Abstract:

Europe’s motorways are highly frequented. Road traffic increases year after year and has a significant impact on our economic system. Motorways are the core of goods traffic and are suffering from increasing accident rate, congestion levels and journey times. To manage traffic flows better and to help increase road safety, modern and effective vehicle restraint systems are highly demanded. With the objectives of the European Road Action Programme, initiated by the European Commision to decrease road fatalities by 50% until 2010 (“Verona Declaration”), the use of safety barriers is an essential contribution to reach this objectives. Therefore a large number of different restraint systems are provided at the market. Thus to make Europe-wide all systems comparable, each system must be examined by an independent test house and the demands are precisely defined in the EN1317.

Key words: EN1317, Crash Tests, concrete barrier application, Project DN1

Introduction

The volume of traffic (predominant heavy goods vehicles in transit traffic) on highways increases rapidly. Compared with other European countries, Romania is ranked high in reference to the number of fatal accidents. Road safety statistics indicate the fatality risk is 11 fatalities/100,000 inhabitants. The risk in terms of number of fatalities/billion vehicle km is 68, which is 7 times higher than the UK. Since joining the European Union both public authorities and international or domestic private sector companies intensified their intention in road safety. To reach their goals, this important engagement will be supported by modern vehicle restraint systems. Passive vehicle restraint systems (steel guard rail, concrete barrier or crash cushion) can not prevent a serious accident, but due to their cushioning and reverting crashworthiness the impact on the occupant will be significantly reduced.

This chapter conduces to explain the EN 1317-1 and -2 (1998) and sums up the significant points of the standard, that are necessary for the application of road restraint systems.
1. **EN 1317 Part 1 and 2 – Crash Tests**

In order to improve and maintain highway safety, the design of safer roads requires the installation, on certain sections of road and at particular locations, the installation of devices to restrain vehicles and pedestrians from entering dangerous zones or areas. The road restraint systems designated in this standard are designed to specify performance levels of containment and to redirect errant vehicles and to provide guidance for pedestrians and other road users. [1]

To compare the test results of all tested products, the accurate terms and test conditions are fixed in the EN 1317-1. They manage, among other things:

- Mass and dimensions of the test vehicles
- Attaching of the measuring instruments
- Calculation method of the stress that affects the occupants
- Type and content of the test report

The second part of the EN 1317 contains the topics performance classes, acceptance criteria for crash tests and test procedures of safeguarding equipment. The three essential criteria of safeguarding equipment are:

- containment level (T1 - H4b)
- impact severity levels (A, B, C) and
- deformation of the system (working width W1 to W8)

By means of these criteria restraint systems can be described and classified easily.

**ASI (Acceleration Severity Index)**

The ASI characterizes the intensity of the impact, and is regarded as the most important rate of impact on occupants.

**THIV (Theoretical Head Impact Velocity)**

THIV describes the theoretical speed of the head, colliding with an obstacle during an impact. It has to be less than 33km/h.

**PHD (Post-Impact Head Deceleration)**

The PHD value describes the head deceleration after an impact and has to be less than 20g (acceleration of gravity).

**Impact severity level**
The impact severity level is composed of the three values ASI, THIV and PHD (see EN 1713-2 table 3).

**Crash tests - Performance classes according to EN 1317**

Table 1 lists all vehicle impact tests. These tests are the basis for the test conditions of the containment levels. To perform an impact test of a vehicle restraint system normally two crash tests are needed, with the exception of the containment levels T1, T2 and N1 where only one crash test is needed (TB 21, TB 22 or TB 31).

To verify the breakthrough protection, the tests (TB 32 - TB 81) are being carried out with heavy vehicles. The vehicle restraint system is being tested on restraining vehicles crashing into it, in accordance with all standards. It is important that no vehicle breaks through and that no essential parts of the restraint system loose or burst off. An impact test would also be negative, if big concrete parts flaked off on the back side and endanger persons or vehicles behind it – even if the vehicle crashing into it would be held back.

Another impact test (TB 11 or TB 21) is being carried out with a passenger car, to check the safety for occupants of lightweight vehicles (Acceleration Severity Index / ASI). The data is being recorded with measuring instruments and tested on abidance of threshold values. These threshold values should guarantee the survival of the passengers in case of impact. In EN 1317-2 table 1 is a listing of the criteria for impact tests (primarily type, impact speed and impact angle of the test vehicle).

The **containment levels** are composed of one or two acceptance test – low angle-, normal-, and higher containment.

<table>
<thead>
<tr>
<th>Containment capacity</th>
<th>Containment levels</th>
<th>Acceptance test</th>
<th>Vehicle total mass in kg</th>
<th>Impact speed in km/h</th>
<th>Impact angle in °</th>
</tr>
</thead>
<tbody>
<tr>
<td>low angle containment</td>
<td>T1</td>
<td>TB 21</td>
<td>1.300</td>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>TB 22</td>
<td>1.300</td>
<td>80</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>TB 21</td>
<td>1.300</td>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>TB 41</td>
<td>10.000</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>normal</td>
<td>N1</td>
<td>TB 31</td>
<td>1.500</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>N2</td>
<td>TB 32</td>
<td>1.500</td>
<td>110</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TB 11</td>
<td>900</td>
<td>100</td>
<td>20</td>
</tr>
</tbody>
</table>
The vehicle occupant **impact severity** assessment indices ASI, THIV and PHD shall conform to the requirements of EN 1317-2.

