Evaluation of motorcycle safety barrier normative

R Capitani and S S Pellari

Università degli Studi di Firenze, Dipartimento di Meccanica e Tecnologie Industriali, Via di Santa Marta 3, 50139 Firenze, Italy

Abstract

Among European Countries, Spain first issued a Standard, UNE 135900:2005, further updated in 2008, that deals with homologation and effectiveness evaluation of road restraint systems components designed to reduce harm for bikers impacting on them. An in depth analysis and critical review of this standard is reported in this paper.

Beside a close examination of the standard requirements, numerical models of the crash test stated by the standard have been set up and simulated to study the effects of slight speed and approach angle variations on test results, remaining within tolerance gaps allowed by the standard. Model were validated against experimental data.

Together with the expected increasing severity of the impact according with speed, a strong influence of approach angle on injury parameters was found. Possible improvements to the norm, in order to make it more robust, are suggested.

INTRODUCTION

Powered Two Wheelers (PTWs) are widely employed for individual mobility in Europe, because of their high capability of blending in traffic, especially in urban scenarios, and the enjoyment of riding. Unfortunately, PTW riders are one of the most vulnerable groups of road users, resulting in 5394 fatalities in 14 European Countries (EU15 without Germany) in 2006 and 22% of road mortal accidents in 2008 [1]. An important part of these accidents and fatalities, about 18%, involves impacts against barriers and road restraint systems, especially in rural areas where the percentage reaches 30% [2]. MAIDS project, on about 923 accidents in France, Germany, Italy, the Netherlands and Spain during 1999-2000, reports that roadside is the second most frequent collision partner (9.0%) for PTWs [3].

From this data, is clear the benefit drawn from devices able to mitigate the consequences of a biker impact against a road restraint system. Recently, some of these devices have been deployed on the market by several manufacturers. Among European Countries, Spain first recognized the need of specific regulations to evaluate the functioning of these devices and decide which of them are useful in avoiding damage and suitable for road use, so, in October 2005 issued UNE 135900 standard, revised in 2008 [4], that deals with this task.

In this paper, an analysis and a critical review of the norm is performed, to underline some aspects that must be considered during the set up of real tests. Moreover, numerical simulation of homologation test are performed, and validated against experimental data, in order to better understand the influence of approach angle and speed on test results.

UNE 135900:2008 STANDARD

This norm is the first one in Europe that deals with the performance evaluation for road restraint systems in case of impacts by vulnerable road users as bikers. Both specifically designed new barriers and additional systems, conceived to fit existing barriers or pillars, must comply with this standard.

In the introduction of the norm text, biker protection devices are subdivided in two classes: punctual and continuous; all barriers specifically designed to reduce harm on bikers are treated as continuous.

