

NEW STANDARDS FOR ROAD RESTRAINT SYSTEMS FOR MOTORCYCLISTS

DESIGNING SAFER ROADSIDES FOR MOTORCYCLISTS

**FEDERATION
OF EUROPEAN
MOTORCYCLISTS'
ASSOCIATIONS**



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EXECUTIVE SUMMARY

Crash barriers are designed with only cars and heavy vehicles in mind. The European testing standard has made no mention of motorcycles for the last decades even though hitting a road restraint system is a factor in 8-17 per cent of rider deaths. In collisions with crash barriers, riders are 15 times more likely to be killed than a car occupant.¹ Lately the European Parliament has identified standard guardrails as “death trap” for motorcyclists.²

Barrier posts are particularly aggressive, irrespective of the barriers’ other components, causing a five-fold increase in injury severity compared to the average motorcycle crash. Motorcycle-friendly systems have been shown to halve the fatalities and offer high rates of return.³

The number of registered motorcycles on European roads has grown by 55% between 1994 and 2004. In France, an impact against a crash barrier is involved in 8% of motorcycle deaths, in Germany in 11% of deaths and 25% of motorcycle accidents. With the rise in the use of powered two-wheelers, this is now a public health issue, as well as a policy area with a great potential for reducing road deaths.

Three main test protocols are in use in Europe today (LIER, UNE135900, BAST), and a new Technical Specification, CEN TS 1317-8, was introduced in January 2012. All have different characteristics, and as a result, the products complying with these protocols offer different benefits in terms of cost and safety.

Beyond the technical specifications of road restraint systems, installation, maintenance and integration in the road environment are all factors to be considered in order to obtain the best cost-efficiency. Different strategies implemented in Portugal, the Netherlands, France, Germany and Spain, are presented for the benefit of policy-makers and road operators.

Further work is needed in order to build on best practices, with the examples of research projects like APROSYS, SMARTRRS, or PILOT4SAFETY, and the work of EURORAP to better understand accident characteristics, design better products, and disseminate best practices.

A full European standard on the evaluation of motorcyclist protection systems, building on TS 1317-8 and replacing it in the current EN 1317 crash barrier testing standard, would have the benefit of leading to better protection of all powered two-wheeler riders across the European Union. It would provide road authorities with a clearly defined standard for evaluating products, and would cement the single market while pursuing the objective set by the European Parliament to phase out dangerous designs⁴.

¹ Barriers to change : designing safe roads for motorcyclists. EuroRAP 2007

² European Parliament own-initiative report in response to the Commission Communication entitled ‘Towards a European road safety area : policy orientations on road safety 2011-2020’. Reference INI/2010/2235

³ ibid.

⁴ No European standard is binding. A national regulation can require conformance to a standard. The use of a TS is totally optional, if the TS becomes an EN member states cannot use other standards to evaluate the same product. However, only a national regulation can require the use of a product.

INTRODUCTION

Ubiquitous along European roads, roadside barriers - guardrails, concrete walls and other types of barriers - represent a paradox in road safety research. They are meant to restrain errant vehicles, avoid damage and injury to property and persons behind the barrier, and save the lives of drivers and passengers ; but are identified by motorcyclists as a clear danger.

Riders from the onset of their training know the threat represented by the most common design, a single beam supported by exposed posts at ground level. A falling motorcyclist, sliding or rolling onto the pavement, will hit one or more posts, which present sharp edges and offer no energy absorption properties. As a result, collision with guardrail posts is an important cause of fatal motorcyclist injury, along with serious limb and organ injury often leading to amputation.

There is, however, little research showing the extent of this threat to the safety of powered two-wheeler users, and even less knowledge of the characteristics of guardrail-related accidents in terms of circumstances, causes, accident profiles, location, and most importantly, consequences for the victims.

Yet motorists and motorcyclists do not have conflicting interests. The safety of all users can be ensured by using road restraint systems that provide the best level of protection in all situations.

This approach is supported by the European Parliament, who in a report this year stated that "the standard guard rails used on European roads are a death trap for motorcyclists, and [called] on the Member States to take prompt action to refit dangerous stretches of road with rails with upper and lower elements [...]"⁵

This objective can be reached at an acceptable cost for the community, as installation costs can be offset by savings on healthcare and pensions. A good example is given by this Dutch rider, who suffered life-changing injuries (bruised lungs and liver, 23 fractures, near-amputation of one arm) after impacting a guardrail post, and said "they said it was too expensive to change the rails ; but my hospitalisation and revalidation is more expensive."

This document aims at providing accurate and complete information on the solutions available to road authorities and infrastructure operators who wish to upgrade road restraint systems, by presenting the current technical standards available, statistical data and in-depth research, accident profiles configurations, as well as best practices and success stories. In addition, it features a comprehensive list of road restraint products available on the market today, their characteristics, their use, the standards against which they are tested, and guidelines on where and how they should be used to the best benefit.



⁵ <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&mode=XML&reference=A7-2011-0264&language=EN>

1 ROAD RESTRAINT SYSTEMS AS HAZARDS FOR MOTORCYCLISTS

1.1. The limitations of guardrails today

Road restraint systems are devices designed to help the driver turn a critical loss of vehicle control into a benign controlled event, absorbing impact energy and reducing injury severity. The most common of these, the crash barrier, is typically designed to guide and restrain errant vehicles, ranging from small cars to heavy goods vehicles.

However, when a motorcyclist impacts one, collides with it or simply slides on a road, road restraint systems turn into major additional hazards. In France, in the year 1993, 1994, 1995, accidents against crash barriers were involved in 8% of all motorcycle fatalities, in addition to 342 'seriously' injured and 385 'slightly' injured (Bradley, 1998). In Germany, the proportion rises up to 11% of fatalities and 25% of motorcycle accidents in one year involving metal crash barriers (Ellmers, 1997).

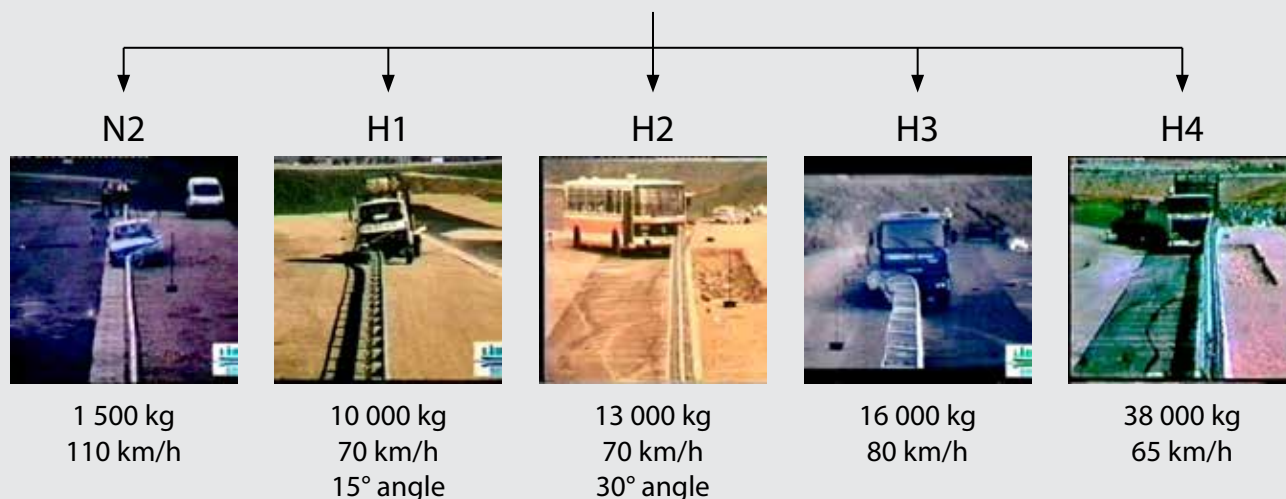
Motorcyclists are particularly at risk of collision on bends and curves, where acceleration and deceleration occur and the stability of the vehicle can be compromised. Published research has shown that riders are 15 times more likely to be killed than

car occupants in this type of collision (Williams, 2004), and the nature of impacts with barriers is such that riders are more likely to suffer injuries to lower extremities, and vital regions of the body, such as the spine, head and thorax (MAIDS, 2004, APROSYS, 2007).

This situation was not improved but rather reinforced with the development of a European standard providing full-scale impact test requirements within the EN1317 (1&2) Standard (1998), a procedure whereby national standards across the European Union are harmonized in a common approach. The norm, which identifies systems according to the type of vehicle they are able to restrain, includes performance indicators (containment, impact severity and deformation levels) used by road authorities to select the restraint systems needed on different types of roads.

Although the standard only includes specific provisions for cars and heavy vehicles - and is therefore inadequate for motorcyclists - it is still in application by EU Member States.

European Norm EN 1317



1.2. Physics and impact mechanisms

During a motorcycle accident, there is a great risk for the rider to hit an obstacle on the roadside (posts, trees, etc). In order to improve their safety in case of impact, one of the first measures is to avoid the possibility for the rider to hit hazards on the roadside.

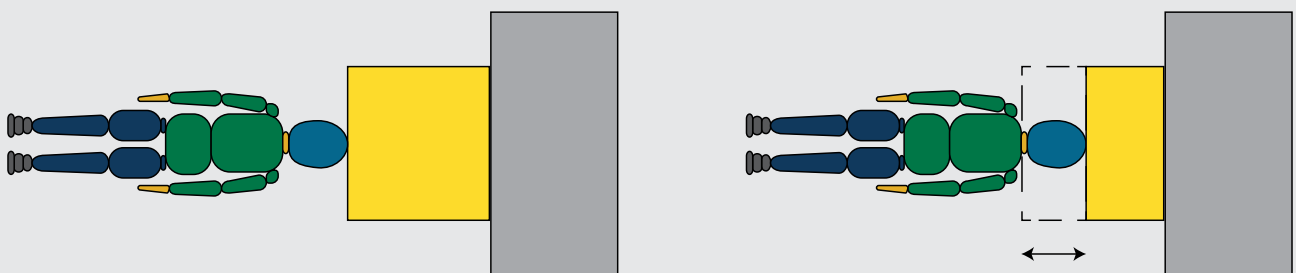
Motorcyclists tend to prefer having clear zones along the road for deceleration or evasive manoeuvres. This concept, known as “forgiving roadside” cannot be implemented everywhere, and roadside barriers remain necessary where obstacles along the road cannot be removed, or where erring vehicles must be contained.

When restraining the motorcycle is the only available solution, the best measure would certainly be to do this in the safest way, making sure the motorcyclist will survive the impact with limited injuries.

We can analyze the situation in a quite simple way : the motorcyclist sliding on the ground has an impact energy associated with him ; the higher the speed, the higher the energy, and more violent is the shock of the impact. To solve the problem, we need the motorcyclist to hit something that can absorb this energy and decelerates him more slowly.



Picture 1 - example of hazards found on the roads



Picture 2 - energy absorbed due to deformation of the component

The severity of the impact can be decreased in two ways: by increasing the contact surface to dissipate the energy of the impact across a larger area, and by cushioning the impact area to provide a slower

and more progressive deceleration. By increasing the contact surface and giving it certain flexibility, the biomechanical forces can be reduced to a level more tolerable for the human body.

What we can see on the roads with this purpose are mostly steel guardrails and concrete barriers, but the issue is that they were originally developed to protect cars and/or trucks occupants. A guardrail usually consists of a steel beam attached to metal posts, and these posts are well anchored along the roadside at regular intervals. A motorcyclist sliding

on the ground can pass through underneath the guardrail, or he can hit a post. Neither one of these possibilities seems to be acceptable : the traditional guardrail is not a good option to restrain the motorcyclist, and when it does, it's hard to agree that striking a metal post, full of edges will cause limited injuries.



Picture 3 - normal steel guardrail

The other common product we can easily find is the concrete barrier. At first glance, as the concrete barrier is continuous, it will restrain the motorcyclist, and we may think it's a good option. But on the other hand, concrete is a material that doesn't have a good deformation, and thus won't absorb appropriately the motorcyclist' impact energy, especially in situations where a high angle impact is likely, such as in bends. As in the recent years it has been argued that a continuous system can be considered safe, even if it's rigid, in 2007 the "Asociación Mutua Motera", Spanish member of FEMA, realized a full-scale crash test according to the Spanish standard UNE 135900 for a "new jersey" concrete barrier profile (which is one of the most conventional

profile and which is considered to be "motorcyclist-friendly" by the common thinking), which resulted in a Head Injury Criterion⁶ (HIC, see annex 5) over 1500 (1,5 time bigger than the limit imposed by TS 1317-8), and traction/compression neck forces out of the limits as well : this clearly explains why rigid systems without any additional deformable part cannot be considered "motorcyclist-friendly" as long as they are not equipped with a successfully tested device. On the other hand, there are no reasons why a rigid safety barrier cannot be equipped with a softer device that may allow it to fit with the crash-test requirements, as it's done for the conventional steel guardrail.

⁶ HIC is a dimensionless index, showing a generic statistical risk of head trauma. HIC is defined for frontal impact with head to vehicle interior contact. The often used threshold levels 650 and 1000, for severe and fatal injury respectively, are an indication of the anticipated risk but cannot predict injuries.



Picture 4 – Images from the full scale crash test on a rigid system : before, during and after the impact



Picture 5 - slip formed concrete barrier



Picture 6 – pre fabricated concrete barrier

However, concrete barriers present some positive characteristics relevant to motorcycle safety. As lane dividers on motorways, in wide curves as well as straight sections, where motorcyclists are likely to impact the restraint system in an upright position and/or at an acute angle, they offer good redirection capabilities, thanks to their smooth, wide impact surface. In such cases, they can prove more effective in redirecting the energy and dissipating it over a larger area than metal rails in absorbing it.

While concrete barriers are more expensive to install than metal designs, they require less maintenance throughout their life cycle, and need less repairs after withstanding an impact.

In addition to these two most common designs, it is worth mentioning the wire rope barrier. Also known as cable barrier, it has been introduced in the past two decades in several European countries. It consists of two or more steel wires held in place by steel posts. According to the manufacturers and the road authorities who chose to install them, they offer several advantages over the classic single

beam design. It is cheaper to install due to the lower weight and reduced use of materials, and it can be used in narrow spaces, as shown below, and for this reason has been used as part of Vision Zero, notably in Sweden, to separate traffic and avoid head-on collisions on single carriageways. Furthermore, the posts are collapsible under the impact of a four-wheeled vehicle, reducing the violence of the impact while transferring the weight load to nearby posts.

Motorcyclists' associations have been quick to denounce the use of this type of road restraint system, seeing it as a downgrade from previous designs. In the case of an upright collision or, the very low impact surface offered by the cable(s) concentrates the kinetic energy on a small surface, potentially making injuries worse and nullifying the effects of protective clothing. Furthermore, the posts are not designed to collapse under the weight of a human being, exposing sliding or falling motorcyclists to the same kind of gruesome injuries caused by single metal beam designs. An example of the specific type of injury that the wire can cause is given in a personal testimony gathered by the



Picture 7 - Wire Rope Barrier

Federation of European Motorcyclists' Associations (FEMA). A man reports an accident suffered by one of his coworkers during a late commuting trip, saying that "after impact with the cable-barrier, the right leg was separated from the body at the joint of the right hip causing fatal bleeding." The victim fainted from the shock and died of blood loss shortly thereafter ; prompting his coworker to add "The blunt trauma caused by a cable of only 10 mm has shocked me for life."

Available data allows for a comparison between the wire rope barrier and the more common single beam rail. The 2008 report by the Transport Research Laboratory (TRL) "Safety Barriers and motorcyclists"⁷ noted that in all cases, the number of incidents between motorcyclists and road restraint systems is relatively low, but these often result in high severity injuries. However, wire rope barriers are associated with a higher injury risk.

