EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

PROGRESS ON THE DEVELOPMENT OF THE ADVANCED EUROPEAN MOBILE DEFORMABLE BARRIER FACE (AE-MDB)

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PROGRESS ON THE DEVELOPMENT OF THE ADVANCED EUROPEAN MOBILE DEFORMABLE BARRIER FACE (AE-MDB)

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ABSTRACT

The European Enhanced Vehicle-safety Committee (EEVC) Working Group 13 has undertaken significant research in order to improve the design and specification of the current MDB face used in ECE Regulation 95 testing. The new improved specification defines a barrier of progressive stiffness. This specification has been accepted by GRSP as an amendment to the Regulation. This barrier face was designed to be a surrogate for cars in the market place when the Regulation was being drafted, reflecting vehicle design of the 1980s. Vehicle design has improved as new Regulations (e.g. ECE Regulation 94) have been adopted as well as consumer testing (e.g. EuroNCAP). It is now widely accepted that the specification of the Regulation 95 barrier face does not reflect evolving vehicle design and impact performance and that a more representative barrier face is desirable.

The International Harmonisation of Research Activities (IHRA) Side Impact Working Group (SIWG) is co-ordinating research that could lead to more advanced side impact test procedures, the aim being to have internationally harmonised test procedures that would be acceptable to many jurisdictions that currently regulate for vehicle side impact performance. One of these test procedures will be based on a full-scale test using an impact trolley onto which is attached a new deformable barrier face, based on the impact performance of modern vehicles. Such an advanced side impact test procedure, if found acceptable, may be implemented around the turn of the decade. The European input into these developments is being provided through EEVC WG13.

The paper presents the latest status of European research on the development of an Advanced European - Mobile Deformable Barrier face (AE-MDB).

BACKGROUND

The EEVC Steering Committee, though the work Working Group 9 (WG9), carried out the research that led to the development of the side impact test procedure which is used within ECE Regulation 95 (R95) and EU Directive 96/27/EC[1] part of the in European Type Approval system. Within WG9's proposals, a recommendation was made to include protection for both front and rear seat occupants, but the use of a dummy in the rear seating position was eventually dropped for practical reasons when the test procedure was applied to the Directive. Thus the Regulation and Directive only require protection systems for a front seated occupant.

EEVC Working Group 13 (WG13) has recently made a proposal for an improved barrier face specification for R95, which has subsequently been accepted by the UNECE Working Party on Passive Safety (GRSP) and incorporated in a revision to the Regulation [2].

Currently there are two main standards for full-scale testing for side impact protection across the world, ECE Regulation 95 (Europe, Japan and Australia) and the equivalent Directive and US Federal Standard FMVSS 214. Although both standards attempt to improve occupant protection they appear to drive vehicle design in different directions, for a number of reasons. One reason may be MDB face design and another the dummy being used to measure the severity of the test.

The International Harmonisation of Research Activities organisation (IHRA) is co-ordinating worldwide research that could potentially lead to a unified set of standards or regulations for occupant protection. The EEVC forms the focal point for European contributions to the IHRA Side Impact Working Group (SIWG), in particular through WG 13. This paper describes the research being carried out in Europe, within WG13, to assist in the IHRA side impact goals with a focus on what would be appropriate from the European perspective.

It is also noted that JASIC, the Japanese standards organisation, have also been carrying out similar research but to date no results have been published in the public domain. To avoid conflicting research JASIC has been invited to attend WG13 discussions on Mobile Deformable Barrier (MDB) issues. Within this co-operation JASIC have actively informed WG13 of their research progress. Although JASIC have not yet published their results a large degree of similarity can be reported between the JASIC and WG13 barrier research, as can be seen in a brief summary of their work in Annex 1.

IHRA SIWG discussions are considering the need for two MDB based test procedures. One test replicating an impact by car-type vehicles and another replicating an impact by large sports utility vehicles (SUV) and light trucks. The latter test is being strongly advocated by the US, as these are seen to present the major source of side impact injury in their markets and the former by Europe, as this larger class of vehicle is not common in the European fleet. The development of the US barrier has been led by the Insurance Institute for Highway Safety (IIHS) and the European barrier face by EEVC WG13.

METHODOLOGY

IHRA SIWG has ensured that its proposals offer the opportunity of evaluating the protection to both front and rear seated occupants, as was recommended by EEVC WG9. This has formed one of the key aims of the study for WG13. The second main aim has been to have a test procedure that reflects the current European accident situation and vehicle fleet.

In order to develop an understanding of current side impacts, including loadings to both front and rear seat occupants, it has been necessary to carry out several full-scale crash tests using modern vehicles, for bullet and target, representative of the current fleet, to establish baseline target goals. Two designs of struck vehicle were used to ensure that results were not biased by the characteristics of one of the selected vehicles. The base line tests were moving car to moving car, replicating the real world accident situation. The bullet car velocity was 48 km/h and the struck car velocity 24 km/h. The impact angle was perpendicular with the centre line of the bullet vehicle aligned with the 'R point' of the front occupant.

A barrier face specification should have similar characteristics to that of vehicles within the current fleet. The initial research, undertaken by WG13, has been to examine the frontal stiffness of modern car, found within the European fleet. These data have then been used to develop an appropriate barrier face specification. Tests using a barrier manufactured to this specification have been carried out in a test procedure, similar to that defined in R95 to recreate the vehicle damage and occupant loadings observed in the full-scale car-to-car impacts. The impact was perpendicular with a trolley mass of 1500kg and impact velocity 50km/h.

It is not helpful or cost effective to mandate two similar full-scale vehicle tests if only one is necessary and can be used to assess injury risk in the other test. Within the WG13 research programme two further tests have been performed with the developing IIHS barrier face[1], used in a perpendicular test, to see whether it is able to replicate the European accident condition as recorded in the four car-to-car tests.

BARRIER SPECIFICATION

The R95 MDB face specification was based upon the results of a set of impact tests, on cars of the 1970-80s impacted into a rigid load-cell wall. Based on these results a set of force-deflection targets, coupled with energy absorption limits, was defined. WG13 believes that this is still a valid methodology to determine the target performance of the AE-MDB face.

JASIC published the results of a large number of tests of modern cars into a similar load-cell wall at the 17th ESV Conference in 2001 [3]. These tests have formed the basis of the revised barrier face specification described in this report, along with a car test performed by TRL. Other tests of cars into a soft-faced wall have been performed in recent years. In these tests the load cell wall face has been covered in 150mm of aluminium honeycomb. Unfortunately these soft-faced load cell wall tests are of no value for defining a barrier face specification, since the most important characteristics needed for an MDB face specification occur within the first 150mm of vehicle crush. The initial stiffness characteristics of the vehicle are obscured by the energy absorbency of the surface of the load cell wall.

Based on the JASIC and TRL load cell wall data TRL, with the support of WG13, have developed a new prototype MDB and associated performance specification. The UK Government funded TRL to develop the new prototype MDB. The design, performance and test results with this MDB have been subject to continuous review and comment by EEVC WG13. The design has also taken into account the EEVC recommendations on the review of the current Side Impact Directive [4]. In particular, the recommendation to raise the ground clearance of the MDB face, but not its upper surface, and to increase the severity of the test. The new barrier has been called the 'Advanced European - Mobile Deformable Barrier' face (AE-MDB).

