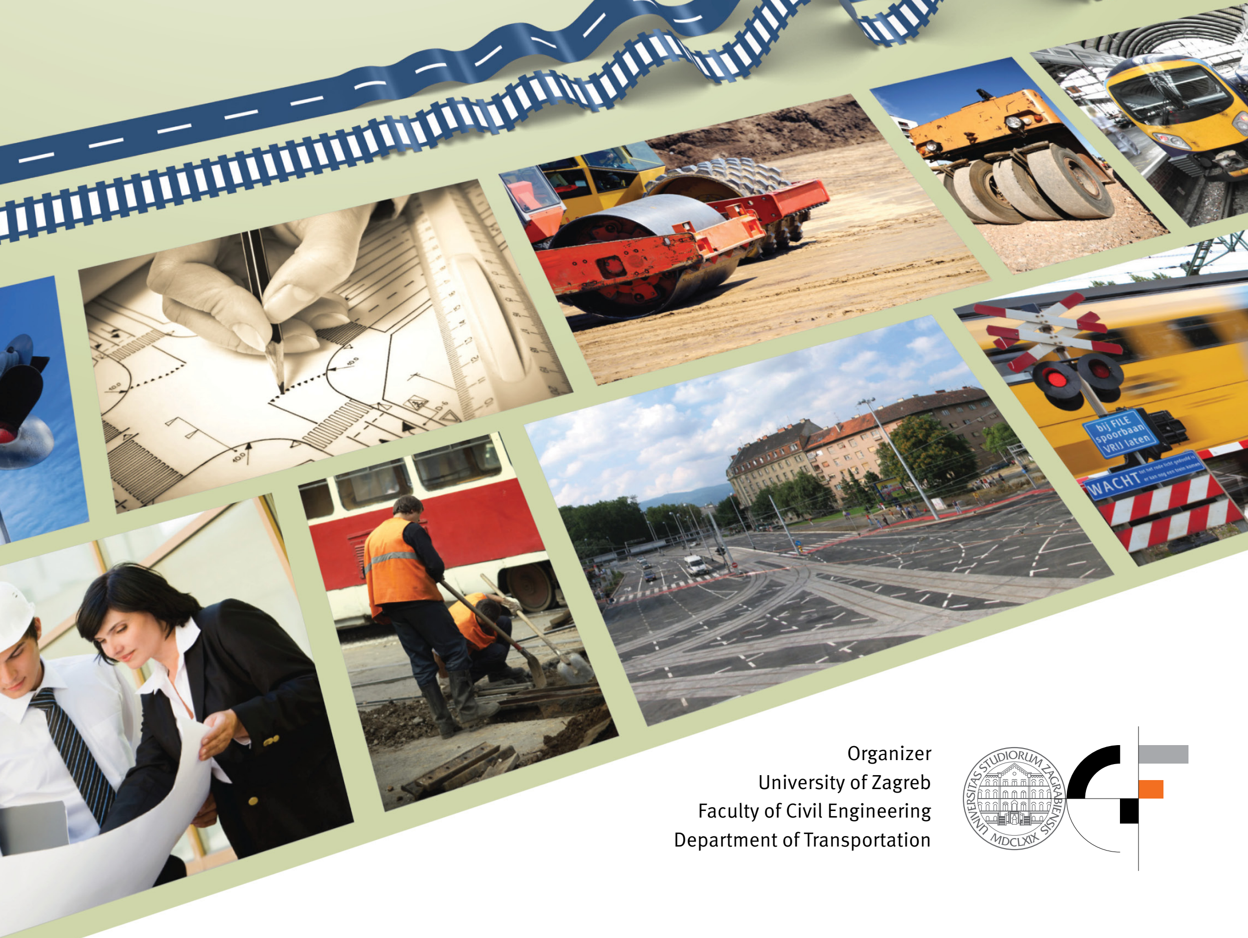
CETRA 2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure II

