

CETRA²⁰¹⁴

3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation



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Stjepan Lakušić

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THE NEED FOR SAFER AND FORGIVING ROADS

Florentina Alina Burlacu, Otilia Tarita-Cimpeanu, Mihai Dicu

Technical University of Civil Engineering Bucharest, Romania

Abstract

Improving road safety has been the key objective for road authorities worldwide for the last years. Lately, many concepts were adopted to reduce the number of fatalities, concepts like self-explaining roads, low cost measures or forgiving roads. As new research findings are published, differing theories evolve and road safety visions change. Nowadays, around 30% of accidents on the entire EU road network are caused by inadequate infrastructure. The way roads are laid out and designed can reduce the exposure to traffic of vulnerable road users, reduce the probability that crash and injury occur when these users are exposed and reduce the severity of injury if it occurs. Substantial and sustainable casualty reductions can be achieved in relatively short time and at relatively short cost by identifying and treating high risk infrastructure sites, creating safer and forgiving roads. The aim of this paper is to improve traffic safety by increasing the awareness of road authorities, in order for them to implement road safety measures following the concepts of forgiving roadsides and taking into consideration the human factors also.

Keywords: road safety, road elements, forgiving roads, traffic accidents

1 Introduction

More than 1.2 million people are killed on the road every year and more than 20 million are injured, according to a World Health Organization recent report. Despite the fact that 10% of the total accidents are single vehicle accidents (typically run-off-road accidents) the rate of these events increase up to 45% when only fatal accidents are considered, [1]. One of the key issues of this dramatic increase for the high rate of this type of accidents is the lack of forgiving roadsides. The forgivingness of the environment and of road users is defined as injury limitation through a forgiving road environment and in the meantime, an anticipation of road user behavior.

A forgiving road is defined as a road that is designed and built in such a way as to interfere with or block the development of driving errors, but also to avoid or mitigate negative consequences of driving errors, allowing the driver to regain control and either stop or return to the travel lane without injury or damage, [2].

A large number of research studies have been conducted in the past years, studies which contributed to the development of the road design standards for improving roadside design. They suggest [3] that the stages in any strategy for improving the siting and design of street equipment can be further developed and extended as follows:

Table 1 Main principles for forgiving roads.

Existing roads	Designed roads
Eliminating unnecessary obstacles	Designing roads without any dangerous street equipment problems
Moving obstacles further away from the roadside	Designing a clear zone at the side of the road
Modifying the structure of the obstacles	Designing street equipment to be more forgiving
Isolating certain obstacles with new and improved types of safety device	Protecting street equipment with a barrier to absorb some of the energy of the impact

To develop a forgiving road environment, certain characteristics must be included and measures should be taken, considering standard road safety measures, but also a practical tool for assessing the effectiveness of a roadside treatment, as can be seen further in this paper.

2 Standard road safety measures for forgiving roads

2.1 Roadside clear zones

A very frequent cause of traffic accidents is the existence of obstacles along the road, obstacles which don't forgive drivers mistakes. These walls, which were inadequate designed and built, modify the incidence of crashes. Their presence has two major implications regarding road safety: the danger of collision and the obstruction of visibility, Figure 1.

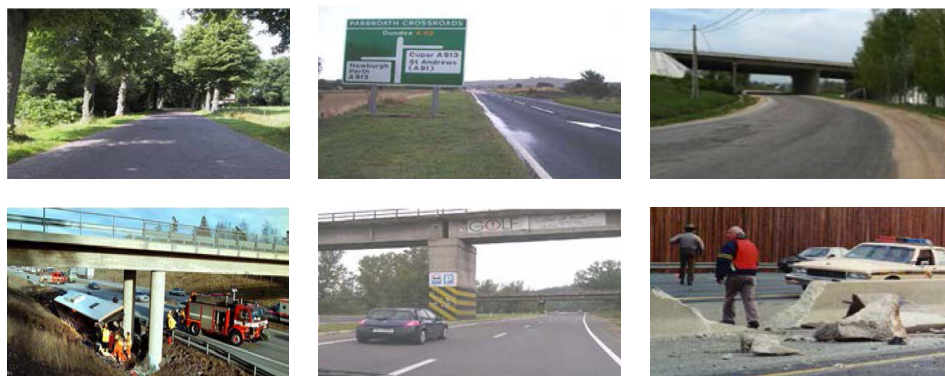


Figure 1 Unforgiving roadside environment [4]

The clear zone is a key safety concept used in road design, Figure 2. It represents the area that begins at the edge of each travelled lane and is available for emergency use by errant vehicles that run off the road. This zone includes any adjoining lane/s, road shoulders, verges and batters.

