Enhancement of side impact protection using an improved test procedure

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ABSTRACT

Several groups of research have been charged to enhance the current European regulatory side impact test procedure (ECE95). The Aprosys project, funded through the 6th Framework Programme of the European Commission, proposed in 2006 a new test procedure called AE-MDB (Advanced European Mobile Deformable Barrier) with:

- an updated barrier face representative of the current European fleet, including SUV,
- an increase in the mass of the trolley,
- a shift in the impact point,
- the addition of a rear occupant dummy.

Questions were raised, and not yet answered, on the added value of this new test procedure with respect to the current one, pointing out the current influence of the AE-MDB face. The purpose of our study is to highlight and quantify the extra-severity brought by AE-MDB and its consequences on occupant protection and car design in side impact. This research presents comparative study of ECE95 and AE-MDB procedure thanks to full scale crash tests, component tests but also virtual testing made on several vehicles of different size (small family and large family vehicles as well as MPV).
The outcome shows a 30% extra-severity for AE-MDB with respect to ECE95 on dummy readings and car deformation. This is not only due to the increase in the trolley weight, but also because of the improvement in the barrier face (geometry and stiffness). It also highlights that vehicle design will be impacted if AE-MDB is chosen for regulation, on restraint systems (rear airbag, belt pretension, better design front airbag…) as well as on structural dimensioning.
This new procedure is representative of the last generation of European cars (its severity is clearly ranked between a test against an SUV and a passenger car). Its application on regulation and/or consumer tests will improve the protection in side impact of occupants on the roads.

INTRODUCTION - AIM OF THE STUDY

Several groups of research such as Aprosys and EEVC WG13 have been charged to enhance the current European regulatory side impact test procedure (ECE95) [1] in order to make it more representative of the average European vehicle fleet. The definition of a new side impact test procedure called AE-MDB (Advanced European Mobile Deformable Barrier) is therefore under progress since 2001.
Different versions of this new barrier AE-MDB have been tested by conducting and analyzing numerous crash tests against wall or against car. Barrier definition V3.9 is the version that fits the best to the initial outline “being representative of the average European vehicle fleet”.
Therefore, PSA Peugeot Citroën decided to increase its knowledge of AE-MDB V3.9 version. Virtual testing has been carried out in order to understand the origin of the changes seen with the use of this new barrier. Full-scale testing was also conducted on several vehicle of different size to make a comparative study between the current regulatory procedure ECE 95 and this new AE-MDB V3.9 procedure.

BACKGROUND

The Aprosys Project was launched through the 6th Framework Program of the European Commission to study a new side impact barrier more representative of the average European vehicle fleet. According to the terms of references defined in the IHRA side working group for the 2003 ESV conference in Nagoya [2] , this barrier should provide:

- an impact environment similar to that seen in car-to-car and small 4WD-to-car side impacts
- a sufficiently stringent test condition for the rear seat dummy while maintaining the same level of severity for the front seat dummy

A first version of barrier AE-MDB (Advanced European Mobile Deformable Barrier) was proposed and studied: AE-MDB V2.

It was based on:

- a 1500 kg trolley
- a corridor created with frontal test of cars to LCW (rigid) data (40 different vehicles crashed on rigid wall) [3] (see Figure 1)
- a definition made of 6 blocks: 3 upper blocks and 3 lower blocks (see Figure 2)

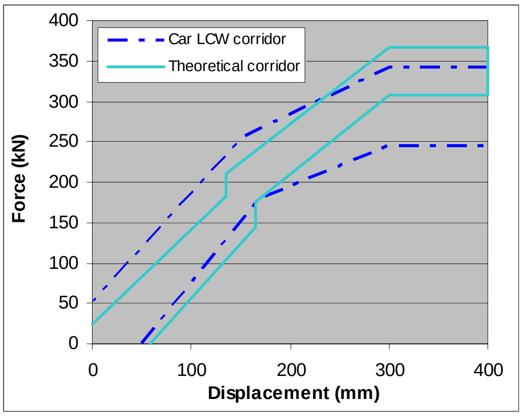


Figure 1. Effective force vs displacement corridor made with load cell wall test results and theoretical corridor as proposed to define AE-MDB.

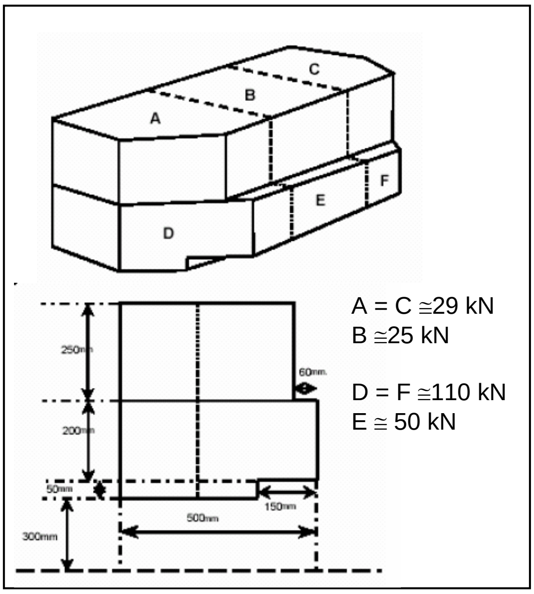


Figure 2. Theoretical characteristics of AE-MDB barrier face.

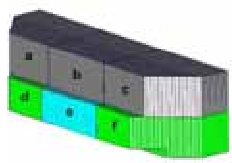
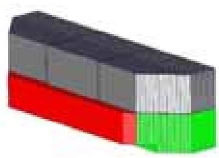
Its validation was done by comparing the results of a car-to-barrier side impact and two car-to-car tests (the bullet car being the LandRover Freelander or the Volkswagen Golf V).
ACEA (Association des Constructeurs Européens d'Automobiles) also contributed to this study (see Table 2).