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THE BEHAVIOUR OF PASSIVELY SAFE ROADSIDE COLUMNS IN IMPACT WITH VEHICLES

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Abstract

Roadside columns are often the point of impact of vehicles with serious and often fatal consequences. To reduce the number and severity of such accidents, a growing number of scientists and experts are trying to find technical solutions for improving behaviour of roadside columns during the collision with a vehicle. It is about columns which can, unlike the usual rigid columns, absorb the energy or break in a controlled way when impacted by a vehicle. These types of columns belong to the category of passive safety road equipment. They are still in the initial stages of implementation in some countries of the European Union. The paper gives a comprehensive overview of passively safe roadside columns with respect to material production and energy absorbing properties and examines the safety level for the passengers in the vehicle. It analyses the behaviour of three types of columns in a collision with a vehicle with respect to the possibility of absorbing a certain amount of energy, failure mode and passenger safety. The analysis has been made based on comparisons of results of the crash tests and numerical simulations of impacts. It describes in detail the advantages and disadvantages of the application of passively safe roadside columns over traditional rigid columns, which are now still usually implemented along the roads.

Keywords: roadside columns, accidents, passive safety, absorption energy, crash tests

1 Introduction

Road safety is now on the agenda more than ever. Traffic accident consequences are presently a major problem. Only in the Republic of Croatia, in the last 10 years, 663 thousand traffic accidents occurred, out of which 6 thousand accidents were fatal, 42 thousand people were severely injured and 187 thousand people suffered minor injuries [1].

Roadside columns, like lightning columns, traffic signal poles and signposts are very often points of impact of vehicles, with severe and often fatal consequences. According to the statistics, every year in the world, thousands of people die and hundreds of thousands are injured after the vehicle s impact with a roadside column. For example, in Great Britain between 2001 and 2006 (inclusive), 12 361 traffic accident occurred when a vehicle struck a lighting column, and 8 849 traffic accidents occurred when a vehicle struck a signal post or a traffic signal [2]. To reduce the number and severity of traffic accidents caused by impacts of vehicles to roadside objects, the European Commission in the year 2000 suggested the usage of passive safety infrastructure along the roads, especially lighting columns with adequate energy absorbing properties at impact.

For illustration, Figure 1 shows the consequences of a vehicle impact at similar speed but on two different column structures: usual rigid column, which is typical for our roads, and deformable column, which belongs to the passive safe infrastructure.

a) Rigid column [3] b) Deformable column [4]

Figure 1 Consequences of the vehicle's impact with different column types

It is known that during the impact of the vehicle with a column a large quantity of energy develops. If the column is the usual rigid one, during the impact it moves slightly and almost all of the energy transfers to the vehicle and its passengers (Figure 1.a). However, implementation of columns that can deform and absorb energy would dramatically reduce energy that the vehicle would have to absorb upon the impact, thus resulting in less aggressive drop in acceleration with respect to time as well as the larger safety of passengers.
The possibility of energy absorption of the column, during vehicle s impact, depends, among other things, on the material out of which the column was created. For example, wooden and concrete columns show little deflection while impacted by a vehicle so the majority of energy created during the impact will be absorbed by the vehicle. However, steel, aluminium and composite columns show higher deflection thus absorbing more energy during impact.
Presently, steel columns are usually implemented along the roads because they are relatively lightweight, cost effective, durable and have an appropriate anticorrosive protection, have good reliable and predictable strenght and behavior and can be fully recycled. However, it has been shown that in the case of impact aluminium columns are far less dangerous obstacles than steel ones because they can absorb 50% more energy than steel ones of the same weight, so that the possibility of physical passenger injury is appreciably reduced [5]. Furthermore, aluminium columns are 1/3 lighter then the steel columns, they have a long lifespan, hardly any maintenance costs and can also be fully recycled.
Recently, for the construction of roadside columns fiberglass reinforced polymers (FRP) have been used as the most expensive alternative to traditional materials, but with excellent energy absorbing values at impact. In comparison with steel and aluminium columns, fiberglass columns are low weight and easy installation, higher yield strength and flame resistant. Furthermore, fiberglass columns are maintenance-free because they are extremely resistant to environmental influences, such as water, chemicals and salt and are therefore less sensitive to corrosion.