In Scotland, between 1990 and 2005, the fatality rate for impacting motorcyclists is 100% for wire rope barriers, against 58.3% for other barrier types. In England, between 1992 and 2005, the fatality rate is 66.7% for wire rope barriers, against 58.7% for other barrier types.

In addition to their safety performance, the cost of wire rope barriers is an important drawback.

In "Improved Road Design for Future Maintenance - Analysis of Road Barrier Repair Costs"⁸ Dr. Hawzheen Karim compares the most prevalent road restraint systems in Sweden : wire rope barriers, w-beam barriers, Kohlswa-beam barriers and pipe-beam barriers.

Wire rope barriers are an attractive option for road authorities and road operators because of their low installation cost, more competitive than other barrier types. However, the data and the statistical models used show that cable barriers have to be repaired even after minor damages As a result, the repair cost per kilometre for cable barriers is almost three times higher than for single beam rails, even though the average cost per repair for both types are almost the same.

The majority of maintenance costs for road barriers result from repairing damage caused by vehicle impacts. Repair costs caused by accidents are higher on roads with 70 km/h or 90 km/h speed limits when compared to repair costs on 110 km/h roads. One of the explanations for this phenomenon is that roads with 110 km/h speed limit have a better geometrical design standard and better safety properties : in the area studied in Sweden, dual carriageways have a better road surface and forgiving roadside, reducing the number of accidents involving an impact on a crash barrier.

⁷ G. L. Williams, J.K. McKillop, R.E. Cookson, "Safety Barriers and Motorcyclists", Transport Research Laboratory for Transport Scotland, 2008
⁸ <http://kth.diva-portal.org/smash/get/diva2:37798/FULLTEXT01>

EXISTING STANDARDS AND PROTOCOLS BEFORE THE INTRODUCTION OF THE TS1317-8

Today, various existing protocols to test Motorcyclist Protection Systems (MPS) are simulating motorcycles accidents, using a sliding motorcyclist impacting the tested system, head first, without the motorcycle. A dummy is launched at a given speed and a given entrance angle, and is made to collide against the MPS, on the post or between two posts. The main differences between tests protocols include criteria such as impact speed, impact point, entrance angle and the part of the dummy which hits the MPS first.

Some countries in Europe have their own norm to evaluate safety barriers, due to motorcycle accidents. We can remark the Spanish Standard (UNE 135900), and the French Test Protocol (L.I.E.R.).

Among the existing protocols, the way to test the MPS (Motorcyclist Protection System) is very similar (except the German one for upright impacts). Basically what is done is a simulation of a motorcyclist sliding on the road, without the motorcycle, and crashing into the MPS. The requirements for the approval of a product vary, and an MPS approved in one country is not guaranteed to receive approval in another.



Picture 8 - Continuous MPS



Picture 9 - Discontinuous MPS

2.1. The need for a European standard

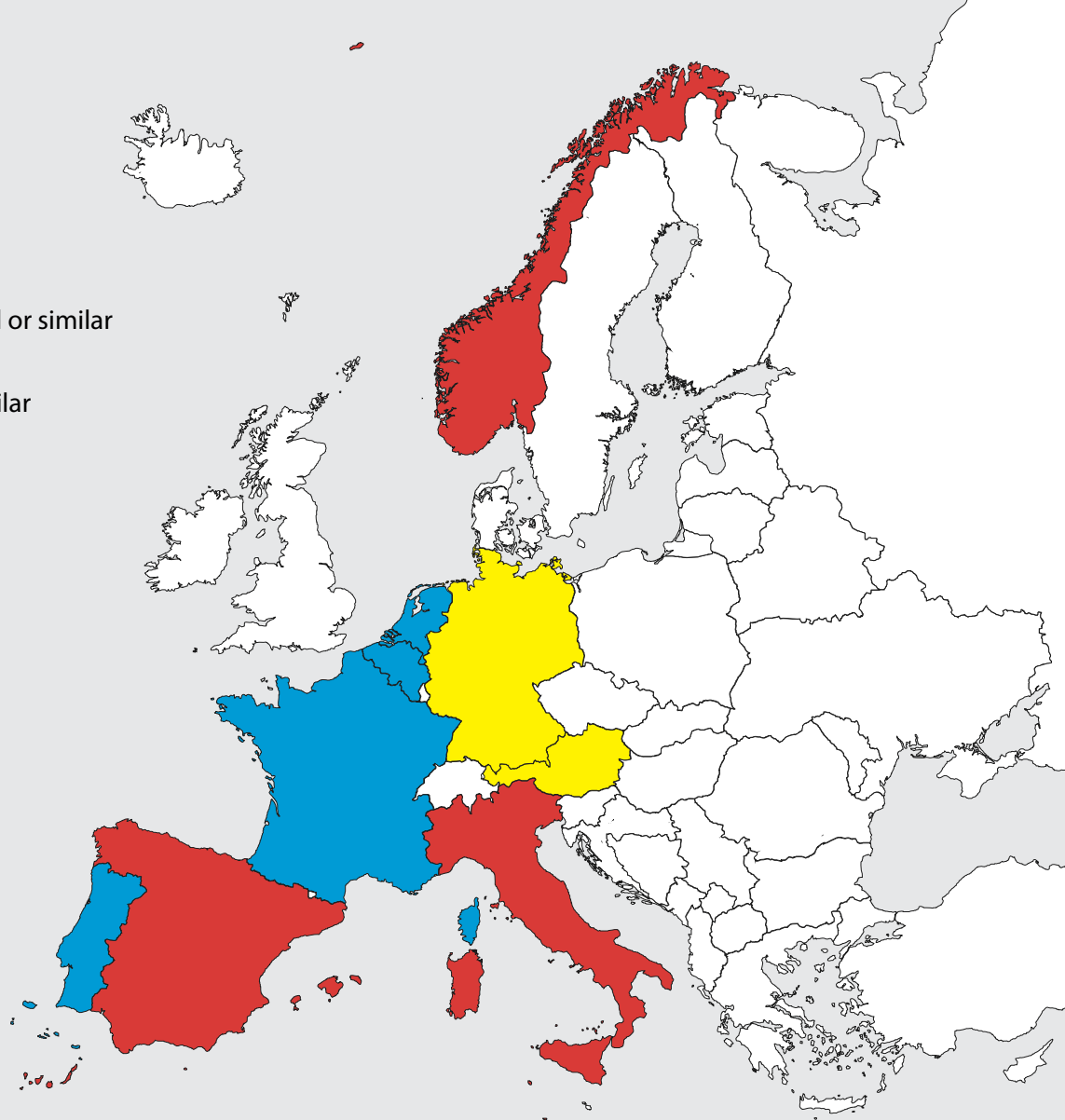
In Europe there are still differing legislations regarding motorcycle safety barriers. In Italy there is the UNI Draft, that regulates the installation of MPS, and it's very similar to the Spanish Standard. In Portugal the approved law 33-2004, July 2008 and the decree 3-2005, May 10th, determine where, how and what type of MPS will be used. The tests procedures used in Portugal are the same as the ones used in France. In Germany, the BAST

homologation procedure is used to approve MPS for safety barriers. According to this procedure deceleration against crash barrier protectors at the point of impact, which should not exceed 60g as a peak value and 40g over a 3ms interval, is measured. The report states that different methods are used to assess two classes of devices. The figure below illustrates regulations in use in Europe.

■ L.I.E.R. test protocol or similar

■ UNE 135900 or similar

■ BAST



Picture 10 - Regulations in use throughout Europe

There are several advantages to having a European Standard, the most important of them is that any product available in the member countries will be tested in accordance with it. In that case, it will be possible to compare the performance and quality of all the MPS, because they all will be tested in the same conditions.

As the criteria for approving MPS are different from one national regulation to another, many types are available across different countries. There are continuous and discontinuous motorcyclist protection systems. There are also MPS using different materials ; such as plastic, steel or wood. Without an approved EN 1317-8, different designs are tested using different protocols, making it impossible to compare them and assess which one has the best characteristics or is the most effective.

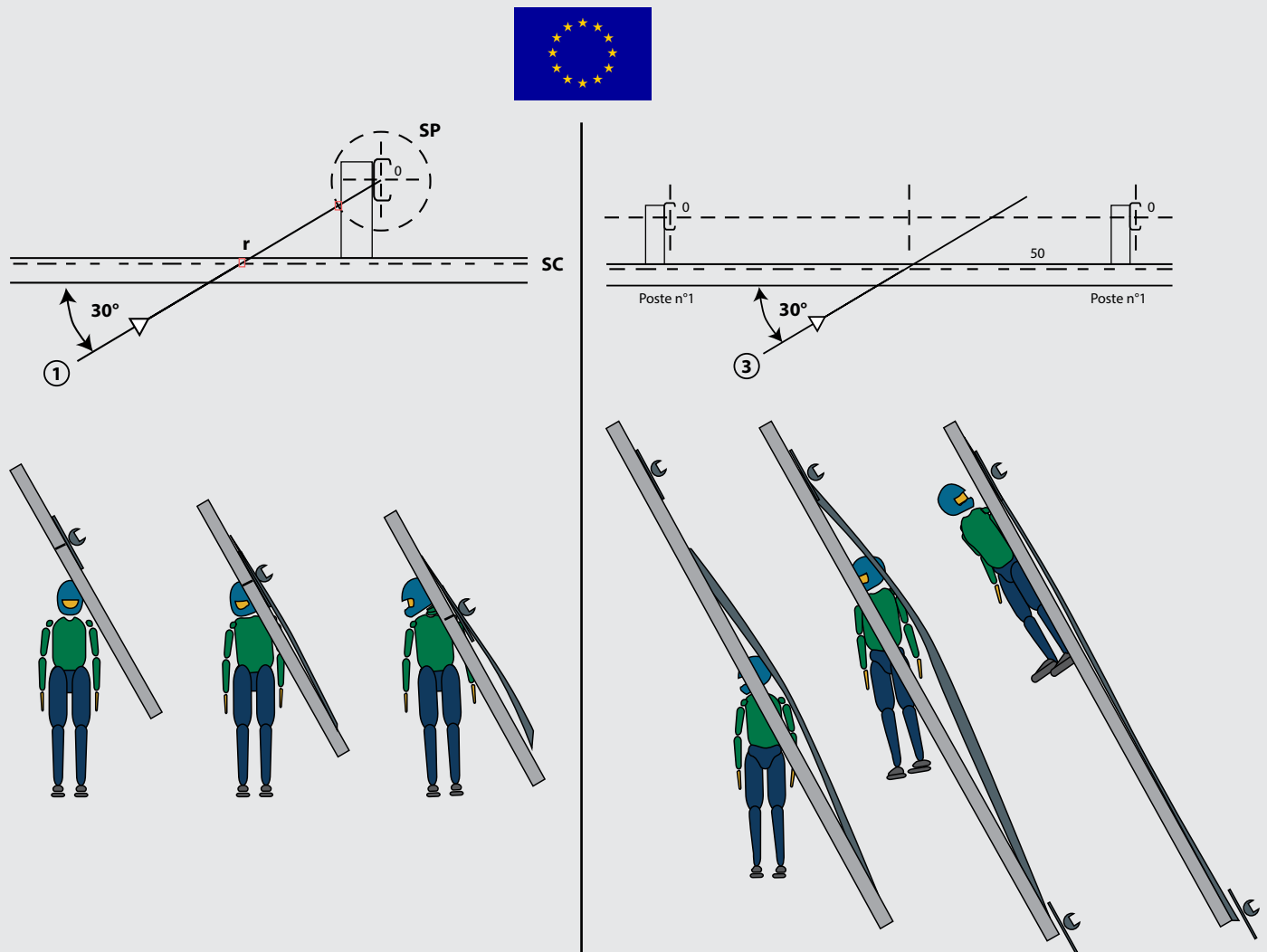
Another advantage of a common standard across the European Union, would be a considerable market increase, covering all European Union Member States. So, for example if a manufacturer in Spain wants to develop a new MPS, it would only need to execute the test procedure for the European Standard, instead of testing his MPS according to national regulations in every country. It would become much easier to sell products across the single market : competition will be increased and better and more affordable products will be available.

2.2. Technical Specification TS1317-8 in detail

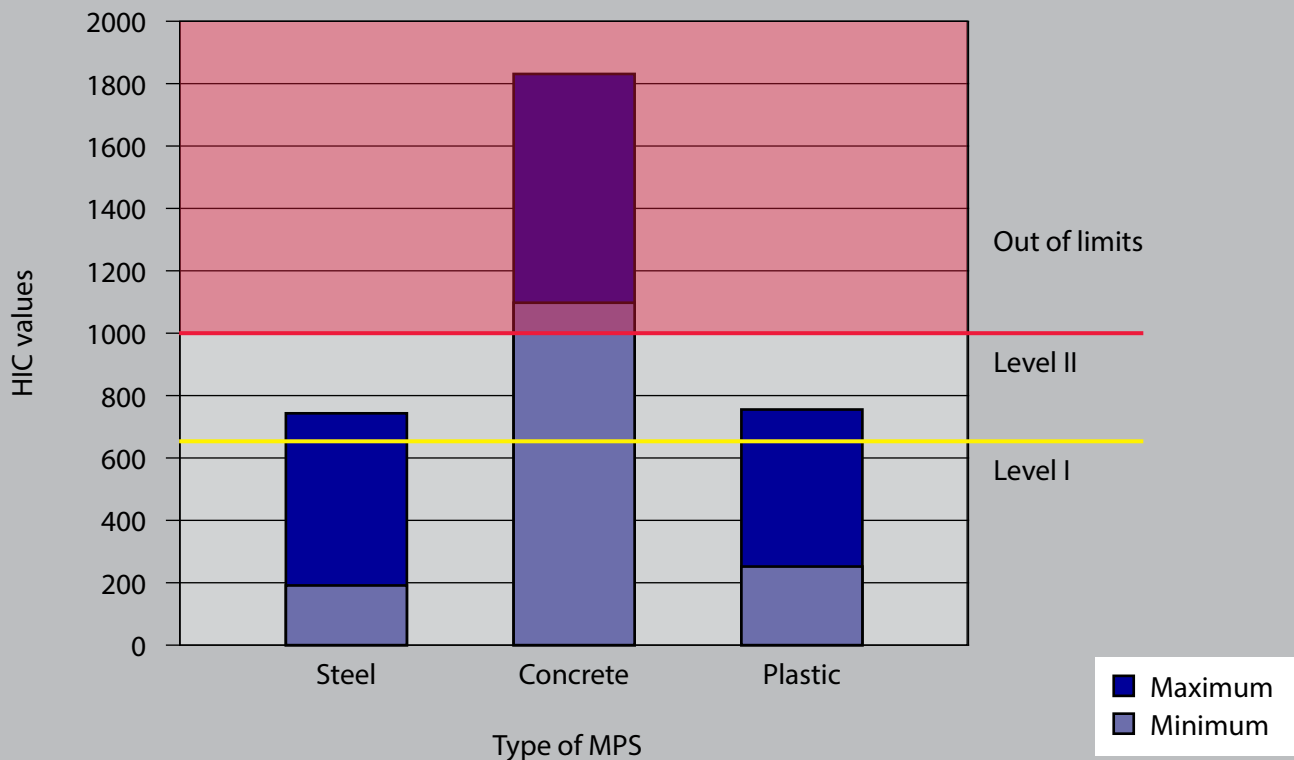
Considering the existing national regulations, the European Committee for Standardization (CEN) has developed the TS 1317-8, which contains provisions for the evaluation of the performance of safety barriers under the impact of a rider sliding along the ground.

The resulting test procedure shall be used together with the existing parts of the EN 1317.

Taking a look at the TS 1317-8, we can see very clearly that it's virtually the same as the Spanish Standard UNE 135900.



