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

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ABSTRACT

The European Enhanced Vehicle safety Committee (EEVC) Working Group 13 (WG13) is working within the IHRA (International Harmonised Research Activities) Side Impact Working Group (SIWG) assisting in the development of a suite of harmonised test procedures for side impact protection. Included in the procedures will be a full-scale barrier based side impact test. This paper presents the current status of a research programme that has been carried out to develop a more appropriate side impact barrier face for use in an advanced side impact test procedure. The Advanced European Mobile Deformable Barrier Face (AE-MDB) test will reflect the ‘car to car type’ accident that is typical in Europe and other regions of the world. The latest research performed by EEVC Working Group 13 in the development of an AE-MDB includes reviews of vehicle force distributions, car to car tests as well as the performance of the current specification AE-MDB tests into a range of vehicles.

It is noted that the European vehicle fleet has developed since the UN-ECE Regulation 95 barrier was first conceived, and as a result an improved test procedure is required. The IHRA procedures are being developed to encourage enhanced protection for both the front and rear seat occupants. The AE-MDB should perform in a way that reflects the current accident situation.

BACKGROUND

The AE-MDB is being developed by EEVC WG13 as part of a contribution to the activities of the IHRA side impact working group, which is co-ordinating worldwide research for various aspects of side impact protection including out of position, interior surface protection, full-scale pole impacts and a full-scale mobile deformable barrier based test procedure. This paper presents the status of the vehicle based AE-MDB test specification and the results of tests performed under the WG13 barrier development programme. It is noted that further research is also being conducted outside of WG13 as part of other research projects including the Advanced Protection Systems (APROSYS) project, and an MDB evaluation in Japan.

There are two MDB based test procedures under consideration by IHRA, one being proposed by the Insurance Institute for Highway Safety (IIHS) and the other by EEVC WG13. The IIHS MDB is representative of an impact by large sports utility vehicles (SUV) and small trucks, which is more reflective of accident severities seen in the US. The AE-MDB is more reflective of the European accident situation, where the MDB is more representative of car-type impacts which form the largest proportion of the European vehicle fleet when compared to SUV type vehicles.

Analysis has shown that the existing ECE Regulatory side impact test procedure (R95), is becoming less representative of the impact severity observed in recent accident data [1]. Overall vehicle intrusion, as seen in real-life side impact accidents is also greater than that seen in laboratory side impact tests, and therefore it has been recommended that the overall side impact test procedure severity should be increased [2]. Edwards et al [1] subsequently proposed several ways to increase the test severity to be able to encourage enhanced occupant protection, which included increasing the speed and/or mass of the MBD and also an increase in ground clearance as supported by data from vehicle structural analyses.

One of the main considerations made by WG13 alongside that of the barrier face specification was that the MDB should be capable of simultaneously loading both the front and rear occupants. This measure was made to ensure that vehicles offer adequate protection to both front and rear seat occupants. This is in line with the original proposal made by EEVC WG9 during the research that led to the development of ECE Regulation 95 and EU Directive 96/27EC, although this aspect was not finally included.

PREVIOUS RESEARCH

The initial development stages of the AE-MDB were reported by EEVC WG13 at the 18th ESV conference held in Nagoya, Japan, 2003 [3]. The barrier development programme was based upon three specific areas for assessment; these were baseline vehicle test results, test and MDB configuration and barrier specification. The test and MDB configuration proposed by WG13 utilises a stationary target vehicle impacted by the MDB travelling at 50km/h. The centreline of the MDB is perpendicular to that of the target vehicle and is aligned 250mm rearward of the target vehicle's R-point. This was set to load both front and rear seat occupants and represent a moving car to moving car side impact; where the initial contact point is aimed at the front seat R-point.

Test and MDB Configuration

As reported previously, EEVC WG13 is of the opinion that from a regulatory perspective a perpendicular test (opposed to angled or crabbed) is the preferred option as it minimises shear loading to the forward honeycomb elements of the barrier face and makes for a less variable test. Furthermore, an analysis of the Co-operative Crash Injury Study (CCIS) database for the UK accidents indicated that perpendicular accidents were equally as frequent as angled impacts [4]. The proportion of casualties that were seriously or fatally injured was 60 percent for perpendicular impacts compared with 45 percent for the angled impacts. This highlights the differences that have been seen between the dummy responses observed in crabbed and perpendicular impacts.

WG13 also believes that a perpendicular impact configuration is the most appropriate for the car based test as suggested by accident data, and is reflective of more than half of the side impact accidents within Europe. These reasons, reinforced by the benefits of repeatability and reproducibility of a stationary target vehicle, formed the basis for the impact configuration of the new test procedure.

Current European side impact requirements are limited to front seat occupants only. The inclusion of a rear seat occupant, as proposed by IHRA, aims to ensure that rear seat occupants are also offered a similar level of safety. This measure requires the AE-MDB impact test to load rear seat occupants appropriately without reducing the loading applied to front seat occupants. Previous studies into the geometrical characteristics of vehicle structures performed by EEVC WG13 indicated that the spacing between the lower rails was similar to the distance between the front and rear seating positions [5]. In order to increase the loading applied to rear seat occupants, the MDB centreline is aimed mid-way between the seating positions. The impact point of the MDB is therefore aimed 250mm rearward of the vehicle R-point.

A measure taken to increase the test severity was to increase the mass of the MDB. The proposed trolley mass was increased from the 950kg specified in R95 to 1500kg. This mass is more representative to that of vehicles in the current vehicle fleet, and is also proposed by IHRA for promotion of harmonisation between test procedures.

Barrier Specification

To increase further the test severity, the initial ground clearance of the AE-MDB face was 350mm. The upper surface of the barrier face is at the same height above ground as that of R95, 800mm, as recommended by Edwards, 2000.

Rigid car to load cell wall (LCW) data, collected from vehicle models dated circa 1970-80s, formed the basis of the stiffness distribution for the R95 barrier face. This measure was based upon force-deflection and energy absorption limits for the individual barrier blocks and the barrier total. The same approach has also been taken to date to develop the AE-MDB corridors. The main source of LCW data available to WG13 prior to the 18th ESV conference (Nagoya) was provided by the Japan Automobile Research Institute (JARI) [3]. The original AE-MDB corridors were subsequently based around these results, and were described by Roberts, 2003. It was proposed that further LCW tests with European vehicles should be performed and compared to the JARI data. WG13 subsequently collected rigid LCW data from seven different vehicle models.

Baseline Vehicle Test Results

The performance assessment for the AE-MDB was based on the results of the 'baseline vehicle test data'. These tests were moving car to moving car perpendicular side impacts; and represented the type of impact that the AE-MDB should be able to replicate. Two different bullet vehicles were used to provide a range of impact scenarios, one being a family sized car and the other a small off road vehicle. Previously, only two target vehicles, a Renault Megane and Toyota Camry, had been used by WG13. It was proposed that the AE-MDB should undergo further evaluation using different vehicle models.

