Passenger Safety on Modern Vehicle Restraint Systems

Topic: Road Safety and Security

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Introduction

On the basis of more than 100 conducted crash tests according to the European Standard EN 1317 DELTA BLOC® is one of the most experienced companies in the development of precast concrete vehicle restraint systems. The range of products contains barriers for temporary and permanent use as well as integrated noise and safety barrier systems.

Risks for Passengers at an Impact

The function of passive vehicle restraint systems – such as safety barriers on roads – is to reduce consequences of vehicles getting off the road by leading them safely back to the lane. Assuming that a safety barrier fulfils all its important requirements (leading the vehicle back, no break through, stable behaviour of the car, no roll over etc.) the major risk for passengers is to get hurt due to acceleration during an impact.

In general, crash tests of safety barriers according to EN 1317-2 are conducted with two tests: one test with a heavy goods vehicle (TB 42 to TB 81) and one with a light passenger car (TB 11). For the evaluation of passenger safety the TB 11 is decisive – due to the lesser weight of the vehicle.

TB 11 impact test

Measuring Passenger Safety

Indices of the EN 1317-1

For the evaluation of the risk for passengers there is the need for trusted data based on measurements during crash tests. The EN 1317-2 makes use of three indices to measure, analyse and classify passenger safety of safety barriers:

1. ASI: Acceleration Severity Index
2. THIV: Theoretical Head Impact Velocity
3. PHD: Post Impact Head Deceleration

While for the THIV and the PHD it is just necessary to verify that these parameters fulfil the requirements (THIV ≤ 33km/h and PHD < 20g) the ASI classifies the safety barrier into three categories: ASI A, B and C.

Table 1: Impact severity levels according to EN 1317-2

ASI class	Values
A	ASI ≤ 1,0
B	1,0 < ASI ≤ 1,4
C	1,4 < ASI ≤ 1,9

The EN 1317-1 defines the ASI as an index *"to give a measure of the severity of the vehicle motion for a person seated in the proximity of point P during an impact". [1]*

Unfortunately the EN 1317-1 does not explain in detail the significance of the ASI value for the safety of passengers. It just says that *"the more the ASI exceeds unity [ASI=1], the more the risk for the occupant in that point exceeds the safety limits". [1]*

When part 1 and 2 of the EN 1317 was published in 1994, the impact severity level comprised only two classes – the ASI A and B. At that time the ASI values were interpreted as shown in *table 2 "Interpretation of ASI values in 1994".* Only in 2006 ASI C was added to the EN 1317-2 as a third class.

Interpretation of the ASI Value

In order to understand what the determined values mean in practice and where they might come from we have to take a look at two more indices – the HIC and the AIS.

HIC and AIS

The indices Head Injury Criterion (HIC) and Abbreviated Injury Scale (AIS) are used to describe the trauma of a passenger involved in a vehicle crash.

The HIC measures the acceleration acting on the head of occupants. This index is normally used for head-on impacts. Therefore a HIC higher than 1000 is basically declared as the threshold value from which high occupant injuries are expected [3]. The HIC for lateral impacts is much less than for head-on impacts [2]. It has to be noticed that the head is not as flexible in transversal direction as in longitudinal direction [4].

The Abbreviated Injury Scale (AIS) describes injuries especially in head and neck area of occupants involved in collisions. The injury severity is divided into six categories (see *table 3 "AIS levels"*).

Table 2: Interpretation of ASI values in 1994

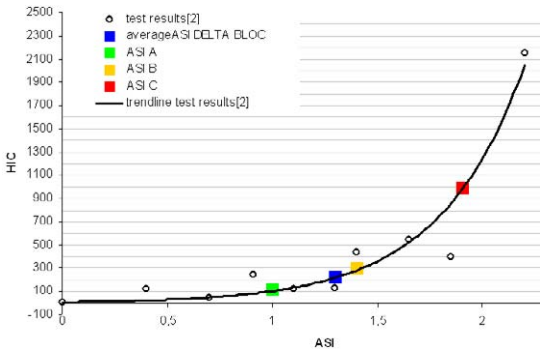
ASI value	Description and interpretation
0 < ASI ≤ 0.7	Redirection of the vehicle coming along with slight injuries of passengers with fastened seat belts. No heavy injuries for unbelted passengers.
0.7 < ASI ≤ 1.0	Higher severity of impact. Slight injuries for belted, severe injuries for unbelted passengers.
1.0 < ASI ≤ 1.4	High risk for most severe injuries. Acceptation for such safety barriers only for special cases.
1.4 < ASI	Risk for fatal injury is too high to install such safety barriers next to roads.