Picture 11 - example of a test protocol using a dummy against an MPS



Picture 12 : Overview of the range of performance of different types of MPS considering the current tested products available (total of around 20-30 tested products)

	Head	Neck					
Severity level	HIC36	Fx (N)	Fz tension (N)	Fz compression (N)	Mx (Nm)	My extension (Nm)	My flexion (Nm)
I	650	Diagram	Diagram	Diagram	134	42	190
II	1000	Diagram	Diagram	Diagram	134	57	190

Performance classes – Maximum Admissible Value

All technical specifications are applied on a voluntary basis, and can coexist with a national standard or technical specification for the same subject (it would not be the case, however, with an EN standard). The European Union public procurement directive (2004/18/EC) however makes it mandatory to reference to existing technical specifications,

and mentions an order of preference in which international/ European documents have preference above national specification methods. One could argue that - for public works within the scope of the directive - a European TS takes precedence above an existing national specification method.

3 MOTORCYCLIST PROTECTION SYSTEMS INSTALLATION

In addition to technical standards, an important point that should not be cast aside is the installation of the approved MPS, in terms of location and length.

First of all, it is essential to establish that roadside barriers should only be installed where they are clearly needed. If there is no dangerous obstacle along the road and errant vehicles will not represent a hazard for other road users, then barriers should be avoided in favour of forgiving roadsides (such as tarmac, dirt or grassy areas along the road).

Installing MPS on all roads featuring crash barriers would be the best solution, but this is difficult to achieve in terms of economic feasibility, and also would take a lot of time (even if countries particularly affected by this issue, like Portugal and Spain, have already implemented a "100% equipping of MPS

on new road barriers installation" policy). In France, the Ministry of Transport estimates that the cost of equipping all crash barriers with MPS would be 600 million Euros ; another study suggested an estimate of 1 billion Euros.

An alternative solution would be to identify the most critical road sections and then install the MPS with optimised cost effectiveness. There are different ways a rider can lose control of his motorcycle, but the most common are when he is travelling at high speed, when he has to break hard to reduce speed and if he breaks too late.

In a bend we usually have all these factors that could lead to the motorcyclist losing control. Bad conditions of the road and bad visibility are factors that contribute to aggravate the occurrence of these situations.



Picture 13 – blind spot



Picture 14 – successive bends

The French national directive says that for new roads MPS should be installed on the external side of highways and roads with separated carriageways when the radius of the bend is equal or less to 400 meters. On the other roads the MPS should be installed in the external side of bends with a radius equal or less to 250 meters. The installation is also necessary in the external side of all bends for crossroads with different levels.

According to the dedicated Spanish OC (Ordeno Circular) the installation of MPS on existing barriers is recommended at outside shoulders in curves in dual carriageways with a radius lower than 400 meters and in deceleration lanes in exits ; in single carriageways with shoulder over 1.5 meters when the radius is lower than 250 meters, and on any other highway that has a speed reduction at curve higher than 30 km/h.

An interesting paper on the subject exists : Improving Motorcyclists' Safety in Spain by Enhanced Crash Test Procedures and Implementation Guidelines, [1], in which a methodology is presented recommending the installation

and warranty of MPS on specific road stretches in the Spanish regional road network of Castilla y León. 4 scenarios for the classification of bends have been developed.

Scenario nº	Curve Length	Minimum curvature radius
1	> 120 m	> 90 m
2	> 120 m	< 90 m
3	< 120 m	> 90 m
4	< 120 m	< 90 m

Table 1 - risk classification of Castilla y Leon roads

For each scenario identified in the paper a list of variables has been developed to be considered as criteria to determine where MPS must be installed. For example, in the scenario nº1 the criteria are :

- Road signs and road marking for the definition of bend layout.
- Position of decrease of minimum curvature radius along the bend not predictable by the rider.

This study is interesting because it introduces new parameters, like the signalization of the curve and the visibility of the minimum radius at the entrance, but it can be remarked that it is based on the statistics of the road network in Castilla y León, and should not be applied to all other roads.

In 2000, FEMA produced the 'Final report of the motorcyclists and crash barriers project'⁹, a project co-financed by the European Union, which provided recommendations to road authorities for replacement and adaptation of crash barriers. For existing installations it recommends that in

motorways and interstate highways the MPS should be installed in the exterior of curves with a radius less than 400 meters. Also crash barriers on entries and exits of motorways should be equipped with MPS, as well as rings roads around major cities.

In country roads, as the speed limits are lower, the report calls for the installation of MPS in curves with a radius of less than 250 meters. In addition, the report identifies dangerous areas, as roads with gravel, slippery roads, working areas and curves where the road surface is of poor quality. They all should have MPS installed.

Well, as seen above, there are many different ways to classify the locations that should have priority in MPS installation. Certainly it's not easy to choose what recommendation is more effective, especially when it comes to design guidelines applying for the entire European Union, but it is clearly necessary to reach a consensus, and the experience of riders should be used when choosing the spots.

⁹ http://www.fema-online.eu/uploads/documents/guardrails/Motorcyclists_and_crash_barriers.pdf

4 SUCCESS STORIES ACROSS EUROPE

Based on background research work, several European countries have attempted to address the guardrail problem. An overview of successful national projects was compiled by FEMA¹⁰ in 2005 in "The Road to Success : improving motorcyclists' safety by improving crash barriers".

A successful approach to reducing the negative effect of dangerous guardrails implies a more global reflection on the road geometry, environment and equipment. All success stories - some of which are described below - implied a global thinking on how to avoid having to resort to guardrails in the

first place. If their use was deemed necessary, they would be included not as stand-alone equipment, but as part of a wider conception of a forgiving road.

Even more importantly, the hallmark of success lies in a close cooperation between researchers, who identify and locate the problem ; policy-makers, who give the impulse, funding and legal background to the project ; and road operators and equipment manufacturers, who deliver the result . Securing this cooperation, if needed through a detailed agenda laid out by the authorities, is the most effective way to roll out change on the road.



Spain : a case study

Concrete results started to arise as from 2008, when Spanish Standardization body AENOR adopted the UNE135900:2008 standard, a revision of the first version introduced in 2005. Following massive public pressure, including calls for installation of motorcycle protective systems by Spanish motorsport celebrities, public authorities announced important investments for the installation of protective systems. The national motorcycle safety action plan

includes the installation of hundreds of kilometers of protection systems, and further investments were made in product research for improvements in impact absorption and barrier design. SMART RRS¹¹, an EU co-funded research project coordinated by the University of Zaragoza, illustrates the new national dynamic created by the adoption of the Spanish standard.



Portugal : best practices in action

Motorcyclist protection systems in Portugal are covered by law 33/2004 of July 28th, 2004 on the "Placement of Crash Barrier Protections on public roads, whether or not comprised in the national road network, envisaging the safety of two wheeled vehicles". It states that all crash barriers should "include a safety perspective for two wheeled vehicles, especially in black spots".

The technical requirements of the MPS to be installed are outlined by government regulations ; which currently mandate the use of systems compliant with the Spanish UNE135900:2008 standard.

¹⁰ <http://www.fema-online.eu/uploads/documents/guardrails/crashbarrier2005.pdf>

¹¹ <http://smartrrs.unizar.es/content.php?seccion=16&elemento=319>

The MPS must be placed on all roads wherever necessary, but especially :

- in curves with a radius under the normal minimum value ;
- in curves with no superelevation or inferior to the mandatory values ;
- in small radius curves with a high downward gradient (> 4%) ;
- in consecutive circular curves in the same direction with a decreasing radius ;
- in cloverleaf junctions and other small radius intersections and on-ramps ;
- at entry points at intersections ;
- in zones prone to skidding or icing.

The law foresaw the installation of MPS in these areas by 2007. In addition, crash barriers in non-urban areas must be replaced wherever possible by obstacle-free shoulders. The list of black spots is established by authorities or companies in charge of road maintenance, and is maintained by the Portuguese Road Safety Body. MPS, replacing or upgrading existing guardrails, must be installed within one year once they have been added to the list.

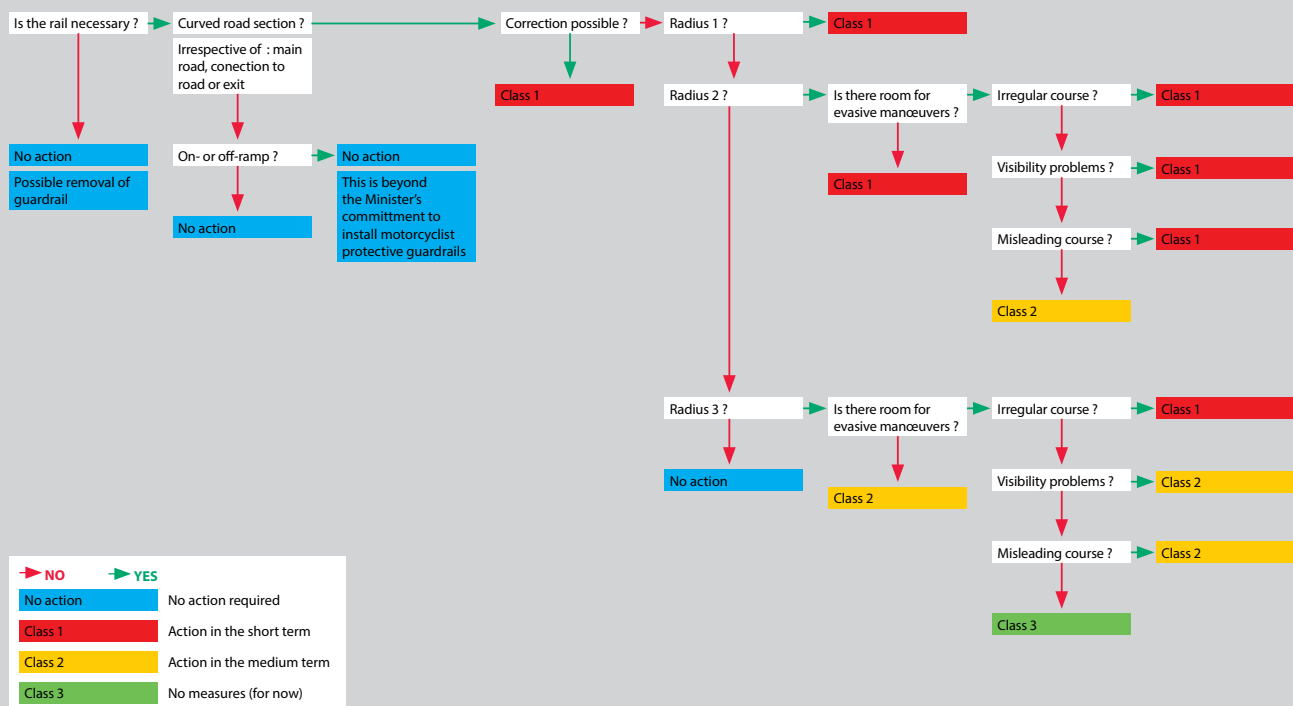
Non-compliance with the provisions of the law can give rise to civil and criminal liability for injuries sustained by road users.



The Netherlands : a careful approach

In the Netherlands, a campaign started by motorcyclists' associations in 2005 in the Utrecht municipality led to the implementation of guidelines by the Ministry of Transport regarding the installation of MPS. The locations for installation are defined in a simple decision tree, detailed below.

The guidelines make provisions for future extensions of the scope of the MPS installation, allowing for the identification of locations suitable for installation at a later point.



Picture 15 - decision tree for the installation of MPS in the Netherlands



Germany : Identifying Black Spots with MVMot

The “Merkblatt zur Verbesserung der Verkehrssicherheit auf Motorradstrecken” (MVMot) - Leaflet to Improve Road Safety on Motorcycle Roads - offers an interesting approach to the identification of black spots for motorcyclists and the implementation of a range of appropriate measures. Published in 2007, this document is the result of a collaborative work, started in 2003, under the direction of the German Road and Transportation Association (FGSVe.V.). It involved representatives from the road authorities of the Federal Government, the police force, road safety institutions, universities, road engineering offices and riders' rights organisations.

The collaborative work was conducted under the understanding that motorcycle safety can only be improved significantly through an approach integrating all three main parameters : the rider, the vehicle, and the road. Therefore, the group set out to develop guidelines to increase motorcycle safety by improving the road infrastructure.

The focus was on avoiding motorcycle accidents, and reducing their consequences ; on roads featuring black spots and on rural roads with a high share of motorcycle traffic, the so-called “motorcycle roads”. The balanced needs of motorcyclists, and car and heavy vehicle passengers were also kept in mind.

“Motorcycle roads” were identified as roads with the following characteristics : a low traffic volume, a low proportion of heavy goods traffic, a sufficient number of curves, no urban areas and differences in elevation along the road. The perfect motorcycle road given as an example is a stretch of country road in a low mountain range with around 2500 vehicles per day, of which 5% of trucks or buses, featuring 26 curves with a radius under 80m and 54 curves with a radius comprised between 80 and 180m.

Here are a few examples of practical safety measures proposed for different situations :



Picture 16 - Signs dispersed behind a motorcyclist protective rail



Picture 17 - Flexible bollards replacing direction signs



Picture 18 - Earth walls replacing guardrails



Picture 19 - Obstructing view cleared, reducing the risk of run-off and/or frontal collision



Picture 20 - Double continuous line to reduce the risk of run-off in curves

The MVMot leaflet introduces a standard process for improving road infrastructure to be implemented on a regular basis, with audits to assess the success of each package of measures. The close-cooperation of experts with different backgrounds and views, especially riders with their perspective and experience, led to comprehensive results.

The document is available in its full form in English and German, and a summarized version is available as a brochure targeted at elected officials and public administrations, focusing on the core issues.

The conclusions are now implemented in most German States by decree or formal instruction.



Norway : a “Vision Zero” road

“Vision Zero” is at the core of road safety work in Sweden and Norway since the mid-1990’s. The concept is to achieve a state where no one would be seriously injured or killed in traffic.

Since humans can always make mistakes, it is impossible to prevent traffic accidents entirely. However, it is considered possible to alleviate their consequences, by making roads and vehicles safer and forgiving of errors.

In Norway, this campaign resulted in the inclusion of motorcycle characteristics in the government’s infrastructure guidelines ; taking the form of Handbook 245 : Motorcycle Safety, a motorcycle guide for highway engineers, first published in 2004. It features guidelines for the design and operation of roads and traffic systems, with a focus on motorcycle safety. It is notably used for road safety audits centered on motorcycle safety.

In practice, the motorcycle safety audit checklist includes elements such as pavement conditions, position of guardrails and whether they are strictly necessary, lighting and position of signage, visibility, clearing of obstacles, and motorcyclist-specific signage. It also encourages engineers to seek alternative solutions to guardrails wherever possible, including, but not limited to : embankments, side slopes for deceleration of fallen motorcyclists, or use of soft topsoil to cover rocks.

Applying these principles on the field is Highway 32 near Oslo, a popular motorcyclist road. It underwent renovations which turned it into the first Vision Zero-compliant road in the world, and was inaugurated by the president of the Federation of European Motorcyclists’ Associations in 2008.



Picture 21 - Problem : lamp post in hazard zone



Solution : clear trees, move light post to the inside of the curve



Picture 22 - Polyethylene subrails have been added to guardrails in outer curves.



Picture 23 : Motorcyclist-friendly steel subrails have also been added.



Picture 24 - Here signposts have been placed behind a guardrail equipped with MPS.



Picture 25 - Dangerous terminals have been replaced with MPS swinging away from the roadway.



Picture 26 - Guardrail terminals present sharp edges and a low contact surface, face traffic directly and are located very close to the roadway. Fitting them with a protective cover reduce the risk of injury on impact.

Since the opening of the road in May 2008, there has not been a single serious motorcycle accident on this stretch of Highway 32. The safety audit concluded that the actions taken have proven beneficial to all road users.



