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FIMCAR
VIII –Full Width Test Procedure: Updated Protocol

frontal impact and compatibility assessment research

The FIMCAR project was co-funded by the European Commission under the 7th Framework Programme (Grant Agreement no. 234216).

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It is part of
FIMCAR – Frontal Impact and Compatibility Assessment Research / Editor: Heiko Johannsen, Technische Universität Berlin, Institut für Land- und Seeverkehr. – Berlin: Universitätsverlag der TU Berlin, 2013
ISBN 978-3-7983-2614-9 (composite publication)

CONTENT

EXECUTIVE SUMMARY

For the assessment of vehicle safety in frontal collisions compatibility (which consists of self and partner protection) between opponents is crucial. Although compatibility has been analysed worldwide for over 10 years, no final assessment approach has been defined to date. Taking into account the European Enhanced Vehicle safety Committee (EEVC) compatibility and the final report to the steering committee on frontal impact [Faerber 2007] and the FP5 VC-COMPAT [Edwards 2007] project activities, two test approaches were identified as the most promising candidates for the assessment of compatibility. Both are composed of an off-set and a full overlap test procedure. In addition another procedure (a test with a moving deformable barrier) is getting more attention in current research programmes.

The overall objective of the FIMCAR project is to complete the development of the candidate test procedures and propose a set of test procedures suitable for regulatory application to assess and control a vehicle’s frontal impact and compatibility crash safety. In addition an associated cost benefit analysis will be performed.

In the FIMCAR Deliverable D 3.1 [Adolph 2013] the development and assessment of criteria and associated performance limits for the full width test procedure were reported.

In this Deliverable D3.2 analyses of the test data (full width tests, car-to-car tests and component tests), further development and validation of the full width assessment protocol and development of the load cell and load cell wall specification are reported.

The FIMCAR full-width assessment procedure consists of a 50 km/h test against the Full Width Deformable Barrier (FWDB). The Load Cell Wall behind the deformable element assesses whether or not important Energy Absorbing Structures are within the Common Interaction Zone as defined based on the US part 581 zone. The metric evaluates the row forces and requires that the forces directly above and below the centre line of the Common Interaction Zone exceed a minimum threshold.

Analysis of the load spreading showed that metrics that rely on sum forces of rows and columns are within acceptable tolerances. Furthermore it was concluded that the Repeatability and Reproducibility of the FWDB test is acceptable.

The FWDB test was shown to be capable to detect lower load paths that are beneficial in car-to-car impacts.

1 INTRODUCTION

1.1 FIMCAR Project

For the assessment of vehicle safety in frontal collisions compatibility (which consists of self and partner protection) between opponents is crucial. Although compatibility has been analysed worldwide for over 10 years, no final assessment approach has been defined to date. From the European Enhanced Vehicle safety Committee (EEVC) compatibility and frontal impact working group (WG15) [Adolph 2013] and the FP5 VC-COMPAT project activities [Thompson 2013], two test approaches have been identified as the most promising candidates for the assessment of compatibility. Both are composed of an off-set and a full overlap test procedure. In addition another procedure (a test with a moving deformable barrier) is getting more attention in current research programmes.

Within the FIMCAR project off-set, full overlap and MDB test and assessment procedures will be developed further with the ultimate aim to propose a compatibility assessment approach. This should be accepted by a majority of the involved industry and research organisations. The development work will be accompanied by harmonisation activities to include research results from outside the FIMCAR consortium and to disseminate the project results early, taking into account recent GRSP activities on ECE R94, Euro NCAP etc.

The FIMCAR project is organised in six different RTD work packages. Work package 1 (Accident and Cost Benefit Analysis) and Work Package 5 (Numerical Simulation) are supporting activities for WP2 (Offset Test Procedure), WP3 (Full Overlap Test Procedure) and WP4 (MDB Test Procedure). Work Package 6 (Synthesis of the Assessment Methods) gathers the results of WP1 – WP5 and combines them with car-to-car testing results in order to define an approach for frontal impact and compatibility assessment.

1.2 Objective of this Deliverable

The objective of this deliverable is to report on the performed full overlap tests and simulation results and the development and validation of the final FIMCAR full overlap assessment procedure.

1.3 Structure of this Deliverable

The deliverable starts with a brief description of the past activities before FIMCAR and of the beginning of FIMCAR towards the development of a full overlap assessment procedure. This section is followed by a summary of the tests and simulations that were performed in the framework of the FIMCAR project. Based on these test and simulation results the FWDB assessment procedure is further developed in Chapter 4. Special emphasis is put on an improved metric that better addresses the benefits from lower load paths, the definition of the test severity and the assessment of load spreading. Chapter 5 summarises the activities to develop requirements for the load cells and the Load Cell Wall. Finally, Chapter 6 addresses the validation of the FWDB test procedure with focus on repeatability and reproducibility as well as load spreading of the deformable element.

The proposed Load Cell Specification and Calibration procedure is attached in Annex A, the proposed Load Cell Wall Specification and Certification procedure is attached in Annex B. Finally the FIMCAR FWDB Assessment Procedure is attached as Annex C.

2 TESTING AND SIMULATION

The main structural interaction problems identified in the FIMCAR accident analyses [Thompson 2013] were under/overriding, low overlap and the fork effect. In order to address the under/overriding aspect of structural interaction, structural alignment was considered as a necessary but not totally sufficient first step [Yonezawa 2009]. To address structural alignment, it was decided to use the approach that all vehicles should have crash structures in alignment with a common interaction zone. The US voluntary commitment for a common vertical interaction zone [Barbat 2005] was considered as a good starting point. A further step to address under/overriding is load spreading in the vertical direction. This can be achieved with vehicles that have multi-level load paths and strong connections between them. Load spreading in the horizontal direction is also an important factor for prevention of the fork effect and addressing accidents with small overlap. Strong cross beams can help provide good interaction in accidents with narrow objects and cross beams extending outboard from longitudinal members can improve structural interactions in cases with small overlap at the corners.

To assess structural interaction, the approach proposed in FIMCAR is that structural alignment in the vertical direction is assessed with a full width test using a Load Cell Wall (LCW). At the same time a small step towards the assessment of vertical load spreading can be achieved. It is proposed that this will be achieved using the **'common interaction zone' (CIZ)** concept.

In FIMCAR Deliverable D 3.1 [Adolph 2013] for both rigid and deformable barrier full width tests, Load Cell Wall (LCW) data was investigated as the method to assess the structural interaction characteristics of a vehicle by measuring the LCW force distribution. The current defacto standard for an LCW is one that consists of 125 mm square elements with the bottom row mounted with an 80 mm ground clearance (Figure 2.1).

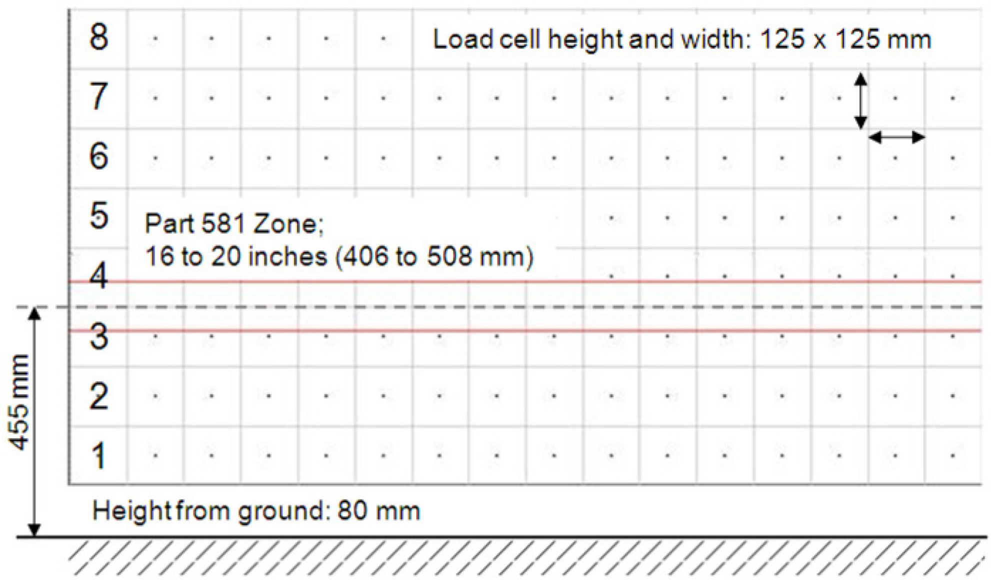


Figure 2.1: Overview of the specifications of the LCW.