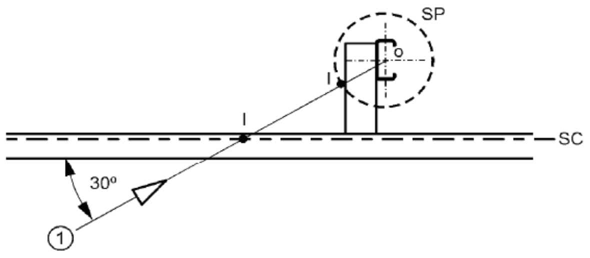

Figure 1. UNE 135900 Centred impact trajectory

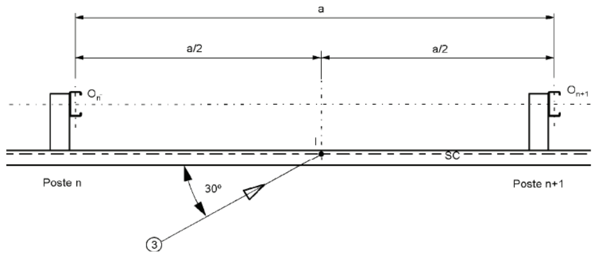

Figure 2. UNE 135900 Middle-vane trajectory

The standard defines two impact speeds, 60 and 70 km/h, and three impact trajectories, all of them have an approach angle, measured between approaching trajectory and longitudinal axis of the barrier, of 30°. This three trajectories lead to a centred, de-centred or middle-vane impact. Centred impact trajectory (Figure 1) passes through the centre of gravity of the pillar section at ground level, while de-centred impact trajectory is 20 cm away from the previous one. Finally, middle-vane trajectory (Figure 2) is adjusted to put the theoretical point of impact exactly midway from the centres of gravity of the sections at ground level of two subsequent pillars. Punctual systems are to be tested with centred and de-centred trajectories, while continuous systems must be tested against centred and middle-vane impacts. The dummy must lie on its back, with the head oriented towards the theoretical point of impact. For all these test, the angle between approach trajectory and longitudinal axle of the dummy, said "position angle", must be 0°.

The norm prescribes that test area must be flat and free of pools, ice, snow or anything else that could destabilize the approaching trajectory and speed of the dummy. Test area itself is divided in two separate zones, one intended for the sliding of the dummy and one for the installation of the safety barrier. Terrain composition and compacting degree of this last area are stated, though a different terrain is admitted in case of test purchaser's particular needs. About the sliding zone, it is prescribed to be smooth and lacking of any kind of obstacle that could affect the free movement of the dummy, but no typology of ground nor friction coefficient for the sliding dummy are prescribed by the norm for this zone. Minimum dimensions of the area aren't reported.

A first consideration on the test setting is that the combination of a 0° position angle and a 30° approach angle of 30° could lead to a potentially instable condition. Looking at a biker wearing riding gear, the plane tangent to the shoulder and the helmet forms an angle of about 30° with his "longitudinal axis"; so, the first point of impact could abruptly move from head to shoulder and back, following minimal variations in head and arms position, position angle or even helmet model. This leads to a great variability of impact dynamics and test results.

An Hybrid III 50th percentile male dummy is to be used for the test, though some changes are required. Specifically, pelvis and dorsal spine must be replaced with other components (78051-60P and –66P) to permit the dummy to assume a standing position, while clavicle on impact side is replaced with a modified one that employs fusible bolts which consent to reproduce clavicle breaking during the impact; finally, a neck protecting foam is implemented to ensure a correct helmet buckle fitting. The dummy must be equipped with an integral helmet, suit, gloves and boots. Hybrid III family dummies are specifically designed to investigate the effects of car frontal crashes, so in these tests the dummy encounters really different conditions from those it was validated for. This means that not all the aspects of his behaviour, nor all of measured solicitations are reliable. Unfortunately, a dummy specifically designed and reliably validated for motorcycle test, biker-barrier crashes, does not exist yet. In the same way, biomechanics still lacks of indexes and relative values able to robustly predict real bikers harm. [5,6]

The norm spends few words concerning the propelling device of the dummy. It's simply stated that it must be designed in a way that leaves the dummy free of any kind of connection with the device itself, or other driving device, at least 2 m before the theoretical point of impact, which is defined as the intersection of the desired dummy approaching trajectory with the part of the protection system that is the nearest to the road.

The norm states that impact speed and angles must be detected no more than 0,50 m before the theoretical point of impact, while the dummy is sliding with the most part of its body laying supine on the ground in a stable way. The norm doesn't specify what fraction of the body is "the most part" nor which parts of the body can be raised from ground, nor which position are allowed for head and limbs. Feedbacks from experimental tests performed by AISICO (Associazione Italiana per la Sicurezza della Circolazione, Italy), one of the accredited test centres for homologation tests, underline that head and limbs position is instead important. It affects body dynamics during and after the impact, determining which part of the body hits first the barrier, and whether or not the dummy is projected upwards and impacts also with the lower side of the part of barrier intended for vehicles or instead remains caught between the barrier and soil.