France : policy and standardization hand in hand

The effort by the French government to improve guardrails started with the report “ Les glissières métalliques dans l’accidentologie des motocyclistes¹² ” published by SETRA (Service d’Etudes technique des Routes et Autoroutes) in 1997. It studied guardrails-related accidents between 1993 and 1995 in France, in order to assess the effectiveness of existing measures in place since 1986 (constant curve radius, increased visibility in curves, quality of the road surface, etc.) and the need for further actions.

Data shows that over the time period, 188 motorcyclists were killed impacting single beam metal rails, representing 5% of all fatal injuries caused by impacting obstacles. In comparison, only 18 deaths (1,7%) are attributable to concrete barriers, and 10 deaths (1%) to other barrier types. When all injuries are taken into account (light, serious and fatal) the trend is reversed : single beam metal rails represent only 10,5% of injuries, and concrete barriers 2,5%. Metal rails without an MPS are therefore associated with higher fatality rates and a lower chance of survival. Obstacles represent just under 50% of all motorcyclist deaths, but only 17% of motorcycle accidents ; however, underreporting is an issue due to the lack of witnesses in single vehicle accidents, which are the most common configuration in crashes against obstacles.

Fatal accidents against all road restraint system types total 8.9% of fatalities. Single beam metal rails are by far the most dangerous obstacle for motorcyclists, killing 63 on average every year - 7.8% of all fatalities.

The trend is even stronger in non-urban areas, where accidents with obstacles represent one third of all motorcycle accidents, and 40% of fatalities. The share of fatalities attributable to road restraint systems soars to 13.3% of the total, and for single beam metal rails alone, 12.1%.

In urban areas, where guardrails are less prevalent and other obstacles such as sidewalks, posts and parked vehicles are the most common obstacles impacted, single beam rails are still responsible for 13 deaths per year, 7.1% of all deaths attributed to obstacles, and 3.2% of all casualties.

Where are guardrail-related accidents the most common? They happen in majority in non-urban areas (79.3% of cases), and more often on single carriageways (47.4% of cases) than on dual carriageways (31.9%).

The road geometry is an important parameter: more than 60% of guardrail-related fatalities are located in curves. Inclination is also a factor, especially in non-urban single carriageways.

The general profile of guardrail-related accidents points at non-urban single carriageways, in tight curves : 30% in curves with a radius over 400m, 17% in curves with a radius between 250 and 400m, and 53% in curves with a radius under 250m.

On dual carriageways, where the curve radius is most often over 400m, more research is needed to identify typical black spots and, if any, the curve radius associated with this type of accident.

The author concludes that while they represent only 2% of all road deaths, guardrail-related accidents are abnormally dangerous because they disproportionately affect motorcyclists. She writes that “Guardrails aim at improving the safety of all road users. The fact that they have a negative effect in certain circumstances makes the situation unacceptable” and notes that while the analysis confirms the importance of curve scenarios, it shows clearly that corrective measures solely aimed at this scenario would not alone solve the metal guardrail problem for motorcyclists.

¹² Karine Pothin, under the direction of Guy Desire, CETE de l’Ouest

The 1999 Directive on Motorcyclists Protection Systems

As a result of the 1997 SETRA report, a 1999 government directive (Circulaire n° 99-68, October 1st, 1999) was published to cover the installation of MPS, including their location and type. It mandates the use of MPS in curves where the radius is under 400m on highways, and 250m on other roads. It acknowledges the results of the SETRA study, underlining that guardrail-related motorcyclist accidents are “abnormally severe” with a severity 5 times higher than average, and their consequences “often spectacular and tragic”.

The directive insists on the need to reduce the risk of accident in the first place, by focusing on visibility of the road, intersections and curves ; on maintaining constant radius in curves, on avoiding sideways road inclination, and on the quality of the road surface (grip, evenness, water flow, cleanliness). All these efforts also contribute to the safety of other road users.

If the use of guardrails is necessary, the use of approved MPS is compulsory in the curve exterior :

- on dual carriageways, in curves with a radius under 400m,
- on all other roads, in curves with a radius under 250m,
- at inclined intersections, on all road types and all curve radii.

During the drafting stage of the directive, a nationwide contest was launched by the Inter-ministerial Road Safety Committee (CISR) calling for innovative and competitive MPS designs. The call for tender offered two possibilities : a new design, or an add-on design for existing systems.

The LIER protocol for MPS testing was created as part of the call for tender in order to select the best available design. Two systems were approved as a result, one new design (MOTO-RAIL by SOLOSAR) and one add-on for existing rails (ECRAN MOTO-TUB by SODIREL). A pre-existing add-on, steel-screen design by SEC-ENVEL was also approved using the protocol.

Assessment and further research in 2011

A decade later, the CETE (Centre d'Etude Technique de l'Equipeement, branch of the Ministry of Transport) is conducting since January 2011 research to answer the following questions : are MPS effective? If yes, on which type of roads, and curves? Where are the points of impact with the motorcyclist? In addition, the conformity of the MPS, its installation and maintenance are also checked whenever possible in order to obtain data on the ageing of the systems.

Based on accident reports established by law enforcement, the team hopes to come up with reliable results, despite the lack of detailed information on many single vehicle accidents, due to the lack of witnesses.

Preliminary results indicate that a significant number of accidents against guardrails occurred on straight road sections, prompting researchers to consider the replacement of all guardrails with MPS, the cost of which is estimated at €1 billion.

Final results are expected to be published in 2012.

5.1. Toward better research and data collection

In 2008, the European Road Assessment Programme (EURORAP), an international not-for-profit association whose members are motoring organizations and national and regional road authorities, produced a review titled 'Barriers to Change'¹³ which provides an analysis of the issues and a series of recommendations for improvements to barrier design. The paper shows that motorcycle crashes cost the European economy billions annually, and argues that the response is not proportionate to the scale of the problem. It examines crash barriers that routinely save the lives of car occupants but can cause traumatic death to motorcyclists, recommends that engineers be provided with clear guidance on the design of barriers and the locations where they should be used. FEMA was part of the panel.

APROSYS (2004 -2009)¹⁴, with its Sub Project 4 on motorcycles, focused on passive safety devices for motorcyclists, including forgiving infrastructure. From the accident data available in the MAIDS, DEKRA, DIANA and COST327 databases, detailed information about motorcyclist road accidents (the causes of the accidents and the most frequent riders' injuries patterns) was compiled and compared with the findings of earlier works in this field (in particular the ISO activities). An optimum number of representative accident scenarios were selected, and impacts with road infrastructure were evaluated. Methods to evaluate and validate infrastructure protective devices for motorcyclists have also been developed. The evaluation of the existing protective devices for motorcyclists was carried out as well. A proposal for a test procedure to evaluate and validate infrastructure protective devices for motorcyclists were developed, and the feasibility of this test procedure was demonstrated. This information, though available publicly, was not used during the preparation process of the CEN draft standard.

SMART RRS (2008 – 2012)¹⁵ : The project investigated available studies on guardrails and statistics and found out that motorcyclists impacting fixed objects occurred in 4% of the cases in urban areas, while it was between 10% and 20% in rural areas, with a fatal outcome 2 to 5 times higher than in other types of accidents. It also discovered that the best solution seems to be the addition of a lower rail to the most common single beam design, as it provides better energy absorption than concrete solutions or wire rope safety barriers. Wire rope safety barriers are viewed by motorcyclists as the most aggressive form of restraint systems. This view is supported by computer simulations and tests, which indicate that injuries will be severe if a rider hits the cables or the support due to the smaller impact surface offered by the cable compared to other designs. This information, though available publicly, was not used during the preparation process of the CEN draft standard. SMART RRS has now developed a smart road restraint system providing better shock absorption features and offering the opportunity to alert motorists and emergency services to an accident happening.

PILOT4SAFETY : in 2008, the European Parliament and Council issued Directive 2008/96/CE on road infrastructure safety management, which foresees a series of safety checks, as well as training and certification of road safety auditors. The Directive focuses specifically on the safety of vulnerable road users, which includes motorcyclists. When the directive is adopted by the Member States, it will apply to the TEN-T road network (covering only a part of the EU highway network), while the highest number of fatalities occurs on the so-called "secondary roads". To overcome this barrier, the PILOT4SAFETY¹⁶ project is aiming at applying the Directive's approaches related to training and certification of Road Safety Experts for the application of Road Safety Audit and Road Safety Inspection procedures to selected secondary roads, in the EU Regions represented in the project. FEMA is part of the advisory board.

¹³ http://www.eurorap.org/library/pdfs/20081202_Bikers.pdf

¹⁴ <http://www.aprosys.com/Documents/deliverables/FinalDeliverables/Final%20SP4%20report%20AP-90-0004.pdf>

¹⁵ <http://smarrrs.unizar.es/>

¹⁶ <http://pilot4safety.fehrl.org/>

Similarly, evaluation studies providing pre-installation and post-installation data are missing as well. France has launched a study to analyze the number of accidents involving motorcyclists before and after the installation of protective guardrails. Results of the study are expected in the next few years. Unfortunately, as far as we know, this is also one of the few, if not the only, ongoing post-installation studies on guardrails and motorcyclists.

Finally, the cost of road construction work over its service life is a function of design, quality of construction, maintenance strategies and maintenance operations, but all these elements are rarely taken into account in the decision making process. Designers often neglect a very important aspect, which is the possibility to perform future maintenance activities. The focus is mainly on other

aspects such as investment costs, traffic safety, aesthetic appearance, regional development and environmental effects. Hawzheen Karim's PhD thesis "Road Design for Future Maintenance – Life-cycle Costs Analyses for Road Barriers"¹⁷ underlines that road authorities have often focused on eliminating costs after they are incurred (i.e. reactive cost management) instead of eliminating costs in the commitment stages (i.e. proactive cost management), leading to impaired maintenance standards and low product quality. In almost all efforts towards efficient maintenance, says Karim, road authorities have ignored improvement potential that exists during the planning and design phase, the underlying causes and consequences of which have not been studied adequately. Karim's study reveals a complex combination of problems which result in inadequate consideration of maintenance aspects.

5.2. From TS to EN1317-8

From an industrial perspective, the lack of a European standard for product approval is seen as an obstacle to a European market for motorcyclists' protective road restraint systems. For those who offer products to protect motorcyclists, having harmonized requirements is the next obvious step.

In 2006, FEMA, the Federation of European Motorcyclists' Associations approached the Centre Européen de Normalisation (CEN)¹⁸, the European standardization body, and asked for liaison status with the Technical Committee in charge of road equipment (TC226) in view of contributing to the drafting of a European-wide standard.

In 2007, the Committee "accept[ed] in principle to work on the protection of motorcyclists in respect of road restraint systems, and ask[ed] the Chairman, the Secretary and the convenor of WG 1, in consultation with FEMA, to prepare the Scope for a new work item based on the existing standards, regulations and technical specifications in the CEN member countries".

In June 2008, the same Committee adopted Resolution 319 calling for the preparation of a part 8 to EN1317 for the "development of a European Standard which reduces

the impact severity of motorcyclist collisions with safety barriers considering the existing national standards and the possibilities of present day technology".

In 2011, the proposal for part 8 of the standard on guardrails was technically ready, validated by all task and working groups, after an internal enquiry for comments and positive evaluation for adoption. However, the technical committee finally decided that further development of the protocol should be undertaken and that experience of its use should be gained before proposing it as a full European standard. The committee therefore proposed the protocol as a Technical Specification (in effect, an experimental standard) and this document was subsequently approved by EU member states. CEN will continue to work towards the transformation of the TS into a full European standard. In the meantime, the TS is available for national authorities to use for the evaluation of MPS, however, because it is not a full standard they remain free to use other national standards. It is thought that several national road authorities plan to adopt it. Only when the protocol becomes a full European standard will member states be obliged to abandon any alternative test protocols.

¹⁷ <http://kth.diva-portal.org/smash/record.jsf?pid=diva2:37798>

¹⁸ <http://www.cen.eu/>

CONCLUSION

Safety barriers, usually designed for cars and heavy vehicles, are threatening the safety of motorcyclists. In order to solve this problem the installation of motorcyclist protective systems (MPS) on the roads seems to be the best solution to improve the safety of car drivers and motorcyclists.

However, some factors have to be taken into account when choosing the MPS to be sure that it will satisfactorily solve the safety barriers issue. To evaluate MPS, some countries such as France, Spain and Germany, for example, started making norms to test them. The problem is that as the norms are different, it's impossible to make a good comparison among the available MPS.

CEN started the development of the TS 1317-8, with the objective of making it the European Standard to evaluate motorcycle protection systems. If approved, all the MPS would be classified according to it, making more reliable and easier to choose, compare and evaluate them.

Already some first solutions in steel or plastic fulfil those new requirements with results far better than the specifications recommended by TS 1317-8, such

as HIC 150 for a steel system and HIC 300 for a plastic one. The second one could also be used in front of aggressive rigid walls such as concrete barriers or tunnels. The Federation of European Motorcyclists' Associations launched The Federation of European Motorcyclists Associations (FEMA) launched a dedicated website (www.mc-roadsidebarriers.eu) to promote motorcyclist-friendly road barriers, featuring a comprehensive database of existing barriers, a listing of manufacturers and guidelines detailing current standards and best practices for the benefit of road authorities.

Much remains to be done, but the measures that have been taken, the research going on, and the efforts of FEMA, are continuously raising awareness regarding the importance of MPS and contributing to change the situation on roads all over Europe.

As removing safety barriers would not solve the problem for the motorcyclists - the obstacles and the hazards would remain - safety barriers equipped with Motorcycle Protection Systems are the only effective way to increase the road safety and effectively protect all road users.



This initiative has been a part of the RIDERSCAN project



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A1. Call for testimonies by the Federation of European Motorcyclists' Associations

In order to support the work of CEN on guardrail standard EN 1317-8, the Federation of European Motorcyclists' Associations (FEMA) launched a call for testimonies to complement available accident records and data on motorcycle accident involving guardrail impacts.

Starting in August 2009, motorcyclists across Europe were asked to report their personal experience, as victims themselves or as relatives or friends of a victim, in as much detail as possible. Information provided includes multiple accident factors, age of the victim, type of rail and point of impact, impact speed and angle, travelling speed, and injuries sustained. The survey is available online in five languages in order to get a wide view of the situation in Europe.

222 testimonies have been collected over three years, between August 2009 and August 2011. A review of the available results highlights trends in accident configurations. In addition, personal comments and perceptions of accident situations offer an insight on the causes and consequences of these accidents. The call remains open to all motorcyclists, their friends and family members should they wish to participate.

- 122 accidents were reported by a victim, and 118 by a relative. The latter mostly reported severe (32%) and lethal (54%) injuries, while the former reported mostly severe injuries (52%).
- 100 cases of severe injury were reported. In most cases, respondents gave ample details on the nature of the injuries. Common cases include traumatic amputation (with limbs severed during impact or damaged beyond recovery, requiring surgical amputation), spinal injuries (often causing permanent disabilities), bruised or damaged internal organs (bruised or punctured lungs, spleen, pancreas, bladder, kidneys) and multiple open fractures. Lower

limb fractures are common, often involving both legs, requiring multiple surgery until the victim can walk again. Some respondents describe heavy, life-affecting limb injuries caused by an the limb impacting a guardrail post, while being otherwise uninjured. In several cases, both legs or arms were amputated.

- In several cases, victims suffered fractures, torn limbs or immediate amputation following the impact of one or several limbs with a support post, to the exclusion of other major injuries.
- In one described case, a motorcyclist slid under the rail and fell into a ravine while the motorcycle hit a support post. She suffered a simple fracture of the toes when her foot hit the rail, but did not suffer injuries from her fall.
- Life-long damage is not necessarily correlated with injury severity. In some cases, simple fractures caused by post impacts on limbs led to permanent damage and reduced mobility. In these cases partial recovery, if any, occurred after 6 months to a year, during which the victim could not work.
- Out of 60 fatal injuries declared, 43 are reported to have occurred due to impact on guardrail posts (70%), and 22 on the rail itself (37% - some accidents involved multiple impact on both posts and rail). 56 fatalities are reported to have happened after impact with single metal or wood rail. The most common causes of death following impact on posts are traumatic amputation or severe limb damage, decapitation, internal trauma (including punctured lungs cause by cracked ribs), bleeding, and head trauma. Impact with posts represents 70% of fatal injuries and 76% of severe injuries.
- Only one accident is reported to have involved a cable barrier, the cable causing a lethal traumatic amputation.