The results from those earlier baseline tests indicated that the AE-MDB performed differently when impacting the Megane than when impacting the Camry. Comparison of the post test vehicle intrusion profiles from the AE-MDB tests with those from the baseline tests indicated that when impacting the Megane, the AE-MDB appeared to be a suitable representation of the European accident situation. However, with the Camry the AE-MDB results were less conclusive suggesting that it may be more suitable for Europe than the IIHS barrier face.

Further baseline car to car and AE-MDB to car tests have been performed since the previous WG13 report. A range of target and bullet vehicles were used in order to provide a broader assessment for the barrier face.

VEHICLE TO RIGID LCW PROGRAMME

The rigid LCW data provided by JARI, gave a clear indication that the frontal stiffness distribution of modern vehicles has changed significantly since the development of the R95 barrier face. WG13 performed additional car to rigid LCW tests in order to confirm that the stiffness distribution in modern European vehicles was comparable to that of the JARI data.

The stiffness distribution; as indicated by JARI and WG13 LCW results together with the AE-MDB version 2 corridors; is shown in Figure 1. The upper frontal structures of the vehicles tested, which align with blocks A, B and C, show a relatively homogenous stiffness distribution and low levels of loading applied. In contrast, the vehicle structures which align with the lower row of blocks do not show such homogeneity. The outer areas are loaded to a greater extent that any other below 350mm of displacement. This load is most likely to have been transferred through the lower rails of the vehicles tested. The centre area (block E) initially indicated large forces after relatively little deformation, it is suggested that this is due to the inertial response from bumper beams and lower rail connecting members. This is exaggerated by the effects of data the filtering processes, which caused loading to be shown prior to vehicle displacement. The load applied to the centre area is, for the most part, lower than that of the outer areas. The loading to this area reaches a similar level to that of the outer areas due to engine loading, which becomes apparent at around 300mm of displacement.

It is accepted that rigid LCW data is unable to clearly highlight the presence of significant lateral connections between lower rails. However, the results are able to provide an indication as to the global stiffness of the vehicles tested. It is currently unclear as to the proliferation of such beam structures throughout the European vehicle fleet, and there is currently no equivalent test procedure which can be used to assess and specify such design, either in terms of barrier design or specification. WG13 has analysed data from LCW tests with a 150mm aluminium honeycomb barrier fitted to the wall. These results were deemed unsuitable for the definition of vehicle stiffness, due to the vehicle structural characteristics being obscured by the presence of the deformable element.

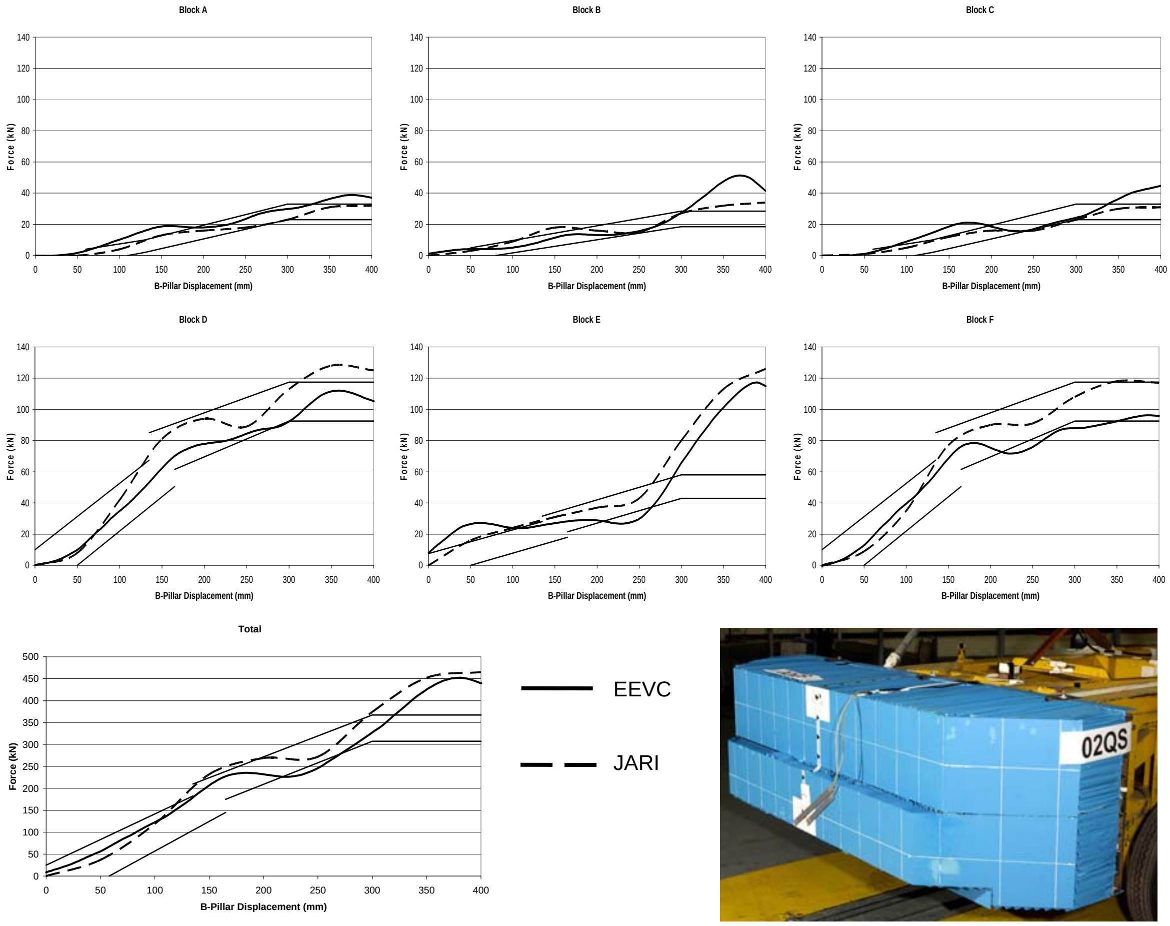


Figure 1 Vehicle to Rigid Load Cell Wall Test Data

Both the Japanese and WG13 data show similar trends across all corridors, and in the case of blocks A, C and E, local and overall force levels are also comparable. For the upper row the WG13 data was slightly above that of the JARI data, whereas the reverse is observed for the lower row. The AE-MDB stiffness corridors have a similar stiffness distribution similar to that of the vehicle data. In general, the total force-deflection traces are very similar and the AE-MDB corridor appears to be a suitable representation of the overall stiffness, up to about 300mm displacement where engine loading becomes apparent.

The information provided by JARI was a 'calculated average' where the force was weighted by vehicle sales data from 1998, with the relative B-pillar displacement normalised. The data was made up from approximately 80 vehicles to LCW tests, and a further analysis based on C-segment vehicle models showed very close similarities between data, which indicated that the full data set was representative of the most common vehicle models. The WG13 data was an averaged force with the relative B-pillar displacement normalised. It was not weighted by vehicle sales, as was the Japanese data, thus any variation could be due to this difference. The WG 13 data was made up of seven vehicle models, and included a small off road model, a multi-purpose vehicle and various D-segment vehicles.