EN 1317 part 2:

“The **working width** (W) is the distance between the side facing the traffic before the impact of the road restraint system and the maximum dynamic lateral position of any major part of the system.”[2]

“The dynamic deflection (D) is the maximum lateral dynamic displacement of the side facing restraint system.”[2]

### Tab.2 and 3 – Working width and Impact severity level

<table>
<thead>
<tr>
<th>Working width</th>
<th>Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>$W \leq 0,6,\text{m}$</td>
</tr>
<tr>
<td>W2</td>
<td>$W \leq 0,8,\text{m}$</td>
</tr>
<tr>
<td>W3</td>
<td>$W \leq 1,0,\text{m}$</td>
</tr>
<tr>
<td>W4</td>
<td>$W \leq 1,3,\text{m}$</td>
</tr>
<tr>
<td>W5</td>
<td>$W \leq 1,7,\text{m}$</td>
</tr>
<tr>
<td>W6</td>
<td>$W \leq 2,1,\text{m}$</td>
</tr>
<tr>
<td>W7</td>
<td>$W \leq 2,5,\text{m}$</td>
</tr>
<tr>
<td>W8</td>
<td>$W \leq 3,5,\text{m}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact severity level</th>
<th>Characteristic values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASI ≤ 1,0</td>
</tr>
<tr>
<td></td>
<td>THIV ≤ 33 km/h</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>ASI ≤ 1,4</td>
</tr>
<tr>
<td></td>
<td>PHD &lt; 20 g</td>
</tr>
<tr>
<td>C</td>
<td>ASI ≤ 1,9</td>
</tr>
</tbody>
</table>

### Additional information

This extract from the EN 1317-1 and -2 does not include the whole content of the standard, it only exemplifies a couple of its passages. In case of doubt, the last version of the standard is valid.
2. Precast concrete vehicle restraint systems – Features & Effects

A modern vehicle restraint system consisting of prefabricated concrete elements and contributes to a remarkable minimisation of accident consequences on roads. It combines safety with economic efficiency. The system succeeded in combining the flexibility of steel systems with the stability of in-situ concrete systems as in uniting the advantages of those – ultimate protection from breaking through and well passenger covering at the same time.

2.1 Functions and Demands

According to the European Standard EN1317 the important features are the protection of vehicles from breaking through the vehicle restraint system in case of impact, the protection of occupants by minimisation of impacting forces and the protection of third parties from caroming vehicles after crashes. A short construction period to minimize the influence on traffic flow, a resistance to small and medium impacts, a simple exchange of damaged elements after serious accidents are only a few points out of the great variety of demands on restraint systems. Furthermore maintenance costs and service life are playing a key role. Particularly with regard to Public Private Projects, where the private partners will be responsible for the road section for a total of 25-30 years. The product range of flexible concrete safety barriers offers various systems with a precisely defined focus. In addition to highest possible safety there is also given a beneficial proportion between investment- and maintenance costs.

Systems are basically divided into the following categories:

- Temporary and permanent systems
- Bridge systems
- Noise barrier systems

The essential system features are:

- “New Jersey Profile”
- the continuous tension bar
- the coupling
- free installation without connection to the subgrade
The modular concept enables a change between the systems without interception.

Most of the systems are based on the “New Jersey Profile”. It was developed near New Jersey, USA, in the late fifties. Since that time the form has been known as the New Jersey Profile and has been used world-wide. It turned out that due to the New Jersey Profile there is a remarkable lower risk of vehicle overturn.

The majority of all impacts on restraint systems occur at a plane angle of up to 12°. Due to the baffle plate of the New Jersey Profile the vehicle is directed back onto the carriageway – a direct contact between the vehicle and the concrete element is mostly avoided. In case of serious impacts at high speeds and big impact angles, the repellent plate prevents breakthrough of vehicles in combination with the continuous tension bar with greatest possible safety. The base is necessary for constructive reasons and serves as both a base area and a catchment for diagonal draining. The water drainage openings conduce to lateral drainage of surface water and thus enable an arrangement of the rainwater infeeds also behind the vehicle restraint system.

In areas of road works the crowded amount of space showed the necessity of especially narrow systems that, nevertheless, guarantee high protection of all road users. The narrow elements are made up of a concrete wall, as well as two galvanized steel angles, which guarantee the required dynamic stability and protection from tilting. 4 elastomer-stands serve as bearings. They assure a safe stability of the elements on the one hand and there again ensure a separation distance to the lateral drainage between steel angles and carriageway. The steel angles are drivable, without hazard, neither for the vehicle, nor the element. A redirection of the vehicles occurs by the repellent plate.
The continuous tension bar goes through each element. Depending on the containment level it is used in various strengths.