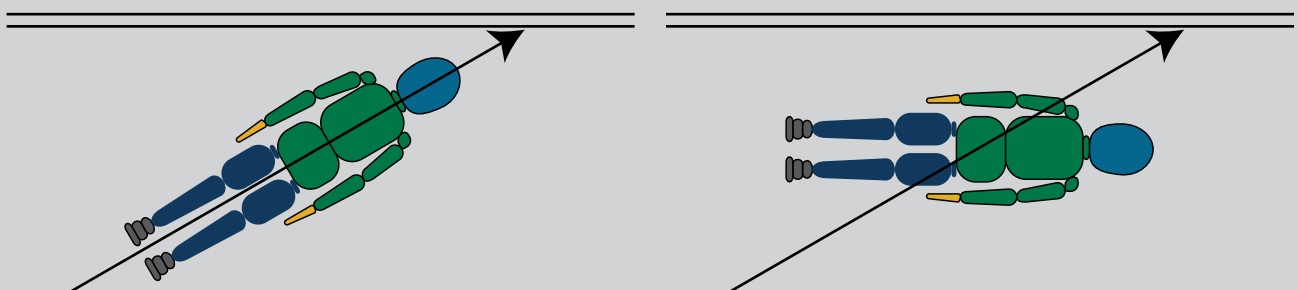
- Out of thirteen accidents reported to have involved an impact on motorcycle-friendly guardrails (double rail or plastic tubing covering the gap between the rail and the ground), ten caused no more than light injuries (abrasion, bruising, simple fractures). In only two cases have more serious injuries been reported (open fractures, head trauma, damage to internal organs), but according to respondents an impact on a single metal rail instead would certainly have been lethal.
- The severity of the injuries caused by post impacts is very high at all collision speeds. Traumatic amputations and other severe injuries are reported at impact speeds not exceeding 30 km/h. Deaths are reported to have happened at impact speeds not exceeding 50 km/h. Impacts at reported speeds of 50 km/h or more mostly cause severe and lethal injuries, with very few cases of light or no injuries (155 cases, of which 25 light injuries, 73 heavy injuries, and 45 lethal injuries. In 12 cases no injury was reported).
- Most reported accidents occurred in the past few years, with 63% of the total between 2006 and 2009. Below is a count of declared accidents by year (with the percentage of total in brackets) :
 - 2011 : 3 (1,25%)
 - 2010 : 3 (1,25%)
 - 2009 : 57 (23,75%)
 - 2008 : 38 (15,8%)
 - 2007 : 21 (8,75%)
 - 2006 : 24 (10%)
 - 2005 : 11 (4,6%)
 - 2004 : 6
 - 2003 : 4
 - 2002 : 4
 - 2001 : 2
 - 2000 : 5
 - 1999 : 4
 - Before 1999 : 29 (12%)
 - Total for 2001-2011 : 173 out of 240 testimonies (72%)
 - Total for 2006-2009 : 146 out of 240 testimonies (61%)

In 29 cases the date of the accident was not provided (12%).

A2. L.I.E.R – French Test Protocol

In order to answer a request from the French authorities who wanted to consider and reduce the severity of accidents of motorcyclists hitting safety barriers, L.I.E.R. developed in 1998 a specific test procedure.

The procedure includes two tests, each involving the launch of a dummy fitted with measuring instrumentation from a sled in two different ways. The dummy is propelled towards the installed test item at 60km/h and 30° entrance angle with the configuration as follows.



Picture 3 - dummy entrance position

For the first test, the dummy is on its back, head forwards, with its longitudinal axis parallel to the launch trajectory. For the second test, the dummy is also on its back, but with its longitudinal axis parallel with the barrier. But in both cases the impact is on the post, there is no test in which the dummy hits between posts. The barrier must be installed in a stabilized soil.

The dummies used in the L.I.E.R. test procedure are made from an assembly of different dummy types : a Hybrid II thorax, limb and shoulders, with a Hybrid III head and neck, and a pedestrian pelvis, and wearing motorcyclist clothing and helmet.

Performance and Acceptance Criteria

The following biomechanical criteria are applied for acceptance of the system :

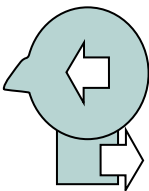
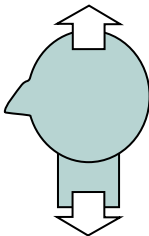
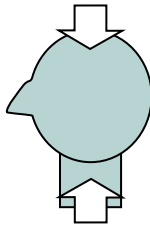
Head	Neck		
Head Injury Criterion (HIC ₃₆)	Neck Shearing Criterion	Neck Traction Criterion	Neck Compression Criterion
			
1000	max 3300 N	max 3300 N	max 4000 N

Table 2 - L.I.E.R. biomechanical criteria

No dummy part must pass through the barrier line. One or more vehicle tests are added to the tests above to check that the overall system (new design or modified existing system) restrains a vehicle under the conditions required for certification.

When the motorcyclist protection system is added to an existing road safety system, the containment level for the other vehicles must be unchanged, the only vehicle test to be performed being the test with the heaviest vehicle. For a new design of safety barrier, the system must satisfy all the specifications from the European Standards EN 1317-1 and 2.

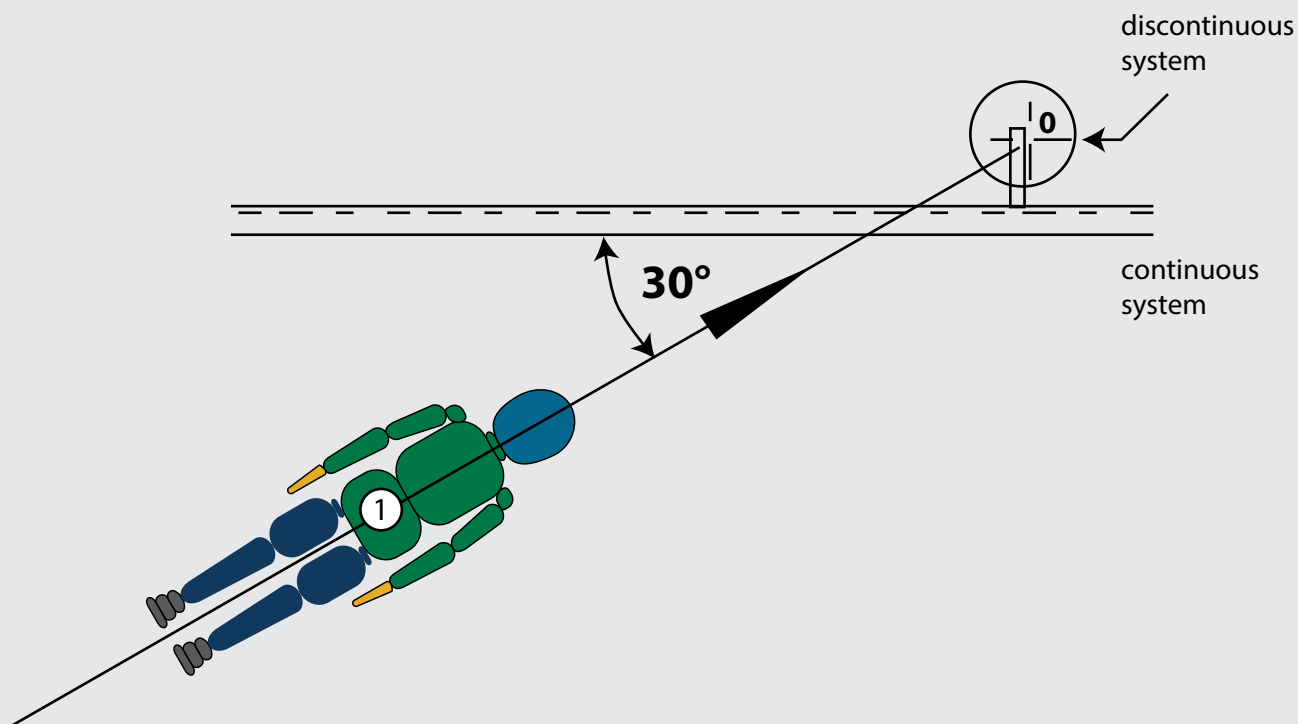
A3. UNE 135900 – Spanish Standard

Published in 2005, the UNE 135900 is a norm for evaluating the performance under motorcyclist impact of a Safety Barrier and it is based in the French L.I.E.R. protocol. In this Standard, also it's simulated a motorcyclist body, separated of the motorcycle, sliding on the ground, totally extended with the face up and the head in advance, and impacting a roadside barrier. The trajectories of the motorcycle and rider are deemed to be different.

The protocol uses a modified Hybrid III featuring a modified shoulder and measurements for neck compression, traction and torsion.

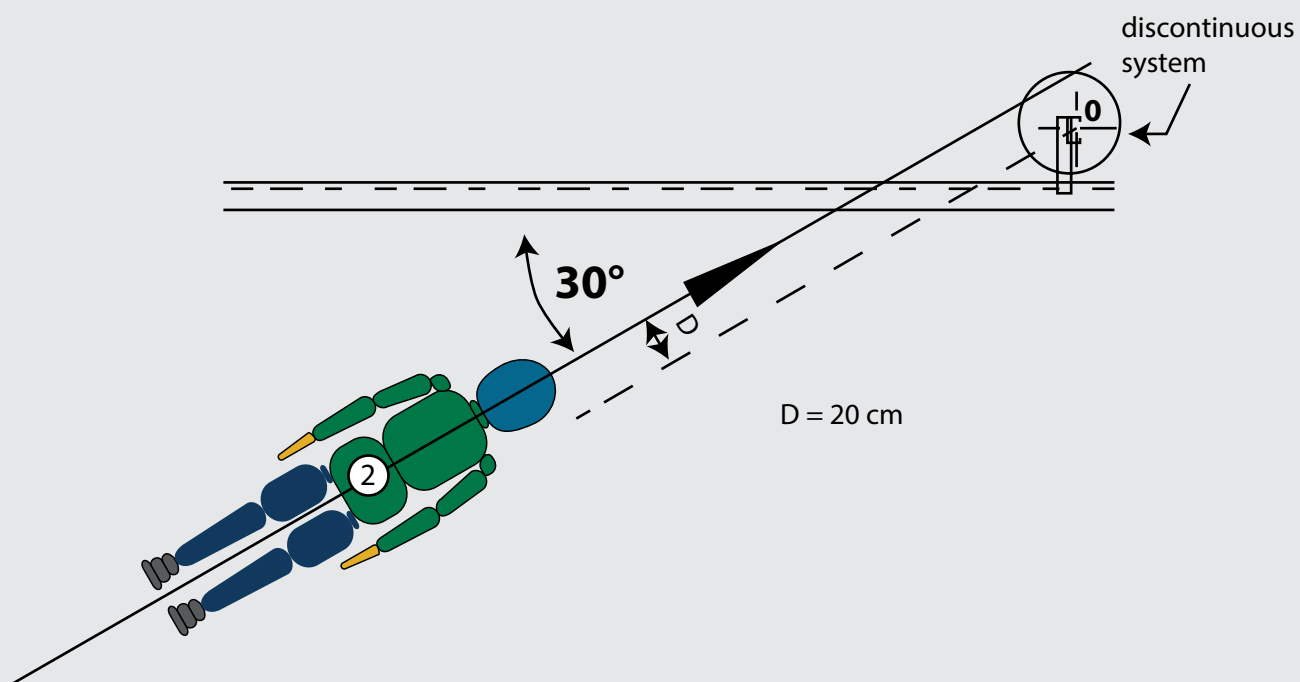
The UNE 135900 defines two different types of MPS, punctual and continuous motorcyclist protection systems. The Hybrid III dummy used in the test shall be equipped with motorcycles clothing, including helmet. The impact speed for the test can be of 60 or 70 km/h and an entrance angle of 30°, with different trajectories. It's performed two launchings for each type of MPS.

The first trajectory is performed for Continuous and Discontinuous Protection Systems. For both cases the dummy is launched with an angle of 30° against the centre of the post, as showed below :



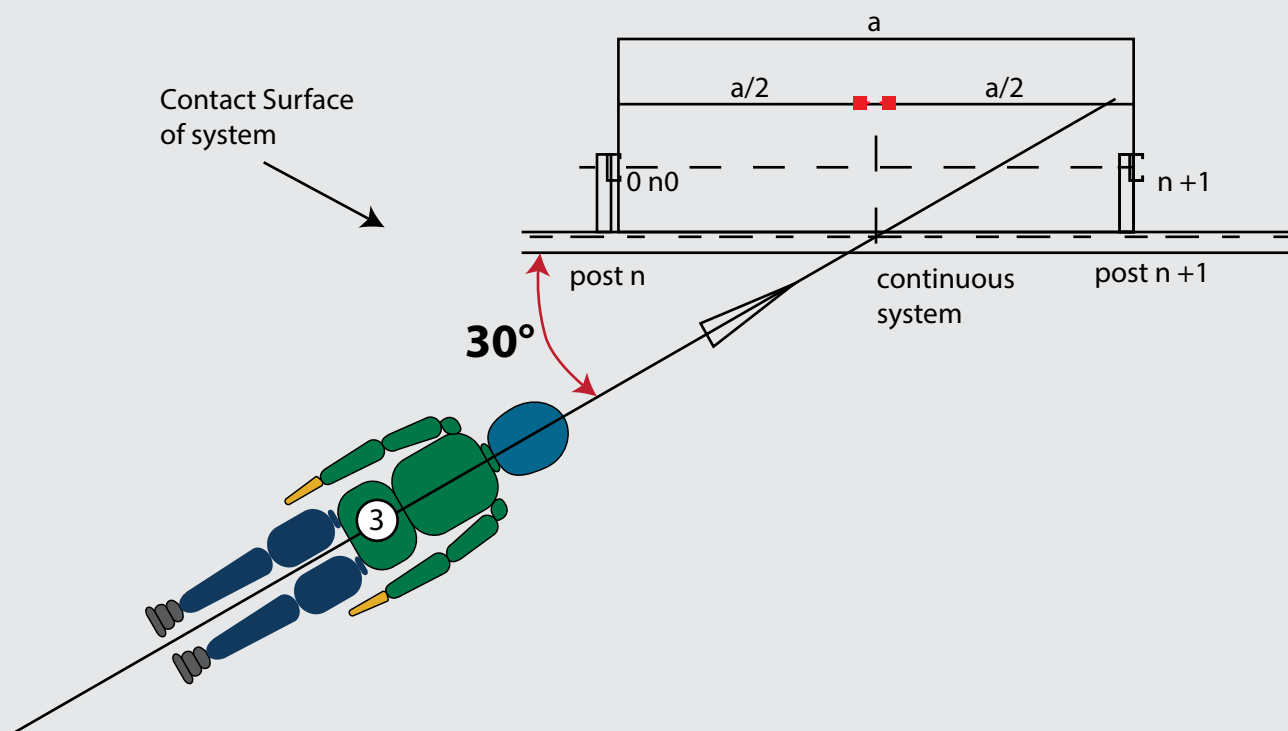
Picture 4 - trajectory one for continuous and discontinuous systems

In the other test configuration for Discontinuous Protection Systems, the dummy is launched against the post, this time not centred, but with an offset of 20 cm.