After two years of studies, Aprosys and ACEA concluded that whereas the barrier V2 is in the LCW corridor, the comparison between the car-to-barrier test in side impact and the "car-to-car" tests showed that it was not consistent to car-to-car deformation. Indeed, door intrusion was too high with the AE-MDB V2, and the distribution of deformation between doors and B-Pillar was not consistent with the distribution seen on car-to-car tests.
Since 2005, the members of EEVC WG13 discussed a series of modifications to the barrier face that could be further developed by Aprosys. All new versions (named V3.x, with x from 1 to 9) were based on V2 characteristics:

- all versions used the same definition by blocks (6 blocks, 3 upper and 3 lower blocks)
- the geometry remains unchanged with respect to V2
- each block stiffness is defined as a percentage of the initial V2 "block D" stiffness (block D is the lower exterior block)
- the barrier weight is still 1500 kg
- an additional bumper element was put in front of the barrier. The bumper definition is taken from the NHTSA FMVSS214 barrier (245 psi / 3+3 mm)

Version V3.9 was selected by the majority of the Aprosys member in 2006.
Its characteristics against version V2 are the following (see Table 1).

Table 1.
Comparison between AE-MDB Version 2 and Version 3.9 in terms of stiffness and design.

AE-MDB Version	Block Stiffness	View
V2	a = c = 29 kN b = 25 kN d = f = 110 kN e = 50 kN no bumper element	
V3.9	a, b and c are unchanged with respect to V2 $d_{V3.9} = f_{V3.9} = 55\% * d_{V2}$ $e_{V3.9} = 60\% * d_{V2}$ Addition of a bumper element (245 psi / 3+3 mm)	

Part of the validation matrix conducted together by ACEA and the Aprosys project with this AE-MDB version V3.9 is shown in Table 2. Each target vehicle have been impacted by a car (car-to-car test) or by a AE-MDB barrier (car-to-barrier test) with the V3.9 and sometimes with V2.

Table 2.
Test matrix of car-to-car or car-to-barrier tests carried out to compare V3.9 and V2 .

Target vehicle (project funding)	Freelander	Golf V	V3.9	V2
Golf V (Aprosys)	x	x	x	
Fiesta (Aprosys)	x	x	x	
Megane (ACEA)	x	x	x	x

Hence, in 2006, AE-MDB V3.9 barrier was selected by the Aprosys project as fulfilling the initial mandate. It was considered as:

- being in the stiffness corridor done with the frontal test of the 40 cars to LCW (rigid) data (See Appendix 1)
- being in between the severity of a car-to-car tests against Golf V and against Freelander

The selected side impact test procedure was the following (see Figure 3) :

- barrier AE-MDB V39
- trolley weight at 1500 kg
- the impact point is centered on R-Point + 250 mm rearward. This backward impact location point enables to take into account rear passengers protection as well as the movement of the 2 cars in a real front-to-side impact
- front and rear seat occupant: a 50th percentile dummies
- test speed: 50 +- 1 km/h

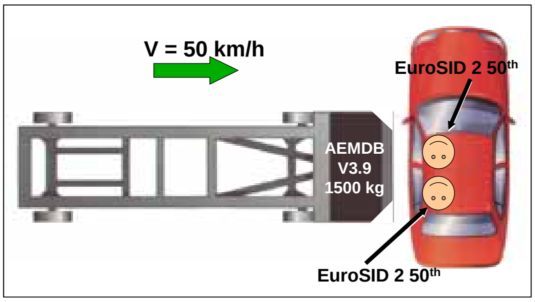


Figure 3. Test configuration for the AE-MDB side impact procedure.

COMPARATIVE STUDY BETWEEN AE-MDB AND ECE 95 TEST

This new side impact test procedure have been designed with the purpose to replace the current regulatory test (ECE regulation 95, also named Progress 950 kg in the remaining part of our study).
Therefore PSA Peugeot Citroën decided to make physical and numerical comparative studies between the current ECE95 test and this new side impact procedure, with barrier AE-MDB V3.9.
The first part of our study is a numerical study that has been performed to analyse separately the influence of each parameter (mass and stiffness). Thanks to modelling, it is relatively easy to understand very precisely the differences seen between old and new procedure and quantify the effect of each change.
The second part of our study has been to conduct full-scale tests on different vehicles in order to have a complete overview of the results with the future procedure and the current procedure on all different sizes of vehicles.

Parametric Study - influence of the two test parameters: increase in mass and increase in stiffness

The AE-MDB V3.9 procedure is carried out with two major evolutions with regard to the current ECE 95: A complete change in the barrier design (AE-MDB against Progress, with an increase in width and in stiffness), and a change in the trolley weight (1500 kg instead of 950 kg).
Aprosys concluded from its studies that the procedure in overall was more severe.
But, we can ask the following questions: is this increased severity the unique consequence of the increased trolley weight? Or is it the consequence of coupling both parameters in parallel: the increase in the trolley weight and a change in the deformable element?

To answer this question, PSA Peugeot Citroën has done a numerical study on a new large family car. This vehicle is therefore a last generation vehicle and its numerical model has been correlated to standard physical tests.
Three calculations have been performed:

- a Progress 50 km/h – Trolley Weight 950 kg
- a Progress 50 km/h – Trolley Weight 1500 kg
- an AE-MDB V3.9 50 km/h – Trolley Weight1500 kg

Figure 4 presents the exterior intrusions at three different level heights for the three different modellings.

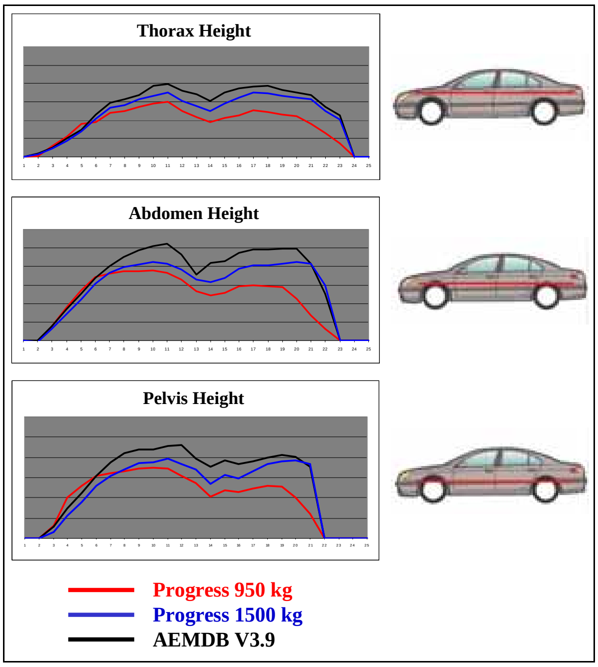


Figure 4. Comparison of the exterior intrusion profile measured at different heights for the three different barriers.