Although the AE-MDB version 2 performance corridors have been modified since those presented at the 18th ESV conference (AE-MDB version 1), the modifications have only been included to make allowance for the geometrical characteristics of the AE-MDB. For example, block E of the AE-MDB utilises the same honeycomb as that of the R95 barrier blocks 1 and 3, subsequently it was given the same corridor in version 1. However, due the step in the AE-MDB, the force applied between 0-150mm displacement is less than that of R95. Therefore the corridor was reduced for this period, and at 150mm the full surface of block E is engaged and the corridor returns to that used in R95. It was the intention that the materials to be used in the construction for the AE-MDB should be based upon those which already exist. In the case of AE-MDB blocks A to C, which form the upper row, the honeycomb to be used was the same as that used for the R95 barrier face block 4.

BASELINE VEHICLE TEST PROGRAMME

Since the previous report at the 18th ESV conference, WG13 has performed four additional baseline tests using two other target vehicle models. In total, eight baseline tests have been performed using four different target vehicles and three different bullet vehicle models. The centreline of each bullet vehicle was aimed at the R-point of each target vehicle, with both vehicle centrelines perpendicular to each other. The speed of each target vehicle was 24km/h, and the bullet vehicles were travelling at 48km/h. This configuration is exactly the same to that of the previous research performed by WG13.

Bullet Vehicle Models

Ford Mondeo – family size vehicle, five-door hatchback. Mark 1 (pre-1996), 1.6l engine, test mass 1390kg.

Land Rover Freelander – small off road vehicle, typical within the European vehicle fleet and available worldwide. 2000 model year, 2.5l engine, automatic transmission, GS model, test mass 1720kg.

Toyota Corolla – small family size vehicle, four-door saloon. 2002 model year, 1.4l engine, test mass 1340kg.

Target Vehicle Models

Renault Megane - small family size vehicle, five-door hatchback. 1998 model year, 1.4l engine, 'AIR' model, test mass 1350kg. Equipped with side airbags.

Toyota Camry – executive four-door saloon available worldwide. 1999 model year, 2.2l and 3.0l engine, test mass for both models 1600kg. Equipped with side airbags.

Toyota Corolla - small family size vehicle, three-door hatchback. 2002 model year, 1.4l engine, test mass 1340kg. Not equipped with side airbags.

Alfa Romeo 147 - small family size vehicle, three-door hatchback. Equipped with side airbags.

The recent baseline tests to a Toyota Corolla and an Alfa 147 were performed using a Land Rover Freelander and a Toyota Corolla. These tests were used to gain further experience of impacts with a small off road vehicle and an average family size vehicle, which provide a representation of the real-world impacts that the AE-MDB procedure should be able to reflect. It was also possible to investigate any differences between three and four/five door vehicles, as the Corolla and Alfa were both three door hatchbacks.

Anthropometric Test Devices

The initial studies by WG13 used the EuroSID-I dummy. Since that research was performed this dummy has been superseded by the ES-2, which is seen as being an improvement over the EuroSID-I. Therefore, WG13 agreed to use the ES-2 and any direct comparison between these evaluations phases should make note of this change.

Toyota Corolla Test Observations

The post test struck side vehicle deformation to the Corolla is shown below in Figure 2 and Figure 3. The Freelander applied loading to the Corolla at a higher level to that applied by the Corolla bullet vehicle, this was indicated by the deformation to the roof and door panel visible just below the height of the door handle. The loading applied by the Corolla was concentrated toward the lower edge of the door and around sill level, in these respective areas, were where the B-pillar was seen to receive most of its loading. There was more door deformation visible in the Freelander test where the lower edge over-rode the sill. There was little sill deformation visible after the Corolla test.

Figure 2 Corolla impacted by the Corolla

Figure 3 Corolla impacted by the Freelander

Alfa Romeo 147 Test Observations

The post test struck side vehicle deformation to the Alfa is shown in Figure 4 and Figure 5. The bullet vehicles applied loading to the Alfa in similar ways to those seen in with the Corolla. Note also that the vertical bend in the door, just rearward of the side mirrors, was pronounced in the Freelander impact, whereas the when impacted by the Corolla this deformation was not present. The form of deformation to the sill and rear panel, beneath the rear window, appeared to be quite similar. In both cases, the lower edge of the driver's door remained engaged with the vehicle sill. But, the visible rotation of the sill about its primary axis and deformation to the underside, suggests that loading has also been applied to a large proportion of this area.