![Image: Course of the tension bar and tension Bar]

Fig. 2.3 – Course of the tension bar and tension Bar

The single elements are tied together with the couplings and form a chain. It comes to a continuous steel tension bar with high tension capacity. The energy is distributed among many elements in case of impact. Thus it is more effectively taken up - a breakthrough is reliably prevented.

2.2 Categories

This listing will give a short overview about the different systems which are currently in use on roads.

**Temporary safety systems** are mostly used at construction sites. Furthermore they are used in cases, where only systems of small system widths are applicable. Setting up one rowed. Fast mounting, a small system width and a fast movement of the elements during the construction time are essential features of such a system. Strains on occupants in case of an impact are minor and after a small impact no damaging occurs.

**Permanent restraint systems** are mostly used on motorways and on dual carriageways. Set up one or two rowed, with or without backfilling. They are a reliable protection against breakthrough of the median and must be resistant against small and medium impacts.
Restraint systems for bridges are also part of permanent restraint systems. Actually there are only a few restraint systems available on the market that could meet the special requirements of a bridge project. A very important feature of the precast concrete barrier is the behaviour of the barrier at a heavy impact and its effects for the bridge structure.

This system offers reliable safety, brings little strain on passenger car occupants and eliminates the endangerment of third parties underneath the bridge.

Noise barrier systems are also part of permanent restraint systems. Depending on the model the restraint- and noise barrier system is either used to secure the central reserve or the verge. Set up single rowed. The noise reduction is achieved with the used absorption material. The most impressive feature of this system is the efficient combination of a vehicle restraint system and a noise barrier wall. The height depends on the requirements of the application – up to 4m.

Transitions were developed for the safe connection of two different systems. They can be installed both on the marginal strip and on the median of motorways. It flexibly
connects EDSP systems to permanent vehicle restraint systems. Due to its very compact design the transition can be installed without concrete foundation. It is therefore a very flexibly applicable system.

![Transition System EDSP – DB 80F](image)

Fig. 8 – Transition System EDSP – DB 80F

2 Tested safety

The testing methods are precisely defined in the EN 1317 in order to be able to compare restraint systems of various types of construction and those of various materials. After positive testing, each product can be described with few code numbers.

- the containment level (e.g. H4b)
- the working width (e.g. W6)
- the Impact Severity Level ASI (e.g. ASI B)

These three values enable to distinguish between steel guardrails, local- and prefabricated concrete safety barriers independently of their style of construction. Thus it is easier to estimate their reaction in case of impact.

![Chain of elements after an impact of a 38t – articulated lorry](image)

Fig. 9 – Chain of elements after an impact of a 38t – articulated lorry (left)

![Small displacement of a safety barrier even in case of extreme impacts](image)

Fig. 10 – Small displacement of a safety barrier even in case of extreme impacts (right)
The crash tests were performed on the testing ground of the TÜV in Munich under the supervision of the Federal office of Road Administration ("Bundesanstalt für Straßenwesen – BASt.").

As a rule the elements of a flexible traffic safety system are loosely set up on the subsoil and are connected to each other with the coupling. Thus the complete safety barrier is considerably restricted to displacement. In case of impact it comes to a reduction of energy due to vehicle’s stepping back. This leads to a lower risk of injury and consequently to a higher safety for occupants of the crashed car. Even in case of bad impacts the system offers the highest possible protection against breakthrough of a vehicle. The displacement of elements is smaller than that of steel systems of the same containment level.

3 Reference project DN1

In 2008 a reference project was launched along the DN1 (Bucharest-Ploiesti), close to Cornu. To prevent cross-overs and break troughs of the median barrier, a tested road restraint system was needed. Therefore the decision was made to apply a H2 restraint system. It was the first time that precast concrete barriers were used in Romania. Installation has been carried out in September 2008. The elements were transported to the construction site by lorry.

Fig. 11, 12 – Installation along the DN1 (Bucharest – Ploiesti) in September 2008

Installation took place by means of a mobile crane. Afterwards the elements were connected to each other with the couplings.
Conclusions

Faster goods traffic, higher traffic density, wider roads, more accidents (rear end collision, cross-overs, wrong way driver,…) and therefore more black spots (a place where road traffic accidents have historically been concentrated) – and all forecasts show that this trend will continue, especially in the eastern EC countries. Hence Road authorities intensify their efforts towards an improvement of road safety. To ensure high quality standards the use of tested systems is mandatory – more than ever. Precast concrete barriers are such an effective and tested road restraint system. Multifarious applicable on many sites (temporary during the construction phase, permanent, on bridges as noise barrier or as transition between steel and concrete), ASI A or B small working width and a high containment capacity complement the system advantages.

Standards and directives

[1] EN 1317-1: 1998 Road restraint systems, Terminology and general criteria for test methods