[1] http://www.highwaysafety.org/presentations/sice.htm

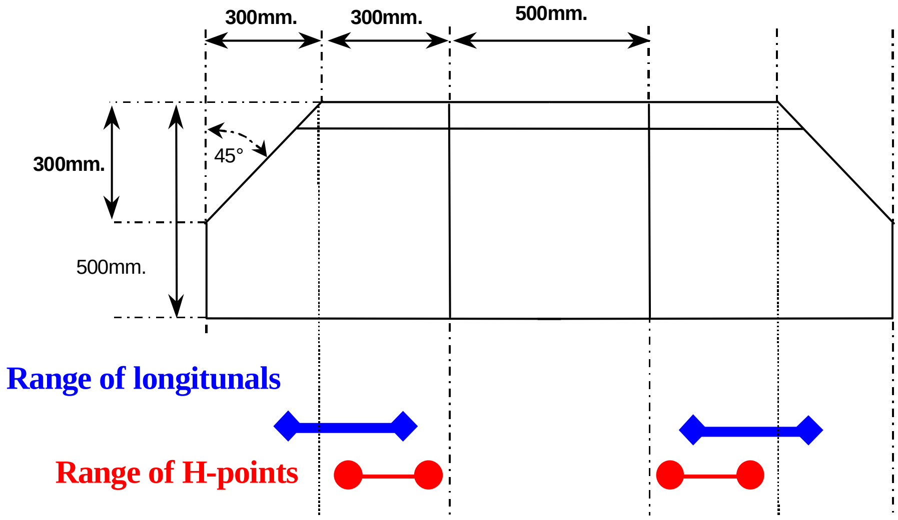


Figure 1 Comparison of vehicle stiff areas and H points

IMPACT CONFIGURATION

Apart from stiffness characteristics it is necessary also to study MDB shape and impact location (lateral position and height). INSIA, A Spanish Research Institute, carried out a structural survey of cars in 1997 within the work programme of EEVC WG15 [5]. Figure 1 shows some of the results of this study, compared to the plan profiles of the AE-MDB barrier face, strongly suggesting that longitudinal rail spacing is very similar to the distance between front and rear seating positions. Thus to load both the front and rear occupants simultaneously the barrier centre line should be located mid way between seating positions. This information coupled with the dynamic load cell wall data has been used as a basis for defining the new barrier design, impact height and fore/aft impact location.

Accident data suggest that perpendicular side impacts occur with two moving vehicles but, in order to minimise test variability R95, adopted a test strategy with a stationary target vehicle impacted by an impact trolley at 90 degrees. To simulate the moving car to moving car situation the US adopted a crabbed barrier test in their FMVSS214 test. EEVC WG13 is still of the view that from a regulatory perspective a perpendicular test is the preferred option as it minimises shear loading to the forward elements of the barrier face and makes for a less variable test.

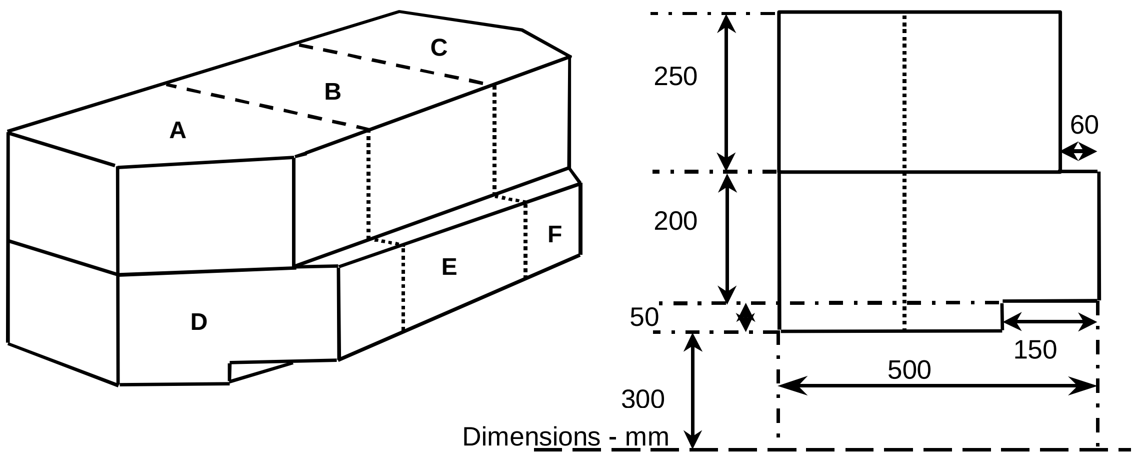


Figure 2 Cross-section of AE-MDB-1 face

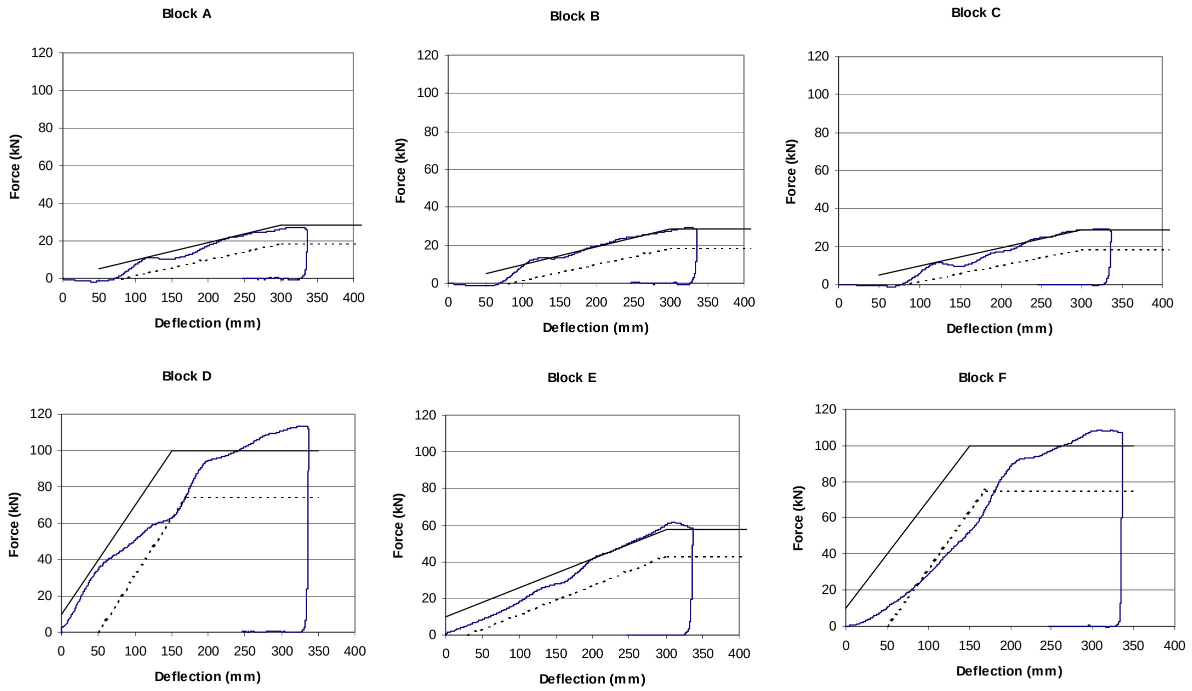


Figure 3 AE-MDB-1 certification test

BARRIER DESIGNS

Design details of the AE-MDB barrier face specification have been published in the IHRA SIWG ESV 2003 status report [6] as well as details of the IIHS barrier face, which was also used to test its suitability for European conditions.

No attempt has yet been made to ensure that the new AE-MDB face is fully within the proposed specification, as the object of the current study was to confirm that the direction of the research was correct. Cellbond[2] manufactured the AE-MDB face used within this programme. To avoid confusion with the R95 barrier specification the block areas have been designated A to F, rather than 1 to 6 as used in the R95 barrier face specification, Figure 2.

To confirm that the Cellbond barrier face was appropriate, one load cell wall test was carried out, as described in the R95 MDB specification. Figure 3 shows the certification performance of the first version of the AE-MDB used in this research programme. It can be seen that the barrier is very close to the desired specification for all of the six areas. The main deviations are in the later crush phases of blocks D and F, the areas representing the stiffer longitudinals. It is suggested that this exceedence, late in the barrier's crush phase, would have little influence on the conclusions drawn from the research reported within this paper. The injury risk parameters, that are the key assessment parameters, would have peaked before this depth of crush would had been reached, assuming that the barrier face crushed that far.

VEHICLE SELECTION

WG13 has so far compared four moving car to moving car baseline tests – Ford Mondeo and Land Rover Freelander into the Renault Megane and the Mondeo and Freelander into the Toyota Camry.

Bullet vehicles

Ford Mondeo – a relatively modern large family low fronted car with reasonable frontal offset performance. Mark 1 model (pre-1996), 1.6l, five-door hatchback, test mass 1390kg.

Land Rover Freelander – a small off-roader vehicle representing the upper limit of a European passenger car and a typical European SUV that is available worldwide. Model year 2000, engine 2.5l, GS automatic, test mass 1720kg

Target Vehicles

Renault Megane – a relatively modern small family car with reasonably good EuroNCAP rating. Model year 1998, version 'AIR', engine 1.4l, five-door hatchback, test mass 1350kg.

Toyota Camry – a large executive car with similar design for Europe, North America and Australia. Model year 1999, engine 2.2l and 3.0l, four-door saloon, test mass 1600kg.