In FIMCAR Deliverable D 3.1 global initiatives or strategies were reviewed that could be incorporated into a new test or assessment procedure and thus promote harmonisation of vehicle safety requirements. A significant activity that was initiated by the automotive industry is the US voluntary commitment [Barbat 2005]. This was developed to ensure that Light Truck Vehicles (LTVs) have structure in alignment with a common interaction zone from 16 to 20 inches (406 – 508 mm), further named as “Part 581 zone” measured vertically from the ground to enable better interaction with cars. The US voluntary commitment states that all LTVs sold by participating manufacturers in the US should fulfil one of the two options below (see also Figure 2.2):

OPTION 1

The light truck's primary frontal energy absorbing structure (PEAS) shall overlap at least 50 percent of the Part 581 zone (Option 1a)

AND at least 50 percent of the light truck's PEAS shall overlap the Part 581 zone (Option 1b)

OPTION 2

If a light truck does not meet the criteria of Option 1, there must be a secondary energy absorbing structure (SEAS), connected to the primary structure, whose lower edge shall be no higher than the bottom of the Part 581 bumper zone.

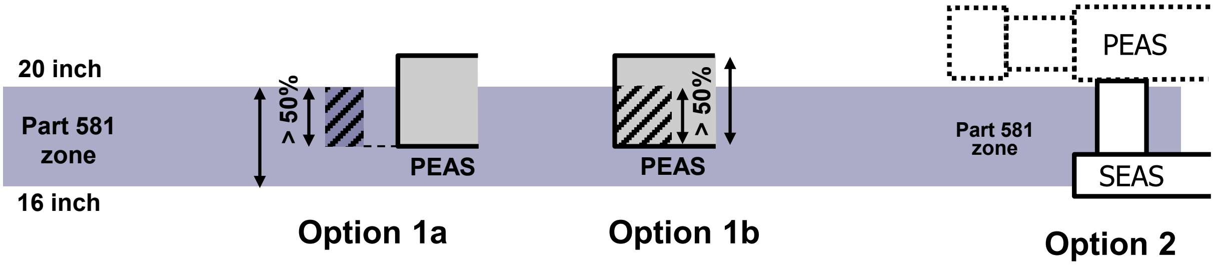


Figure 2.2: US voluntary commitment for improved compatibility of LTVs [Yonezawa 2012].

The US voluntary commitment is not desirable for regulatory application because ideally regulations should be ‘performance based’ and the voluntary commitment is ‘design based’. A design based requirement is generally more restrictive for the layout of a vehicle and hence is less desirable for regulatory application. However, accident data analyses from the IIHS [Teoh 2011] and NHTSA [Greenwall 2012] have shown that the introduction of the US voluntary commitment has helped to reduce casualties in LTV-to-car crashes. But it could not be definitely said that this improvement is due to the PEAS and SEAS requirements or due to general improvements in safety.

Given this information, it is important for FIMCAR to incorporate some of the concepts of this informal standard as it provides both a benefit and a potential for acceptance in jurisdictions outside of Europe.

3 SUMMARY OF TESTS AND SIMULATIONS PERFORMED

In total eleven full width tests were planned in Work Package 3. These tests were meant to provide additional data for the development of the metric and also to provide data to analyse repeatability and reproducibility of the proposed test and assessment protocol. Car-to-car tests were performed in Work Package 6 and are described in FIMCAR Deliverable D 6.1 [Sandqvist 2013]. Nevertheless as some of the results of these car-to-car tests are very important for the development of the full width test, key results are described in Chapter 6.1.2. In addition to the full width tests component tests were planned and conducted to investigate the performance of the load cell wall and the deformable barrier face. Due to the cooperation with Japan within the FIMCAR project three additional full width tests were conducted by JAMA to answer questions which came up during the project.

The matrix in Table 1 gives an overview of the tests performed in Work Package 3. As the tests were performed by different institutions, a template was developed to make sure that the analyses were done in the same way. Reports for all the tests can be found in Annex D: Full Width Test Reports.

Table 1: Test matrix of full scale, sled and component tests conducted in work package 3.

Purpose	No.	Kind of testing	Laboratory	Vehicle Type	Test date CW/YY	Status	Barrier		Test speed (km/h)	Dummy choice *with ribeye	
							FWRB	FWDB		HIII 50% male	HIII 5% female
Repeatability / Reproducibility	1	Full scale	BASt	Supermini 1	09/12	DONE		x	56	Front left*	Front right*
	2	Full scale	BASt	Supermini 1	10/12	DONE		x	56	Front left*	Front right*
	3	Full scale	FIAT	Supermini 1	47/11	DONE		x	56	Front left	Front right
Further Validation / Robustness	4	Full scale	IDIADA	Supermini 1	33/11	DONE		x	56	Front left	Front right
	5	Full scale	PSA	Supermini 1	33/11	DONE		x	56	Front left	Front right
	6	Full scale	IDIADA	Supermini 2	25/11	DONE	x		50	Front left	Front right
	7	Full scale	Renault	City Car 1	32/11	DONE		x	56	Front left	Front right
	8	Full scale	FIAT	Supermini 2	38/11	DONE		x	56	Front left	Front right
	9	Full scale	TRL	SUV 1	12/12	DONE		x	56	Front left*	Front right*
	10	Full scale	BASt	Small Family Car 1	17/12	DONE		x	50	Front left*	Front right*
	11	Full scale	BASt	Supermini 2	24/12	DONE		x	40	Front left*	Front right*
	12	Full scale	IDIADA	SUV 2	36/12	DONE		x	56	Front left	Front right
	13										
Tests external partners	14	Full scale	JAMA	K-Car 1	46/11	DONE		x	55	Front left	Front right
	15	Full scale	JAMA	SUV 3	14/12	DONE		x	55	Front left	Front right
	16	Full scale	JAMA	K-Car 2	39/11	DONE		x	55	Front left	Front right
Component tests / Load spreading on load cell measurements	17	Sled Test	BASt		22/11	DONE	x		15	-	-
	18		BASt		22/11	DONE	x		15	-	-
	19		BASt		22/11	DONE	x		15	-	-
	20		BASt		22/11	DONE	x		20	-	-
	21		BASt		22/11	DONE	x		25	-	-
	22	Component	TRL		24/11	DONE		x	40	-	-
	23		TRL		24/11	DONE		x	40	-	-
	24		TRL		24/11	DONE		x	40	-	-
	25		TRL		24/11	DONE		x	40	-	-
	26		TRL		24/11	DONE		x	40	-	-
	27	Component	BASt		June 2010	DONE			static	-	-

3.1 Full Width Tests

In total twelve full scale tests against the FWDB or FWRB were performed in FIMCAR. Three additional tests from JAMA were performed to further investigate the metrics and the FWDB. All tests were conducted with the HIII 50% dummy on the driver side and the HIII 5% female dummy on the passenger side. This consistency was necessary to compare the data.

Additional instrumentation with regard to the chest loading were added in some full scale tests. Therefore, BASt offered their RibEye measurement system to use it in FIMCAR tests in order to gain a better understanding of the thorax loading in high acceleration tests.
The objectives of the tests are described in the following sections. Test reports are in included in Annex D. The individual results of the tests were used in different ways and are mainly part of Chapter 4.

3.1.1 R&R Analyses with Supermini 1

Three full scale tests with the Supermini 1 were performed at two different test labs (FIAT and BASt). These tests were used to add additional data for the Repeatability and Reproducibility analyses of the full width deformable barrier test procedure. The height and the weight of the test vehicles were adjusted so that they had the same ride height. The Supermini 1 was selected because this is a single load path vehicle which is a worst case situation in terms of repeatability. The longitudinals of the vehicle are located mainly in LCW Row 4. However, it is still in alignment with the US voluntary agreement. The dummy selection was HIII 50 % on the driver seat and HIII 5 % on the front seat passenger seat.

The test reports can be found in Annex D, the results of these tests are discussed in Chapter 6.1.1.

3.1.2 Raised and Lowered Supermini 1

Two full scale tests with a raised (at PSA) and a lowered Supermini 1 (at IDIADA) were performed in order to investigate the sensitivity of the metric. The raised Supermini 1 had the longitudinals just slightly above the common interaction zone which means that it should not pass the metric. The lowered Supermini 1 was conducted at IDIADA and had the longitudinals still in the common interaction zone. In FIMCAR a series of car-to-car tests with Supermini 1 cars in aligned and non-aligned conditions was conducted in order to compare the performance.

The test reports of the FWDB tests can be found in Annex D, the results of these tests are discussed in Chapter 6.2.

3.1.3 Vehicles with far Forward Lower Load Path

Two vehicles were tested to answer the question if vehicles with a far forward lower load path would be discriminated by the full width metric developed. City Car 1 was selected and tested at Renault and a Supermini 2 was selected and tested at Fiat.