With the use of AE-MDB, there are two steps on the way of a more severe procedure. The weight of the trolley causes a first increase of the exterior intrusions (see the blue curve compared to the red one in Figure 4).
The new deformable face, much stiffer than the Progress one, creates a second increase in the exterior intrusions. In overall, intrusions are at least 40% higher on V3.9 barrier than on the current ECE 95.

Looking at B-Pillar intrusions, we find the same type of conclusions (see Figure 5).

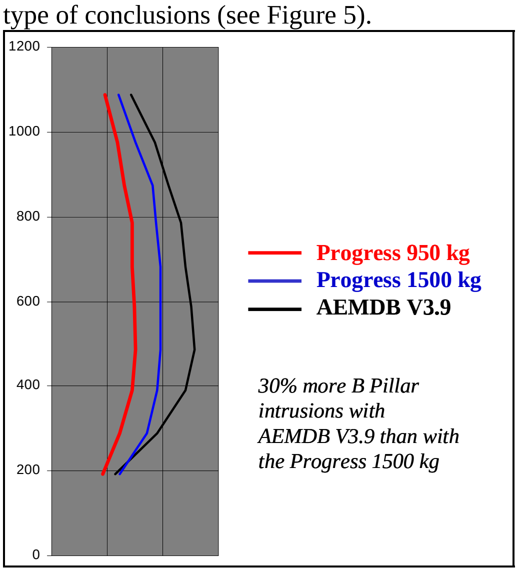
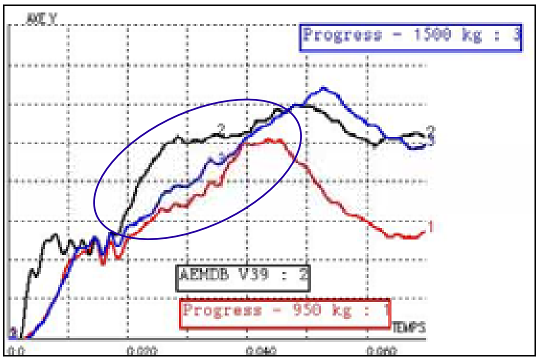
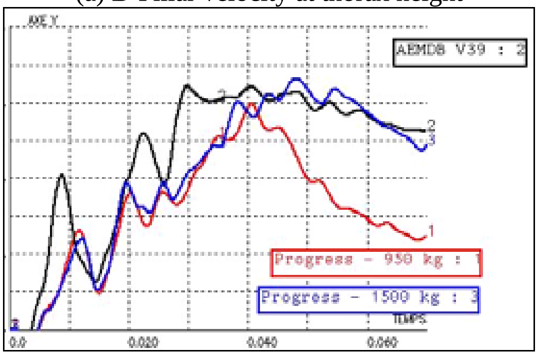


Figure 5. Comparison of the B-Pillar intrusion profile for the three different barriers.

There are 30% more B-Pillar intrusions with AE-MDB V3.9 than with the Progress 1500 kg.
As they have a direct impact on biomechanical criteria, door and B-Pillar velocities were also compared between the different calculations.
Figure 6 presents door velocity at abdomen height and B-pillar velocity at thorax height.



(a) B-Pillar velocity at thorax height



(b) Door velocity at abdomen height

Figure 6. Comparison of the velocity measured at different heights for the three different barriers.

The first slope of the velocity curves is far much greater in AE-MDB V3.9 than in Progress-1500 kg or 950 kg. This phenomenon is a consequence of the higher stiffness of the deformable face which introduces a higher initial velocity on the vehicle. Dynamic displacements are therefore higher. This is related to what we have seen above on the intrusions (greater intrusion with AE-MDB V3.9 than with Progress – 1500 kg).
Comparing both calculations with Progress 950 kg and 1500 kg, we can see that the initial slope is identical. The impact of the increase of the trolley weight is seen on the maximal level of velocity. This higher level will have a direct impact on biomechanical criteria.

As a conclusion, the higher severity of the new AE-MDB side impact procedure is not only linked to the increase in the trolley weight. Indeed, the stiffness of the deformable face in comparison to ECE 95 leads to higher initial dynamic displacements and intrusions. The increased trolley weight leads to higher levels in maximal velocities.

Therefore, coupling both phenomena (increased trolley weight and higher barrier stiffness) leads to more severe test procedure with higher biomechanical criteria and intrusions.

COMPARISON OF THE TWO PROCEDURES THANKS TO FULL-SCALE TESTS

In order to have a better knowledge of the new AE-MDB procedure, PSA Peugeot Citroën performed full-scale testing of vehicles of different sizes against AE-MDB V3.9: Small Family Car, Large Family Car and MPV.
The result of each car in the AE-MDB V3.9 test (1500 kg – 50 km/h) has been compared to the result of the same car in the current ECE 95 Progress test (950 kg – 50 km/h).

Structural behaviours (door and B-Pillar intrusions and velocities) have been compared as well as biomechanical criteria on the driver.

Tests are conducted with EuroSID 2 dummies and the same seat position is always used.
Since current ECE 95 has no rear dummy, the rear area is not analysed in this section but will be studied in a specific chapter.

Small Family Car

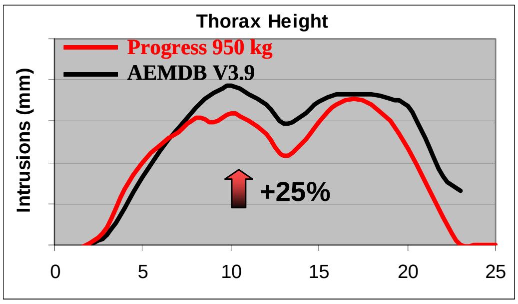
On the small family car test, the B-Pillar was much more loaded with AE-MDB V3.9 than with current ECE 95. A rupture occurred on the lower part of the B-Pillar on the AE-MDB test whereas the B-Pillar was intact in the ECE95 test (see Figure 7 and Figure 8).

Figure 7. B-Pillar structural deformation for the Progress 950 kg test.