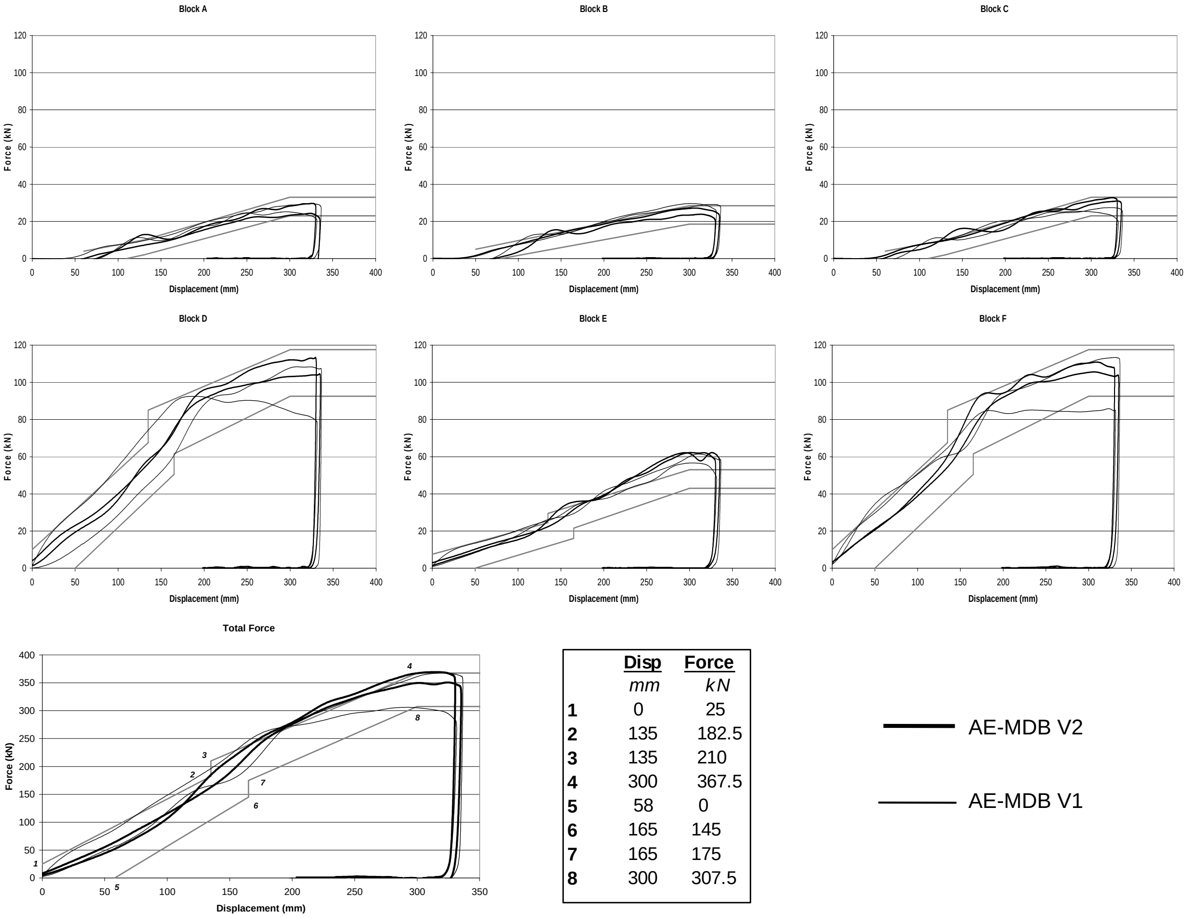
Figure 4 Alfa impacted by the Corolla

Figure 5 Alfa impacted by the Freelander

All of the vehicles impacted by the Freelander indicated that most of the load was being applied approximately midway up the door(s), from observations of vehicle damage. However, the Mondeo and Corolla mostly loaded the target vehicles toward the lower edge of the door(s). With the Freelander, the presence of a high beam connecting the lower rails was evident on each target vehicle. A pre-test measurement of this beam showed it to be positioned approximately 560mm above ground level. With the family sized vehicles, the presence of such beams was not as clear, but measurements of the Mondeo and Corolla located the beams approximately 430mm and 480mm, respectively, above ground level.

AE-MDB TEST PROGRAMME

The current specification of AE-MDB face that has been published is version 2. The barrier version evaluated by WG13 and published at the 18th ESV conference was version 1, the only difference being the build specification to reflect the changes that had been included in the revised R95 barrier face. Prior to the vehicle tests with the AE-MDB V2, two LCW certification tests were performed at two different laboratories in order to ensure that the barriers used met the specification required. The results from the V2 tests, in bold black lines, are shown in Figure 6 alongside those of the V1 tests performed previously by WG13.



	Disp mm	Force kN
1	0	25
2	135	182.5
3	135	210
4	300	367.5
5	58	0
6	165	145
7	165	175
8	300	307.5

Figure 6 AE-MDB Certification tests

The certification test results showed that the barriers did suitably meet the design specification, although block E was slightly stiffer than desired after approximately 200mm displacement. Further barriers were subsequently constructed and used for assessment of the specification.

Toyota Corolla Test Observations

The post test deformation of the Corolla after being impacted by the V2 AE-MDB is shown in Figure 7. There was very little roof and upper B-pillar deformation visible. The loading from the barrier was applied over a greater area than that of the Freelander. The lower edge of the doors were deformed in a manner more like that of the Freelander than the Corolla, and subsequently the door over-rode the sill. The level of sill deformation appears to be between that seen in the baseline tests.

Repeatability Evaluation

In an assessment of repeatability; three AE-MDB V2 to Corolla tests were analysed. The results show comparable dummy and deformation results between all of the tests, which were performed at two different laboratories. However, a different trend in door velocity was recorded between laboratories, which can be attributed to different measurement methods.

Figure 7 Corolla impacted by the V2 AE-MDB

Alfa Romeo 147 Test Observations

The post test deformation of the Alfa after being impacted by the V2 AE-MDB is shown in Figure 8. There was less roof and upper B-pillar deformation when compared to that of the Freelander impact, and in this area a closer comparison can be made with the Corolla impact. The most notable differences between the barrier and baseline vehicle impacts is the larger loading to the lower edge of the door, and the lower levels of loading to the sill seen with the AE-MDB. There was no engagement between the door and sill, which did not rotate as it did in the baseline tests, allowing for greater levels of intrusion. In the area of the rear panel the form of deformation was comparable to that of the baseline tests.

Figure 8 Alfa impacted by the V2 AE-MDB

Vehicle intrusion profiles

In all of the tests performed by WG13 the geometrical characteristics of each target vehicle were mapped before and after each impact. A grid was applied to each vehicle with rows at a height of 300, 425, 550 675 and 800mm above ground level. Vertical columns, originating from the Driver's R-point, extended fore and aft at increments of 125mm. The only exception to this was with the AE-MDB to Alfa test, where the grid was measured at 130x200mm increments and do not translate directly to the points measured in the baseline Alfa 147 tests.

Toyota Corolla

The marking scheme for the Toyota Corolla prior to impact is shown in Figure 9. The post test intrusion profile for each row is shown in Figure 10 to Figure 15. The data set contains the two baseline results from the Corolla and Freelander impacts, and also three AE-MDB to Corolla tests.

In general, the deformation produced by the AE-MDB was between the levels of the two baseline tests for all rows. The vertical profile at the R-point position showed the AE-MDB to be mid-way between the baseline tests, which also reflected a similar shape. The B-pillar deformation for rows A to C was almost the same as that from the Corolla baseline test. However, the intrusion either side of the B-pillar was mid-way between that of the two baseline tests. The AE-MDB profiles for rows D and E were higher than that of the Corolla, and at the driver's door the peak intrusion was at a level similar to that of the Freelander. The presence of the stiff B-pillar is clear in all of the AE-MDB profiles, but it is only just visible in the lower Corolla baseline profiles. The B-pillar is not visible for the Freelander profile, which produced 'square shaped' intrusion with the maximum level at row C; 550mm above ground level. The peak level of intrusion for the Corolla test was at row D; 425mm above ground level. The peak level for the AE-MDB tests was at row C; 550mm above ground level.

A comparison between the AE-MDB profiles shows very similar global and local intrusion levels, with similar shaped intrusion.