Generally, the width of the required clear zone increases as the design speed increases. On the basis of accident analysis in the Netherlands, the SWOV (Dutch Institute for Road Safety Research) has estimated that the minimum width of clear zones for three types of roads should be as follows [5]:

- 3.5 meters for single-lane regional highways;
- 7 meters for single-lane federal highways;
- 10 meters for motorways.

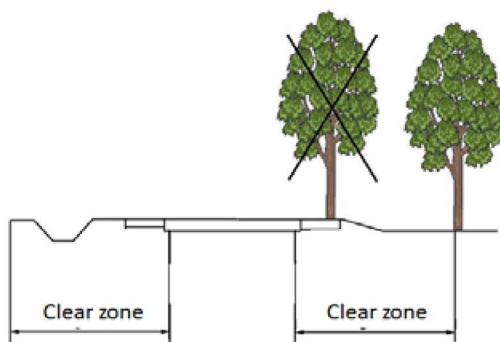


Figure 2 Roadside clear zone concept

The Clear Zone should be kept free of fixed, non-frangible hazards. It is not always possible, but all practical measures should be taken to provide this. Acceptable alternative options include safety barriers and physical measures to reduce travel speed. Less desirable alternatives include the use of narrower Clear Zones and compensatory measures such as delineation improvements.

2.2 Safe drainage structures

The drainage structures are an essential element of roads. They are designed to collect the pluvial water, but unfortunately they are very dangerous for road users. Because of the high water volume, they were designed very deep and with a high lateral slope of the walls, and in some cases they were even made of concrete, Figure 3.



Figure 3 Unsafe drainage structures

The development on new drainage systems which can cope with the expected amount of rainfall, yet don't create unsafe conditions for traffic users is not an easy task, but it is a necessary compromise. In developed countries, permeable drainage systems are commonly used in the proximity of roads, following the idea that they will be more dry than wet, even in areas with heavy rain. If the side of the trench is porous, evaporation is faster, and not just for the water seeped through the sides of the trench in the ground, but for any other type of infiltration. This is also a sensible ecological measure and it is called shallow green ditches. It has been discovered that most of the critical pollutions of the water from the road, such as oil and petrol will be destroyed by soil bacteria. For the case in which the water permeability of the soil is low, a subsurface piped solution is recommended.

Increasing the distance between the drain and the road will reduce the likelihood of a stray vehicle entering the drain and will provide room for pedestrians and other vulnerable road users away from motorised traffic, Figure 4. The ideal distance depends upon the usage of the road, but a typical recommended distance is 1.5 metres.



Figure 4 Safe drainage systems

2.3 Safe barrier systems

A barrier system is represented by a series of posts and cross beams, usually steel but sometimes concrete or wood, used to physically prevent vehicles passing a defined line, typically the edge of a road or the median line. Although larger vehicles may ride over barriers (Figure 5), they can be effective against the majority of motorized and non-motorized vehicles. However, the effectiveness of a barrier and indeed the danger that it may pose depend on how well it has been designed, located and installed.



Figure 5 Unsafe barrier systems

Safety barrier ends are usually considered hazardous when the termination is not properly anchored or ramped down in the ground or when it does not flare away from the carriageway. Crashes with “unprotected” safety barrier ends often “unforgiving” can result in a penetration of the passenger compartment with severe consequences.

Barrier systems should be used in areas where in case of a run off accident, the consequences of leaving the road by a vehicle would be much worse than if it would hit the parapet. The main role of the barrier systems is that they diminish the severity of a run-off-road accident when they are good designed and installed. For this to happen, they must have the property to absorb the shock of impact and prevent bouncing a vehicle back on the road just after a collision, as can be seen in the Figure 6.



Figure 6 Safe barrier systems with proper ends

The median barriers are designed to avoid front collision between vehicles travelling from opposite directions, but also they have an impact on pedestrians, as they encourage them to use safer areas to cross the road, Figure 7. A distinction needs to be made between the medians used to guide directional traffic management and those used for safety reasons. The second category must have a more solid construction, since their function is to divert vehicles tending to go over the median axis and absorb as much of the kinetic energy during the collision. To prevent the execution of u-turn maneuver on national roads with intense traffic, there have been installed on the median axis plastic barrier systems, in the colors red and white, filled with sand. Their presence on the roadway was properly marked with signs and road markings.



Figure 7 Safe median barriers

2.4 Rumble strips

Shoulder rumble strips have been proven to be a low cost and extremely effective treatment in reducing single vehicle run-off-road crashes and their severity, Figure 8.



Figure 8 Shoulder rumble strips

For rural freeways the Crash Modification Factor for the use of milled rumble strips has been estimated combining different studies in [1]:

- 0.89 (which means potential reduction of crashes of 11%) for single vehicle run-off-road crashes, with a standard error of 0.1;
- 0.84 (which means potential reduction of crashes of 16%) for single vehicle run-off-road fatal and injury crashes, with a standard error of 0.1.