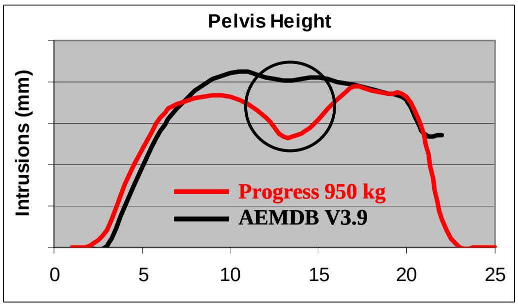
(b) AE-MDB V3.9 Test

Figure 8. B-Pillar structural deformation for the AE-MDB V3.9 test.

On the intrusion graphs (see Figure 9 and Figure 10), we clearly see this rupture of the B-Pillar. (+126% intrusions in the area).
Elsewhere, intrusions are approximately 25% higher with AE-MDB V3.9 than with Progress barrier.



(a) Intrusion profile –Thorax height



(b) Intrusion profile –Pelvis height

Figure 9 . Small family car - Comparison of the intrusion profile measured at different heights for the two different barriers (Progress 950 kg and AE-MDB V3.9) (a) Thorax height and (b) Pelvis height.

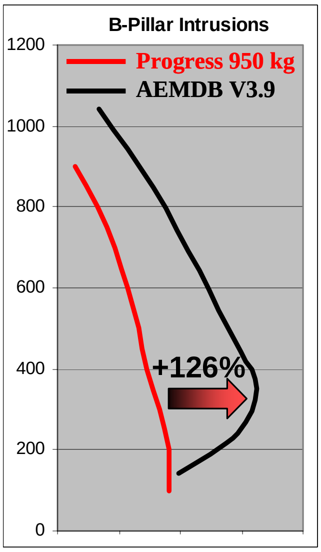
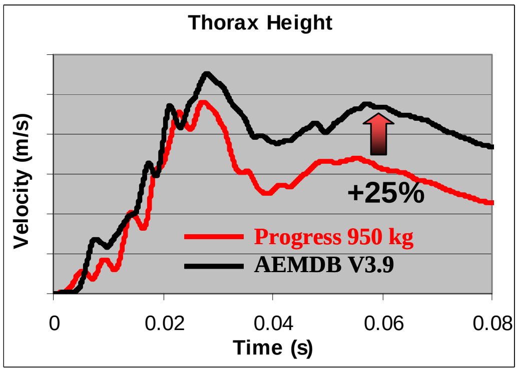
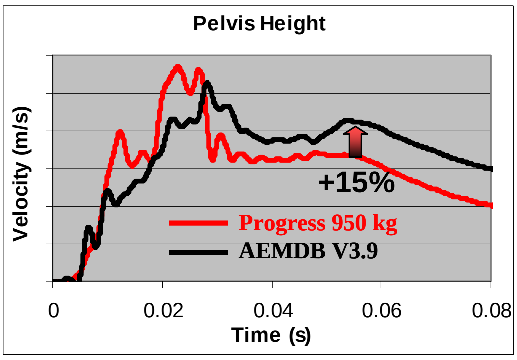


Figure 10 . Small family car - Comparison of the B-Pillar deformation profile for the two different barriers (Progress 950 kg and AE-MDB V3.9).

Doors velocities are also heighten up to 25% at their maximal level with the use of barrier AE-MDB V3.9 in place of Progress barrier at 950 kg (see Figure 11).



(a) Door velocity –Thorax height



(b) Door velocity – Pelvis height

Figure 11. Small family car - Comparison of the door velocity measured at different heights for the two different barriers (Progress 950 kg and AE-MDB V3.9) (a) Thorax height and (b) Pelvis height.

This increase in door velocities will lead to worse biomechanical criteria. This is shown in Figure 12 which represents biomechanical criteria versus EEVC regulatory limits and in Figure 13 where biomechanical criteria are scaled to the Euro NCAP 4 points limits.

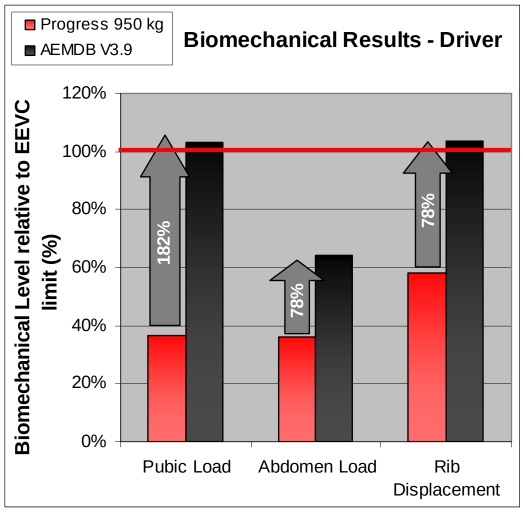


Figure 12. Small family car - Comparison of the driver biomechanical results for the two different barriers (Progress 950 kg and AE-MDB V3.9) with respect to EEVC limits.

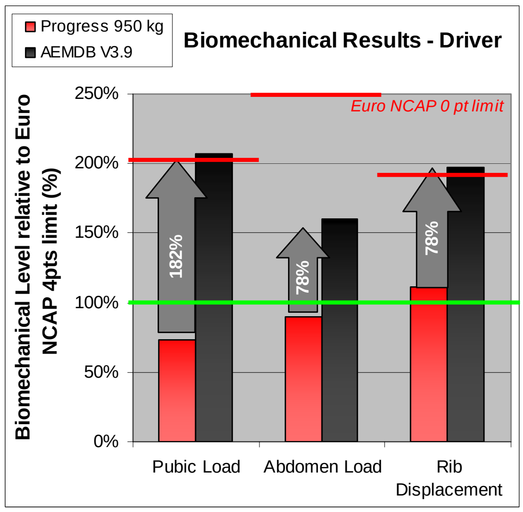
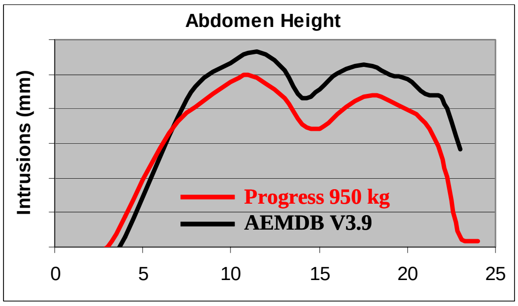


Figure 13. Small family car - Comparison of the driver biomechanical results for the two different barriers (Progress 950 kg and AE-MDB V3.9) with respect to Euro NCAP limits.