Picture 5 - trajectory two for discontinuous systems only

If the MPS tested is a Continuous Protection System, the second launch performed is like the one showed below. The dummy hits the barrier in the middle, between two posts.



Picture 6 - trajectory three for continuous systems only

Performance and Acceptance Criteria

The biomechanical parameters for the acceptance of the MPS are divided in two levels :

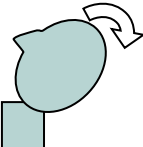
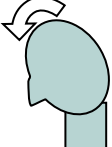
Severity level	Maximum Admissible Values						
	Head	Neck					
	HIC ₃₆	F _x (N) 	F _z _{tension} (N) 	F _z _{compression} (N) 	Moc _x (N.m) 	Moc _y _{extension} (N.m) 	Moc _y _{flex} (N.m) 
I	650	Graph 1 ¹⁹	Graph 2	Graph 3	134	42	190
II	1000	Graph 4	Graph 5	Graph 6	134	57	190

Table 3 - UNE 135900 biomechanical criteria

The acceptance criteria also depends on the impact speed of the tests performed (60 or 70 km/h). No cuts in the dummy (only in the equipment) and no separation of extremities (only the breakaway

mechanism of shoulder is allowed) are permitted. Also its prohibited dummy's snagging, no part of the dummy shall overpass the MPS and no pieces over 2kg shall be detached from MPS.

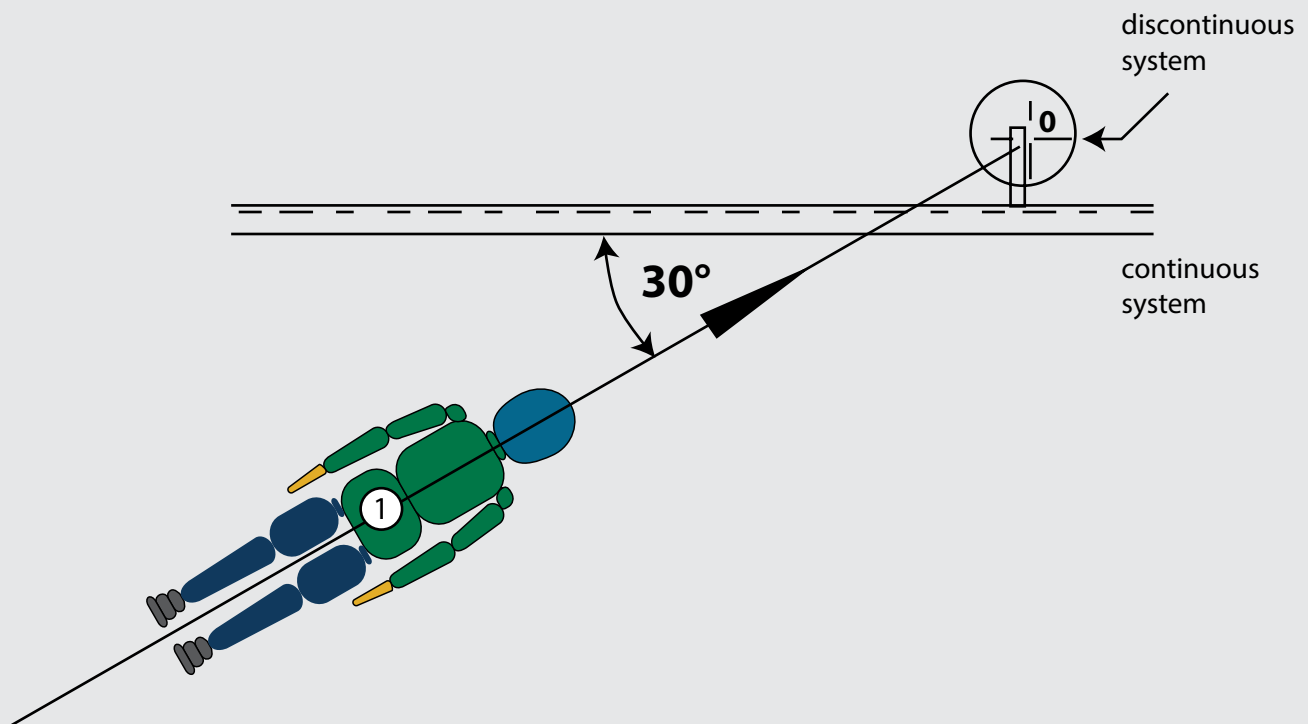
¹⁹ The graphs 1 to 6 are included in the annex about neck injury criterion (Annex A4)

A4. CEN TS1317-8 – European Technical specification

The full-scale impact test consists of launching a dummy at a given speed against a barrier with MPS. At the moment of the impact, the dummy is sliding with its back and legs stably in contact with the ground and shall be equipped with a proper motorcycle helmet and clothes.

Three theoretical approach paths are defined. If the test laboratory judges that the impact point identified in this standard for a given test is not representative of the most severe testing conditions, the impact point may change accordingly.

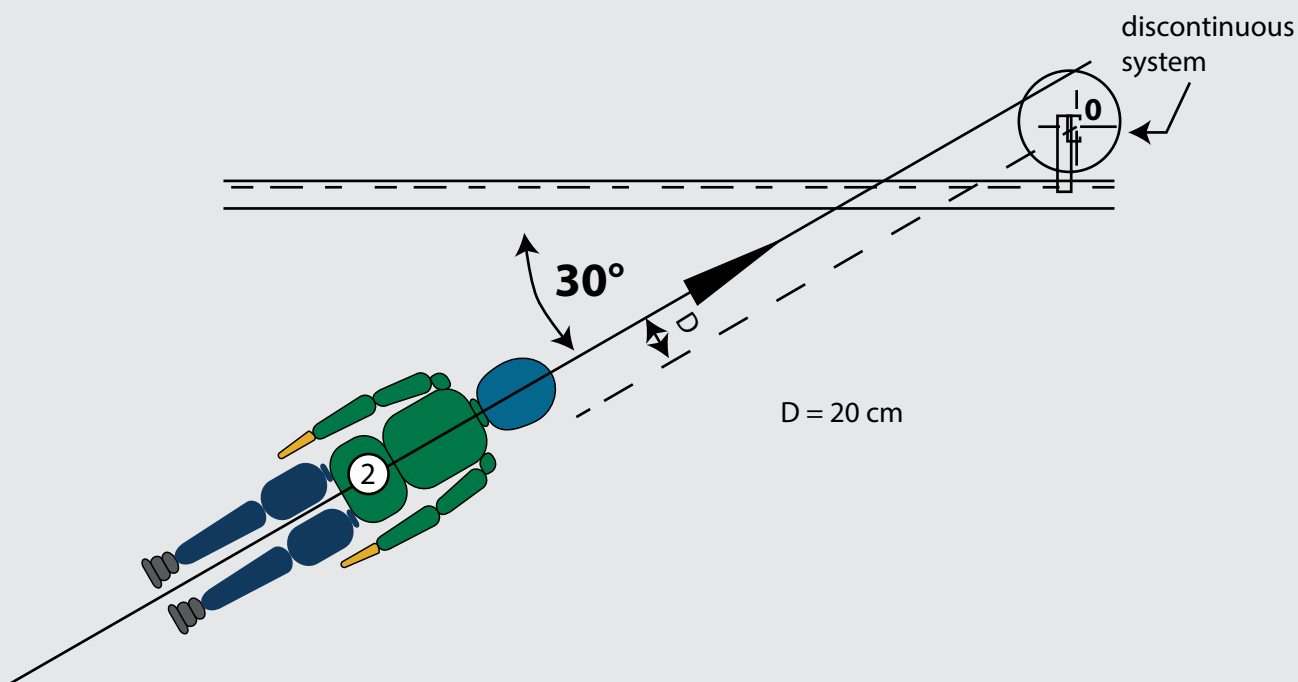
In the launch configuration 1, the approach path of the dummy is defined by a line, parallel to the ground, passing through the centre (O) of the post section and forming a 30° angle with respect to the centreline of the un-deformed test item. For a continuous system, if the test item is not fitted to a post-and-rail type safety barrier, point 'O' shall be the centre of an anchorage, a connection between elements of the test item or any other point deemed to result in the highest severity impact. For a discontinuous system, 'O' is the centre of the item onto which the MPS is fitted. This launch configuration is applicable to all types of MPS and, is generally intended to represent the configuration resulting in the most severe impact-related injuries.



Picture 7 - launch configuration one

For the second launch configuration, the approach path of the dummy is defined by a line parallel to the ground and parallel to a line at 30° to the centreline of the un-deformed test item, passing through the point 'O' (centre of the post section). The approach path shall be 20 cm upstream of the 30° line passing through 'O'.

This configuration is only applicable when the test item is a discontinuous system. If the test item is not fitted to a post-and-rail type safety barrier, point 'O' shall be the centre of the item onto which the MPS is fitted. The purpose of this configuration is to impact the edge of the discontinuous system which may be potentially aggressive and/or to achieve maximal deceleration of the ATD.



Picture 8 - launch configuration two

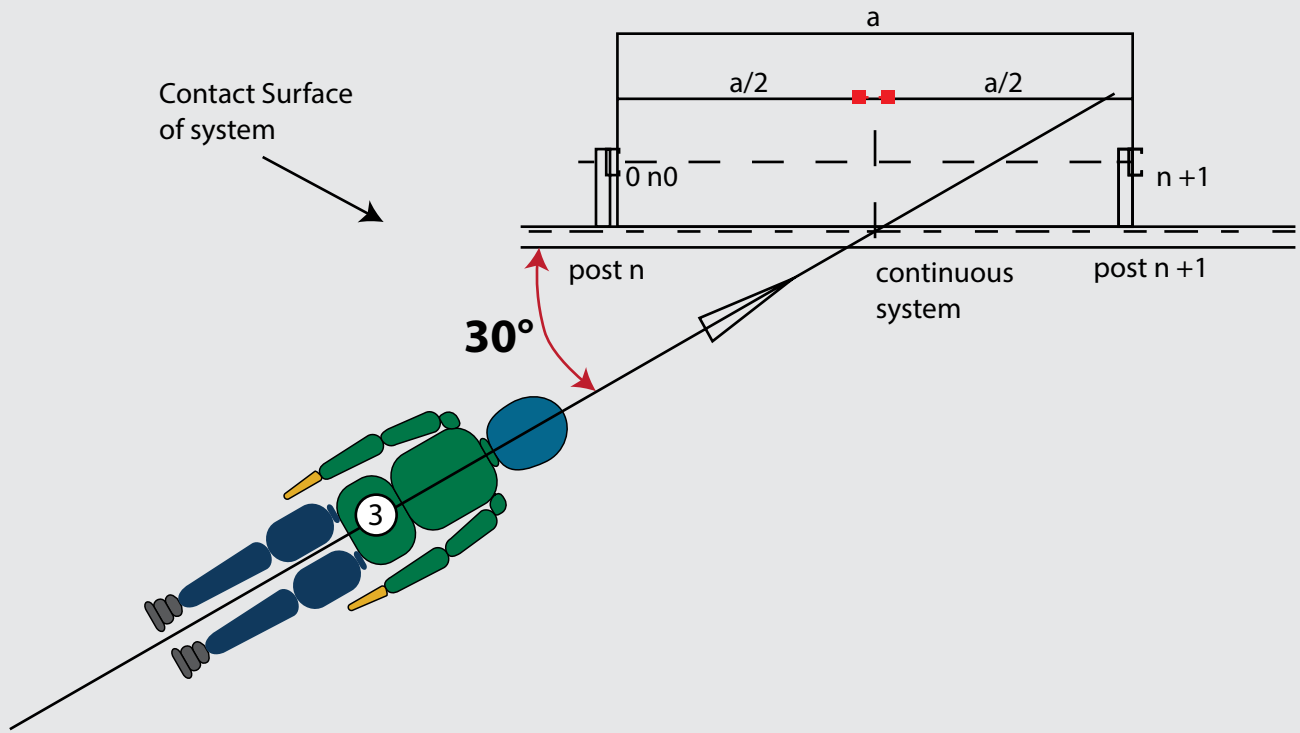
The approach path of the dummy in the third launch configuration is defined by a line, parallel to the ground, passing through point 'I' (centre of the barrier, see picture 9) and forming a 30° angle with respect to the centreline of the un-deformed test item. 'I' is the intersection of the surface in contact with ATD during the test and the perpendicular bisector of the segment joining 'On' and 'On+1'. 'On' and 'On+1' are the centres of the sections of two consecutive posts of the barrier. If the system is not a post-and-rail type safety barrier, points 'On' and 'On+1' shall be the centres of two consecutive

anchorage or element connections of the test item or any other point deemed to result in the highest severity impact.

This launch configuration is only applicable to continuous systems and is primarily intended to test the robustness of the test item where it is most flexible and to evaluate the potential for the trapping of limbs in the area where this is most likely to occur. However, in some cases, the injury criteria values measured on the ATD may be higher for this configuration than for Configuration 1.

This launch configuration is only applicable to continuous systems and is primarily intended to test the robustness of the test item where it is most flexible and to evaluate the potential for the

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Picture 9 - launch configuration three

Performance and Acceptance Criteria

The performance of an MPS is determined by the speed class, which is determined by the impact speed of the tests performed. The speed can be of 60 or 70 km/h. The performance is also defined by the severity level, which is determined by the level of biomechanical indices obtained from the dummy instrumentation during the test.

A tested MPS which satisfies the requirements of a given speed class will be deemed to comply with

the test conditions corresponding to the speed classes of lower speeds, with the same severity levels, unless it contains some mechanism that does not work acceptably at a lower impact speed.

According to the table below, each impact test can be classified in two severity levels (level I and II). The severity level is achieved only when the values of all biomechanical indices are equal to, or less than the corresponding maximum limits.

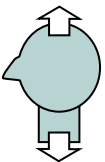
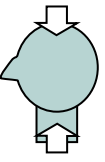
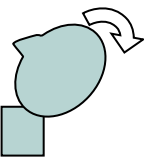
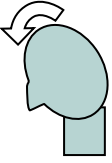
Severity level	Maximum Admissible Values						
	Head	Neck					
	HIC ₃₆	F _x (N) 	F _z _{tension} (N) 	F _z _{compression} (N) 	Moc _x (N.m) 	Moc _y _{extension} (N.m) 	Moc _y _{flex} (N.m) 
I	650	Graph 1 ²⁰	Graph 2	Graph 3	134	42	190
II	1000	Graph 4	Graph 5	Graph 6	134	57	190

Table 4 - TS 1317-8 biomechanical criteria

²⁰ The graphs 1 to 6 are included in the annex about neck injury criterion (Annex A4)

A5. Injury Criterion

Head Injury Criterion (HIC)

The Head Injury Criterion (HIC) is the main criterion adopted to evaluate the impact severity of a motorcyclist against a MPS. It is a measure of the likelihood of head injury arising from an impact. The HIC is intended to judge the head injury risk quantitatively. In the case of an accident, cranial and spinal injuries arise from a deceleration during the crash, in particular at the moment of impact. The higher the head deceleration, higher is the HIC. The

dummies used in crash tests have several sensors fixed to the head area which record the absolute value of the deceleration and its dependence on time. It is plausible that this head load is higher the larger the value of the deceleration and the longer the deceleration lasts.

There are 6 different levels to classify head injuries, as we can see on the table 2.

Level	Assessment
1	<u>Slight damage to brain</u> , with headache, dizziness, no loss of consciousness, contusions
2	Concussion with or without skull fracture, <u>less than 15 minutes</u> of unconsciousness, detached retina, face and nose fracture
3	Concussion with or without skull fracture, <u>more than 15 minutes</u> of unconsciousness without severe neurological damage, <u>multiple skull fracture</u> , loss of vision, multiple facial fracture, cervical fracture without damage to spine
4	<u>Multiple skull fracture</u> with <u>severe neurological damage</u>
5	Concussion with or without skull fracture, <u>more than 12 hours of unconsciousness</u> , hemorrhage in skull and critical neurological condition
6	Death, cervical fracture with damage to the spine

Table 5 - levels of head injury based on the Abbreviated Injury Scale (AIS)

A small HIC value doesn't mean that the head injuries will be of low levels. Likewise, a high HIC doesn't imply high level injuries. The real meaning is that with higher HIC values, the higher the probability of getting high level head injuries.