[2] www.cellbond.co.uk

Both of the struck vehicles were equipped with side airbags for the front seat occupant. All the side airbags were triggered by the vehicle onboard airbag firing system except for the Camry impacted by the IIHS barrier, which was manually fired 6 ms into the impact. The timing for the 'naturally fired' airbag in the Camry AE-MDB test was 9.6 ms.

CAR TO CAR IMPACT PERFORMANCE AND OCCUPANT LOADING

Data are available on R95 barrier tests into the side of European vehicles from both Regulatory and EuroNCAP based tests. Unfortunately no data are available on loads sustained by the rear occupant, which forms part of the focus of this research.

Vehicle Test Results

Renault Megane vehicle damage

Figure 4 Megane impacted by the Mondeo

Figure 5 Megane impacted by the Freelander

Toyota Camry vehicle damage

Figure 6 Camry impacted by the Mondeo

Figure 7 Camry impacted by the Freelander

Figure 4 and Figure 5 show the form of damage caused to the Renault Megane by the Mondeo and Freelander and Figure 6 and Figure 7 damage to the Toyota Camry. Intrusion is noted low down in the Mondeo tests, confirming that this is a low fronted vehicle. In addition, localised intrusion can be noted into the two doors from the Mondeo's stiff longitudinals. The Freelander has a flatter and stiffer structure front structure compared to the Mondeo and consequently induces much flatter damage. Nevertheless it can be seen that door intrusion exceeds that of the B-pillar, even in the Freelander impact, suggesting that the B posts are a strong vertical element in the side stiffness of these particular test vehicles.

One of the noticeable features of the vehicle impact intrusion in the Toyota Camry is the presence of the door beam. In both tests, intrusion below the rigid beam is noted, particularly in the Mondeo test.

No roof damage is noted in the two tests with the Mondeo and only slight damage is noted in the tests with the Freelander.

MDB IMPACT PERFORMANCE

Figure 8 and Figure 9 show the damage inflicted on the Megane by the two different barriers and Figure 12 and Figure 13 show the damage to the Camry. Figure 10, Figure 11, Figure 14 and Figure 15 show the barrier damage to enable visual comparisons to be made of energy absorbency and damage to the respective barrier faces.

All of the target cars were left-hand drive vehicles and all were struck on the driver's side, except for the IIHS test into the Camry, which was a right hand side test to the passenger side.

Significant differences can be seen between the IIHS barrier face induced damage, which caused very flat damage to both vehicles, compared to the AE-MDB barrier face damage, which resulted in the probing type of damage observed in the Mondeo and Freelander tests. Impacts by the Mondeo do not appear to generate the sill damage observed in the other tests. The IIHS barrier, being a much higher barrier face, caused damage to the roof at the top of the B post, which was not observed in the vehicle tests.

Details of intrusion profiles are presented later in Figure 16 to Figure 30.

Some indication of energy absorption can be obtained from an examination of the MDB faces, post impact. Both the AE-MDB faces show significant deformation, unlike the IIHS barrier face, which shows minimal damage. The most noticeable damage to an IIHS barrier is seen in the Camry test, Figure 15, where the bumper element has been rolled downwards. This low-level barrier damage will have been caused by engagement with the Camry sill, suggesting that the Camry sill is a relatively stiff body part, at least compared to that of the Megane. The AE-MDB barrier face has deformed around the areas of the stiff wheel arches, the door beam and vertically where the B post has loaded it. Such damage suggests that the AE-MDB barrier face cannot be 'held off' by localised vehicle stiffening, similar to that observed with the R95 barrier face. In terms of observable damage, the AE-MDB barrier face appears to load the cars as do other cars, whereas the IIHS barrier face is a close surrogate to a profiled rigid barrier, since it sustained little permanent deformation in either of the tests.

Renault Megane vehicle damage

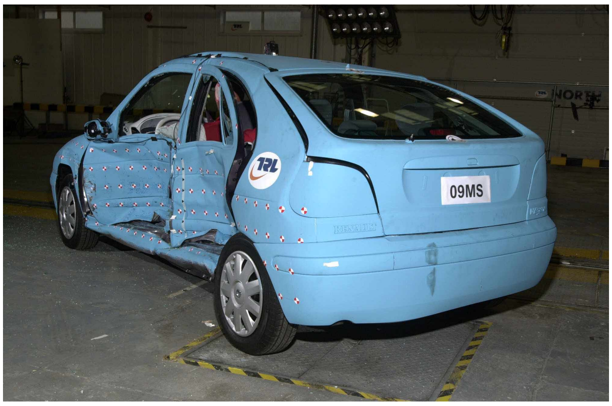


Figure 8 Megane after impact by the AE-MDB barrier face

Figure 9 Megane after impact by the IIHS barrier face

Renault Megane MDB damage

Figure 10 AE-MDB post impact deformation – Megane

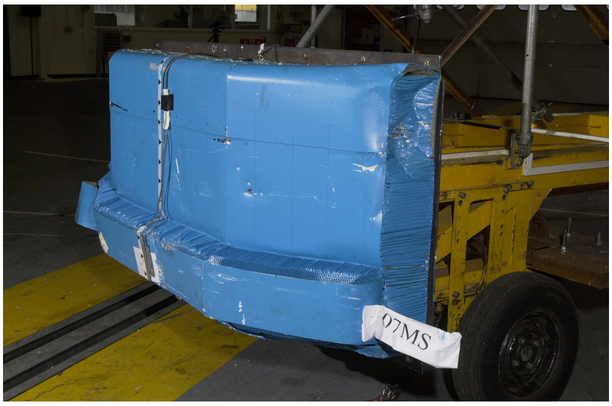


Figure 11 IIHS post impact deformation - Megane

Toyota Camry vehicle damage

Figure 12 Camry after impact by the AE-MDB barrier face

Figure 13 Camry after impact by the IIHS barrier face

Toyota Camry MDB damage

Figure 14 AE-MDB post impact deformation – Camry

Figure 15 IIHS post impact deformation - Camry

Vehicle Intrusion

Vehicle intrusion profiles have been measured in all of the tests to permit quantifiable comparison. The side of each vehicle was mapped by target markers on 125 mm centres, based on the front seat R point. Figure 16 and Figure 23 show the mark-up points on the Megane and Camry used to assess post impact vehicle intrusion. The letters A – E signify the horizontal rows of markers and column R is a vertical plane located at the front seat R point. Row E on the Camry was placed on the door 125 mm below row D but in order to study sill intrusion another row F was added, just below Row E, but on the sill.

Megane intrusion profiles are shown in Figure 17 to Figure 22 and Figure 24 to Figure 30 show the Camry intrusions.

Renault Megane intrusion

Figure 16 Mapped intrusion points - Megane

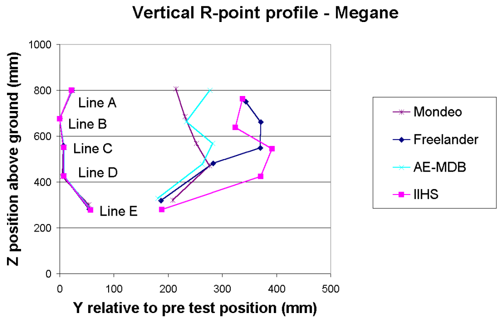


Figure 17 Row R - Megane intrusion profile (pre and post impact)