2 Types of passive safe columns

Passive safety roadside columns in the European Union countries are tested and classified in accordance with the European Standard EN 12767:2007 [6]. This Standard specifies performance requirements and defines levels in passive safety terms intended to reduce the severity of injury to the occupants of vehicles impacting with the permanent road equipment support structures. Consideration is also given to other traffic and pedestrians.

According to [6] three categories of passive safety roadside columns are considered:
· high energy absorbing (HE),
· low energy absorbing (LE),
· non-energy absorbing (NE).

Energy absorbing columns slow down the speed of the vehicle considerably and thus the risk of secondary accidents with structures, trees, pedestrians and other road users can be reduced. Non-energy absorbing columns permit the vehicle to continue after the impact with limited reduction of speed.

Furthermore, the Standard contains the rules for executing and interpreting the results of crash tests under different impact conditions and different vehicle speeds. Two crash tests are required, one at 35 km/h, to ensure satisfactory functioning of the support structure at low speed, and a second at one of the 3 speeds 50, 70 or 100 km/h.

In the [6] occupant safety levels in the traffic at the moment of impact are specified, from 1 to 4, with increasing levels of safety reflected by higher numbers. Levels 1, 2 and 3 provide increasing levels of safety in that order by reducing impact severity, while level 4 comprises very safe support structures, meaning small constructions that will cause minor damages to the vehicle upon impact. The Standard also defines roadside columns with no performance requirements for passive safety as class 0.

To declare the occupant safety level, two values are measured in crash tests: ASI (Acceleration Severity Index) and THIV (Theoretical Head Impact Velocity). ASI is a measurement of the severity of the impact. This is a non-dimensional value of the vehicle acceleration, which the occupant undergoes in the vehicle upon impact. The Standard applies across a range of 1.4 for the lowest safety level to 0.6 for the highest safety level.

THIV value is the speed measure at which occupant's head impact in interior parts, Figure 2. The Standard applies across a range from 44 km/h for the lowest safety level to 11 km/h for the highest safety level.

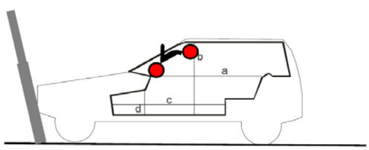

Figure 2 Determining the THIV value

Performance type of the columns is determined on basis of vehicle speed upon impact with the column, energy absorption category of column and occupant safety level, as is shown in Table 1.

Table 1 Performance type of the columns [6]

	Alternatives
Speed class [km/h]	50, 70 or 100
Energy absorption category	HE, LE or NE
Occupant safety level	1, 2, 3 or 4

The officially certified performance is expressed, for example 70 HE 3 where:
70 – means vehicle speed in [km/h] upon impact with the column,
HE – means high energy absorbing column,
3 – means the item has an occupant safety level of 3.

A scheme of the passive safe column classification and the safety level according to [6] is given in the Figure 3.

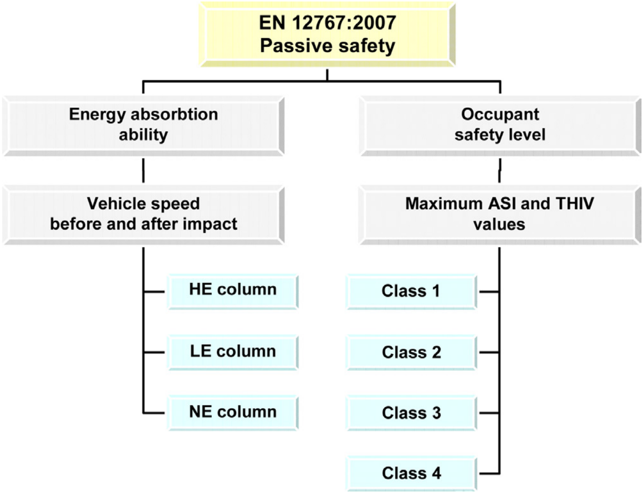

Figure 3 Column classification and safety level according to [6]