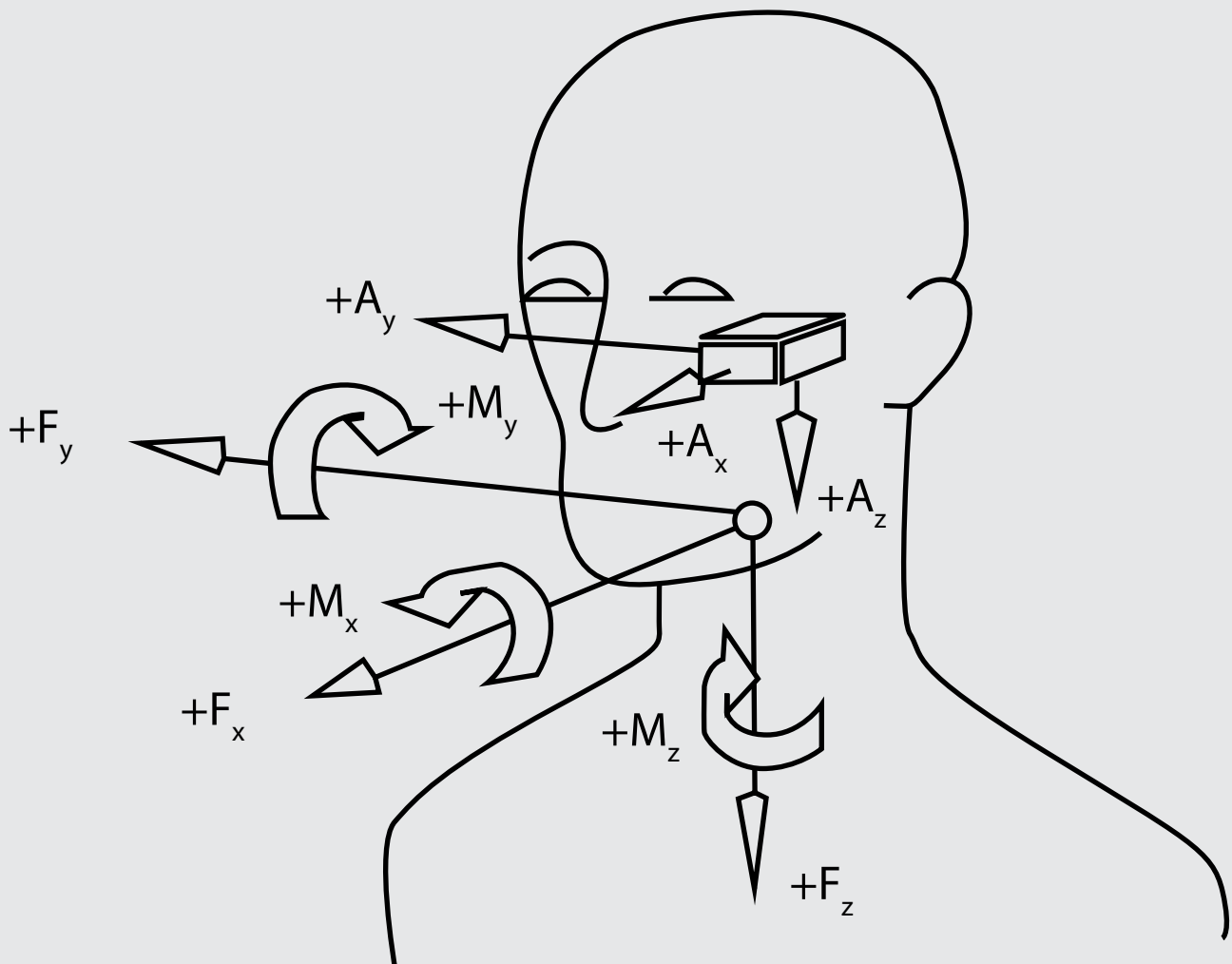
For example with a HIC of 650 the probabilities are of 90% injuries level one, 55% of injuries level 2, 20% of injuries level 3 and 5% injuries level 4 (combined injuries are possible).

The TS 1317-8 has two levels of acceptance according to the HIC, level 1 for tests results equal

or less than 650 and level 2 for results equal or less than 1000. What we need to have in mind is that smaller the HIC value, the better it is.

An interesting point is that if two products approved by the TS 1317-8, one obtained a HIC of 150, and the second a HIC of 640, for example, they will be classified with the same level. Also a third product with a HIC of 670 would be classified as level 2. Defining the severity in only 2 levels can be dangerous, and sometimes not point very well the difference between the MPS.

$$HIC = \left\{ \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a dt \right]^{2.5} (t_2 - t_1) \right\}_{\max}$$



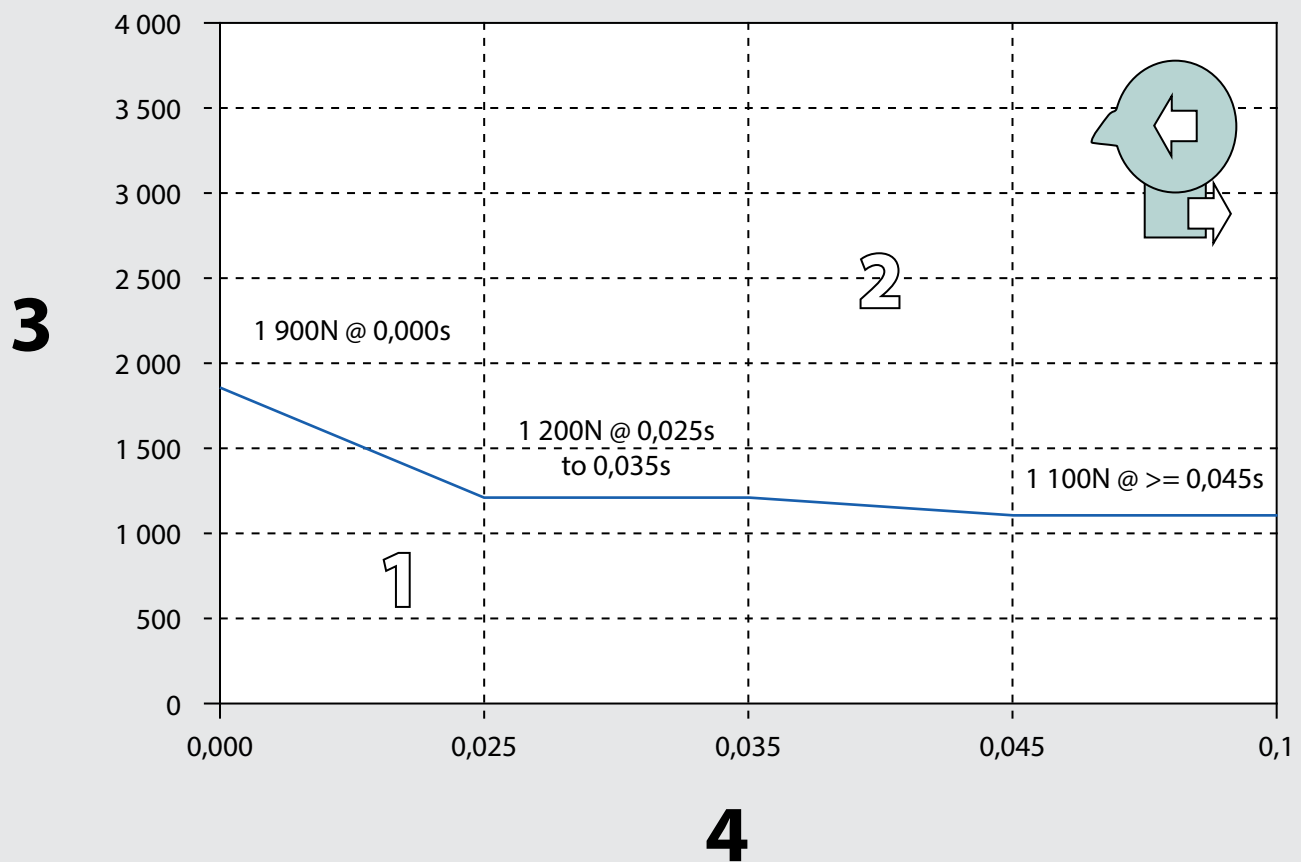
Picture 10 - forces and moments measured for the HIC

Neck Injury Criterion

For the evaluation of the neck injury, the European Standard takes into account the forces and also the time these forces act on the neck. Putting in a very simple way, bigger the time, small shall be the forces, to have an acceptable result.

This criterion is classified in 2 levels as well. The forces are measured and each standard and test procedure has its own table to classify if the values are valuable or not. Smaller values mean that the product is safer.

Graphs 1 to 6 shows gives the maximum permissible load durations for given neck loads levels.



Graph 1 - Anterior-posterior neck shear force criterion neck for level I

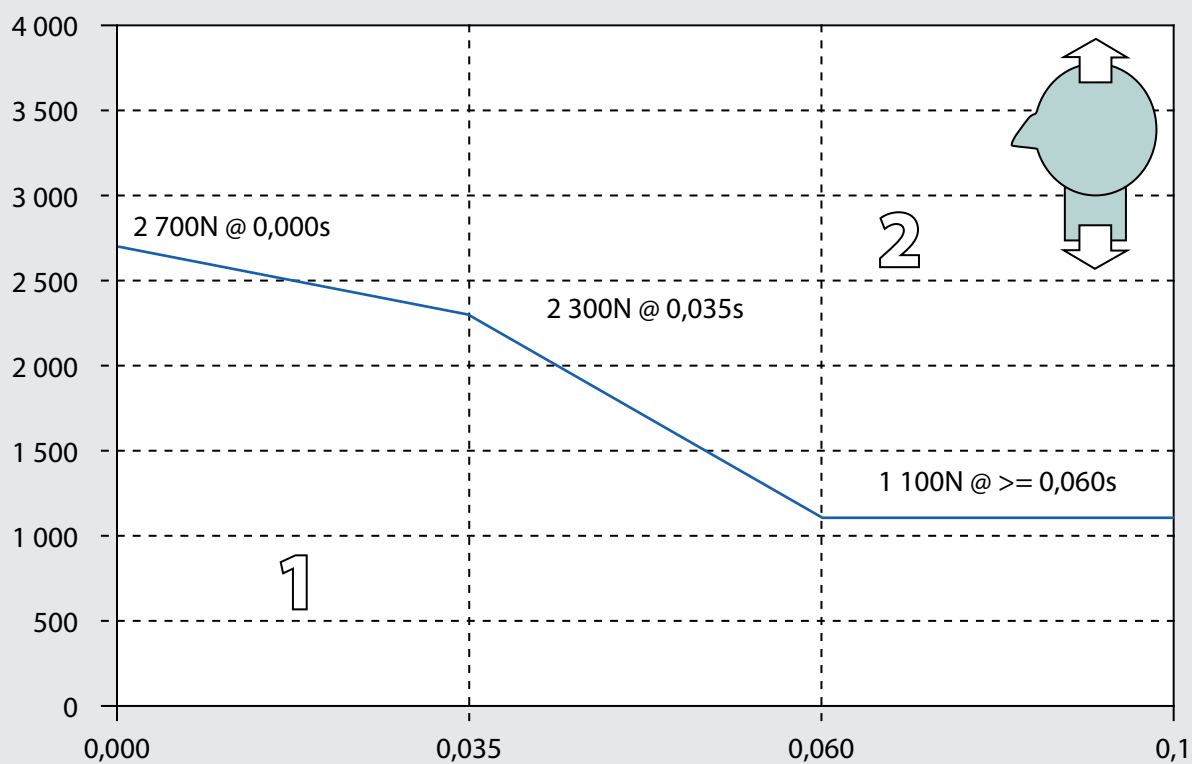
1 – Pass

3 – Anterior-posterior neck shear force (N)

2 – Fail

4 – Permitted duration for a given shear force (s)

3



4

Graph 2 - Axial neck tension criterion for level I

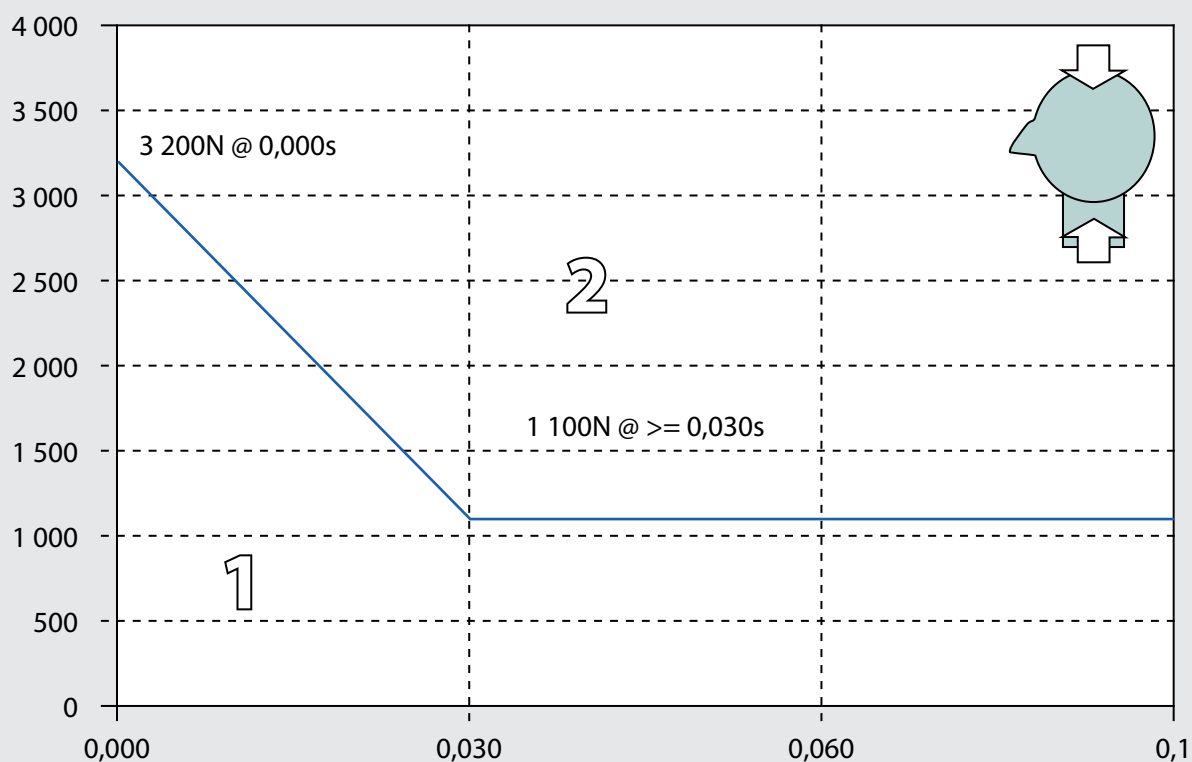
1 – Pass

3 – Axial neck tension (N)

2 – Fail

4 – Permitted duration for a given tension force (s)