The test reports can be found in Annex D, the results of these tests are discussed in Chapter 6.1.3.

3.1.4 SUV with and SUV without a Lower Load Path

The performance of SUVs with different structural concepts was investigated with car-to-car tests in Work Package 6. Three vehicles were selected: SUV 1, Small Family Car 1 and a SUV 2. These vehicles were also tested against the full width deformable barrier to check how the vehicles perform with the developed metric.

Side impact tests and front and side impact simulations were carried out with SUV 3 and Large Family Car 1 with different load path configurations on SUV 3. Simulations for the vehicles in the FWDB were performed to investigate their performance with the proposed metrics.

The test reports can be found in Annex D, the results of these tests are discussed in Chapter 6.1.2. Car-to-car tests are further documented in Deliverable 6.1 [Sandqvist 2013].

3.1.5 Comparison of different Test Speed

The test speed for both full width test procedures was carefully selected in Work Package 3. Analyses of accident data have shown that a test speed of 50 km/h would be appropriate for AIS 3 injury levels and 35 to 40 km/h were appropriate for AIS 2 injury levels. However, FIMCAR relied on analysis of pre-existing test data in addition to the FIMCAR tests. The pre-existing tests were usually performed at 56 km/h (or 55 km/h in JNCAP test). Therefore a Supermini 2 test against full width rigid barrier was performed with 50 km/h and a Supermini 2 test against full width deformable barrier was performed at 40 km/h to investigate if changes in the metric were necessary.

The test reports can be found in Annex D, the results of these tests are discussed in Chapter 1.1.1.

3.2 Component Tests

There were a number of component tests conducted during the FIMCAR project. These results were mainly used to answer questions regarding the load spreading of the deformable element and the performance of the load cell wall.
The next chapters were meant to give an overview of all component tests performed.

Further results are discussed in Chapter 4 and Chapter 6.3.

3.2.1 LCW Dynamic Calibration Tests

The objective of these trolley tests was to investigate if a dynamic load cell test is needed for the certification and specification procedure. Following this a crash test trolley was used with a stiff front plate crashing against aluminium honeycomb barriers and measuring the forces with an LCW. The objectives of these five tests were to investigate the repeatability of forces in different load cells, analyse the influence of protective coverings for load cells (wood plate) and analyse the influence of increasing test speed on load cell forces, acceleration and deformation.

The test report can be found in Annex D, the results are discussed in Chapter 6.3.

3.2.2 Sled Tests to investigate Load Spreading

The objective of this component work was to determine the reasons for the unexpected differences in peak loads seen between individual load cells. This was done by TRL by performing additional component tests to investigate whether the aluminium backing plate or the interface between the two layers affects distribution of load between cells.

The tests and the outcome are reported in Chapter 6.3.

3.2.3 Load cell Tests with Excentric Loading

For the development of the certification and specification of the load cells additional component tests were necessary to investigate the performance of different load cells in eccentric loading conditions. As a starting point two load cells from BASt were calibrated in a more advanced way than before. Based on these results it becomes obvious that additional tests from further test laboratories were needed. Thus, load cells from IDIADA, TRL, BASt and Japan were sent to Humanetics to perform these tests

The development of the certification and specification protocol for the load cells and the tests performed are explained in Chapter 5.2.1.

3.3 Simulations

To support the investigations of WP 3 a large number of simulations was conducted by WP 5. Main objective of these simulations was to validate the test results and assessment procedures. Furthermore specific analyses were conducted to investigate the influence of the front end structures on the compatibility metrics. Most of the simulation work was already described in FIMCAR Deliverable D3.1 [Adolph 2013]. Therefore a short description of these analyses is presented in this chapter. The analyses of the simulations will be discussed in the development chapter (Chapter 4) or validation chapter (Chapter 6).

3.3.1 Variable Crossbeam Heights

Main objective of this analysis was to investigate the influence of a PEAS design where the cross beam and the longitudinal were not in vertical alignment. For that reason five modifications of the PEAS were modelled and the effect on the assessment criteria were investigated.

Within the analyses for the FWDB following remarkable observations were made:

- The wall force limit for 400 kN was reached after a later time (37 ms versus 44 ms), whereby no engine dump occurred.
- The basic model fulfils the requirements for all proposed metrics.
- The modification 2 (lowered cross beam) also fulfils the requirements of the metrics while this was not the case for the other modifications.

For more details see FIMCAR Deliverable D3.1 [Adolph 2013]).

3.3.2 Influence of Towing Eye

Goal of this study was to analyse the effect of hard points located in the front end on the metrics. In partial the towing eye respectively the towing eye attachment was analysed in FWRB and FWDB crash configurations.

The most important conclusion was that the deformation pattern of the EAS differs depending on the test procedure. While the effect of these very stiff structures disappeared in the FWRB test after applying a CFC60 filter (which is the standard filter for such a channel) the towing eye had an influence to the wall force in the FWDB test. However, the results of the simulation with the towing eye attachment showed not influence on the assessment metrics in both crash configurations. Additional simulations were done with the GCM models from CRF. These analyses support the results from the PCM models.

For more details see FIMCAR Deliverable D3.1 [Adolph 2013].

3.3.3 Effect of Cross-Over Vehicles

The objective was to simulate cross-over vehicles in order to investigate the effect of differences in ride heights according to FWB assessment criteria. Simulations were conducted with the Parametric Car Model (Large Family Car) which is tested against the FWRB and the FWDB. The cross-over version is modified by a horizontal offset of the barrier of 60 mm.

Main finding of this analysis was that a raised vehicle could fail the assessment metrics of both test procedures. This means only to raise the vehicle and its structures will decrease the structural interaction in car-to-car crashes.

For more details see FIMCAR Deliverable D3.1 [Adolph 2013].

3.3.4 Investigation of Step Effects

To check the metrics for step effects a set of car-to-FWB and car-to-car simulations was conducted. The objective of this analysis was to investigate the robustness of the metrics in terms of step effects and to ensure the correct assessment of the metrics. Furthermore the results of the FWB tests should be verified in car-to-car simulations.

The outcome of this investigation was that the wall force depending criteria correlate well with the most relevant crash structures. No step effects could be observed in both test procedures. The results of the car-to-car simulations showed that the vertical misalignment of the PEAS lead to lower peak values for the deceleration but the intrusion increased.

For more details see FIMCAR Deliverable D3.1 [Adolph 2013].

3.3.5 SEAS Analyses

The Objective of this study was to investigate the influence of the SEAS in car-to-car crashes and to identify characteristics of appropriate SEAS that are able to improve structural interaction. Therefore geometrical modifications in terms of varied stiffness and SEAS positions were done. First the modified PCM models were crashed in an adapted ORB test to identify the force level of the SEAS. Furthermore this test configuration should be checked, if it is able to assess a SEAS in a correct manner (provide benefits in car-to-car crashes). After that the PCMs were run against the FWRB and FWDB with 50 km/h. The main objective was to check if the SEAS could be detected on the LCW.

3.3.5.1 **First Modifications**

Figure 3.1 shows the baseline configuration of the used PCM (Large Family Car, LFC). The PEAS are in alignment with Row 3 and 4 and the SEAS are in alignment with Row 2.

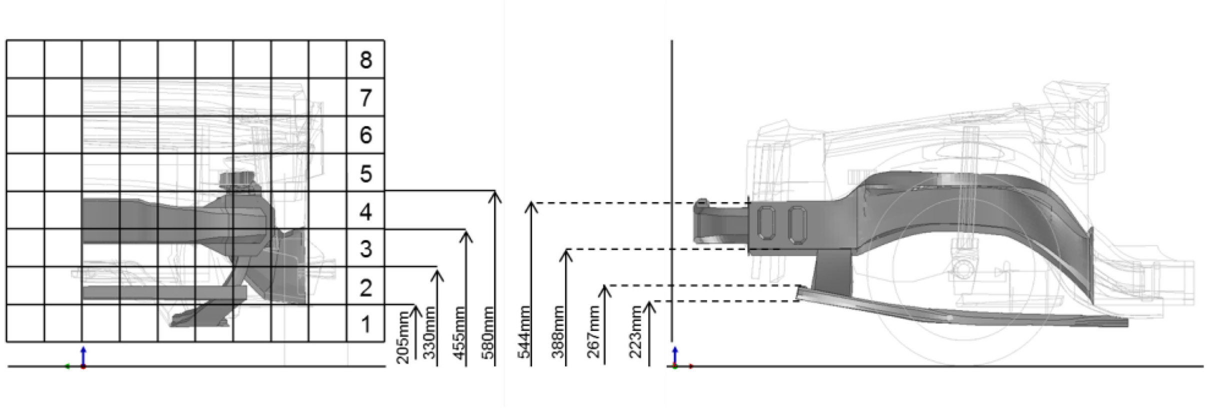


Figure 3.1: Baseline configuration of the PCM (LFC).