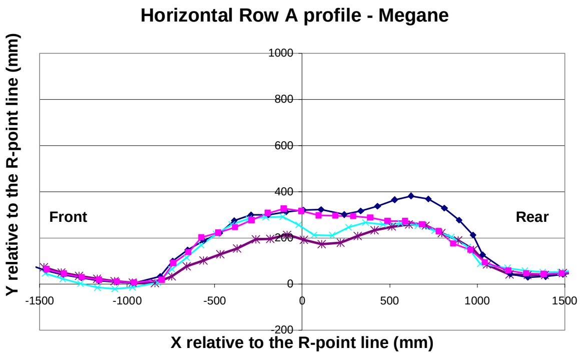


Figure 18 Row A - Megane intrusion profile

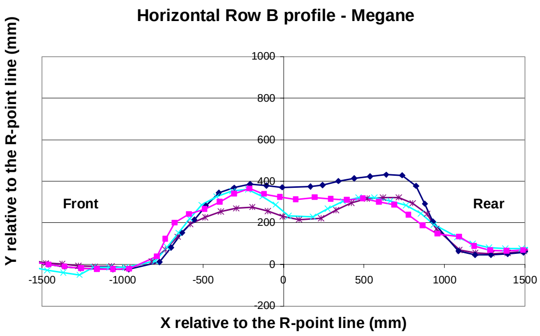


Figure 19 Row B - Megane intrusion profile

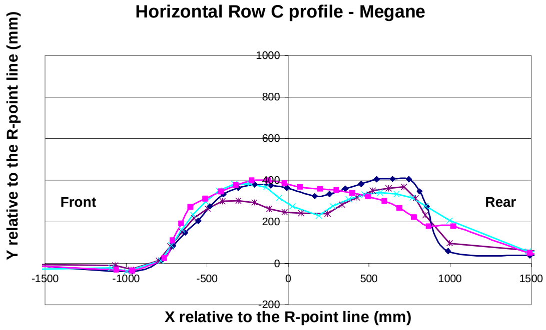


Figure 20 Row C - Megane intrusion profile

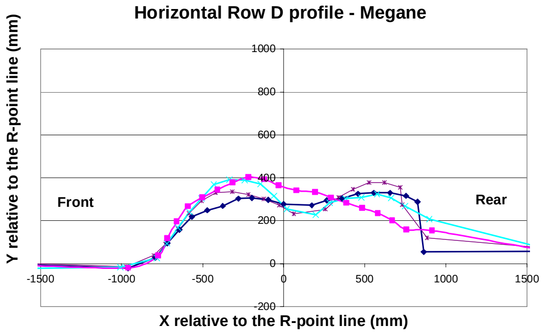


Figure 21 Row D - Megane intrusion profile

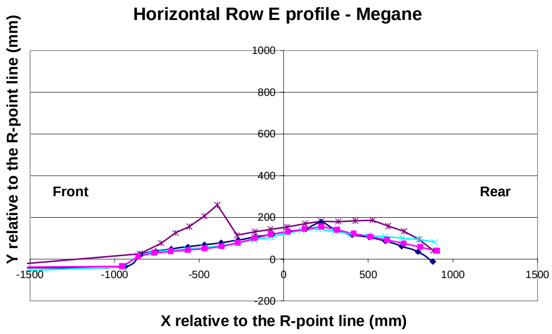
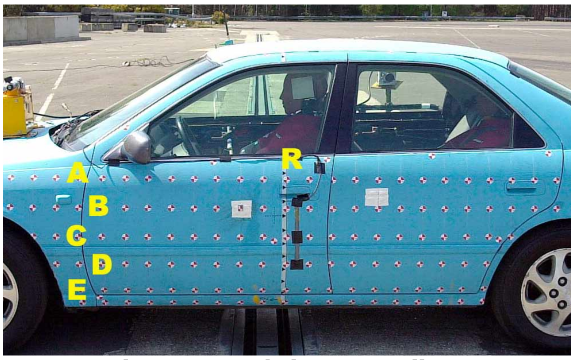


Figure 22 Row E - Megane intrusion profile

As observed in the post-impact deformation measurements of both car and barrier the intrusion profiles associated with the IIHS barrier face are vertically and horizontally flat. The horizontal lines of intrusion clearly demonstrate that intrusion varies with vertical height above the sill. The least variance in intrusion being seen in the IIHS test suggesting that it is too stiff even compared to the large European car/SUV. In terms of vertical intrusion profile at the drivers seating position, the AE-MDB fairly well matches the profile of the Mondeo test and the Freelander up to about mid-door height, line D. Above line D intrusion is much greater with the Freelander and IIHS barrier face. The intrusion at the lower levels with the IIHS barrier face is unrepresentative of both car-to-car tests.

Toyota Camry intrusion



Row E on door - Row F below E on sill

Figure 23 Mapped intrusion points – Camry

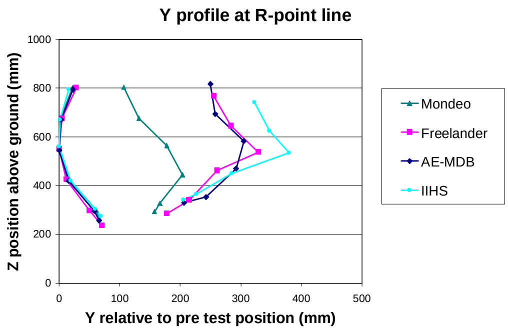


Figure 24 Row R - Camry intrusion profile (pre and post impact)

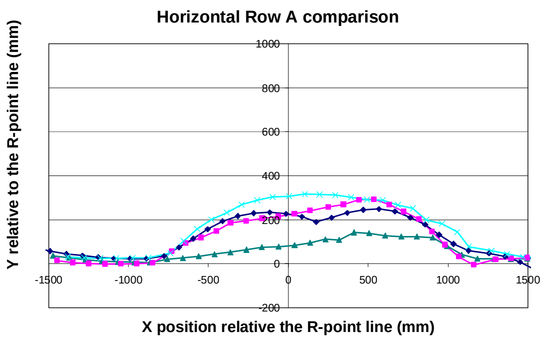


Figure 25 Row A - Camry intrusion profile

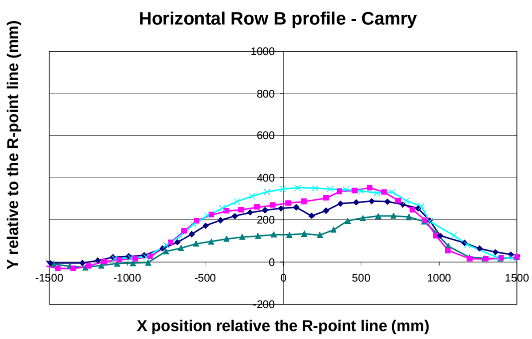


Figure 26 Row B - Camry intrusion profile

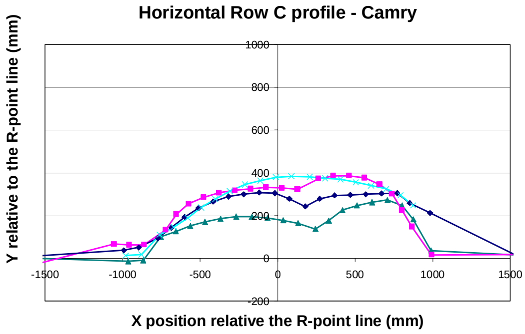


Figure 27 Row C - Camry intrusion profile

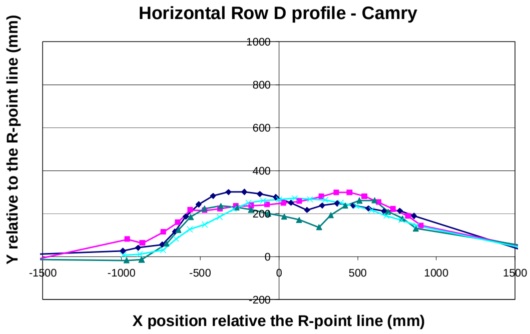


Figure 28 Row D - Camry intrusion profile

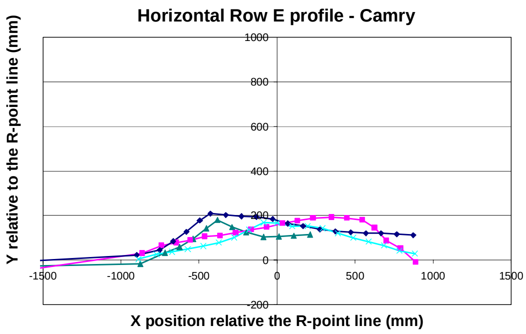


Figure 29 Row E, on door - Camry intrusion profile

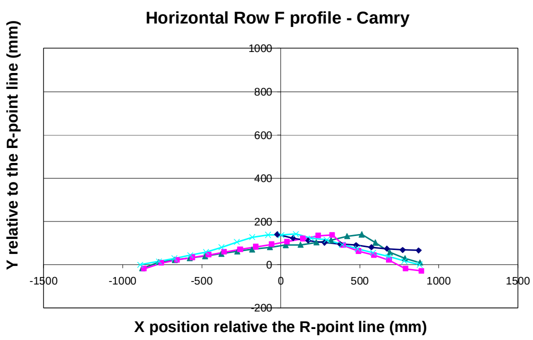


Figure 30 Row F, on sill below Row E - Camry intrusion profile

The Camry vertical intrusion profile, Row R, in the in the Mondeo test is significantly less compared to that generated in the other tests, Figure 24. When compared to the Megane intrusion profiles, Figure 17, it suggests that the side structure of the Camry is stiffer than that of the Megane.