3



4

Graph 3 - Axial neck compression criterion for level I

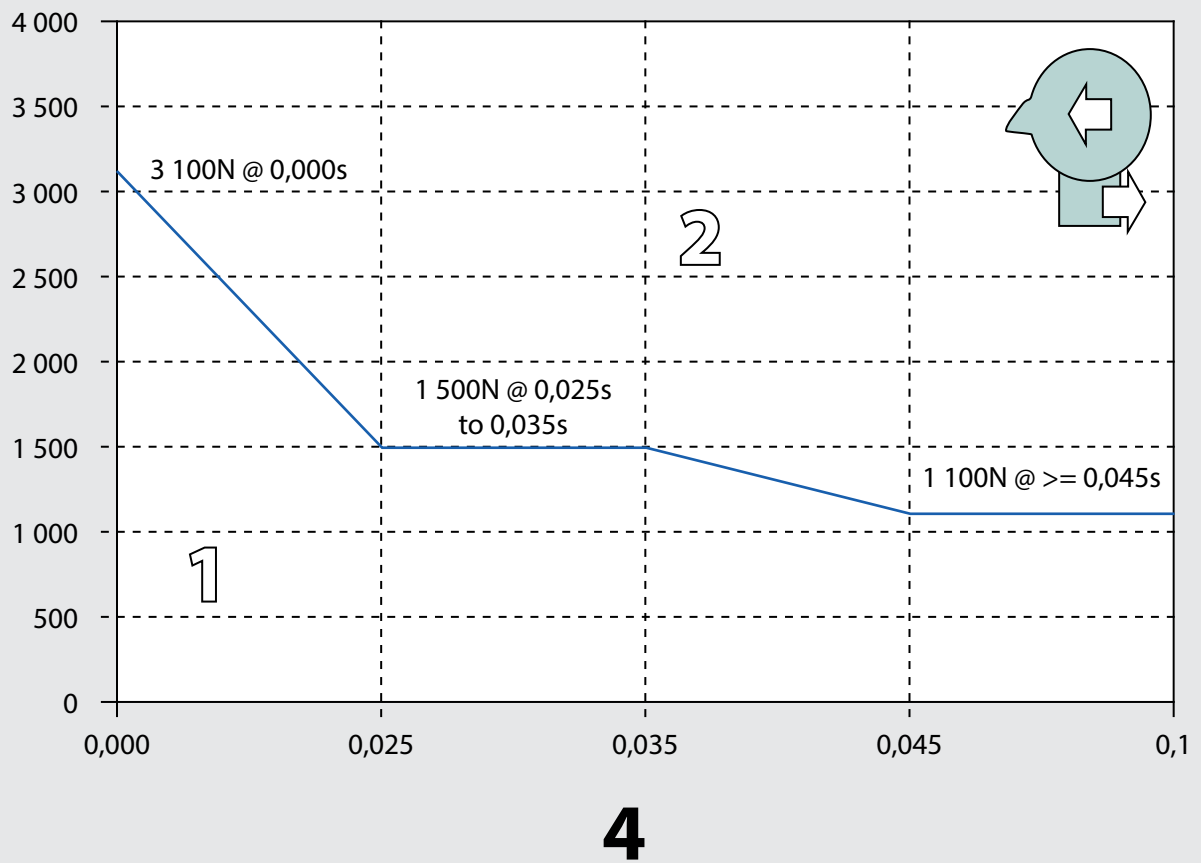
1 – Pass

3 – Axial neck compression (N)

2 – Fail

4 – Permitted duration for a given compression force (s)

3



Graph 4 - Anterior-posterior neck shear force criterion for level II

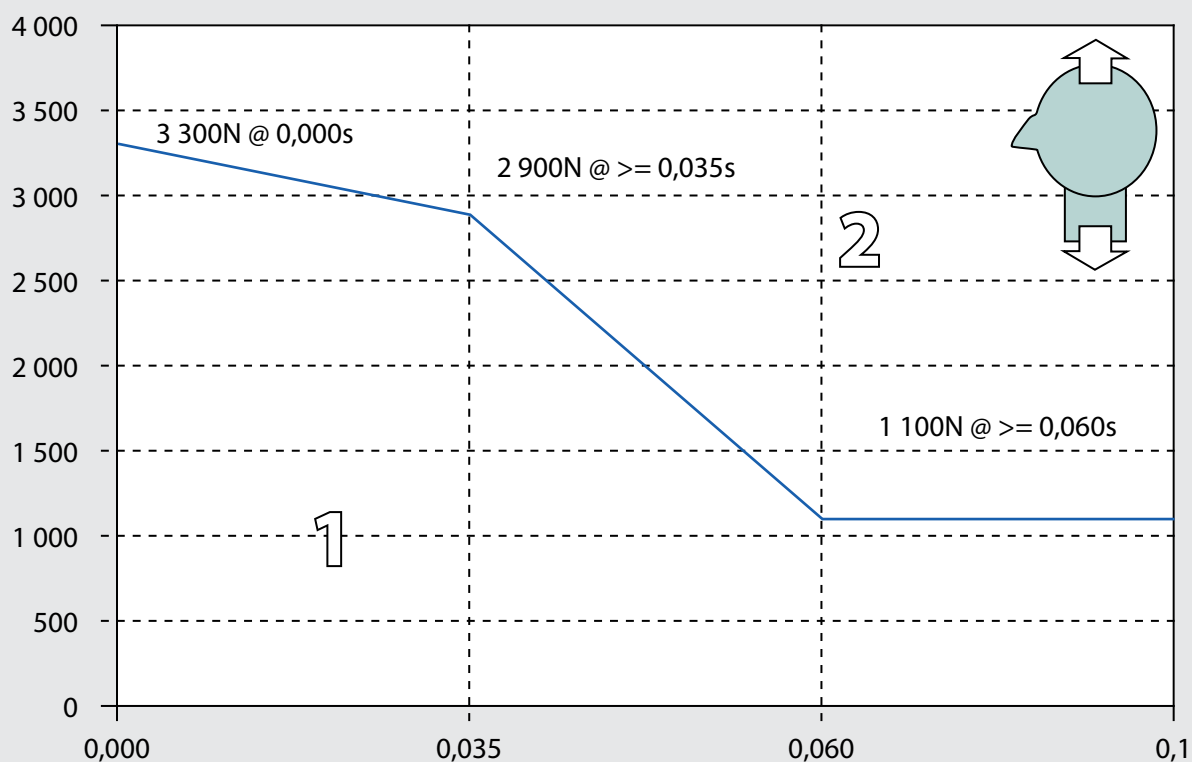
1 – Pass

3 – Anterior-posterior neck shear force (N)

2 – Fail

4 – Permitted duration for a given shear force (s)

3



4

Graph 5 - Axial neck tension criterion for level II

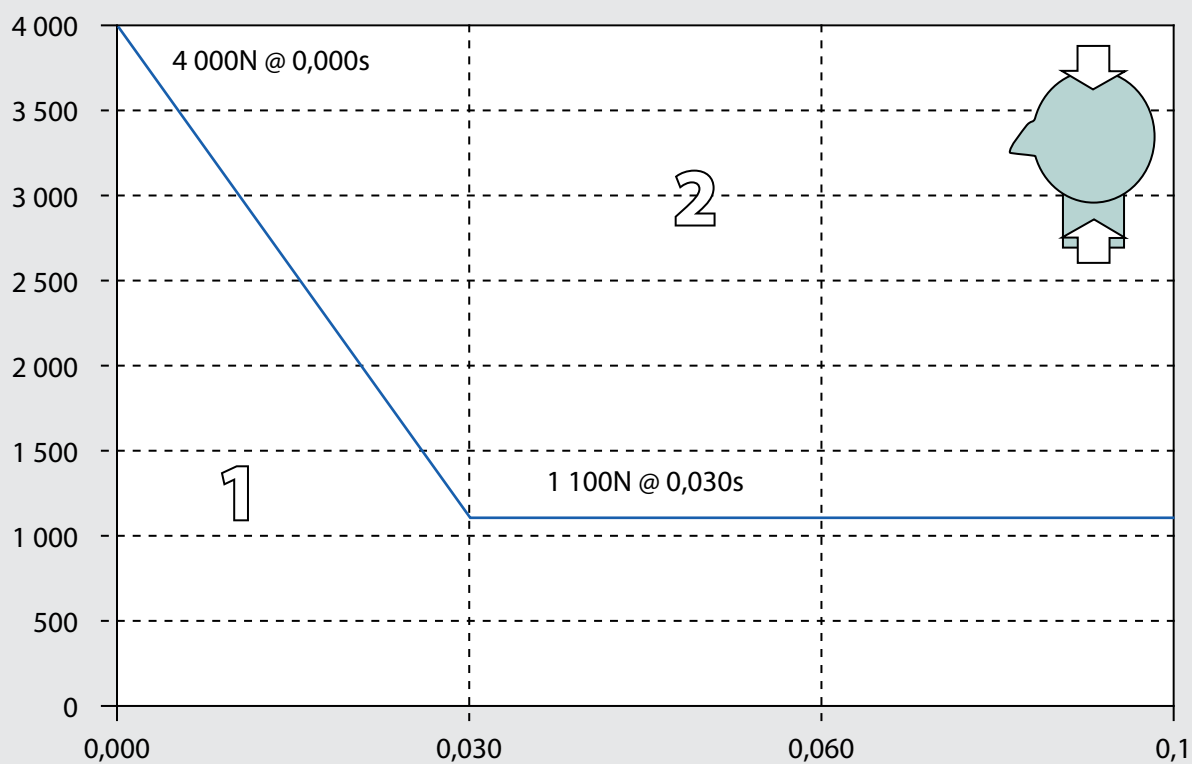
1 – Pass

3 – Axial neck tension (N)

2 – Fail

4 – Permitted duration for a given tension force (s)

3



4

Graph 6 - Axial neck compression criterion for level II

1 – Pass

3 – Axial neck compression (N)

2 – Fail

4 – Permitted duration for a given compression force (s)

A6. Anthropomorphic dummies

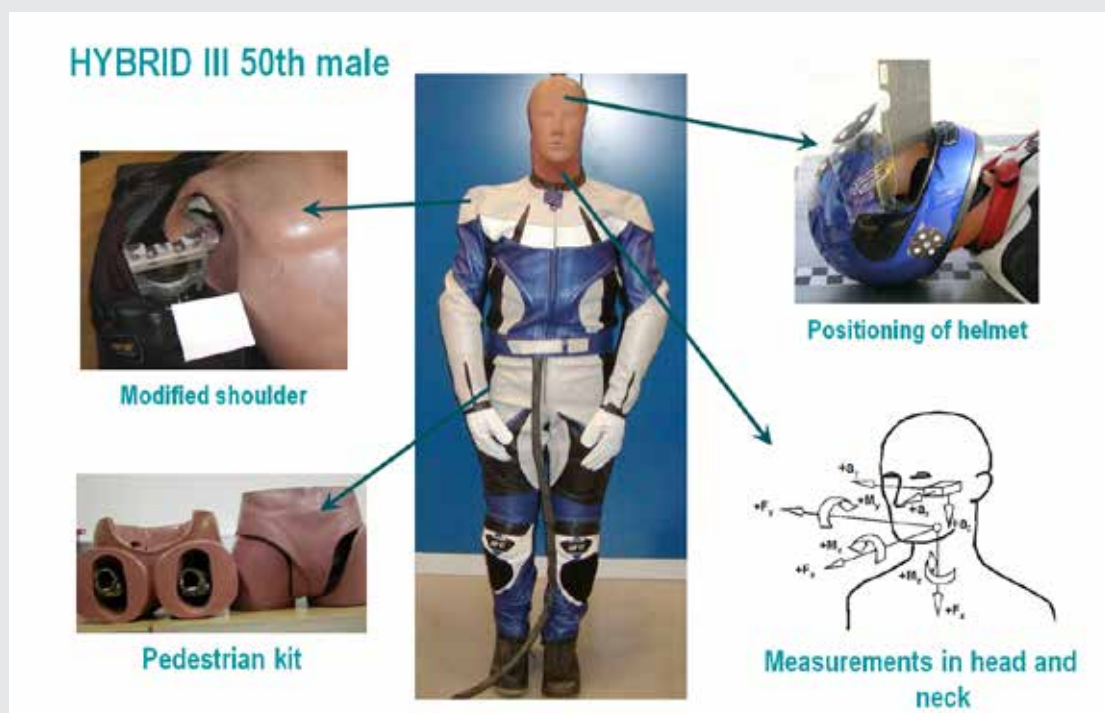
In addition to laying out accident configurations, test protocols must specify the type of dummy used in the test, if any.

The different crash tests described in this document do not use the same type of dummy. For instance, the 1993 BAST protocol "Technical Regulations for Delivery of Guardrail-Post Protections", used in German uses a 35kg wooden cylinder to simulate the impact of a motorcyclist's body. But for better, more accurate results, a crash test dummy should be used : this is the approach followed in the Spanish standard UNE 135900 and LIER protocol.

The conception of accurate test dummies began with cars crash tests, which aimed at reducing the number of victims in car accidents. The first tests were made using cadavers in an attempt to obtain fundamental information about the human body's ability to withstand the crushing and tearing forces typically experienced in a high-speed accident. Also during studies of car crash accidents, many tests were performed using animals, and through this tests many improvements were made. For example, using the results, in the 60's General Motors developed the collapsible steering column which cut the risk of steering-wheel death by fifty percent.

With the information gathered from animals and cadavers testing, the first dummy the "Sierra Sam" was created in 1949 to test aircraft ejection seats. However, cadaver and animal testing bring as many problems as solutions. All the moral issues involved made it very hard to keep performing these tests, and some alternative had to be created. Nowadays it is no longer practiced by any of the major automobile makers.

The more recent Hybrid II dummy is capable of generating test data with sufficient biofidelity to be used for automotive crashworthiness testing. It has also non-automotive applications, which include equipment and injury potential studies of recreation vehicles, wheel chairs, medical equipment and sports gear. The size and weight of the Hybrid II 50th Percentile Male Test Dummy represent the "average" of the USA adult male population. The design incorporates the range of motions, centres of gravity and segment masses determined by anthropometric studies to simulate those of human subjects. The head and neck are made of three-piece skull welding with vinyl skin and has a two-piece back-plate welding for access to instrumentation. The cylindrical rubber neck assembly is mounted on neck bracket with fixed angle of 15 degrees forward.



(source : CIDAUT)

Today, no specific motorcyclist test dummy suitable for the sliding impact configurations used in the standards exists on the market : the only available models are derived from sitting dummies (for use inside vehicles) and pedestrian dummies.

Eurosid and other dummies cannot be used for motorcyclist testing due to the absence of hip joints allowing them to be placed in an upright position. It is important to launch the dummy in a straight, upright position to ensure the repeatability of the results, which cannot be guaranteed if the dummy shifts position during the launch. The only suitable hip joint is the pedestrian kit for use with the Hybrid III model dummy.

The Hybrid III dummy is an evolution of the Hybrid II, its primary benefits being an improved neck response in forward flexion and a head rotation that better simulates that of humans. It also features improved biofidelity in the femur range of motion, and the ankle and foot. Its pedestrian kit allows it to be used to simulate the impact of human lying or standing.

The skull and skull cap in the Hybrid III are one piece cast aluminium parts with removable vinyl skins. The neck is a segmented rubber and aluminium

construction with a centre cable. It accurately simulates the human dynamic moment/rotation flexion and extension response.

The APROSYS research project²¹ therefore suggests in its conclusions the use of a Hybrid III 50th Percentile Male dummy (Title 49, CFR Part 572, Subpart E), equipped as follows :

- Pedestrian kits that allows a standing position,
- Neck bracket in -7° position,
- Both original clavicles will be changed by frangible clavicles which are described in the 3.2 section,
- Neck foam, reference 1039006.

The Hybrid III dummy was designed for frontal impact testing. However, as the dummy offers no biofidelity in lateral loading, the measurement results may be misleading. This is especially problematic as most test protocols in use and at the drafting stage include impacts against guardrails at an angle, which means that a reading for the severity of the impact against the shoulder is needed.

The Hybrid III dummy used in the Spanish standard UNE 135900 is equipped, among other features, with a frangible shoulder to take into account shoulder impacts at an angle.

²¹ <http://www.aprosys.com/>

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