As a first step the position of the SEAS in x-direction was modified, see Figure 3.2. Former simulation with a modified FORD Taurus model indicated that an appropriate SEAS will bring benefits if it is located between 180 mm and 400 mm behind the cross beam [Park 2009]. This modifications only affected the longitudinal and the cross beam of the SEAS. The position of the vertical connection was not changed in the first step.

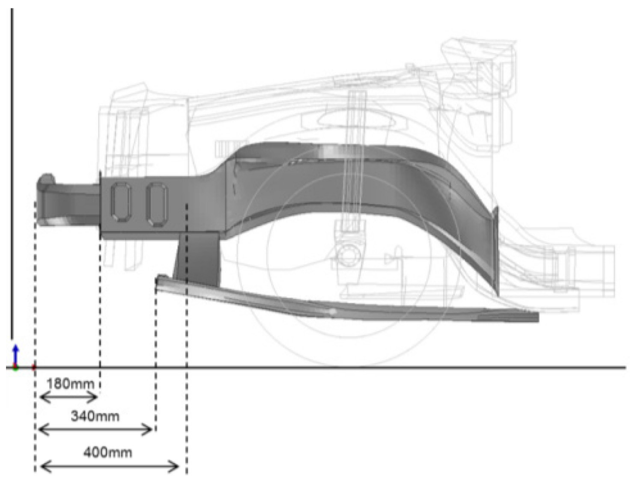


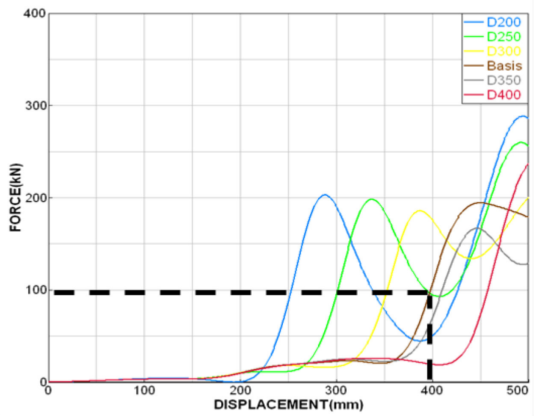
Figure 3.2: Upper and lower boundaries of the first SEAS modifications.

In total five modifications were modelled (in addition to the baseline model):

D200 → SEAS 200 mm behind cross beam
D250 → SEAS 250 mm behind cross beam
D300 → SEAS 300 mm behind cross beam
D350 → SEAS 350 mm behind cross beam
D400 → SEAS 400 mm behind cross beam

3.3.5.2 **ORB Simulations**

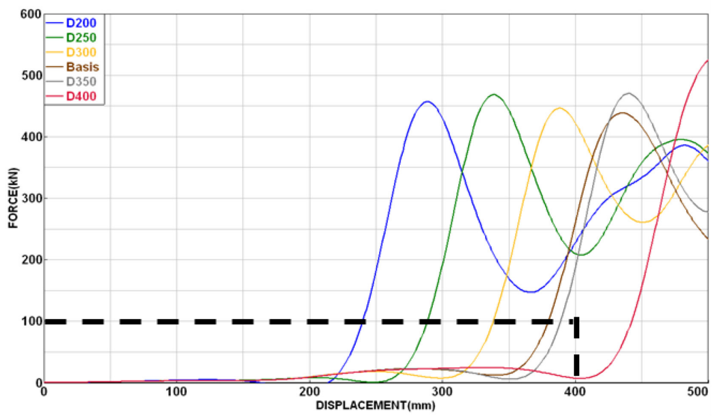
The six models were crashed against the ORB with 40 km/h. The results are shown in Figure 3.3. The analysis showed that depending on the SEAS location the vehicle was able to pass the ORB criterion (D200; D250; D300). If the lower load path is located further rearward the structure was not able to apply 100 kN within 400 mm displacement (Basis; D350; D400).



Modification	s @ F_{max} [mm]	F_{max} [kN]
D200	288	203
D250	337	198
D300	387	186
Basis	400	73
D350	400	68
D400	400	26

Figure 3.3: Simulation results of ORB crashes.

As already figured out in the PDB simulations [Lazaro 2013] the sub frame was relative weak. Due to this only the far forward SEAS could apply enough forces to the ORB. A second run was conducted with reinforced SEAS (stiffness increased by factor 2).



Modification	s @ F_{max} [mm]	F_{max} [kN]
D200	288	457
D250	338	468
D300	388	446
Basis	400	257
D350	400	183
D400	331	25

Figure 3.4: Simulation results of ORB crashes with reinforced subframes.

Figure 3.4 shows the results with the reinforced sub frame. All modifications, except D400, pass the ORB test. Due to the very stiff structure the force increase very fast and to a relative high level.

Following the intention of the ORB test to check SEAS on vehicles that do not meet the US volunteer agreement Options 1a and 1b, the results indicate that all modification should bring benefits in car-to-car crashes.

3.3.5.3 **FWRB and FWDB Simulations**

To check if the SEAS structures can be detected in FWRB and FWDB test all modifications (initial stiffness of SEAS and reinforced SEAS) were crashed against both barriers with 50 km/h.

Figure 3.5 and Figure 3.6 show exemplarily the row forces and the sum forces for the simulations with the reinforced sub frame against FWRB and FWDB with 50 km/h. The red circles mark the maximum forces applied to Row 2. The reinforced SEAS apply very high forces to the wall, in particular to the FWRB, which is unrealistic compared to real cars but highlighted the effect on the LCW readings due to the SEAS.

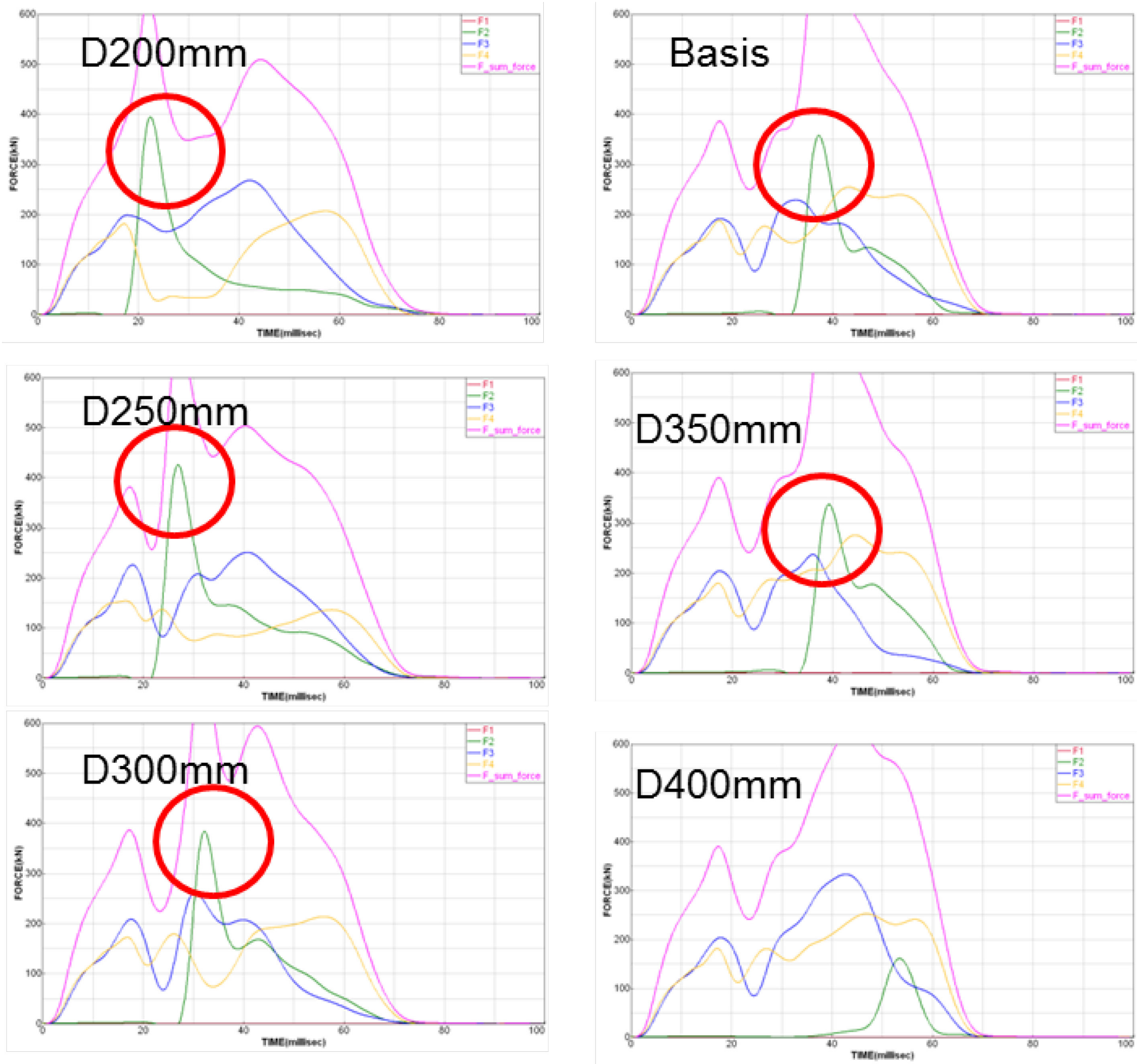


Figure 3.5: Simulation results of FWRB test with reinforced sub frame.