Table 3: AIS levels

Injury Scale	Category	Injuries
0	None	no injury
1	Minor	light brain injuries with headache, vertigo, no loss of consciousness, light cervical injuries, whiplash, abrasion, contusion
2	Moderate	concussion with or without skull fracture, less than 15 minutes unconsciousness, corneal tiny cracks, detachment of retina, face or nose fracture without shifting
3	Serious	concussion with or without skull fracture, more than 15 minutes unconsciousness without severe neurological damages, closed and shifted or impressed skull fracture without unconsciousness or other injury indications in skull, loss of vision, shifted and/or open face bone fracture with antral or orbital implications, cervical fracture without damage of spinal cord
4	Severe	closed and shifted or impressed skull fracture with severe neurological injuries
5	Critical	concussion with or without skull fracture with more than 12 hours unconsciousness with haemorrhage in skull and/or critical neurological indications
6	Fatal	death, partly or fully damage of brainstem or upper part of cervical due to pressure or disruption, fracture and/or wrench of upper part of cervical with injuries of spinal cord

Correlation between ASI, HIC and AIS

In a serious, scientific study Dr. Mazyar Shojaati from ETH Zurich analysed the correlation between these three parameters. He carried out 9 crash tests with Hybrid III dummies for his analysis. The measurements show an exponential correlation between the parameters ASI and HIC [2]. Therefore the threshold value for the HIC of 1000 corresponds to ASI 1.9, the limit of ASI C.

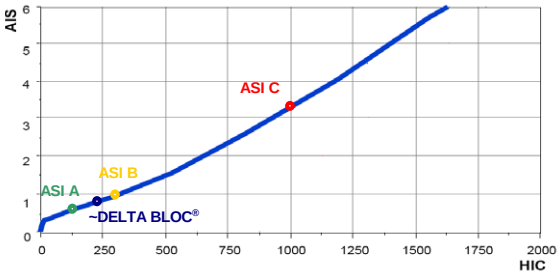


Correlation between ASI and HIC

Table 4: Correlation between ASI and HIC

	ASI	HIC
ASI A	≤ 1,0	125
Average DELTA BLOC®	~ 1,3	225
ASI B	≤ 1,4	300
ASI C	≤ 1,9	1000

The relation between HIC and AIS (see chart below) makes passenger impacts due to crash tests transparent.



Correlation between AIS and HIC

ASI A means a maximum HIC of 125 and therefore an Injury Scale of 0.6 (category: "None to Minor"). The DELTA BLOC® systems have an average HIC of 225, the Injury Scale is 0.8 (category: "None to

Minor"). Restraint systems achieving ASI B have a maximum HIC of 300 and therefore an Injury Scale of 1 (category: "Minor"). The severity index level ASI C allows a HIC up to ~1000 resulting an Injury Scale of 3.2 (category: "Serious to Severe").

Table 5: Correlation between AIS and HIC

AIS category	AIS	HIC
None to Minor	0.6	125
None to Minor (average DELTA BLOC®)	0.8	225
Minor	1	300
Serious to Severe	3.2	1000

It has to be mentioned that the AIS classification is in whole numbers. For interpretation of the differences between the AIS values, a smooth transition from one category to the other was assumed.

Summary and Conclusions

The comparison of ASI, HIC and AIS shows that ASI A and B are both appropriate values for restraint systems.

The Abbreviated Injury Scale describes a range of injuries, where ASI A can be classified between category 0 and 1. ASI B (≤1,4) can be interpreted as category 1. Within one category a lower ASI of course causes less risk of injuries.

References:

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

[2] Correlation between injury risk and impact severity index ASI, 2003, Shojaati, IVT,

[3] NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features, Washington DC, 1993

[4] ASI measuring method, Shojaati and Schueler, IVT, ETH Zurich