The norm states that a precision of ±1% and a tolerance on desired speed of -0%, +6% is requested for speed measures. Both approach and position angles must be checked with a precision of ±0,5° and their values must be within ±2° of prescribed angle. Also point of impact is to be measured, with an accuracy of ±15 mm, and must result no more than 60 mm far from actual point of impact, that is the point where should be the first contact between dummy and barrier if longitudinal axis of the dummy exactly copies the desired trajectory. For real tests, which are mainly performed outdoor, is difficult to achieve greater accuracy in positioning, but the tolerance gaps allowed for approach angle and speed seem significantly wide, because impact dynamics and moreover injury indexes may change considerably while moving between the range borders.

Numerical models of three biker protection devices were built and several crash test simulations were performed varying approach angle and speed to estimate the influence of these parameters on test results. Model building, simulations and their results will be described and discussed in the following paragraphs.

NUMERICAL EVALUATION

In order to understand the influence of approach angle and velocity of impact on device testing, numerical simulations were performed.

Three road restraint systems (thereinafter Barrier 1, 2 and 3), each featuring a different impact attenuator for motorcyclists, were modelled [7, 8], reproducing a configuration that complies with the centred impact scenario prescribed by the norm. CAD models of every system were built, meshed and imported in MADYMO environment, arranging the centred impact UNE 135900:2008 scenario.

The models were validated against experimental data. These data for Barrier 1 were provided by the manufacturer, while, for Barrier 2 and 3, data were provided by experimental tests performed by AISICO. AISICO also provided drawings of tested devices, that were used for geometry reconstruction. In this study, only 60 km/h centred impact scenario was considered because experimental data of middle-vane impact for all three barriers weren't available. Validation was performed comparing some injury parameters obtained in the simulation with the corresponding obtained from the experimental data. In Table 1 the results of model validation are reported, where the simulated value is expressed as percentage of real data.

Validation results, percentage of real test data					
	HIC36	Neck Compression	Neck Traction	Flexion Torque on neck	Extension Torque on neck
Barrier 1	105	n.d.	71	n.d.	n.d.
Barrier 2	96	67	125	101	94
Barrier 3	132	141	92	119	78

Table 1 Model validation results

From Table 1 arises that Barrier 3 model seems less accurate than others, though many data weren't available for Barrier 1 and its validation involved fewer parameters. Still, a good match results from kinematics comparison between simulation and actual impact. As discussed below, from simulations resulted a significant sensitivity of test results on approach angle and speed, with variations of the same order of the deviation of simulation data from real ones. So, part of the difference may be caused by approach speed and angle slightly different from standard in real impacts, that surely are within the tolerance gap but are unknown. Moreover, the aim of this study was to investigate the sensitivity to norm parameters of barriers and protection devices, specially searching for characteristics common to all the three devices analyzed; the aim was not to gather forecasting abilities on their performance. So, sensitivity studies have been performed and reported also for Barrier 3.

Figure 3. Barrier 1

Figure 4. Barrier 3

Figure 5. Dummy position after real crash test on Barrier 3

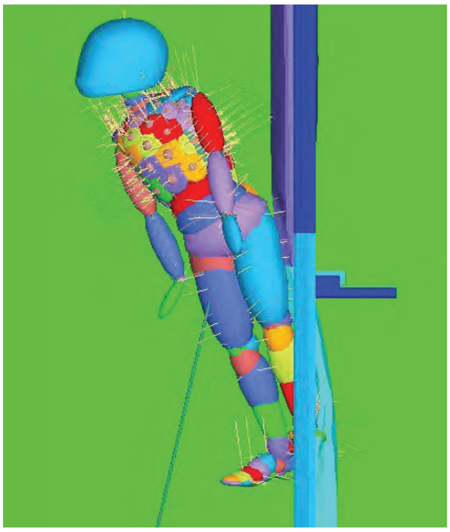

Figure 6. Dummy position at the end of crash test simulation on Barrier 3

On each device model, the centered impact test has been simulated several times, changing every time approach angle or speed. Both parameters were varied in a manner such to cover all the tolerance gap allowed by UNE 135900:2008. Angle ranges from 27° to 33°, with steps one degree wide, while extreme values of speed interval are 59 and 64 km/h, with one kilometer per hour steps.