Flat unimodal deformation of the Camry is observed at all levels in the IIHS test. The IIHS intrusion is greater at the higher levels than in the other three tests. In nearly all of the other profiles bimodal intrusion is noted about the B post, above the sill level.

There is evidence to suggest that the intrusion generated by the AE-MDB face, at the levels of rows A and B, is a close surrogate for the Freelander, both producing deformations greater than that generated by the Mondeo.

DOOR IMPACT VELOCITY

Previous research has indicated that door intrusion velocity is an important factor in determining impact severity, as it is the door surface that actually impacts the occupant. Door velocity measurements were made in front of the chest of the two occupants in a position that would not affect dummy kinematics. Measuring techniques were the same for all tests except the IIHS Camry test but the data suggest that equivalent results have been obtained. Figure 31 to Figure 34 show the front and rear door velocity profiles for all tests.

Renault Megane door velocities

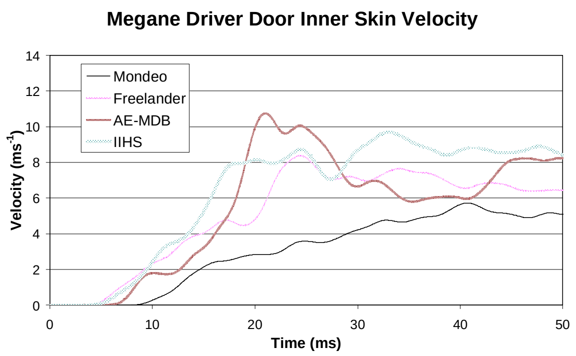


Figure 31 Front occupant door velocities – Megane

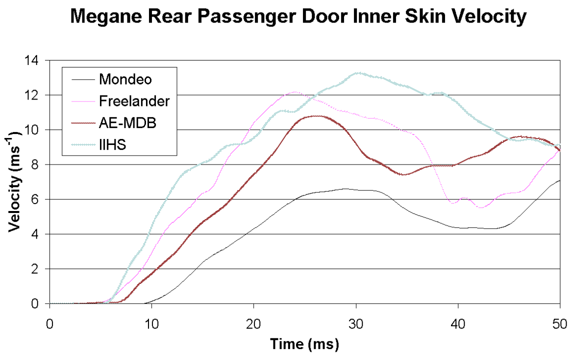


Figure 32 Rear passenger door velocities - Megane

Toyota Camry door velocities

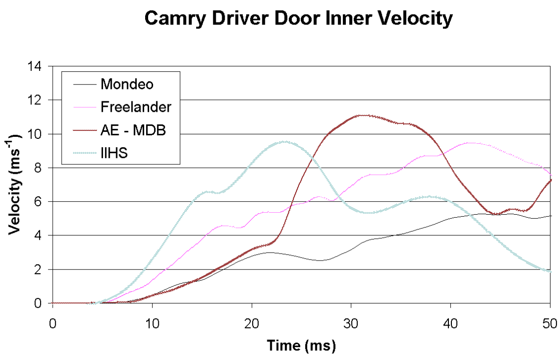


Figure 33 Front occupant door velocities - Camry

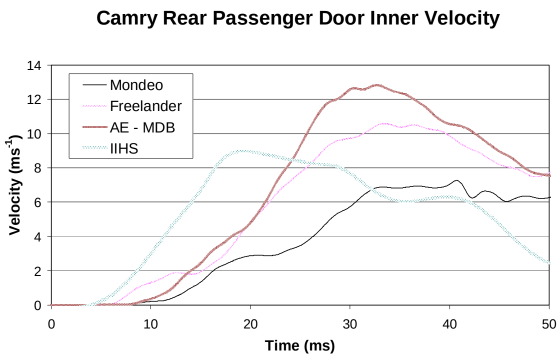


Figure 34 Rear passenger door velocities - Camry

In all of the tests the IIHS barrier face induces velocity profiles exceeding that of the vehicles and AE-MDB barrier face, again confirming the lack of energy absorbency in the barrier face and the likelihood that the doors are bouncing off the face of the barrier. In the Megane tests the AE-MDB face appears to be inducing similar intrusion velocities to that of the Freelander. In the Camry the initial AE-MDB velocity closely matches that of the Mondeo for the front door and that of the Freelander and Mondeo for the rear. Later in the velocity profile histories the AE-MDB face produces some of the highest door intrusion velocities. This may be caused by the excessive stiffness noted in the Blocks D and F, which exceeded the specification, Figure 3.

Table 1 Peak driver results from both car-to-car and MDB-to-car tests

DRIVER		EuroSID-1 Renault Megane				EuroSID-1 Toyota Camry			
		Mondeo	Freelander	AE-MDB-1	IIHS	Mondeo	Freelander	AE-MDB-1	IIHS
HIC		72	250	214	454	98	144	121	266
Chest Defn. (mm)	Top	6.3	25.5	24.3	45.0	7.3	24.2	20.4	32.8
	Middle	6.8	25.3	18.0	47.7	13.3	24.7	23.8	28.6
	Bottom	9.5	24.3	15.1	49.2	19.2	29.6	30.8	29.7
V*C	Top	0.02	0.22	0.27	1.16	0.03	0.15	0.18	0.40
	Middle	0.03	0.22	0.12	1.18	0.06	0.23	0.24	0.29
	Bottom	0.07	0.17	0.05	1.27	0.10	0.42	0.40	0.31
Back plate force Fy (kN)		0.89	0.37	0.09	3.09	0.89	5.01	>5	0.24
Abdomen (kN)		1.17	2.38	1.14	1.64	1.29	1.96	2.15	1.45
Pelvis (kN)		4.27	4.57	4.72	4.54	4.28	4.61	6.23	5.44

Note
The Mondeo and Freelander tests are moving car-to-moving car tests.
The AE-MDB and IIHS tests are moving barrier to stationary car tests – perpendicular impact.

Table 2 Peak rear sear passenger results from both car-to-car and MDB-to-car tests

REAR PASS.		EuroSID-1 Renault Megane				EuroSID-1 Toyota Camry			
		Mondeo	Freelander	AE-MDB-1	IIHS	Mondeo	Freelander	AE-MDB-1	IIHS
HIC		706	107	38	60	476	39	53	446
Chest Defn. (mm)	Top	7.2	7.3	21.0	31	8.3	13.8	18.9	24.7
	Middle	5.6	4.0	4.5	11.0	4.1	6.8	16.9	15.9
	Bottom	5.7	11.1	3.4	12.0	4.4	3.7	15.2	14.3
V*C	Top	0.02	0.02	0.1	0.32	0.06	0.07	0.16	0.27
	Middle	0.01	0.02	0.01	0.06	0.01	0.02	0.12	0.13
	Bottom	0.02	0.09	0.01	0.09	0.02	0	0.12	0.10
Back plate force Fy (kN)		n/a	0.02	0.04	0.05	n/a	0.07	0.02	0.61
Abdomen (kN)		2.43	4.36	1.63	2.3	1.79	1.74	2.34	2.67
Pelvis (kN)		6.97	7.21	6.39	9.60	4.03	3.34	6.27	5.13

n/a – data not available

EUROSID-1 ASSESSMENT

In order to determine the biomechanical impact severity of the different tests, measurements made with the EuroSID-1 dummy must be examined. Table 1 and Table 2 shows the peak values for all the injury risk assessment parameters, for both front and rear seated occupants, as well as back plate forces. Although back plate forces are not used for injury risk assessment, since it is not a biofidelic load path, they can be used to indicate whether dummy interaction with the vehicle seat could have influenced the injury parameters.

Most of the test results are within the range that one might expect from such a test and no specific anomalies are noted. The only parameter that is of note is the back plate force for both front and rear seat occupants. High back plate forces could suggest possible reductions in the values recorded by biofidelic criteria, under-predicting the severity of the impact. In most of the tests back plate forces are insignificant but two tests with the Toyota Camry driver suggest high levels of dummy to seat interaction. Interaction is also noted with the Megane driver in the IIHS test, relative to the other tests.