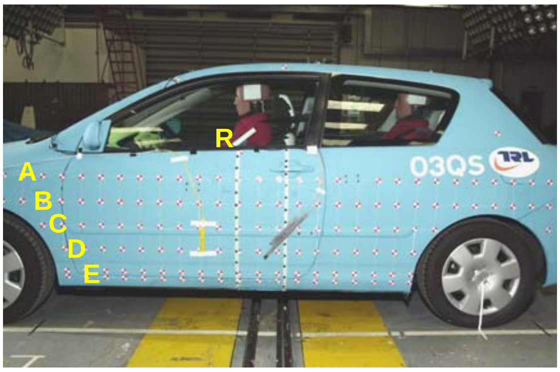


Figure 9 Toyota Corolla Map

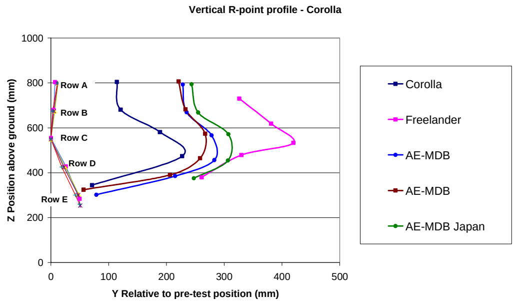


Figure 10 Corolla R-point profile

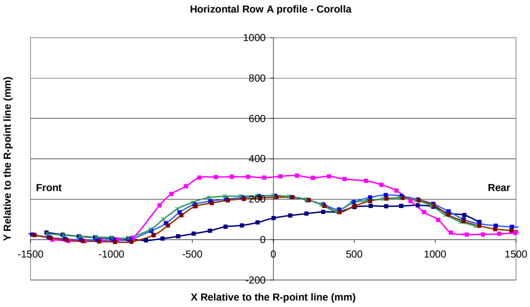


Figure 11 Corolla Row A profile

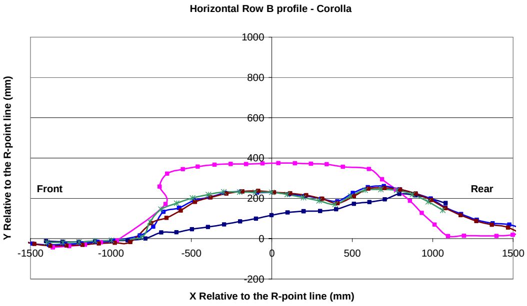


Figure 12 Corolla Row B profile

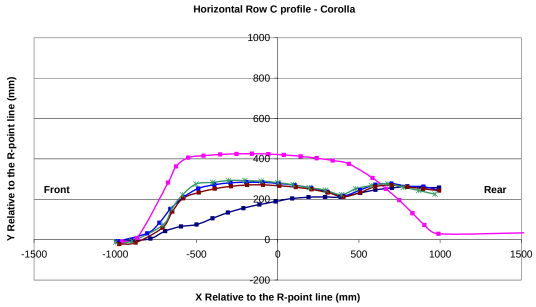


Figure 13 Corolla Row C profile

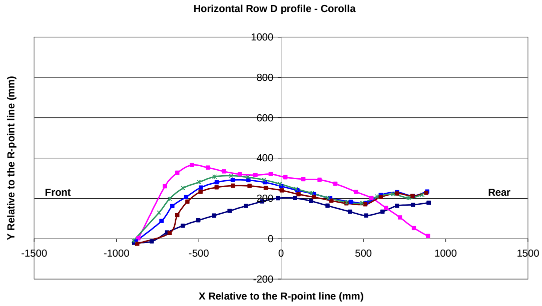


Figure 14 Corolla Row D profile

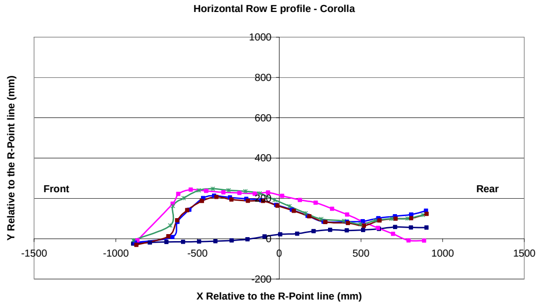


Figure 15 Corolla Row E profile

Alfa Romeo 147

The marking scheme for the Alfa Romeo 147 prior to impact is shown in Figure 16. The post test intrusion profile for each row is shown in Figure 17 to Figure 22.

Rows A to C show the level of AE-MDB intrusion to be similar to that of the Freelander along the driver's door. Toward the rear of the vehicle, the stiff B-pillar is visible in the barrier profile with lower levels of intrusion. Rows D and F show a similar level of intrusion between the two baseline tests. Whereas the intrusion from the AE-MDB was larger than both of the baseline tests for the full length of the profile. The largest difference was recorded mid-way along the lower edge of the door by 200mm above that of the Freelander. The peak intrusion for the Freelander was at row C; 550mm above ground level, and for the Corolla it was at row D; 425 mm above ground level. The peak intrusion for the AE-MDB was at row D.