The main findings for the FWRB configurations were:

- Sub frames in modifications D200 to D350 could be detected
- Force levels measured in Row 2 are on same level for modifications D200 to D300
- Depending on the position of the SEAS the maximum forces were applied in different points of time but too late in the impact (after total forces reached 200 kN)

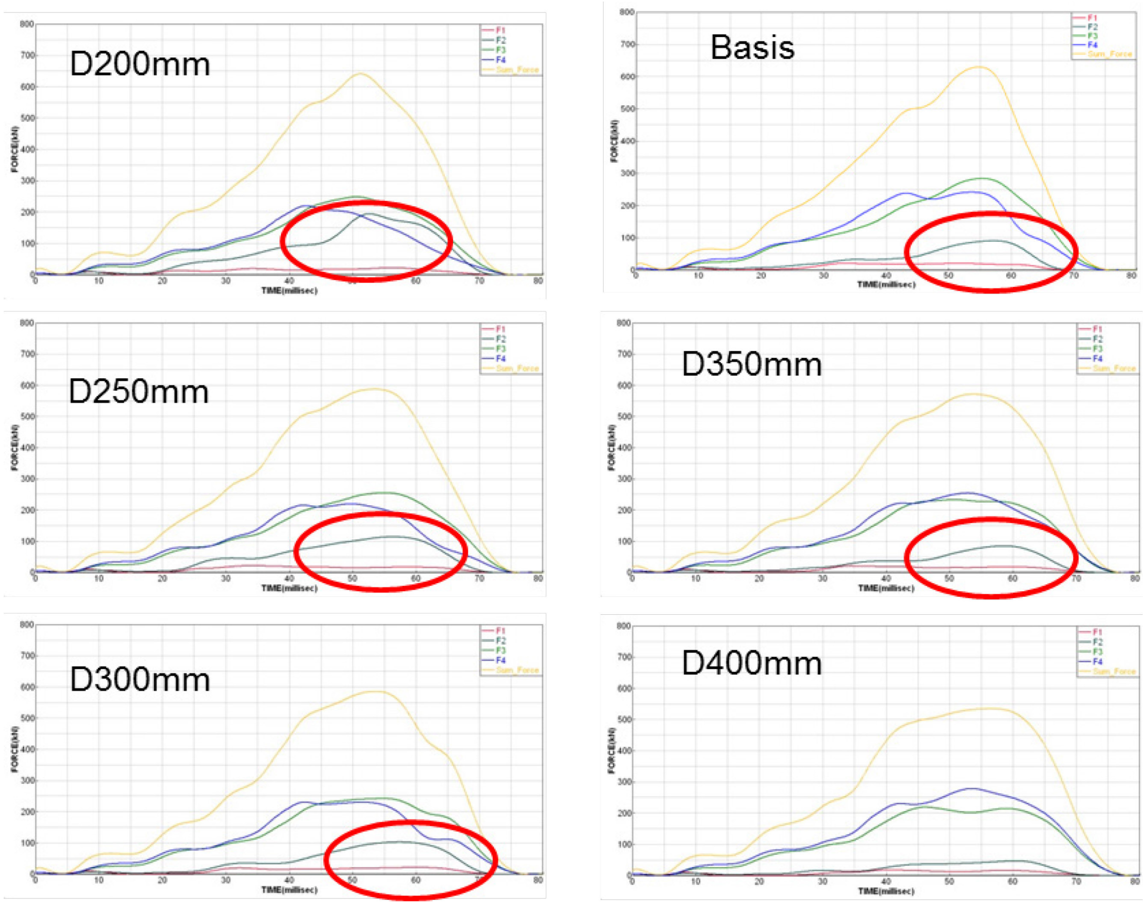


Figure 3.6: Simulation results of FWDB test with reinforced sub frame.

The main findings for the FWDB configurations were:

- Sub frames in modifications D200 to D350 could be detected
- Due to the load spreading of the honeycombs forces are also applied to Row 1
- Reinforced sub frames applied higher forces but too late in the impact (after 40 ms)

3.3.5.4 **Car-to-Car Simulations**

To analyse the modifications in car-to-car crashes the modified LFC was raised by 70 mm and crashed (both vehicles 56 km/h, 50% overlap with respect to the bullet vehicle) against the baseline super mini, large family car and the executive car, see Figure 3.7. These three bullet vehicles pass the FWB metrics in their baseline configuration.

The results of this investigation showed that the SEAS did not affect the structural interaction of the two cars in all configurations. The main reason for that is that the SEAS of both cars did not meet during the crash or interact just a short moment. This also counts for the configurations where the SEAS should meet the colliding PEAS.

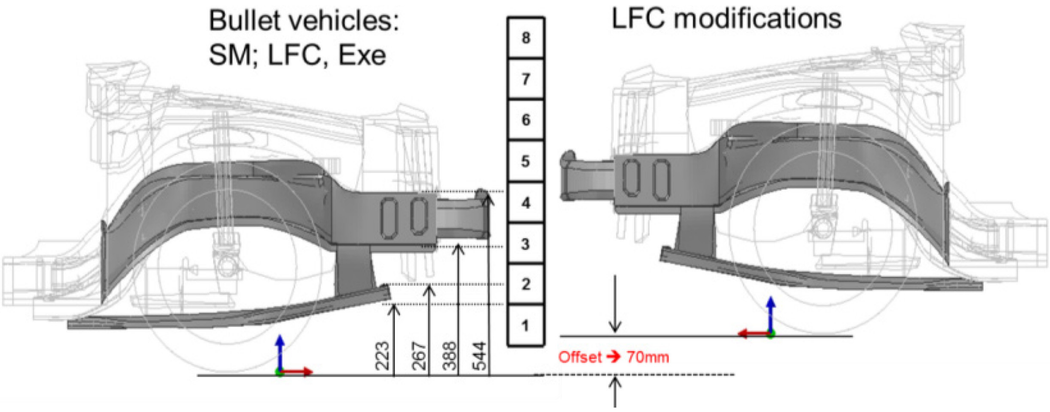


Figure 3.7: Car-to-car configurations with first modifications

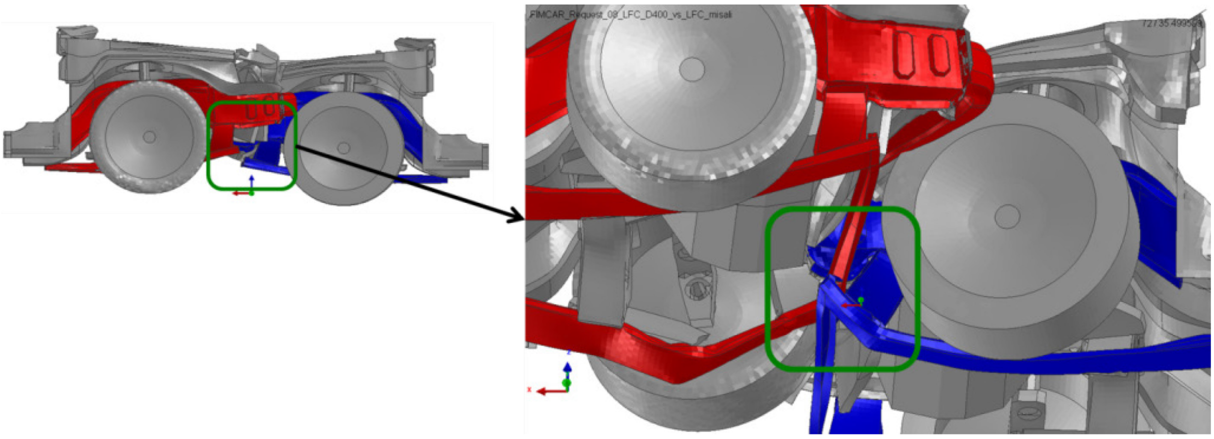


Figure 3.8: Simulation results of car-to-car crash (D400 red; LFC blue).