Test comparisons

The dummy measurements made in the barrier tests can be assessed and compared in a number of different ways. In this analysis they are compared against each of the vehicle baseline tests since the barrier is attempting to replicate the real world impact situation, knowledge of which had been obtained by simplified accident reconstructions. Figure 35 to Figure 38 graphically display the relationship between the four test conditions in relation to the critical injury criteria for that body part. The critical values are those defined in R95: HIC - 1000, rib deflection - 42 mm, V*C - 1.0 m/s, abdomen force - 2.5 kN and pelvic force 6.0 kN. The red horizontal line on the graphs at value 100% indicates the threshold of test failure, as defined in R95 for the EuroSID dummy.

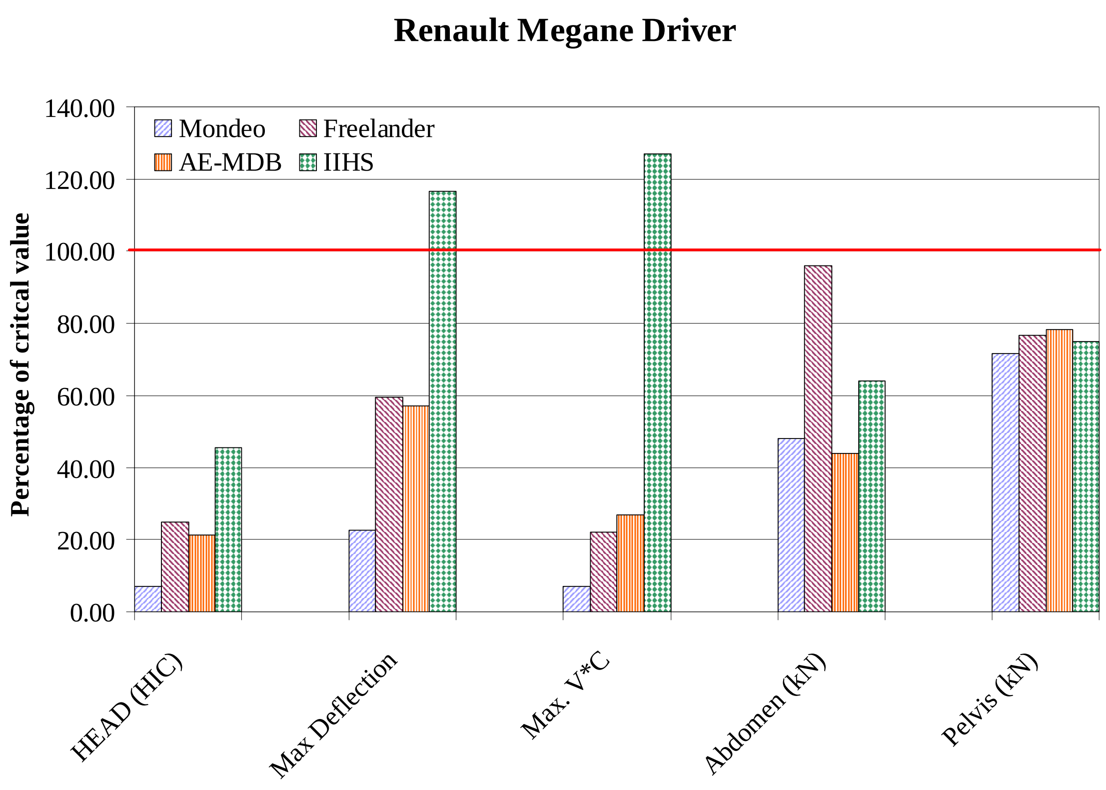


Figure 35 Comparison of Megane driver responses

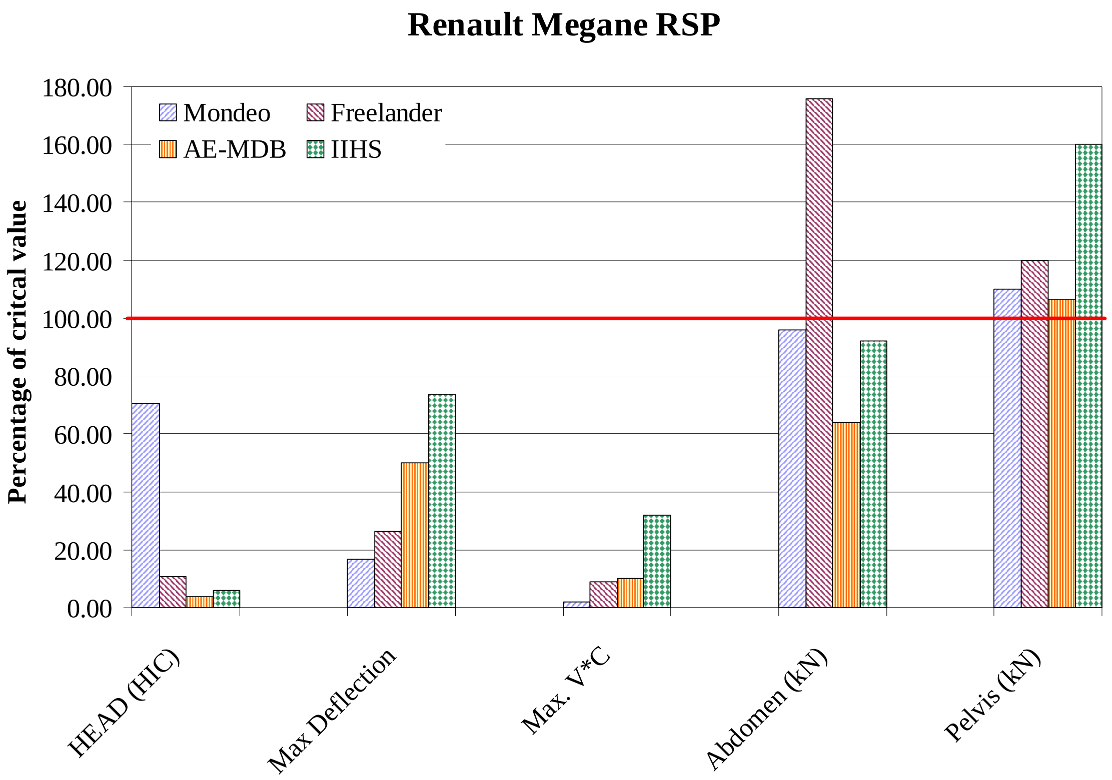


Figure 36 Comparison of Megane Rear Sear Passenger responses

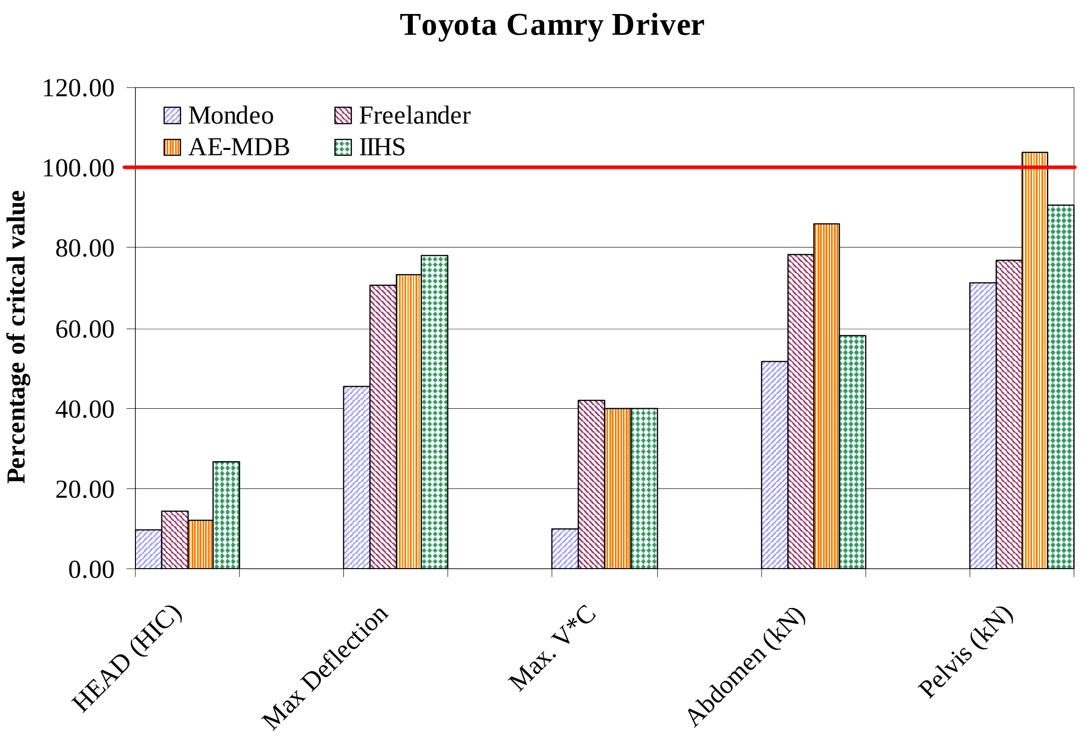


Figure 37 Comparison of Camry driver responses

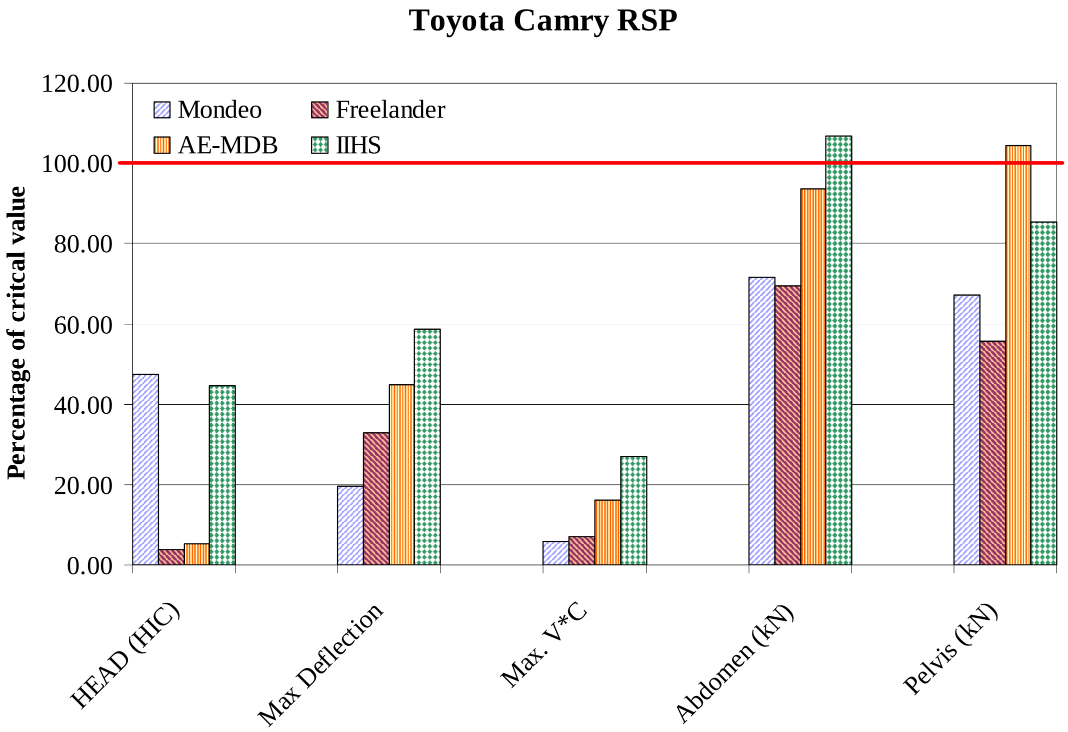


Figure 38 Comparison of Camry Rear Sear Passenger responses

DISCUSSION

Head protection

In a full-scale test procedure only one possible head contact, out of many possible ones, can be assessed, assuming that a contact does occur. HIC, as a head injury assessment parameter, is presented but is not considered to be the most important assessment parameter, within this comparison programme, as IHRA are also proposing a supplementary head contact test procedure, based on the free-motion headform[6]. Within the test programme some minor head strikes with parts of the vehicle interior have been noted, with the rear occupant in the moving car tests. No head contact was observed for the front seat occupant in any of the tests. It is noted that one of the design features of the high IIHS barrier face is the encouragement of head protection systems to protect against head contacts with high intruding structures. Head contact was not observed in the two IIHS tests thus one might question the efficacy of this design feature.

None of the HIC values have been significant, the highest being 70% of the critical value for the rear seat occupant. EEVC WG13 is of the view that head protection is best assessed in the proposed IHRA pole test procedure and headform test procedures. Since the pole would be aligned with the head of the front seat dummy it would more reliably encourage head projection systems compared to a high barrier face, which in these tests did not generate any head contact.

Body protection

The test results can be viewed from a number of different perspectives. The paper does not review dummy time history data.

MDB assessment based on the Renault Megane

Front seat occupant

Figure 35 compares the severity of the various impacts as assessed by the front seat occupant in the Renault Megane. The figure clearly suggests, based on the biomechanical assessment, that the IIHS barrier generates a much more severe impact particularly to the thorax, compared to that of the car-to-car baseline tests and is a more severe test than that using the AE-MDB face. Two upper body parameters exceed the injury criteria threshold value in the IIHS MDB test. The AE-MDB face appears to replicate the Freelander impact to the thorax and pelvis and the abdomen in the Mondeo impact.

The back plate force for the driver (3kN), in the IIHS test is much higher than that observed in any other Megane test and seating position. Currently no explanation is offered for this unexpected result.

Rear seat occupant

Figure 36 compares the severity of the various impacts as assessed by the rear seat occupant, in the Renault Megane. No explanation is currently offered for the unexpected very high abdominal force recorded in the Freelander test.