3 Behaviour of the passive safe columns

3.1 Non-energy absorbing columns (NE columns)

Passive safe columns which do not absorb energy (NE columns) are designed to shear or fail at the base upon impact, after which the column keels over the top of the vehicle and fall on the ground behind it, Figure 4. After the impact, the vehicle continues its movement with a limited reduction in speed and relatively minor damage. In this way, a lower primary risk of passenger injuries is achieved, but higher risk of secondary crashes of the vehicle with trees, pedestrians and other traffic participants exists because of the vehicles continuation of movement and the column fall.

Figure 4 Non-energy absorbing column behaviour [6]

Behaviour of NE columns upon impact of the vehicle in a crash test has been shown in Figure 5. The crash test has been conducted in the leading European centre for vehicle reliability and crash tests research TTAI (TÜV Rheinland TNO Automotive International) [7]. Crash tests were conducted with a impact speed of 35 km/h and 100 km/h. For the column to satisfy the classification for the speed of 100 km/h in accordance to [6], it was necessary that the vehicle had an exit speed of minimal 70km/h, which is measured at 12 m beyond the impact point. In this test the measured exit speed was 84.8 km/h, so it was higher than the threshold. The ASI and THIV values were in accepted value.

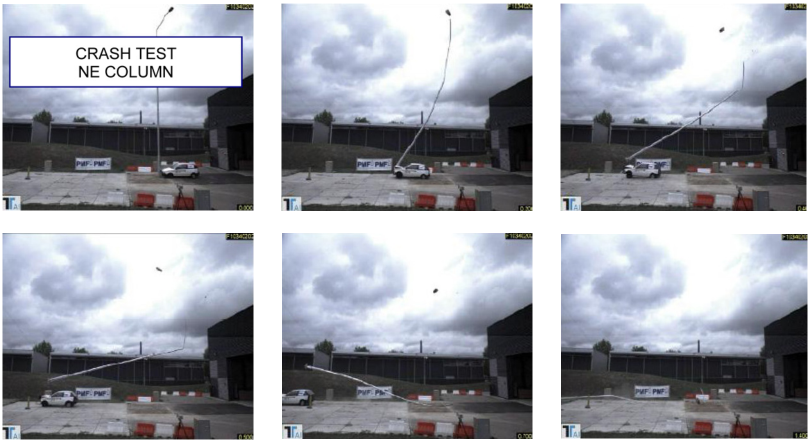

Figure 5 Crash test with a non-energy absorbing column [7]

After the column hits the ground (from the vehicle impact with the column until falling down of the column approximately 1.5 sec passes), the column wrinkled on different locations, but there was no breakage on or next to the welds. After the impact, all the column parts fell behind the vehicle, there were no deformations on the roof of the vehicle and the windshield was undamaged, Figure 6. It can be seen that upon vehicles impact with such a column the occupant injuries would be considerably smaller than in the case of an impact with a regular rigid column.

Figure 6 Column detail and vehicle after the crash test [7]

3.2 High energy absorbing columns (HE columns)

During the impact, a high energy absorbing column (HE columns) flattens and rolls under a vehicle, thus absorbing energy, Figure 7.

Figure 7 High energy absorbing column behaviour [6]

Such columns considerably slow down and stop the vehicle upon impact. Because of this the risk of secondary collisions of the vehicle with objects along the road, trees, pedestrians and other road users is reduced, however the severity of the impact for vehicle occupants can be high.