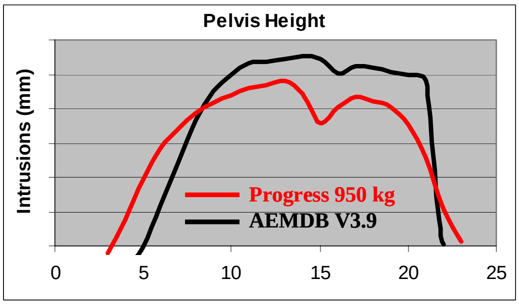
Rib deflexion and pelvis load go over the EEVC regulatory limit. Pelvis load may be a consequence of the rupture of the base of the B-Pillar seen in the AE-MDB test.
Rib deflexion is the consequence of a bottoming out of the thorax airbag caused by the increase of dynamic door displacement.

Large Family Car

On this vehicle family, conclusions are equivalent to the ones derived on the small family car. Doors intrusions (see Figure 14) are heighten up from 20% with the AE-MDB V3.9 test and B-Pillar intrusions by 15% (see Figure 15).



(a) Intrusion profile - Abdomen height



(b) Intrusion profile - Pelvis height

Figure 14. Large family car - Comparison of the intrusion profile measured at different heights for the two different barriers (Progress 950 kg and AE-MDB V3.9) (a) Thorax height and (b) Pelvis height.

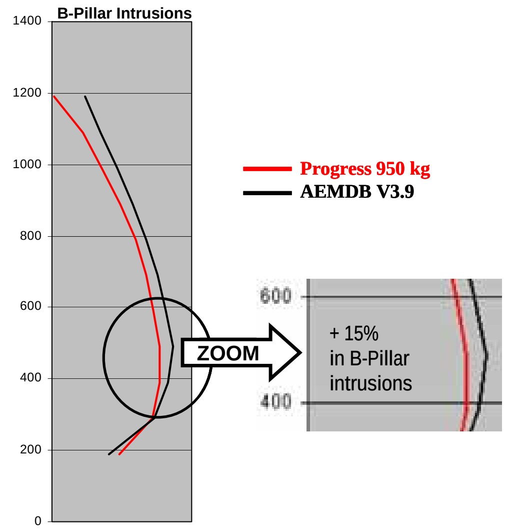
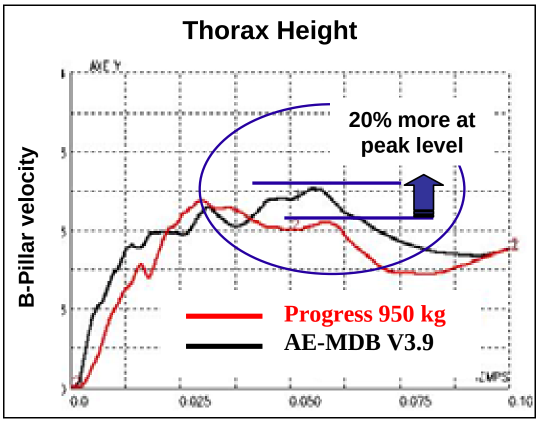
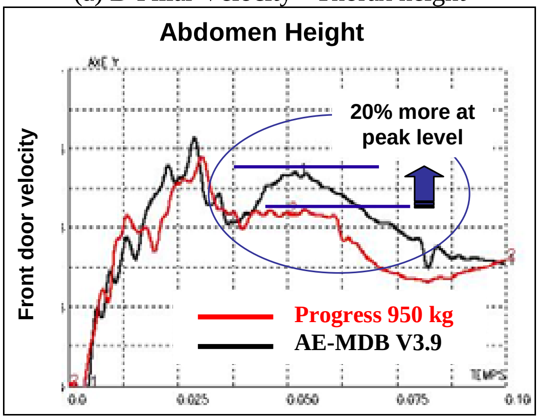


Figure 15. Large family car - Comparison of the B-Pillar deformation profile for the two different barriers (Progress 950 kg and AE-MDB V3.9).

Door and B-Pillar velocities are about 20% higher with AE-MDB V3.9 (average of 1.5 m/s more at peak level) (see Figure 16).



(a) B-Pillar Velocity - Thorax height



(b) Front Door velocity - Abdomen height

Figure 16. Large family car - Comparison of the door velocity measured at different heights for the two different barriers (Progress 950 kg and AE-MDB V3.9) (a) Thorax height and (b) Abdomen height.

This increase in intrusion and velocity are shown in Figure 17 and 18 which present biomechanical criteria versus EEVC regulatory limits and versus Euro NCAP 4 points limits.

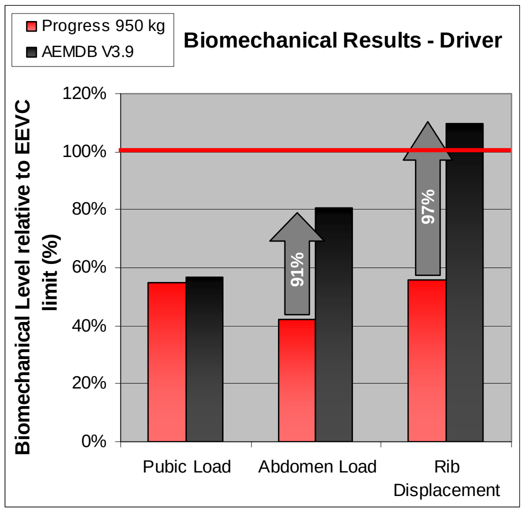


Figure 17. Large family car - Comparison of the driver biomechanical results for the two different barriers (Progress 950 kg and AE-MDB V3.9) with respect to EEVC limits.