As highlighted in Figure 3.8 the results indicated that the vertical connection between the SEAS and the PEAS offers a good support to the penetrating structures. In almost every case the SEAS were not activated before they meet this vertical connection. Because this part was not modified it was located very far rearward.

3.3.5.5 **Summary of First Modifications**

The conducted simulations showed that the ORB test does not discriminated between appropriate (provides benefits in car-to-car crashes) and inappropriate SEAS. Thus the ORB test produces "false positives" which means that the test assess a cars structure as good while the car-to-car test showed no improvements in the structural interaction.

Based on the results of the car-to-car simulations that the vertical connection between PEAS and SEAS can bring benefits in car-to-car crashes additional modifications were done.

3.3.5.6 **Second Modifications**

To analyse the effects of a far forward located vertical connection on car-to-car crashes two further modifications were modelled. Based on the baseline LFC model, that was raised by 60 mm to align it with Row 4 (raised baseline LFC fails the metrics), the vertical connection as well as longitudinal and cross beam of the SEAS were moved forward and the cross section of the cross beam was increased, see Figure 3.9.

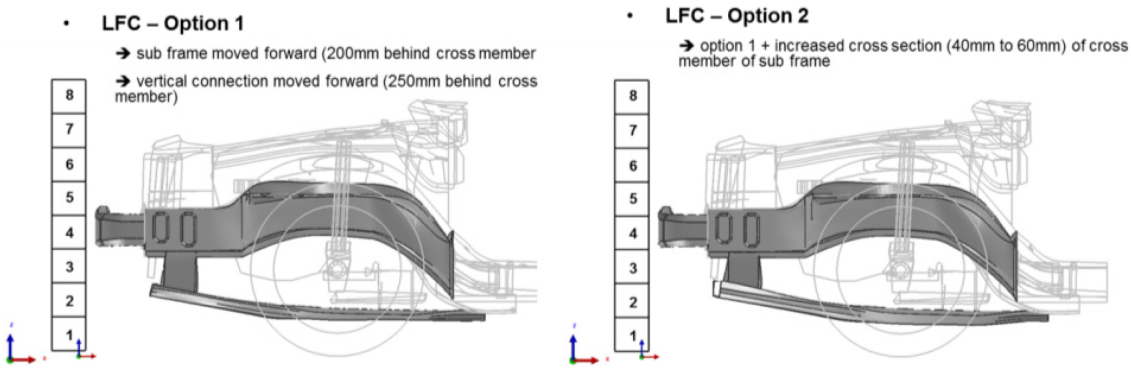


Figure 3.9: Second LFC modifications (vehicles were raised by 60 mm to align them with Row 4).

The following four models were used for this analysis:

LFC baseline	(passes all metrics)
Raised LFC	misaligned with Row 4
LFC – Option 1	subframe 200 mm and vert. connect. 250 mm behind cross beam
LFC – Option 2	option 1 + increased cross section (40 mm to 60 mm)

All modifications were run against the FWDB with 50 km/h. For the analysis two assessment metrics including the new proposal taken into account a limit reduction due to forces applied in Row 2 were used, see Chapter 4.1. Table 2 and Table 3 show the results of the FWDB test with 50 km/h. The raised LFC and the modifications fail both metrics. Although, the intention of the second metric is to promote lower paths the modifications were not able to apply enough forces. The main reason for that is that the limit reduction criteria (70 kN) were defined with respect to 56 km/h collision speed, while the simulations were conducted with 50 km/h. Taking into account the results of the analysis of the test severity, see Chapter 3.3.6 the forces applied to the wall will decrease with reduced collision speed.

Table 2: Simulation results with FWDB 50 km/h of second modifications (metric without Limit Reduction).

Current Metric			
	Misaligned (aligned row 4)	**Option 1** (subframe and vertical connection far forward)	**Option 2** (subframe cross section increased and vertical connection far forward)
F_{sum} [kN]	458	427	467
$0.2F_{sum\_@\_40ms}$ [kN]	91,6	85,4	93,4
F_4 [kN]	190	146	155
F_3 [kN]	61	66	81
F_2 [kN]	32	46	63
	fail	fail	fail

Table 3: Simulation results with FWDB 50 km/h of second modifications (LR metric).

Limit Reduction Metric			
	Misaligned (aligned row 4)	**Option 1** (subframe and vertical connection far forward)	**Option 2** (subframe cross section increased and vertical connection far forward)
F_{sum} [kN]	458	427	467
F_4 [kN]	190	146	155
F_3 [kN]	61	66	81
$F_3 + F_4$ [kN]	251	212	236
$0.4F_{sum\_@\_40ms}$ [kN]	183,2	170,8	186,8
$0.2F_{sum\_@\_40ms}$ [kN]	91,6	85,4	93,4
F_2 [kN]	32	46	63
LR [kN]	(-38 → 0)	(-24 → 0)	(-7 → 0)
	fail	fail	fail

The last step was the analysis of the performance of the modifications in car-to-car crashes. Figure 3.10 shows the geometrical configurations. The cars were run against each other with 56 km/h and 50 % overlap.

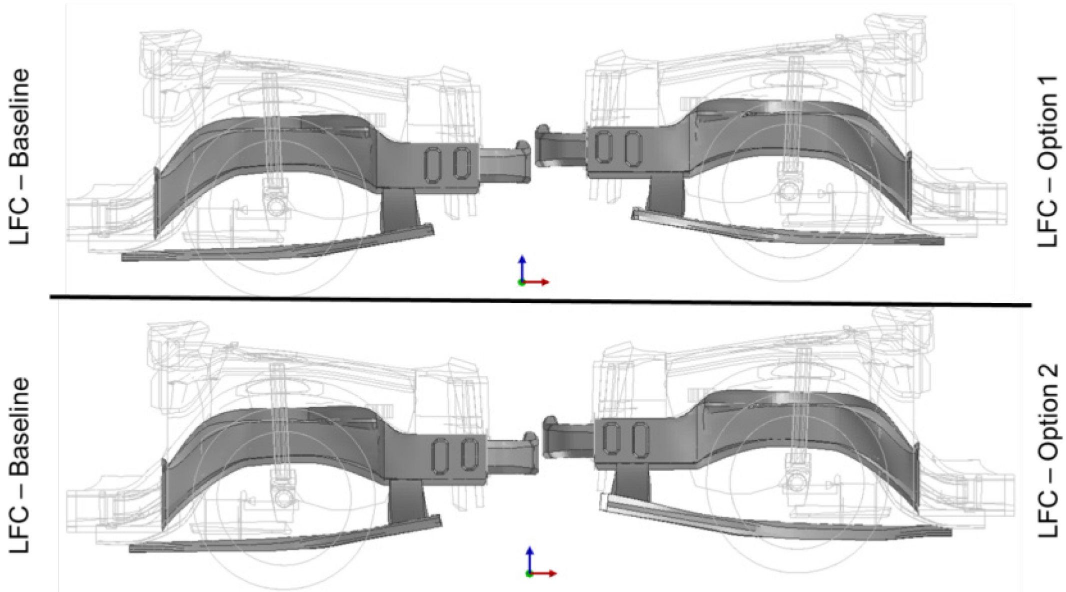


Figure 3.10: Car-to-car configurations with second modifications.

The intrusions and decelerations were analysed. Table 4 shows the measured intrusions. Even though the intrusions for the overridden car are higher (underriding car hits the opposing wheel which moves rearwards and causes the higher intrusions) the trend shows that the modifications for LFC – Options two reduces the intrusions.

Table 4: Intrusion measurements of car-to-car simulations with second modifications.

	baseline	modified car
baseline - misaligned	-125mm	-220mm
baseline - option 2	-98mm	-122mm

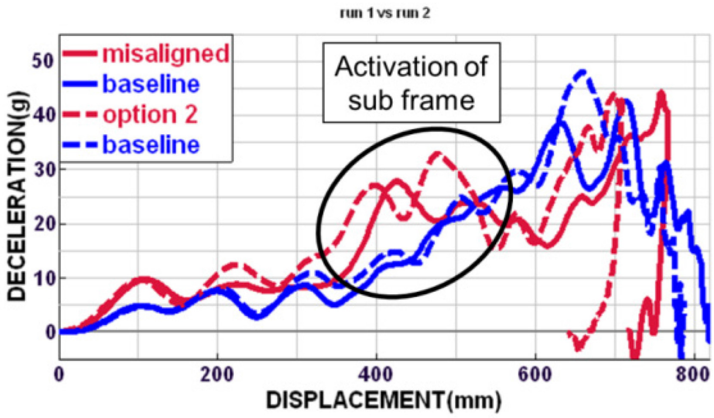


Figure 3.11: Deceleration-displacement plots of misaligned against baseline LFC and option 2 against baseline LFC.