Figure 16 Alfa Romeo 147 Map

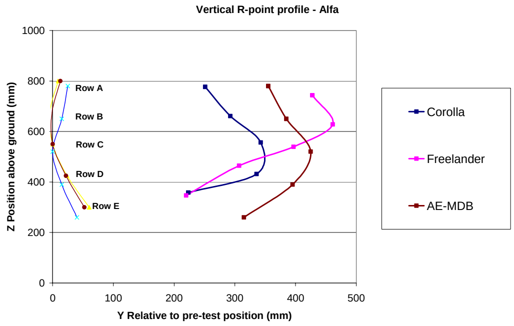


Figure 17 Alfa R-point profile

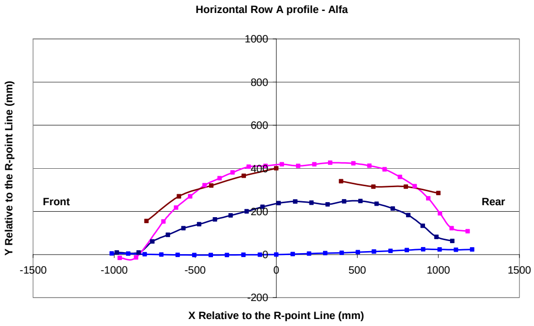


Figure 18 Alfa Row A profile

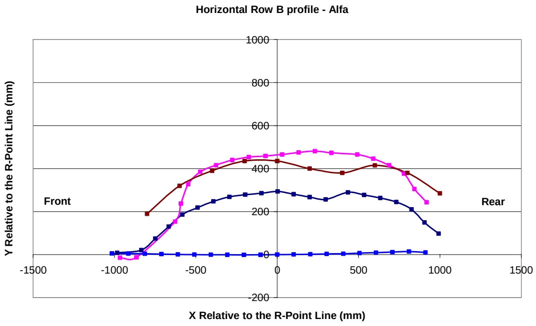


Figure 19 Alfa Row B profile

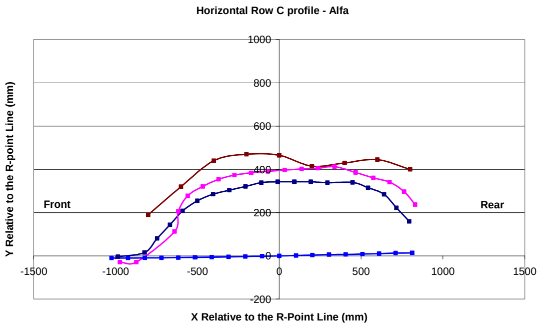


Figure 20 Alfa Row C profile

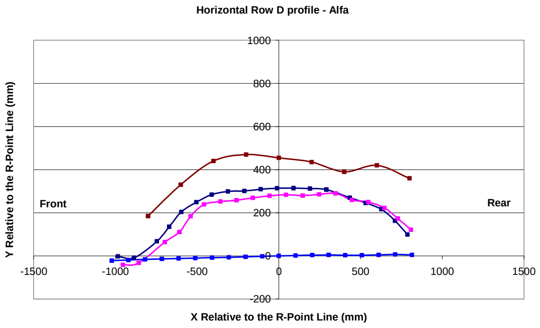


Figure 21 Alfa Row D profile

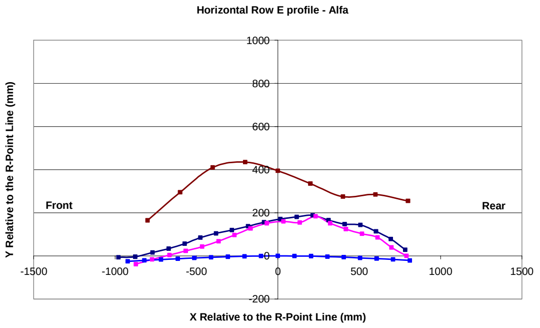


Figure 22 Alfa Row E profile

In reviewing all of the full-scale test data, it is possible to highlight some general trends as assessed by post impact deformation. The baseline tests to all of the vehicles showed that the post impact deformation caused by the Freelander was generally higher than of the Ford Mondeo. In the case of the Megane and Corolla the AE-MDB deformation was between the baseline results. With the Camry the AE-MDB deformation was, in places, above that of the baseline data for rows A, D and E, and for the Alfa this was the case for most rows. Higher levels of door intrusion, in comparison to the B-pillar, were more prominent with the Megane and Camry. A more homogeneous profile was observed with the Corolla and Alfa.

The Freelander has been seen to induce peak intrusion levels at a height of around 550-675mm above ground level on all target vehicles, which is due to the higher level of frontal load paths. Conversely, the family sized vehicles generally loaded around 300-425mm above ground level. The height of AE-MDB peak loading was between that of the baseline vehicles at approximately 425-550mm.

Door intrusion velocity

The importance of door intrusion velocity has previously been highlighted by WG13 as an important measure in determining impact severity as it is the generally door which contacts the occupant and causes injury.

The measurement technique was changed from acceleration based measurement to suitable linear potentiometers, which are believed to be more accurate. Tests to the Megane and Camry used acceleration based measurements, apart from those with the AE-MDB V2, which used potentiometers. The baseline Corolla tests were also acceleration based, and all other Corolla and Alfa tests used potentiometers. One particular characteristic seen with the acceleration based data was higher levels of residual velocity toward the end of the impact. The measurements were taken from the inner door skins at positions close to the driver and rear seat passenger (RSP) dummy thoraxes, but not in a position to interfere with the dummy kinematics. No comparable data was available from the AE-MDB to Alfa 147 test.

The comparative door velocities for all impacts can be seen in Figure 23 to Figure 30. The velocities recorded in the Megane driver and Corolla driver doors show the AE-MDB velocities to be higher than those recorded in the baseline tests. Whereas, in all other positions the AE-MDB V2 barrier was generally between or lower than those of the baseline tests. Peak driver door velocities were not much above 12m/s in the baseline tests and the peak recorded with the AE-MDB V2 was approximately 9m/s using these techniques. For the rear seat passengers, again the largest velocity was recorded at around 12m/s, and 8m/s was recorded with the AE-MDB V2.