For rural two lane roads the Crash Modification Factor for the use of milled rumble strips has been estimated combining different studies in [1]:

- 0.85 (which means potential reduction of crashes of 15%) for single vehicle run-off-road crashes, with a standard error of 0.1;
- 0.71 (which means potential reduction of crashes of 29%) for single vehicle run-off-road fatal and injury crashes, with a standard error of 0.1.

Given the very low standard errors these results can be considered extremely reliable in estimating the potential effect of milled shoulder rumble strips on these types of roads.

2.5 Frangible poles

Where it is not feasible to eliminate roadside hazards, it is possible to make them less injurious by changing their design as long as this takes account of real world accident data and current vehicle design. Frangible poles can be effective in reducing the severity of pole related crashes. These types of utility poles are specifically designed to collapse or break away on impact and reduce the severity of potential injuries. Two types of frangible lighting poles are most used are [6]:

- 1 Slip-base type poles;
- 2 Deformable poles.

2.5.1 Slip-base tire poles

Slip-base poles are widely used on freeways and other high speed roads in many countries and they are becoming more widely used. The slip-base poles consist of a normal pole stem, catering for mounting heights up to approximately 15 m. The base involves two plates clamped together with three equally spaced bolts. These plates and bolts are released during an impact, allowing the pole stem to break away from its foundation with minimal impact on the vehicle. The decision to use slip base poles will depend on the space available and the resultant likelihood that a falling pole would cause injury to other users of the roadside area. For example, a slip base pole will usually be inappropriate where pedestrian or cyclist traffic is common because a falling pole would pose an unacceptable risk to those road users, Figure 9.

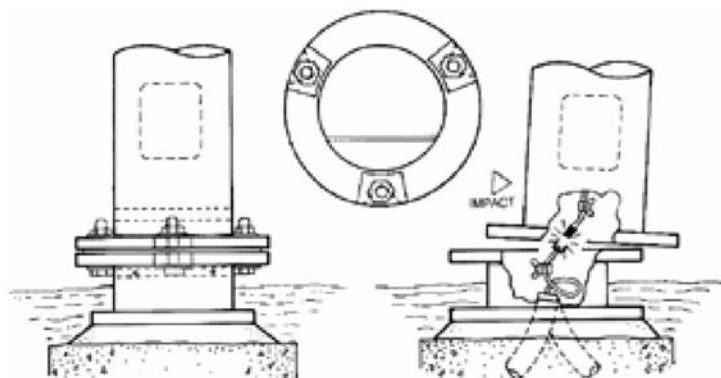


Figure 9 Slip-base poles [7]

2.5.2 Deformable poles

Deformable poles (Figure 10) provide a satisfactory degree of crash worthiness at lower vehicle impact speeds (ex: up to 80 km/h). They are particularly suited to low vehicle speed and/or high pedestrian activity areas. Impact absorbing poles differ from slip-base type poles in that in a vehicle impact they remain attached to the base structure and absorb any impact energy. The deformation of the pole is controlled by designed weakening of the pole stem over the lower 4m to 5m length.

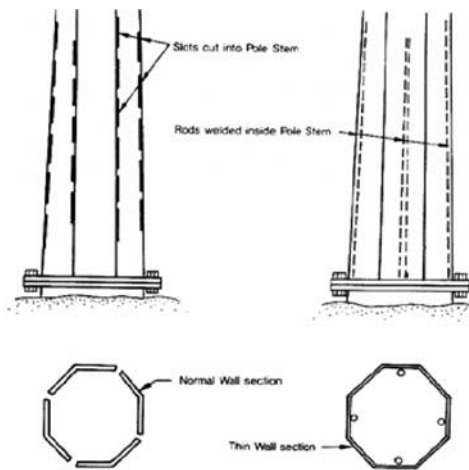


Figure 10 Deformable poles [7]

3 Conclusion

Forgiving road environments constitute a basic tool in preventing or mitigating an important percentage of road accidents related to driving errors. As everybody makes mistakes, drivers will eventually keep doing bad manoeuvres or actions. Over 80% of accidents are related to driver's error and about 25–30% of fatal accidents involve crashes with fixed roadside objects. This type of accidents is mainly caused due to driving errors that lead to lane/road departure. The existence of a forgiving road environment would prevent accidents of this type (and generally accidents that involve driving errors) and/or would reduce the seriousness of the consequences of such accidents. The first step in creating a forgiving road environment is the identification of error patterns that lead to accidents, in order to conclude to measures to be taken for rendering a road environment of forgiving nature. What is of outmost importance is to select the appropriate measure for each type of error, in terms of infrastructure enhancement. This paper has briefly reviewed concepts for designs of typical roadside elements. Although many nations have already begun to recognize and implement the “forgiving roads” concept, there are still perplexing questions regarding the nature and the extent of roadside treatments for a specific type of road and the cost effectiveness of this type of activity.

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