Figure 3.11 shows the deceleration-displacement plots of the same configurations. Compared to the misaligned LFC (red graph) the LFC option 2 shows a clear peak (red dotted graph) due to the early activation of the sub frame, which indicates the improved structural interaction.

3.3.5.7 **Summary of Second Modifications**

Summarising the results of the second modifications it could be shown that a far forward located vertical connection is able to improve the structural interaction of cars which PEAS are not in alignment. However due to the fact that the limit reduction metric uses thresholds defined by analysing 56 km/h FWDB crashes the modified LFCs were not able to pass the LR metric.

3.3.5.8 **Conclusions**

The main objective of this request was to analyse the influence of SEAS in car-to-car crashes and to identify characteristics of appropriate (improve structural interaction) SEAS. The main findings were that the structural interaction was improved due to the vertical connection and the increased cross section of the sub frame, even though the modifications (LFC option 1 and LFC option 2) were not able to pass the metrics (with and without LR). The analyses also showed that the ORB test is a test procedure that is not capable to discriminate between appropriate and inappropriate SEAS. Furthermore the following SEAS characteristics were identified to bring benefits in car-to-car crashes:

- Far forward position of the sub frames cross beam
- Far forward vertical connection between SEAS and PEAS
- Large cross section to provide enough support for penetrating structures

Additional analyses for the vertical load spreading are also reported in Chapter 4.3. More details concerning PEAS and SEAS interaction can be found in Stein et al. 2013/1.

3.3.6 Different Test Speed

Based on the analysis of the test severity for full width crash test, see Chapter 4.2, simulations were conducted to check if the assessment metrics works independent from the test speed. The GCMs and the PCMs were crashed against the FWRB with 56 km/h and the FWDB with 40 km/h, 50km/h and 56 km/h. A detailed description of the investigations and the results is given in Chapter 4.2.

3.3.7 Volvo Simulations

Volvo simulation with the car models of the Large Family Car 1 and the SUV 4 were performed to add data for the development of metric and to answer open questions. The advantage of this work was that simulation with full vehicle models was done which are more detailed compared to the generic car models. The SUV 3 was simulated against the FWDB and FWRB to generate more data for the metric development and to investigate the performance of a vehicle with a high PEAS and a lower load path. In addition to this simulation with SUV 3 striking Large Family Car 1 at 50 km/h (side impact) were done.

The results are reported in Chapter 4.3.

4 FURTHER DEVELOPMENT OF FULL WIDTH DEFORMABLE BARRIER PROTOCOL

4.1 Further Development of Metric

The FWDB metric was originally developed and reported in FIMCAR Deliverable 3.1 can be summarised as follows:

- Up to time of 40 ms
  - $F4 \geq [MIN(100, 0.2F_{T40})$ kN
  - $F3 \geq [MIN(100, 0.2F_{T40}]$ kN
  - where F_{T40} = Maximum of total LCW force up to time of 40 ms

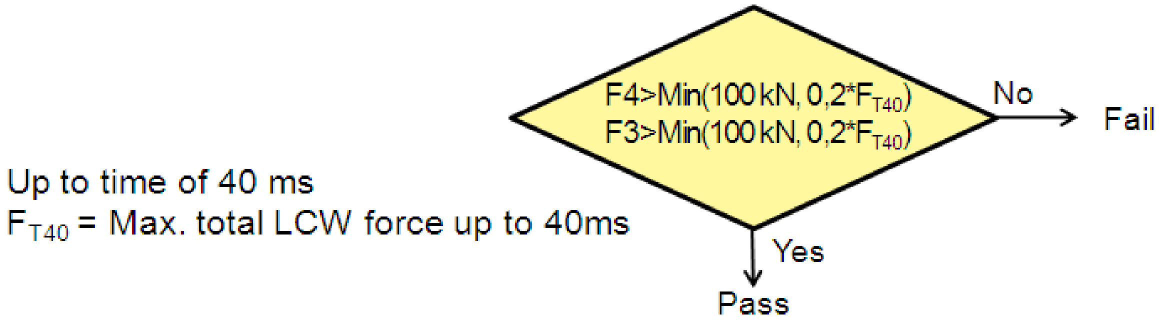


Figure 4.1: FWDB metric with forces in Row 3 and 4 up to 40 ms.

The concept of this metric is to ensure that all vehicles have adequate structure in alignment with the common interaction zone by using a minimum load requirement for Row 3 and Row 4. To ensure that light vehicles are able to meet the requirement, it is specified in terms of a fraction of the load that the vehicle applies to the wall as well as an absolute value. The absolute value is also necessary to ensure that the requirement for the strength of the SEAS for vehicles with their SEAS in alignment with the common interaction zone is not over-onerous; it is effectively limited to 100 kN.

The objective for the development of a metric modification was that it should allow designers greater freedom for the design of vehicles with lower load paths whilst still ensuring that the vehicle has adequate structure in the common interaction zone for good compatibility. This should help encourage the development of this type of vehicle which is desirable because this type of vehicle (i.e. one with load paths at multiple levels compared to a single level load path one) has been shown to have better compatibility in terms of structural interaction potential.

The concept for the metric modification was:

- Reduce the load required in Row 3 by a part of the amount of load that the vehicle’s lower load path applies to Row 2.
- Still require same minimum load in Rows 3 and 4 overall to ensure that the vehicle has adequate structure in alignment with the common interaction zone.

The methodology used to develop the metric modification was:

- Determine max load that vehicles without subframes apply to Row 2.
- Subtract load that vehicles apply above this load in Row 2 from load requirement for Row 3. To ensure that the situation does not arise where there is no load (or structure) in alignment with Row 3, the limit reduction was capped at 50 kN.

Following this methodology and using the data from available tests shown in Figure 4.3 the following modified metric was developed:

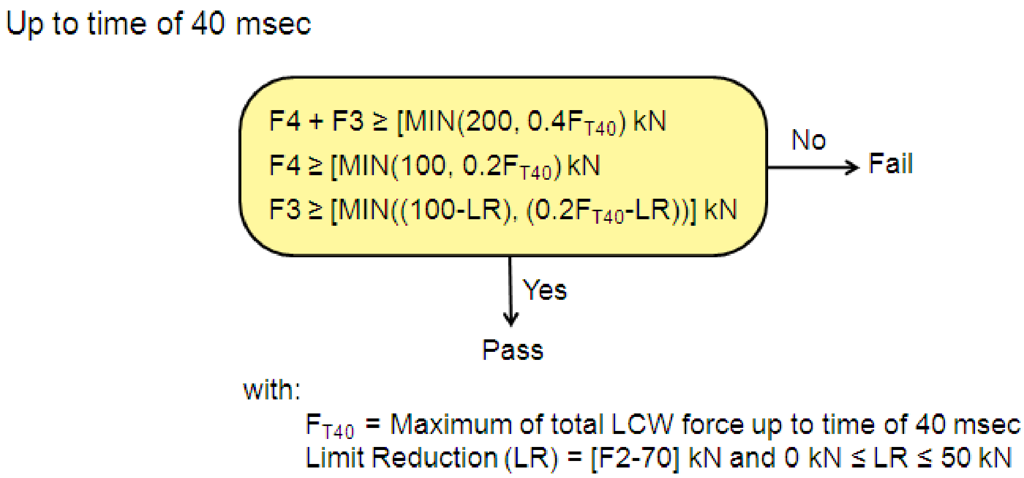


Figure 4.2: FWDB Metric with Limit Reduction.

Notes:

- Additional requirement on (Row 3 + Row 4) was needed to ensure that the overall load limit on Rows 3 and 4 remains the same as for the original metric when limit for Row 3 is reduced.
- Maximum load that vehicle without subframe applies to Row 2 is 70 kN by Nissan Micra (from Figure 4.3 which summarises currently available test data).
- The Limit Reduction (LR) is capped at 50 kN to ensure that some load is applied to Row 3 and hence that some structure is in alignment with it.
- Further validation of the proposed performance limits is recommended, in particular consideration of light cars and the influence coming from the proposed change in test speed to 50 km/h is needed.