Behaviour of high energy absorbing columns upon impact of the vehicle will be shown on the example of composite lightning columns testing [8]. In crash tests, conducted in accordance with EN 12767 in Finland, 10, 12.4 and 15 m high columns were tested with the vehicle speed of 35 km/h and 100 km/h at the point of impact. Crash tests were conducted with the Peugeot 205.
After the conducted crash tests the Russian laboratory Computational Mechanics Laboratory (CompMechLab) performed crush tests numeric simulations with the finite elements method (FEM) for some lightning column types at different vehicle speed. Lightning poles of different heights were analyzed, with different inner and outer diameters and different quantities of reinforcement in the composite material structure. For conducting a nonlinear dynamic analysis upon impact of the vehicle with the column, a LS-DYNA computer programme was used. 3-D FE models of columns and vehicles were created, Figure 8. In the analysis some nonlinearities were taken into account such as the dynamical impact on different vehicle speeds, plasticity in columns and parts of vehicles, contact interaction between simulated vehicle and the column and the progressive damages in the column material.

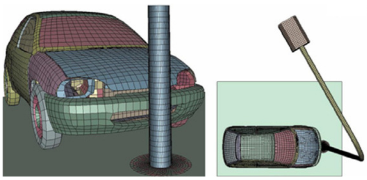

Figure 8 3-D FE model of vehicle and column [8]

Figure 9. illustrates a FE simulation of the composite column behaviour and the vehicle at the speed of 100 km/h upon impact. It can be seen that during the crash test the column went through a plastic deformation and after that sliding under vehicle.

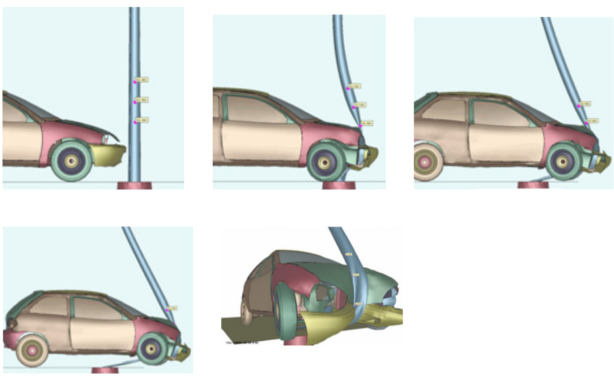

Figure 9 The FE simulation of the crash test of HE column [8]

Figure 10. shows a comparison between the real crash test and the FE simulation of the vehicle and column after impact. It can be seen that the damage on the vehicle upon the impact with that type of column is smaller, and the occupant safety greater than in the case of the crash with a usual rigid column.

Figure 10 Vehicle after impact [8]

3.3 Low energy absorbing columns (LE columns)

Columns that can absorb low levels of energy (LE columns) are a good combination of energy absorption and passenger safety because they have some of the qualities of both HE and NE columns. They are designed to yield in front of and under the impacting vehicle, before shearing or detaching towards the end of the impact event. The behaviour of such columns is shown in Figure 11.

Figure 11 Low energy absorbing columns behaviour [6]

The vehicle speed will be reduced and the damage will be smaller than if it had hit an high energy absorbing column. Because of the before mentioned reasons, LE columns are convenient for implementation on standard roads. In Figure 12 and Figure 13 crash tests of vehicles with steel columns from the 100 LE 3 class are shown. The tests were conducted at vehicle speed of 35 km/h and 100 km/h.

a) Column and the vehicle after the crash

b) Column after impact - the column stopped the vehicle

Figure 12 Crash test at speed of 35 km/h [9]

a) The vehicle and the column before crash test

b) The column after the impact – vehicle speed was reduced to 60 km/h

Figure 13 Crash test at speed of 100 km/h [9]

4 Advantages and disadvantages of passive safe columns

The advantages of the passively safe roadside column over traditional rigid columns are: a lower risk of severe injuries to vehicle occupants, easier replacement if hit by vehicle and do not require a safety barrier. With the implementation of NE columns the highest passenger safety is achieved because after the impact the vehicle continues its movement but with decreased speed and minimum damage on the vehicle in relation to other column types. Thus, NE columns can be the most appropriate choice on non-built up roads with insignificant volumes of non-motorised users.