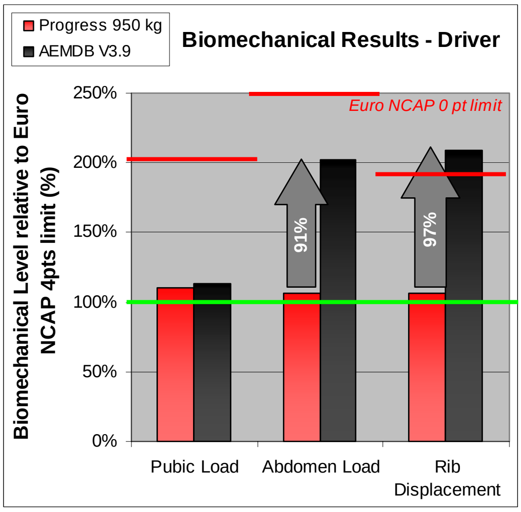
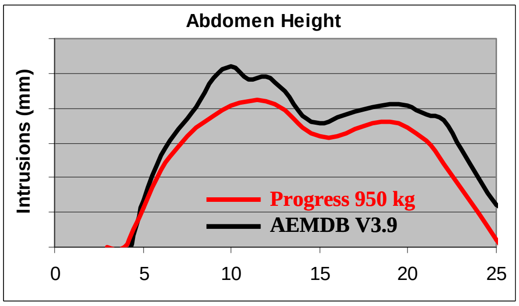


Figure 18. Large family car - Comparison of the driver biomechanical results for the two different barriers (Progress 950 kg and AE-MDB V3.9) with respect to Euro NCAP limits.

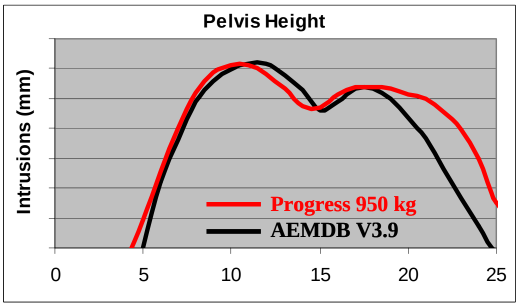
Biomechanical criteria that were all under the 4 points Euro NCAP limit in the Progress 950 kg test increased up to 100% more with the use of AE-MDB V3.9. We can even note that rib displacement would pass over the regulatory limit.

MPV

Again, doors and B-Pillar intrusions are heighten up from 20% with the AE-MDB V3.9 test (see Figure 19 and Figure 20).



(a) Intrusion profile - Abdomen height



(b) Intrusion profile - Pelvis height

Figure 19. MPV - Comparison of the intrusion profile measured at different heights for the two different barriers (Progress 950 kg and AE-MDB V3.9) (a) Thorax height, (b) Pelvis height.

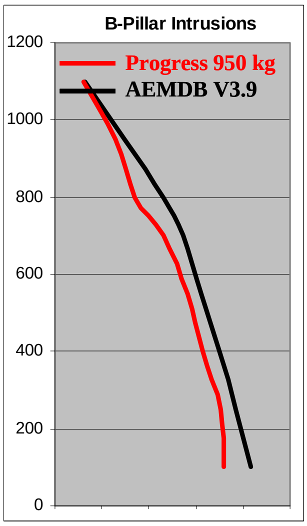
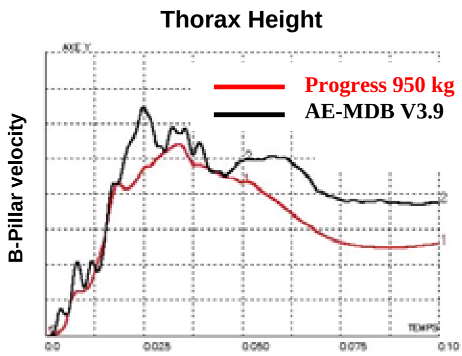
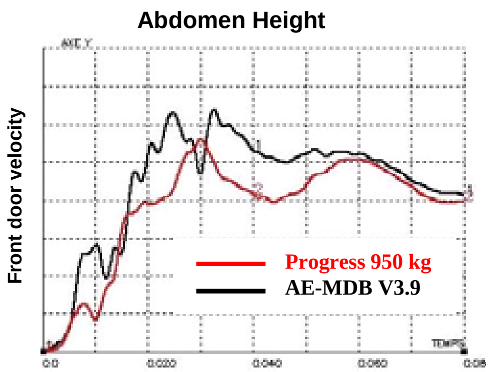


Figure 20. MPV - Comparison of the B-Pillar deformation profile for the two different barriers (Progress 950 kg and AE-MDB V3.9).

Velocities, again, are in this case higher with AE-MDB V3.9 than with Progress. The initial slope is clearly steeper (as a result of the increased barrier stiffness), causing the dynamic displacement to be greater. This will have an effect on the thorax airbag that will have less space to absorb the energy at the beginning of the crash (risk of bottoming out) (see Figure 21).



(a) B Pillar Velocity - Thorax Height



(b) Door Velocity - Abdomen Height

Figure 21. MPV - Comparison of the door velocity measured at different heights for the two different barriers (Progress 950 kg and AE-MDB V3.9) (a) Thorax height and (b) Abdomen height.

As usual, the consequences of the extra severity in intrusion and velocity will be shown in the biomechanical results, see Figure 22 and 23 which represent biomechanical criteria versus EEVC regulatory limits and Euro NCAP 4 points limits.

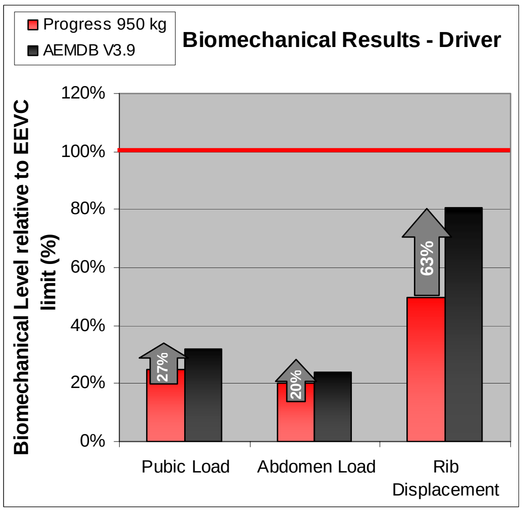


Figure 22. MPV - Comparison of the driver biomechanical results for the two different barriers (Progress 950 kg and AE-MDB V3.9) with respect to EEVC limits.