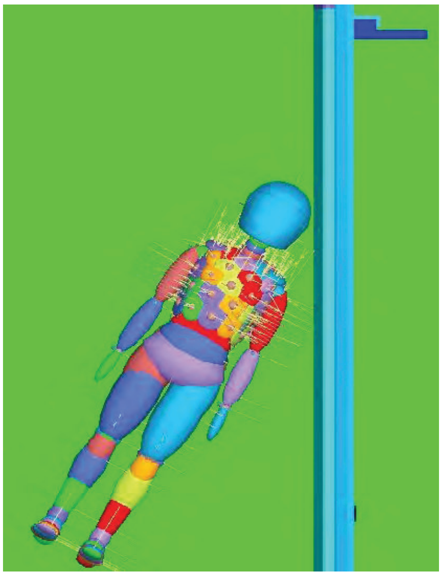

Figure 7. Crash test on Barrier 2, beginning of the simulation

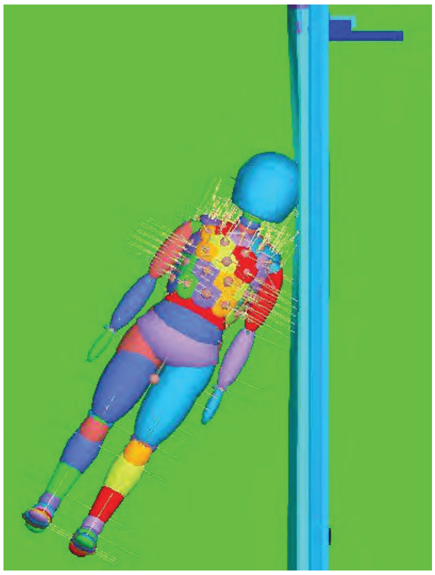

Figure 8. Crash test on Barrier 2, simulation after 25 ms

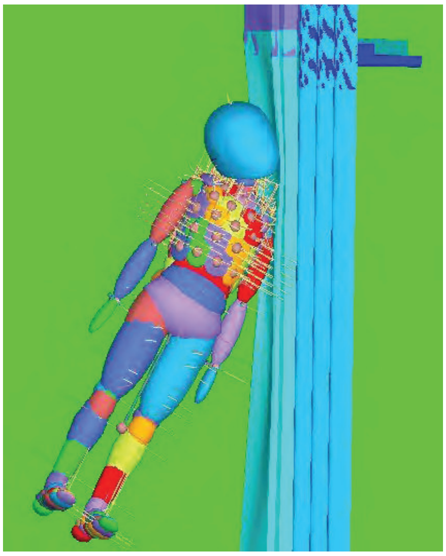

Figure 9. Crash test on Barrier 2, simulation after 50 ms

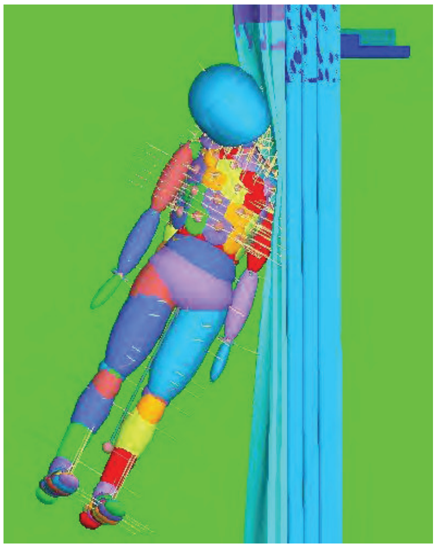

Figure 10. Crash test on Barrier 2, simulation after 75 ms

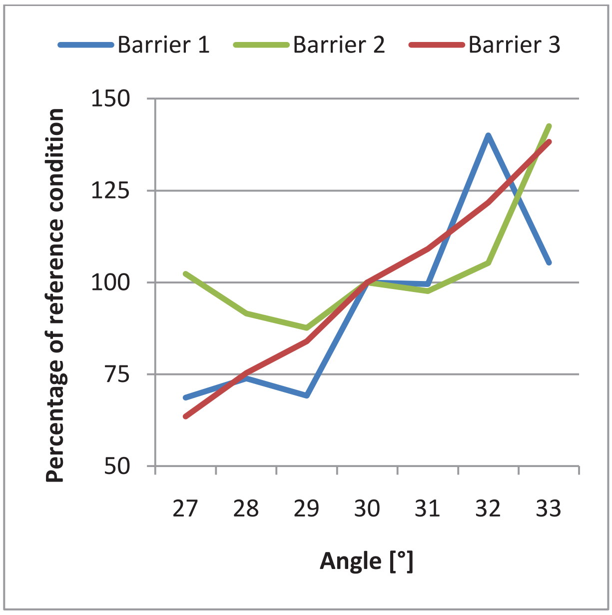

Figure 11. Approach angle influence on HIC_{36}

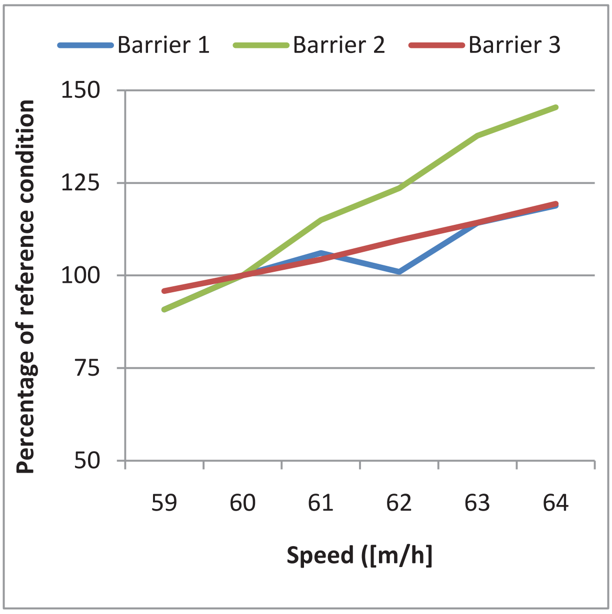

Figure 12. Approach speed influence on HIC_{36}

