcyclists, since the grip changes in the middle of the curve.	 Resurfacing should be performed over the entire length of the curve.
➢ **Road surface milling** is very dangerous for motorcyclists, since the front (steering) tyre on a motorcycle is narrow.	 *(Source: D. Sagadin)* The Rules on the regular maintenance of public roads (Official Gazette of the Republic of Slovenia, No. 38/16) provide that milling of smooth asphalt surfaces is a measure for *temporarily* increasing the friction capacity of the road surface and removal of a major unevenness. For this reason, milling should never be a long-term solution (asphalted 24 hours after repair or on the same day). Another option (temporary solution, until replacement of the top layer of the road construction) is improved friction though high-pressure cleaning. The third option is applying a thin top coating.
➢ **Height difference between the carriageway and verge ("tooth") and "sharp cut-off" on the shoulder**: a height difference between the carriageway and the verge of 5 cm or more causes loss of control of a motorcycle when the rider strays onto the verge or when over-correcting direction on returning from the verge to the carriageway. Another problem is caused by a sharply cut edge of the carriageway, which causes the angle on returning to the carriageway to be much greater than that moving from the carriageway to the verge, and this causes the motorcyclist to "ride" the edge of the carriageway. When the motorcyclist turns the front wheel to a sharp angle on returning to	

the carriageway, this can cause them to end up in the oncoming traffic lane (“slingshot effect”).	The Rules on the regular maintenance of public roads (Official Gazette of the Republic of Slovenia, No. 38/16) provide that verges must be regularly maintained so as not to endanger traffic. The Rules also provide that the inspection service must ensure the infilling of verges as part of regular maintenance. The Rules on the types of maintenance on public roads and the level of regular maintenance of public roads (Official Gazette of the Republic of Slovenia, Nos. 62/98, 109/10 – ZCes-1 and 38/16 – invalid regulation) provide that the height of the verge may not be more than 3 cm lower than the edge of the carriageway, and that the verge must be even and firm. A height difference between the carriageway and the verge arises generally in places with inappropriately constructed longitudinal drainage (precipitation water erodes the verge) and on small-radius curves without expansion of the carriageway (back wheel of a long vehicle close to the centre of the curve rides over the verge rather than the carriageway). This problem can be solved for instance by constructing a “safety shoulder” (at an angle of 30° instead of 90° during asphalting). The verges also need to be maintained. ***Safety shoulder***  More effective and durable measures are the installation of trapezoid grid plates on the inside of the curve and making asphalt/concrete verges.

nova preplastitev z varnim robom	new resurfacing with safety shoulder
obstoječa vozišćna konstrukcija	existing carriageway construction
tamponska plast	buffer layer
nova bankina	new verge
obstoječa bankina	existing verge

Trapezoid grid plates (Source: MAIBACH VuL GmbH)

- **Out-of-grade and slippery drain covers** are also a danger to motorcyclists on curves.

Drain collars (housing) are brought to the right level, and the drain covers themselves are replaced with anti-skid covers.

(Source: Vodotehnik, d.o.o.)

	 Installing special anti-skid drain covers (Source: Geveko Markings)

8. CONCLUSION

Motorcyclists fall within the group of vulnerable road users for numerous reasons. This has also been recognised by the European Commission, so in the amended version of Directive 2008/96 (Directive 2019/1936) motorcyclists are expressly classed in the group of vulnerable road users.

The popularity of motorcycles is growing continuously in Slovenia. A total of 85,802 single-track motorised vehicles were registered in 2010, and 126,317 in 2019. The biggest growth was in 2016 and 2017, mainly due to a change in the law and compulsory registration for power-assisted bicycles. Slovenia is showing an average 2.5% growth rate in registered single-track motorised vehicles.

Along with the growth in the number of motorcyclists on the roads, there is an increasing probability of their involvement in traffic accidents. Although in recent years the total number of traffic accidents has been falling in Slovenia, the number of accidents involving motorcyclists has been growing. As a proportion of the total number of injuries and fatalities in traffic accidents, the number of seriously injured and dead motorcyclists is significantly higher relative to their number in the breakdown of road users.

In the past, DRSI carried out a range of activities in the area of improving traffic safety for motorcyclists, but the majority of these activities were curative.

The present guidelines place Slovenia alongside seven countries that have adopted regulations and guidelines in the area of project design, equipping and maintaining roads for the greater safety of motorcyclists. The guidelines address the areas of equipping and maintaining roads and roadside areas for the greater safety of motorcyclists.

The guidelines address the implementation of various new features that have already been in use in places abroad for some time, and DRSI has been testing them and monitoring their effectiveness. The guidelines precisely define the conditions and methods of setting up safety equipment for motorcyclists, they present possible methods of guidance and additional information through traffic signalling and traffic equipment, and they also present examples of practices in Slovenia and abroad during the equipping and maintaining of roads. Attached to the guidelines is a list of motorcycle sections where additional measures are implemented for greater motorcyclist safety along an entire road section or just in dangerous or exposed places.

The guidelines were created in cooperation between two university faculties and with the active participation of the contracting authority DRSI (Uroš Brumec, mag. inž. prom.) and its engineer DRI, d.o.o.

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