The high HIC generated in the Mondeo test is observed in a moving vehicle to moving vehicle test. Review of the film records suggest that this glancing contact may not have occurred if the target vehicle had been stationary but such contacts will be evaluated in the proposed IHRA interior surface test.

The biomechanical results suggest that in the rear seating position the lower part of the occupant is more severely loaded than the upper, with both the abdomen and pelvic values being close to or exceeding critical values. The IIHS barrier face highly loaded the pelvis and generally loaded the dummy more than did the other impacting cars and barrier face. It should be noted that the door-trim moulded arm rest of the Megane is perfectly aligned with the abdomen of the EuroSID-1 dummy, thus loading to the abdomen will be a combination of how this element behaves as well as door intrusion characteristics.

From an examination of the post-impact barrier faces it appears that energy was being absorbed by the AE-MDB face but very little in the IIHS barrier, which appears to be all but rigid.

From this particular vehicle assessment the AE-MDB version 1 appears to be a reasonable surrogate for a European vehicle, as defined by the Mondeo and Freelander. The IIHS barrier face is too aggressive, overloading the upper body and the pelvis of the rear occupant.

Impact assessment based on the Toyota Camry

Front seat occupant

Figure 37 compares the severity of the various impacts as assessed by the front seat occupant, in the Toyota Camry. As for the Megane the most seriously loaded part of the dummy was the lower body with the critical pelvis criteria just being exceeded in the AE-MDB test. The difference between the two barrier impacts compared to the car tests is not as obvious as that seen by the Renault Megane driver. In general both barrier faces load the dummy slightly more than did the two vehicles.

The Freelander is the more aggressive bullet vehicle, compared to the Mondeo and the two barriers generally replicate Freelander behaviour.

Of particular concern with this dummy and seating position are the very high back plate forces measured in the Freelander and AE-MDB tests, exceeding 5kN. Forces of this amplitude are not common and are severely penalised in the EuroNCAP star rating system. It is not fully understood what the consequences are of such high forces on the measurements made at other body levels. These two tests should be viewed with a degree of suspicion as there is the likelihood that the biomechanical values may be lower than might have been recorded in the absence of such high back plate forces.

Rear seat occupant

Figure 38 compares the severity of the various impacts as assessed by the rear seat occupant in the Toyota Camry. Both of the barrier faces generated higher loadings to the rear occupant than did the two cars, apart from the Mondeo HIC, which was higher due to contact with the C pillar. For the rear occupant both the barriers applied more severe loading to the occupant, with the IIHS measurements being in excess of that of the AE-MDB face, apart from the pelvis force.

Comparison of AE-MDB with IIHS barrier face

Differences are noted between the two MDB faces from all aspects of the comparison. The Renault Megane appears to be a more discriminating vehicle in showing difference between the loading from the barrier faces compared to the Toyota Camry but similar comments can be made.

It is thought that the two target cars were primarily designed for different markets, the Megane having being targeted on Europe and the demands of the European Regulation 95 test procedure and the Toyota Camry designed primarily for compliance with FMVSS 214. It should also be noted that the door of the North American Toyota Camry is structurally different to that of its European equivalent. The vehicles tested in this programme were of European specification.