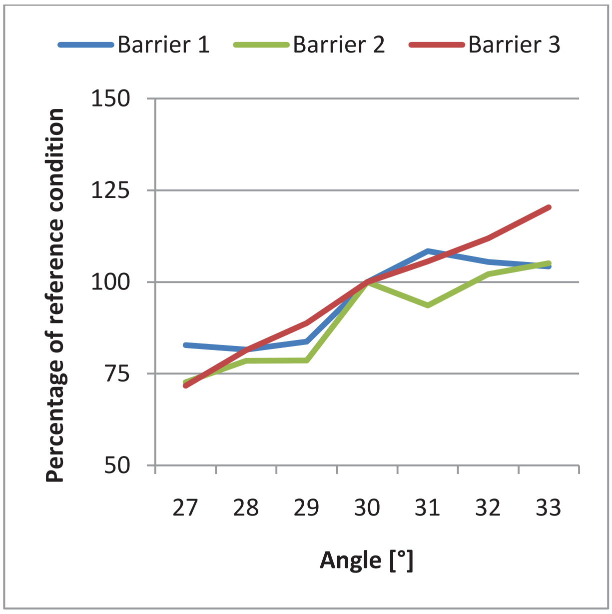

Figure 13. Approach angle influence on neck compression

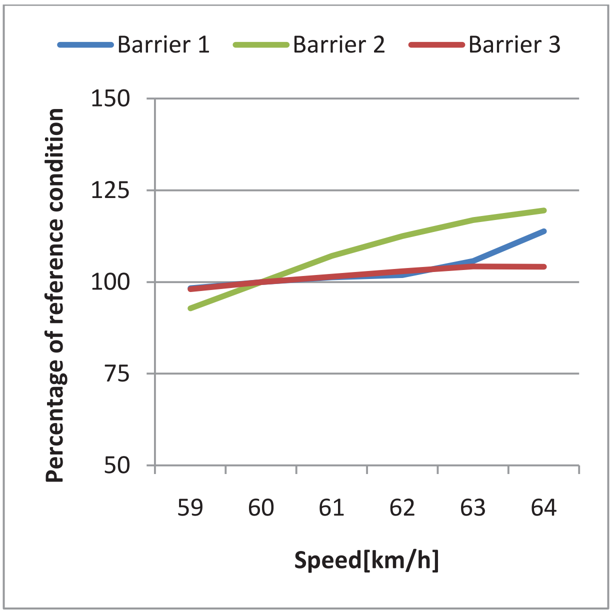

Figure 14. Approach speed influence on neck compression

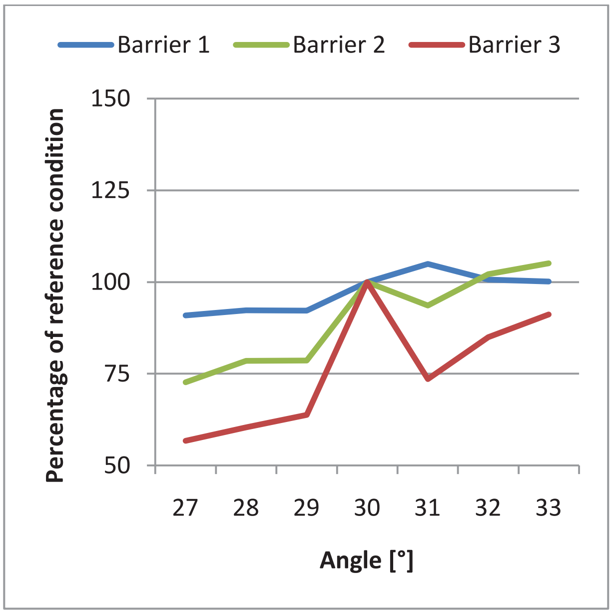

Figure 15. Approach angle influence on neck extension

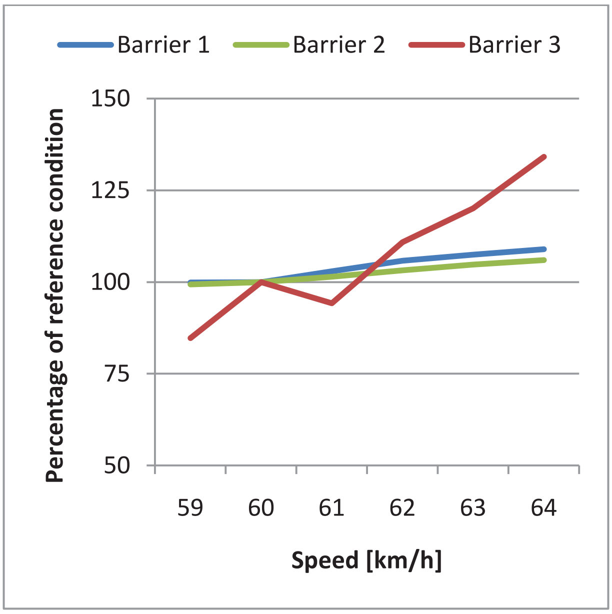

Figure 16. Approach speed influence on neck extension

The main injury indexes considered are HIC_{36}, and neck axial force, both in extension and in compression. In Figure 11, Figure 13 and Figure 15, the influence of approach angle is plotted, while Figure 12, Figure 14 and Figure 16 show the effect of approach speed variations on these indexes. For each curve, data are expressed as percentage of the reference condition: 60 km/h approach speed and 30° approach angle.

Though with few exceptions, a general trend clearly rises from the graphs above. Both approach angle and speed variations, within the allowed tolerance gaps, have a significant effect on all injury indexes. Moreover, approach angle results more influent than speed. The maximum effect is revealed on HIC_{36} which value, moving from one border to the opposite of tolerance gap, could double or even more.