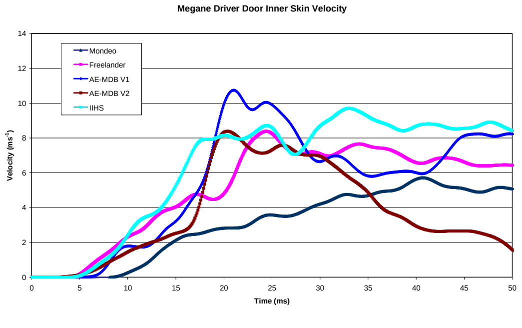


Figure 23 Megane driver door velocities

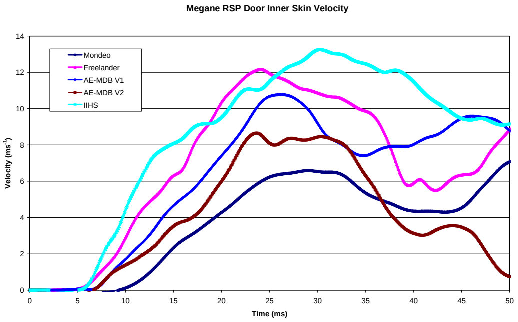


Figure 24 Megane RSP door velocities

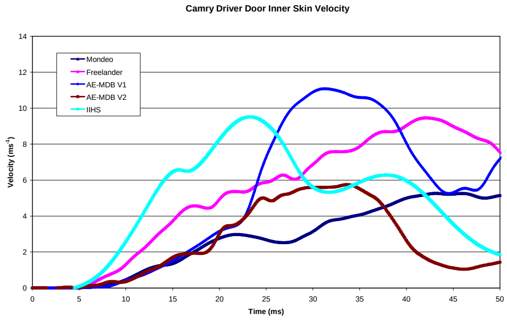


Figure 25 Camry driver door velocities

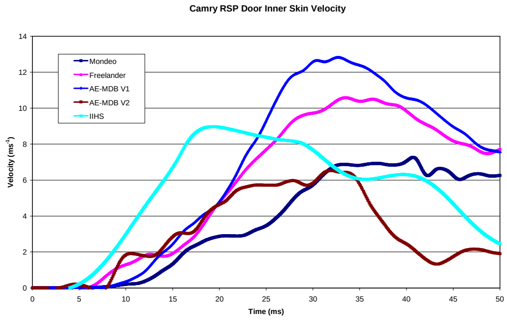


Figure 26 Camry RSP door velocities

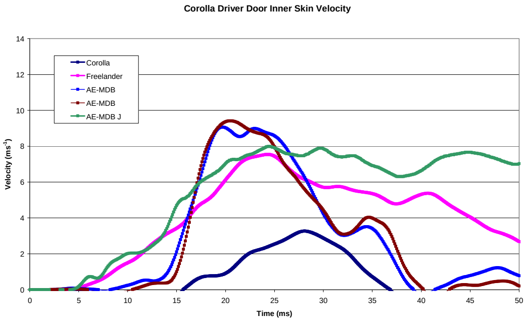


Figure 27 Corolla driver door velocities

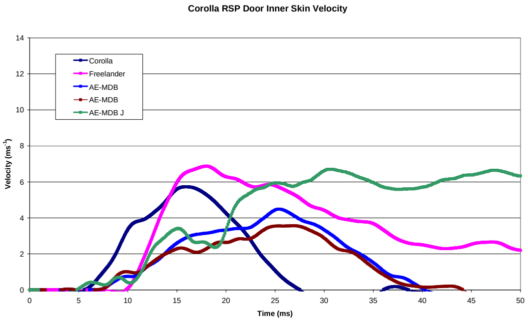


Figure 28 Corolla RSP door velocities

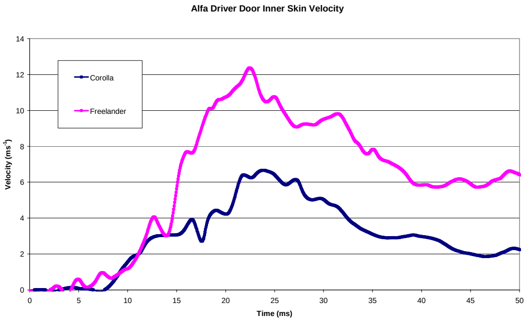


Figure 29 Alfa driver door velocities

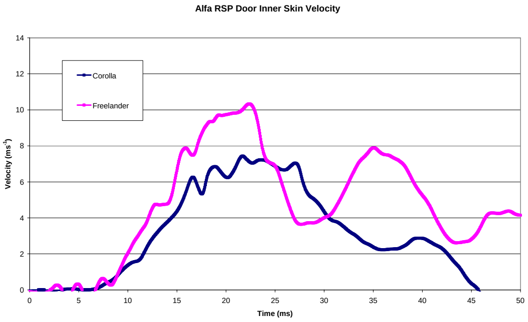


Figure 30 Alfa RSP door velocities

Driver and passenger dummy responses

The test procedure is aimed at encouraging enhancements in occupant protection and reduction in injury risk. It is hoped that if the procedure were to move into a regulatory framework, improved dummies and associated injury criteria would also be adopted.

Throughout the research programme WG13 have used the best ‘tools’ available. In the Megane and Camry tests WG13 used the EuroSID-I and for the latter tests, to the Corolla and Alfa 147, the ES-2 was used. In the case of all Alfa tests, the ES-2RE dummy was used in the driver’s seat and the ES-2 in the rear. These measures can be used to predict the severity of the test based upon current predictions of injury risk. A summary of all WG13 results is shown in Table 1.

		Renault Megane Target Vehicle (EuroSID-I)				Toyota Camry Target Vehicle (EuroSID-I)			
DRIVER		Mondeo	Freelander	AE-MDB V1	IIHS	Mondeo	Freelander	AE-MDB V1	IIHS
HEAD (HIC)		72	250	214	454	98	144	121	266
Rib Deflection (mm)	Upper	6	25	24	45	7	24	20	33
	Middle	7	25	18	48	13	25	24	29
	Lower	10	24	15	49	19	30	31	30
Viscous Criterion	Upper	0.02	0.22	0.27	1.16	0.03	0.15	0.18	0.4
	Middle	0.03	0.22	0.12	1.18	0.06	0.23	0.24	0.29
	Lower	0.07	0.17	0.05	1.27	0.10	0.42	0.40	0.31
Abdomen (kN)		1.2	2.4	1.1	1.6	1.3	2.0	2.2	1.5
Pelvis (kN)		4.3	4.6	4.7	4.5	4.3	4.6	6.2	5.4
Rear Seat Passenger		Mondeo	Freelander	AE-MDB V1	IIHS	Mondeo	Freelander	AE-MDB V1	IIHS
HEAD (HIC)		706	107	38	60	476	39	53	446
Rib Deflection (mm)	Upper	7	7	21	31	8	14	19	25
	Middle	6	4	5	11	4	7	17	16
	Lower	6	11	3	12	4	4	15	14
Viscous Criterion	Upper	0.02	0.02	0.10	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
	Lower	0.02	0.09	0.01	0.09	0.02	0.00	0.12	0.10
Abdomen (kN)		2.4	4.4	1.6	2.3	1.8	1.7	2.3	2.7
Pelvis (kN)		6.6	7.2	6.4	9.6	4.0	3.3	6.3	5.1

		Toyota Corolla Target Vehicle (ES-2)					Alfa Romeo 147 Target Vehicle (ES-2RE/ES-2)		
DRIVER		Corolla	Freelander	AE-MDB V2	AE-MDB V2	AE-MDB V2 J	Corolla	Freelander	AE-MDB V2
HEAD (HIC)		138	444	353	309	144	68	361	230
Rib Deflection (mm)	Upper	6	21	21	27	23	5	51	50
	Middle	1	11	10	14	12	7	38	39
	Lower	3	3	3	6	6	18	44	47
Viscous Criterion	Upper	0.01	0.24	0.16	0.29	0.20	0.01	0.67	0.61
	Middle	0.00	0.11	0.05	0.09	0.07	0.03	0.65	0.75
	Lower	0.00	0.01	0.01	0.04	0.04	0.17	1.05	0.97
Abdomen (kN)		0.6	2.0	1.3	1.6	1.3	0.7	1.9	1.3
Pelvis (kN)		0.9	5.7	3.7	3.6	3.4	2.5	4.6	4.3
Rear Seat Passenger		Corolla	Freelander	AE-MDB V2	AE-MDB V2	AE-MDB V2 J	Corolla	Freelander	AE-MDB V2
HEAD (HIC)		183	215	394	294	209	86	253	177
Rib Deflection (mm)	Upper	21	29	24	24	25	25	21	12
	Middle	11	24	14	17	14	18	9	3
	Lower	0	13	13	10	11	10	3	9
Viscous Criterion	Upper	0.14	0.15	0.15	0.23	0.21	0.12	0.12	0.07
	Middle	0.04	0.16	0.08	0.14	0.08	0.08	0.03	0.01
	Lower	0.00	0.06	0.07	0.07	0.08	0.03	0.01	0.04
Abdomen (kN)		1.4	0.8	2.3	1.9	2.1	0.1	1.2	1.4
Pelvis (kN)		1.1	1.7	3.2	3.5	3.7	1.7	4.0	5.4

Table 1 EuroSID-I and ES-2 Dummy Results

The driver and rear seat passenger dummy injury parameters for the Corolla and Alfa target vehicles are shown in Figure 31 to Figure 34. These have been calculated as percentages of the critical values as defined in ECE Regulation 95. These levels are as follows:

HIC	1000
Rib deflection	42mm
V*C	1.0m/s
Abdomen force	2.5kN
Pelvic force	6.0kN

The head injury criterion (HIC) recorded by the driver dummy in the Corolla tests showed the response of the AE-MDB tests to be between that of the two baseline tests. This was also the case for abdomen and pelvis. The maximum rib deflection and viscous criterion were at a similar level to that of the Freelander baseline test. For the rear seat passenger, the maximum rib deflection was between that of the baseline tests and the viscous criterion was slightly above. In the case of the abdomen and pelvis, the barrier results were above those of the baseline tests.