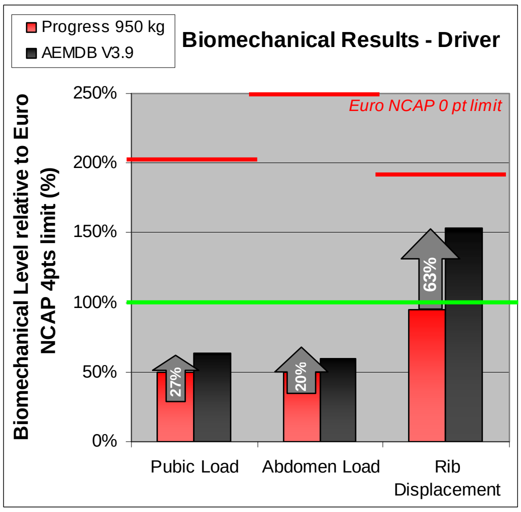


Figure 23. MPV - Comparison of the driver biomechanical results for the two different barriers (Progress 950 kg and AE-MDB V3.9) with respect to Euro NCAP limits.

All the biomechanical criteria are increased with the use of AE-MDB V3.9. Rib deflections are heightened up by 63% as a result of a higher dynamic displacement and an increased deformation of the seat.
Biomechanical criteria are not as much increased on this vehicle size than on the other tested (small family vehicle and large family vehicle). MPV's are quite favoured by the height of the seat. The dummy being seated higher is less affected by the structural behaviour.

Driver protection: Conclusion

The same conclusions can be derived from the different sizes of vehicles by comparing ECE 95 side impact procedure (Progress barrier 950 kg) and AE-MDB procedure. The introduction of the AE-MDB V3.9 barrier always leads to higher door and B-Pillar intrusions, an increase by 25% as an average. On some vehicles, the more severe deformations have even generated the loss of some structural parts. (Rupture of the B-Pillar base for example, which was unseen on the ECE 95 test) Door and B-Pillar velocities are hence also penalized by 30%. Initial dynamic displacements are higher (as a result of the stiffer body barrier) and lead to thorax airbags with less space to deploy and to absorb energy. Maximal velocities are heightened up causing the injury risk on dummy to be higher in case of a bottoming out for example.

Therefore, in all cases, biomechanical criteria could reach up to 125% more in the worst cases. On some vehicles, some biomechanical criteria even go over EEVC regulatory limit.

REAR OCCUPANT PROTECTION

The introduction of AE-MDB barrier, with its higher width and its impact point located rearwards, enable to introduce an assessment of the rear passenger protection in side impact. The Progress barrier, currently used in ECE 95, is too narrow and centred on R-Point (in comparison to R+250 mm for AE-MDB barrier), and therefore does not impact the vehicle in the area of the rear occupant. Yet, a good discrimination of the rear passenger protection offered by the different vehicles was not possible with the Progress barrier.

This part of the study presents the assessment of the level of protection of the second row for the different cars tested and presented previously (Small Family Car, Large Family Car, MPV). We first studied the structural behaviour of the rear area in front of the dummy. Then, in a second part, we processed dummy readings.
As we could not compare the level of protection of this second row in the AE-MDB test to the one obtained in the Progress test (no passenger), we have plotted, in the three figures below (Figure 24 to 26), the velocity of the rear door compared to the velocity of the front door. This will enable us to have a point of comparison for rear door velocities.

Only the charts of the velocity at thorax height are shown hereafter. The graphs measured on the other location would show the same trends.
Velocities of the three different sizes of vehicle (small family car, large family car and MPV) are plotted in figure 24 to 26.

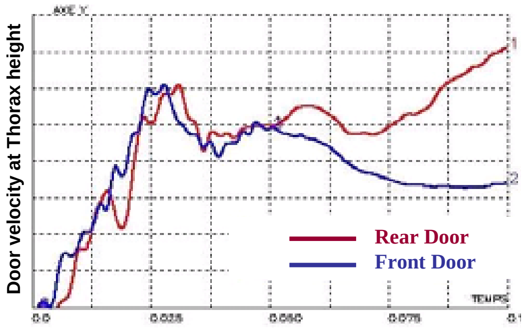


Figure 24. Small Family Car – Comparison of the door velocity measured on the front and on the rear door at the thorax height on the AE-MDB V3.9 test.

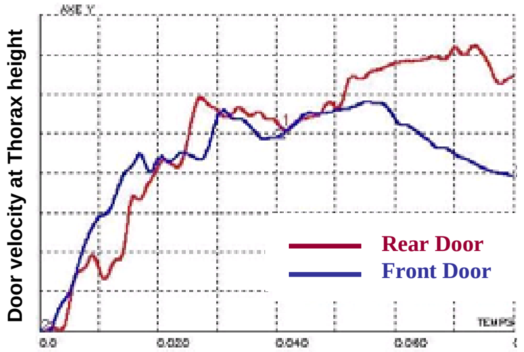


Figure 25. Large Family Car – Comparison of the door velocity measured on the front and on the rear door at the thorax height on the AE-MDB V3.9 test.

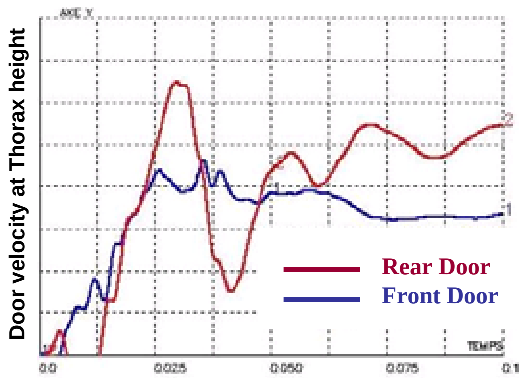


Figure 26. MPV – Comparison of the door velocity measured on the front and on the rear door at the thorax height on the AE-MDB V3.9 test.

For each car, we can see that rear door velocity is higher than front door velocity. Rear door velocities have higher initial peak values and have very often higher maximum level. We can also see the effect of the rotation of the car, rear door velocities "finishing" at a very high level (much bigger than the front door) at time 100 ms and after.
For example, on the MPV graph, there is at least 30% more velocity 50 ms after impact and the higher initial peak value will lead to 25% more dynamic displacement.
Thus, we can clearly see that rear door structural behaviour is not at the same level as the front door. The current level of protection offered on rear passengers is therefore not at the level as the one offered to the front driver.