Among analyzed devices, Barrier 3 shows the highest percentage variations, but also the most regular and linear behavior, except for neck extension (Figure 15 and Figure 16).

FINAL CONSIDERATIONS AND IMPROVEMENT PROPOSALS

UNE 135900:2008 deals with biker safety matter on infrastructure side, and finally fills a gap in normative corpus. Its adoption in whole UE is certainly desirable and would lead improved awareness of the dangers of road barriers and to really better conditions for bikers and other vulnerable road users. Following the spread of this norm, there are some aspect that should better defined or more accurately specified in further versions or updates.

1. About head position, and specifically its height from ground, it should be stated or, even better, it might be taken into account that the head could impact the barrier sliding on the floor as well as raised from it with different consequences on redirection and risk of hooking. Also limbs, mainly arms, position would benefit of a more accurate positioning.
2. As described before, an approach angle of 30° leads to a great uncertainty of the body part that impact first the barrier, so the value should be varied or, better, each test could be split in two different impacts: one with an approach angle lesser than 30°, i.e. 20°, to obtain a shoulder impact, and the other with a greater approach angle (40°) that would certainly lead to an head impact. If a single approach angle is preferred, it should be the highest one, since an head impact is more severe on head and neck and as severe as a shoulder one for thorax [8].
3. One other improvement, that would significantly enhance the fairness of the evaluation of a biker protection device, is taking into account the great sensibility of injury parameters to impact angle and speed and approach angle. This could be achieved in two ways. The first is adjusting threshold values according with measured speed and angles; the HIC_{36} limit, for instance, would became a function of the

detected two angles and speed instead of a single value as it now is in the norm. Otherwise, the tolerance gap for approach angle could be modified, moving the reference value from center to the lower limit of the gap, which represents the most favorable condition, as for impact speed in the actual norm. According to this modify, the actual 30°±2° would become 30°-0°,+4°, maintaining the same tolerance gap width.

REFERENCES

1 European Road Safety Observatory (ERSO) "Annual statistic report" 2008.

2 Pothin, Desire "Les glissieres metalliques dans l'accidentologie des motocyclistes: Etude d'enjeu a partir du fichier national des accidents." Rapport d'etude, Service d'Etudes Tecniques des Routes et Autoroutes (SETRA), 1997. (in French)

3 MAIDS Final report 2.0, 2009.

4 UNE 135900:2008 Standard.

5 Peldshus, Schuller, Koenig, Gaertner, Ruiz, Mansilla, "Technical bases for the development of a test standard for impacts of powered two-wheelers on roadside barriers", Paper 07-0332 from 20th ESV (Enhanced Safety of Vehicles) conference, Lyon, France, 18-21 June, 2007.

6 García Peña, Garcia Ruiz, Gallo, Mansilla, Molinero, Peldschus, "Development of a Test Standard for the Evaluation of Motorcyclist Impacts on Road Safety Barriers", paper 09-0789, TRB (Transportation Research Board) 88th annual meeting, Washington D.C.. U.S.A., 11-15 January 2009.

7 Placidi, Fattorini, Fraschetti, "Gli strumenti di simulazione come ausilio alla progettazione delle barriere di sicurezza stradali", Proceedings from Workshop "La ricerca e sviluppo come ausilio alla progettazione", Roma, Centro Sviluppo Materiali S.p.A., 22 June 2001. (in Italian)

8 Vieira, Almeida, Ferreira, Vasco, Bartolo, Ruben, Santos, "Development of an impact absorber for roadside barriers", LS-DYNA Users forum, Bamberg (Germany), 30 September- 1 October 2008

9 Peldschus, Schuller, Garcia, Pérez-Magallón, Mansilla, "Comparison of Impact Configurations for the Development of a Crash-Test Standard in Motorcycle Safety Using a Human Model", SAE paper 2008-01-1900, published on 17th June 2008.

ACNKOWLEDGEMENTS

The authors wish to acknowledge AISICO for the data provided and knowledge shared.