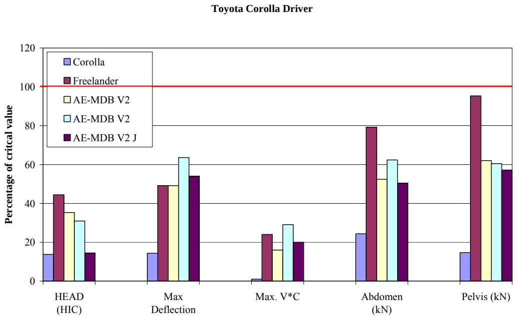


Figure 31 Corolla driver dummy response

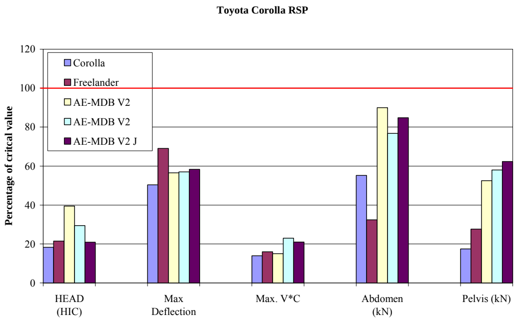


Figure 32 Corolla RSP dummy response

In the Alfa tests, the response of the driver dummy, when impacted with the AE-MDB, was always between the baseline car test results and generally closer to those of the Freelander. The chest deflection was above the critical level specified by R95, signifying a 30% risk of injury ≥ AIS3. For the rear seat passenger, the HIC, rib deflection and viscous criterion of the barrier test were between or below the baseline values, whereas the abdomen and pelvis results were higher.

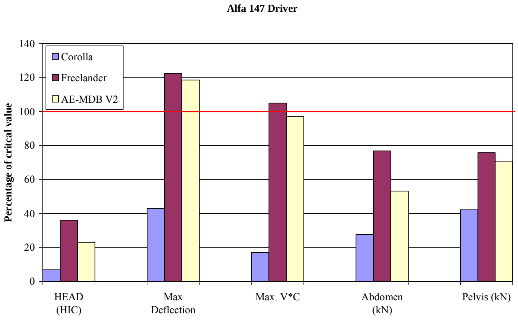


Figure 33 Alfa driver dummy response

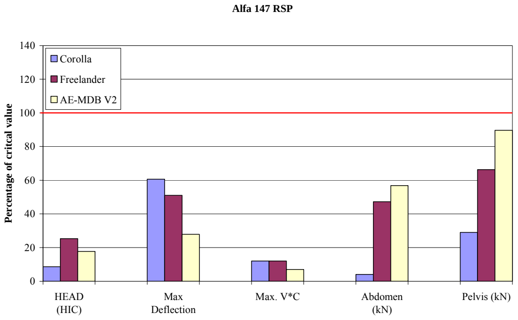


Figure 34 Alfa RSP dummy response

DISCUSSION

The post test intrusion characteristics seen with the AE-MDB show that the barrier is able to replicate, to some extent, the form of deformation seen with the baseline vehicle tests. In the case of the Megane and Camry reported by Roberts et al, which were five and four door vehicles respectively, more intrusion was caused to the front and rear doors than to the B-pillars of the target vehicles. This trend was visible in both the barrier and baseline tests. However, the door deformation with the AE-MDB was generally at a similar level to that of the most severe baseline test, whereas the loading to the B-pillar was similar to that of less severe baseline test. The tests to some of the target vehicles also showed that the form of intrusion with AE-MDB was similar to that of the baseline tests. Similar trends were visible to the deformation and the doors and B-pillar.

In reviewing the biomechanical data from all of the available driver dummy results, the AE-MDB data was often between or slightly higher than that of the baseline data. The areas where the barrier results exceeded the baseline data, and in the case of the Alfa the critical value, were the pelvis in the Megane, the abdomen and pelvis in the Camry and the ribs in the Corolla and Alfa.

For the rear seat passenger, the higher loading was generally seen in the abdominal and pelvic areas. The velocity profiles of all vehicles, where measured, suggest that the AE-MDB loaded the target vehicles at a similar rate to those of the Freelander baseline test, and in the case of the Corolla the peak velocity with the AE-MDB was slightly higher by approximately 1m/s. It should be borne in mind that the measurement method used for the Corolla baseline tests were different to those with the barrier, thus the magnitude of this difference may be less or greater than that recorded.

Based upon the results seen so far, WG13 believes that modifications to the AE-MDB design specification may be needed in order to reduce the post test ‘differential intrusion’ between the doors and B-pillar. The severity of the AE-MDB test procedure was either between that of the baseline tests. In some areas slightly more severe than the baseline tests, but this was not a trend that could be observed in all of the target vehicles.

FUTURE RESEARCH

In order to increase the amount of loading applied by the AE-MDB to the B-pillar, WG13 is considering various modifications to the design specification.

One modification is based upon the application of a ‘beam’ type element being applied across the lower row of blocks. The beam element would be constructed from high strength honeycomb sandwich, which would try to replicate the presence of significant lateral connections between longitudinal frontal structures that are present in some vehicles.

An alternative modification, would be to change the stiffness of block E to be more reflective of the rigid LCW data. The initial block stiffness could be increased along with the stiffness toward the end of the current corridor.

Further modifications that have been discussed are based upon a change in stiffness distribution for the lower row of blocks, along with the inclusion of a beam element as described above.

At the time of this report some numerical simulation of different AE-MDB modifications has taken place to provide guidance to future plans, but no barriers to a revised specification have been manufactured or tested.

CONCLUSIONS

1. The completed review of the stiffness of modern vehicle frontal structures has complemented the previous data studied and presented by WG13, which lead to the current stiffness distribution for the AE-MDB.
2. From baseline vehicle testing, the AE-MDB has been shown to be representative of the baseline deformation profiles in some areas.
3. The deformation produced by the AE-MDB is, in some cases, above that of the baseline tests in the softer areas of the target vehicles (mid doors).
4. In the stiffer area of the target vehicles (B-pillar), the deformation caused by the AE-MDB was less than that applied by the most severe baseline test.
5. Most of the dummy injury parameters were well below the critical values used in the current European regulatory procedure, even when localised intrusion is greater than that of the severe baseline test.
6. The ongoing research may lead to some revisions of the existing AE-MDB design specification. However, no firm direction was available at the time of writing this paper.

REFERENCES

[1] Edwards M, Hobbs A, Davies H and Lowne R. 2000. *Review of the Frontal and Side Impact Directives: Final Report.* PR/SE/095/00, TRL Unpublished report.

[2] EEVC Committee. 2000. *EEVC report to EC DG Enterprise regarding the revision of the frontal and side impact directives.* EEVC Committee.

[3] Roberts A K, van Ratingen M R, (on behalf of EEVC WG13). 2003. *Progress on the development of the Advanced European Mobile Deformable Barrier face (AE-MDB).* The 18th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Nagoya, Japan. Paper No. 126.

[4] Lowne R, (on behalf of EEVC WG13). 2001. *Research progress on improved side impact protection: EEVC WG13 progress report.* The 17th International Technical Conference on the Enhanced Safety of Vehicles (ESV). Amsterdam, The Netherlands. Paper No. 47.

[5] INSIA. 1997. *Structural Survey of Car. Definition of the main resistant elements in the car body.* EEVC WG15 Document. Doc No 20.

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