Figure 27 presents the biomechanical criteria of the rear passenger with respect to 4 points Euro NCAP limit.

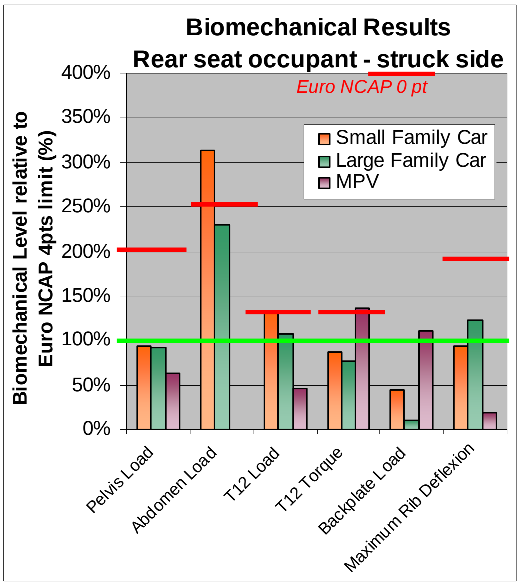


Figure 27. Comparison of the driver biomechanical results measured on AE-MDB V3.9 for the three different car size with respect to Euro NCAP limits.

From figure 27, we can conclude that all vehicles are far beyond the 4 points Euro NCAP limits. Therefore, in order to reach the same level of protection for the back and the front, these vehicles should be loaded on the rear as well as on the front and should be equipped with performing restraint devices and should reinforce their structural dimensioning.

DISCUSSION

The first major point in analysing the AE-MDB V3.9 side impact procedure in comparison to ECE 95 is its better representativeness of the average European vehicle. Its design itself is done by comparing it to car-to-car tests. Thus, validation tests, conducted by the Aprosys project and by ACEA, have shown that deformation, loading patterns and biomechanical criteria were representative of car-to-car tests (in between a Freelander and a Golf V).

Numerical studies carried out by PSA Peugeot Citroën showed that the AE-MDB V3.9 side impact test procedure show a higher severity than the ECE 95 procedure thanks to two major evolutions:

- an increased trolley weight (1500 kg instead of 950 kg)
- a stiffer body barrier with use of the AE-MDB V3.9 instead of the Progress.

Thanks to the virtual testing, we have seen that the coupling of both phenomena (increased trolley weight and stiffer body barrier) leads to worse biomechanical criteria and higher intrusions. The increased trolley weight has an effect on maximal door and B-Pillar velocities, whereas the barrier stiffness itself has an effect on the intrusions and the initial dynamic displacements. In overall, the increased severity of the new AE-MDB side impact procedure compared to ECE 95 is about 30% more.

Full-scale testing, done on different PSA Peugeot Citroën vehicles of different sizes, has shown deterioration in the structural behaviour by about an average of 25%. (Some non-linear phenomena have even appeared with the use of the AE-MDB V3.9 barrier such as complete loss and rupture of structural parts that were not seen with the Progress barrier used in the ECE 95 procedure). Intrusions and velocities are higher, as well as biomechanical criteria.

The increased severity seen with AE-MDB side impact procedure will have a direct influence on the conception of vehicles.
In order to keep the same protection level as the one offered in the current ECE 95 on in the consumer tests, the structural behaviour will have to be the same as the one seen today with the Progress barrier. Therefore B-Pillars will have to be stiffer, and doors reinforcements bigger. Structural basement of the car should also be able to support bigger loads coming out from doors and B-Pillar. These structural improvements will enable future vehicles to show lower intrusions and velocities despite the more severe barrier loading.
New load paths could also be studied by trying to transmit a higher proportion of energy through the seat or the console.

Introducing rear passenger protection in the side impact test procedure will also lead to a general structural reinforcement and especially the rear area. Nowadays, vehicles have usually no structural door reinforcement in the rear door. But these will become essential in order to control structural rear velocities and thus rear biomechanical criteria.
In order to deal with this new side impact procedure, each vehicle will have to add an average of 15 kg structural reinforcements to its weight, (in the structural baseline, with door reinforcements, and with new load paths through the seats for example).

Restraints devices will also have to be more performing. Especially on the rear area that usually hasn’t, on nowadays vehicles, any specific devices for the improvement of side impact protection. Rear side impact airbags, absorbing energy foams in the rear panel, and seat-belt pretension will have to appear on the future vehicles.
Therefore, taking into account AE-MDB side impact test procedure will lead to a better equipped compartment area as well as a reinforced structural behaviour.

CONCLUSIONS

This new AE-MDB side impact procedure is more representative of the last generation vehicles. Its severity is clearly in between a crash against a Freelander and a crash against a Golf V.
Its integration in consumerism or regulatory procedure will lead to a global reinforcement of the structural area and a better level of equipment for future vehicles. This will have a direct consequence on the improvement of security in side impact for car users for front occupants as well as for rear occupants.

ACKNOWLEDGMENTS

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APPENDICES

Appendix 1

Figure 28 presents the response of the two versions of barrier (AE-MDB V2 and AE-MDB V3.9) in the corridor created from the frontal test of cars to Load Cell (rigid) Wall and the theoretical corridor that has been derived from the theoretical characteristics of the V2 barrier face.

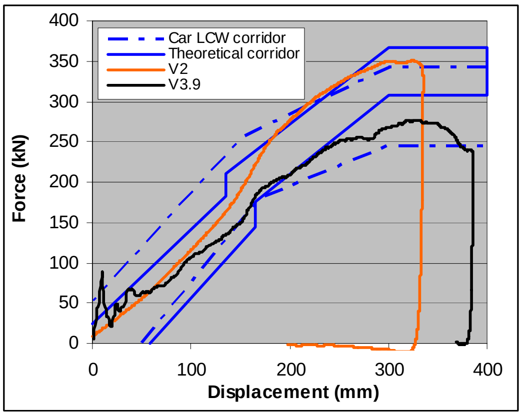

Figure 28. AE-MDB V2 and V3.9 response compared with the two corridor proposed to define AE-MDB

We can notice that version V3.9 of AE-MDB barrier is in the corridor only in the first 200 mm of displacement. But being our of the corridor after 200 mm of crush is not a problem since biomechanical criteria always occur before 200 mm of barrier deformation.