Test experience has shown that it is possible to defend a vehicle against a rigid impact by means of areas of localised vehicle stiffness[7]. The US FMVSS 214 barrier face is a much stiffer barrier face than that of the R95 barrier face, thus one might hypothesise that the Camry could have locally stiff areas that may be acting as defensive load paths whereas the Megane may not have the equivalent structures since they are of little use interacting with the R95 barrier face. This could explain the differences between the discriminating ability of the two tested vehicles.

Both of the test vehicles were equipped with seat back deploying airbags, in the front seating position. Within the research so far carried out, it is not possible to quantify the affect of the two airbags and their influence on the test results or to comment on their protection equivalence. It is likely that impacting cars and barriers will trigger the airbag firing mechanisms at different times since the firing mechanisms may have been optimised for the current regulatory tests. No information is available on possible airbag optimisation but such considerations should be made when comparing these vehicles in similar but different tests. It is likely that changes in dummy performance could be engineered by means of re-tuned airbags. It should be noted that in the Camry test the IIHS airbag was fired 6 ms into the impact compared to 9.6 ms for the AE-MDB test. It is not known if this 3.6 ms change would have had any significant influence on the front dummy responses, but one might hypothesise that the airbag may have afforded more protection to the front seat occupant in the Camry - IIHS test compared to the Camry - AE-MDB test.

The Renault Megane clearly suggests that the AE-MDB face, in the proposed perpendicular test procedure, is the barrier face that is more appropriate to the European accident situation, as recreated in the two moving car to moving car baseline tests. The Toyota Camry results do not support this hypothesis to the same degree but there are trends to suggest that the AE-MDB barrier may be the more appropriate barrier compared to the IIHS.

Little damage was noted to the IIHS face in either of the two vehicle tests. Thus it is possible that localised stiffening in the struck car could be used to defend against the bullet barrier intrusion in a way that may not occur with a bullet vehicle, which has areas of high and low stiffness, as seen in the vehicle load cell wall tests.

The research reported to WG13 by JASIC (Annex 1) broadly supports these findings of the higher severity of the IIHS MDB test in comparison with impacts by cars and an MDB based on similar principles to the AE-MDB

FUTURE RESEARCH

The current version of the AE-MDB has been developed based on load cell wall test mainly of Japanese cars and assessed against two bullet vehicles, which were considered to be appropriate examples of the European vehicle population. So far, the research programme has used two target vehicles for the baseline tests, as it was important to ensure that the results would not be biased by any unique attributes that may be found in the vehicles themselves. Results from testing these two vehicles have shown that the two vehicles have not produced the same results but some common trends are noted. Since the two vehicles do not give similar results it would be advisable to evaluate other European vehicles with the two barrier faces to see if the observations made with the Megane and Camry tests were representative of the European fleet. In addition, further load cell wall tests with modern European vehicles would be advisable to compare with the stiffness characteristics determined from the published Japanese tests.

The two vehicles forming the basis of this evaluation were equipped with side airbags for the front seat occupant. Side airbags are not currently mandated and are protection features offered by these vehicle manufacturers as a means of giving the desired level of occupant protection as assessed in the current regulation(s) and consumer tests. At least one other vehicle, not equipped with side airbags, should be evaluated to ensure that the observations are not being biased by airbag attributes. In addition at least one further vehicle should be evaluated equipped with front seat airbags since the Megane and Camry did not yield results of equivalent magnitude.

The evaluation has also been made with the EuroSID-1 dummy, the current regulatory test device in Europe. It is expected that the IHRA test procedures will eventually use a more advanced test dummy, possibly WorldSID. The conclusions reached in this study ideally need to be confirmed with the final test dummies to ensure that the results have not been compromised by the selection of the assessment device.

CONCLUSIONS

1. A review of the stiffness of the front structures of modern cars has been undertaken showing that the existing MDB face, used within ECE Regulation 95, may be inappropriate for a future more advanced barrier based test procedure.
2. Four moving car to moving car baseline tests have been performed to identify performance expectations from a new advanced barrier based test procedure which would be applicable to the development and approval of protection systems for both front and rear seated occupants.
3. A new barrier face specification has been developed within the activities of EEVC WG13 as a contribution to the IHRA work on side impact. It has been evaluated in two vehicle tests.
4. The new barrier face has been called the Advanced European Mobile Deformable Barrier face (AE-MDB).
5. Comparative tests have also been performed using an alternative barrier face (IIHS), designed to reflect the attributes of the large SUV or Light Truck, common in the North America, but not Europe.
6. The performance of the barrier faces, as assessed by vehicle intrusion attributes and biomechanically based measurements is not consistent, the AE-MDB producing a much larger variation in the Megane, compared to the Camry.
7. For at least one European car, the IIHS MDB is a much more severe test than car-to-car or small SUV to car tests while the AE-MDB is much closer to these baseline tests.
8. Results from a parallel study in Japan lend support to the conclusions regarding the higher

severity of the IIHS MDB test in comparison with car-to-car impacts.

9. It is expected that the AE-MDB face specification will require some refinement and a broader based evaluation before it could be used in the advanced side impact test procedure.
10. The biomechanically based evaluation has been made with the EuroSID-1 dummy. It is expected that the new IHRA advanced side impact test with an MDB will use an advanced side impact dummy, possibly based on WorldSID. The MDB face will need to be validated with the new dummy.

REFERENCES

1. European_Council, *Directive 96/27/EC of the European Parliament and of the Council on the protection of occupants of motor vehicles in the event of a side impact*, . 1996.
2. EEVC, *EEVC - www.eevc.org*, .
3. Yonezawa, H., T. Haragae, and Y. Ezaka. *Japanese research activity on future side impact test procedures*. in *17th ESV Conference*. 2001. Amsterdam, Netherlands.
4. EEVC-WG13-16, *EEVC Report to European Commission 'A Review of the Front & Side Directives'*, . Jan 2000, www.eevc.org.
5. INSIA, *Structural survey of Cars. Definition of the main restraint elements in a car body.*, in *EEVC WG15, Working Document 20*. 1997.
6. Seyer, K. *International Harmonised Research Activities Side Impact Working Group Status Report*. in *ESV 2003 Conference Proceedings*. 2003. Japan.
7. Hobbs, C. *The Influence of Car Structures and Padding on Side Impact Injuries*. in *12th ESV Conference*. 1989. Gothenburg, Sweden: NHTSA.

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ANNEX 1

Summary of the Study of New Side Impact Test Method Used in Japan
A Contribution by JASIC

OVERVIEW

In this study, JASIC manufactured a barrier face prototype (J-MDB) that suits current market conditions, and executed actual side impact tests using two compact cars, Vehicle A and Vehicle B. The study included car - to - car and MDB - to - car tests using the J-MDB and the IIHS MDB.

JASIC manufactured a new barrier face prototype based on the average dimensions (17th ESV Conference, paper 221) and average front-end rigidity of Japanese vehicles. The features of the barrier face, which has a previously proven laminate construction, are shown in the figure below. With this prototype, JASIC were able to get close to the average front-end rigidity that was our target.

SUMMARY

The results of the current series of tests confirmed that the car-to-car test and the J-MDB to car test produced practically the same results. In the IIHS-MDB to car test, on the other hand, head area injury responses were strikingly severe. The SUV and IIHS-MDB results were relatively close, but because of their different front ground heights and rigidity distributions, the IIHS-MDB results were somewhat more severe in categories such as the amount of deformation of B-pillar and HIC value of the front dummy. As for other categories, this tendency was reversed in some cases due to the vehicle type of the struck vehicle.

CONCLUSION

The following two points can be emphasised regarding the results of the tests conducted in Japan.

1) JASIC were able to make a barrier face that simulates the front-end rigidity of Japanese vehicles. From the results of tests conducted in Europe using AE-MDB, which simulates an equivalent front-end rigidity, it appears that vehicles up to compact SUVs can be covered by this method by considering the ground height and the impact point.

2) As future tasks, JASIC think that the vehicle structure must be considered when considering the point of impact. Specifically, in the case of compact cars whose pillar B and quarter panel are covered by the flat part of the barrier face, the relationship between the vehicle and the centre of the barrier has to be studied because these vehicles were not involved in any of the worst cases.