LE and HE columns considerably slow down the vehicle and reduced the risk of secondary collisions of the vehicle with pedestrians, cyclists and other traffic participants. That's why they have the advantage on built-up roads where there is a significant volume of non-motorized users.

The application of passive safe columns is suggested on rural roads, especially where it is difficult to use safety barrier, or where the safety barrier itself could cause a traffic accident, for example on a roundabout splitter island. They are less necessary where there is an existing barrier, or where there is a building or rocks exist close to the road.

As it is mentioned, when crashing into a usual rigid column there is a high risk for the passengers in the vehicle, and the risk is minor for other road users. However, on point of impact with a passive safe column, the risk is smaller for the passengers in the vehicle but there is also a small chance of a secondary accident because of the column falling to the side walk and this presents a potential risk for other drivers and pedestrians in the vicinity. The risk for pedestrians is much greater in urban than in rural areas. The risk depends on the number of pedestrians and exposed columns and therefore the recommendations of the [6] is that the passively safe columns are not appropriate on places where a large number of pedestrians on a regular basis is expected. In these cases, pedestrian safety might need to be considered separately as the risk of an errant vehicle is greater than that from a falling column or signposts.

5 European Commission guidelines regarding the roadside columns

In accordance with the European Commission guidelines [4] columns on new roads should be located beyond the safety zone. If this is not possible, only passively safe columns should be used. All columns should be tested according to the Standard EN 12767:2007.

In the EU countries until recently highway columns should have been placed behind safety barriers. With the law change, it has been allowed that along the highways columns without safety barriers be placed but under the condition that they are tested and certified in accordance with the [6]. It is decided that without safety barriers, along the highways, safety class 100 NE 3 columns can be placed. These columns do not absorb energy and secure the maximum safety for the passengers in the vehicle that crashed into a column.

Passive safe columns should be used on main roads where the probability of their fall on the board walk is small or where a small number of pedestrians is expected in the vicinity. National Annex for BS EN 12767 [11] for rural roads recommends the usage of non energy absorbing columns 100 NE unless there is a significant number of pedestrians or cyclists expected because of the risk of a falling column. In urban areas the usage of 70 LE or HE lightning columns is recommended and 70 LE signposts.
Old rigid steel, concrete or wooden lightning column can be replaced with energy absorbing or breakaway column. These columns can be made out of steel, aluminum, wood or composite materials and are recommended in places where pedestrian lanes aren't that close to the columns. Existing wooden or steel columns can be modified into ones which can break when during impacted by a vehicle. Figure 14 shows possible modifications of a rigid column.

Figure 14 Examples of the break-away NE columns [4]

6 Conclusion

Traffic accidents will always be present, but they can be reduced, the number as well as the consequences. One of the ways for reducing the severity of accidents is the usage of passive safe equipment along the roads, specifically passive safe columns. The European Commission recommendation with the goal of decreasing the number and the severity of traffic accidents is the usage of these types of columns along the roads. Although, with the usage of columns that can brak-away or absorb energy in a controlled way, the safety of drivers is increased, but the risk for pedestrians and other road users increases as well because of the possibility of a falling column. Because of this, during the designing of the roadside equipment, especially new columns, new materials and column failure modes must be considered. With this approach the severity of injuries of passengers in the vehicle upon impact will be reduced and higher safety will be achieved for other road users, especially for pedestrians. For the traffic safety to be brought to a higher level, the society should constantly put an effort in the road improvement. The cost of investing in safety increment is surely smaller than the damages that traffic accident cause.

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