	Smart Fortwo	Ford Fiesta	FIAT Panda	Nissan Micra	VW Golf	Opel Astra	Opel Astra 2	FIAT Bravo	Ford Focus	Ford Focus lowered	Ford Focus raised	Rover 75 standard
Subframe	Yes	No	No	No	No	Yes	Yes	No	No	No	No	Yes
Row 4	106	166	140	105	106	182	179	182	149	95	151	248
Row 3	80	175	133	123	150	127	142	100	65	151	35	116
Row 2	61	54	50	70	61	84	93	47	21	35	21	78
Row 1	36	26	36	29	30	20	15	23	19	21	0	13
Row (1+2)	83	79	86	97	91	100	108	69	40	56	21	80

	Rover 75 weak	Rover 75 strong	Renault Laguna	Mercedes E-Class	Honda CRV	VW Touareg	Volvo XC90	Nissan Micra 2	Renault Twingo	FIAT 500	Citroen C3 lower	Citroen C3 raised	Renault Koleos
Subframe	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	No	Yes
Row 4	255	301	172	171	235	320	295	98	77	146	113	142	192
Row 3	84	88	117	154	179	133	85	134	153	139	137	62	151
Row 2	94	70	74	68	64	20	30	58	107	123	61	29	101
Row 1	13	11	15	25	5	15	0	31	67	45	18	45	31
Row (1+2)	103	76	81	93	69	31	30	88	170	158	79	74	112

Figure 4.3: FWDB tests – Row load forces in kN up to 40 ms Note: Row (1+2) load calculated by adding Row 1 and Row 2 loads at each time step and then determining max load up to 40 ms.

The advantage of the modified metric can be seen by comparing how easily the Small Family Car 1 car meets the metric modifies performance limits (Table 5). It should be noted that the Small Family Car 1 has a quite high Primary Energy Absorbing Structure (PEAS) but also has a Secondary Energy Absorbing Structure (SEAS) subframe loadpath and was proofed to perform well in aligned and misaligned car-to-SUV tests.

Table 5: Comparison of Small Family Car 1 Row load forces with original and modified metric performance limits.

Row	Force Value KN	Original Metric Performance Limits kN	Modified Metric Performance Limits kN
F4	188	100 (109)	100 (109)
F3	107	100 (109)	85 (94)
F4+F3	295	N/A	200 (217)
F2	85	N/A	N/A
Total	543		

It is seen that with the modified metric the load requirement for Row 3 is reduced which enables the Small Family Car 1 to meet the metric requirements more easily than for the original metric. Indeed, if the original metric was implemented a manufacturer may have considered the Small Family Car 1 design inadequate and altered it because it was too close to the limit. This would not be the case for the modified metric.

It is recommended that further validation of the suggested values for the performance limits is undertaken to ensure that this metric is appropriate for regulatory application, in particular if a test speed of 50 km/h is chosen because the performance limits suggested above were formulated based on the available test data which had a test speed of 56 km/h.

4.2 Definition of Test Severity / Velocity

It was important to establish a test severity for the full width test procedures to ensure the candidate procedures were representative of the real world conditions. The existing UN-ECE Regulation 94 was used as a benchmark for the offset tests. A similar European benchmark was not available for the full width test and therefore a justification for test severities was developed in the project.

A review of reconstructed German accidents in the GIDAS database was developed by BASt and is presented in Figure 4.4. In principle the analysis combines the injury risks resulting from accidents with certain velocities with the accident risks at these velocities. The vertical axis is labelled “accumulated risk” but may also be referred to as “accumulated incidence” or “incidence” and represents the proportion of injuries reported over a range of delta-vs. Each point on the line is the average value for a moving window of 10 km/h to identify the potential contribution of a test delta-v related to real world crashes that occur within the window +/- 5 km/h for each reference delta-v. This conservative approach assumes that the test severity only influences vehicle designs and resulting occupant safety for crashes within this severity window. The example illustrates the peak incidence of MAIS 2+ injuries at 52 km/h and the speed range over which the risks are summed (47 to 57 km/h). All curves (MAIS 2, 2+, and 3+) exhibit peaks for delta-v around 52 km/h and fall off sharply after delta-v 55 km/h. This is not unexpected as the majority of collision cases occur for impact speeds below 50 km/h.

The real work data indicates that the highest risks for MAIS2+ injuries are in the range 47 to 57 km/h and that this impact severity should be used to direct future car designs. Given that a full width test delta-v usually involves a rebound velocity of approximately 10% the impact speed, a test speed of 50 km/h was selected for a full width test severity, regardless of the barrier face selected.

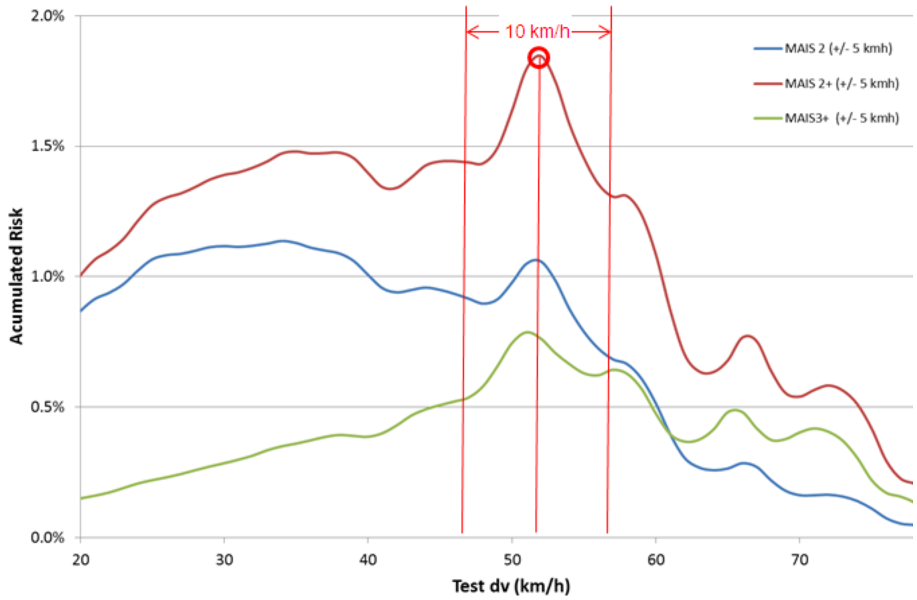


Figure 4.4: Incidence of injuries in high overlap accidents (overlap > 75 %).

4.3 Vertical Load Spreading

Structural interaction was a high priority work item in FIMCAR. The groups identified sub elements of such as structural alignment, horizontal load spreading and vertical load spreading. The latter is a particularly important issue to investigate as benefits of lower load paths and SEAS have been identified in earlier projects and international activities relating to higher vehicles, like SUVs, need to be addressed. To further investigate vertical load spreading, three specific tasks were identified:

1) Report on recent international research related to evaluation and performance of lower load paths and SEAS, specifically how far forward must a structure be positioned so that it can interact with a collision partner
2) Identify what characterises “appropriate” SEAS which provides a benefit in a car-to-car crash
3) Identify potential methods to assess or identify an appropriate SEAS

The benefits of vertical load spreading were identified in the VC-Compat project and confirmed in the FIMCAR car-to-car tests. Details of these tests are presented in the following sections.

4.3.1 Recent International Research

The most significant issue that was discussed during the development of a FW test was the issue of detecting structures behind the bumper cross beam that may not be directly loading a load cell wall early in the impact. Both Japan and the US were reviewing the loading patterns of vehicles on a FWRB to develop compatibility metrics for their full width legislated test. Japan had proposed that the structure of the vehicle should be evaluated before the engine begins loading the LCW. This approach was used in FIMCAR to develop of the FWRB metric (Reported in FIMCAR D3.1Adolph et al. 2012). This limited the evaluation of vehicle structures to the very forward structures and any forward mounted subframe or block beam could not be assessed before motor-LCW contact. The proposal of the Auto Alliance for an Over Ride Barrier (ORB) was made as one method to assess the SEAS of vehicles that are not otherwise detected in a FWRB. The test apparatus is shown in Figure 4.5 and details of the test procedure can be found in the paper of [{Patel 2009 #20}].

Figure 4.5: Example of ORB test configuration [{Patel 2009 #20}].

The importance of the vertical load distribution and its evaluation in a full width test was a critical issue in the WP3 activities in FIMCAR. Concerns were made about the potential to introduce a regulation that would legislate a vehicle type from the market. Vehicles with higher structures, like off road vehicles, could have difficulty meeting a requirement for applying loads into a certain vertical region on the FW barrier. It is undesirable to create a legal requirement that cannot be met by vehicles because they cannot be constructed to meet other requirements without the prove that not meeting the crash test criteria will necessarily result in unsafe cars. Thus the FWRB was seen to need supplemental test information.

The FWDB barrier was part of the WP3 activities and its proponents have claimed that it may be possible to identify lower load paths. JAMA provided test data of a vehicle which has SEAS located 378 mm behind the bumper cover and PEAS that is positioned within the Part 581 zone (Figure 4.6). Although the vehicle met the FWDB metrics, JAMA concluded that the FWDB was not able to measure the loads in the SEAS due to the weak crush strength of the first layer and the SEAS was not able to penetrate into the second, stiffer, layer.

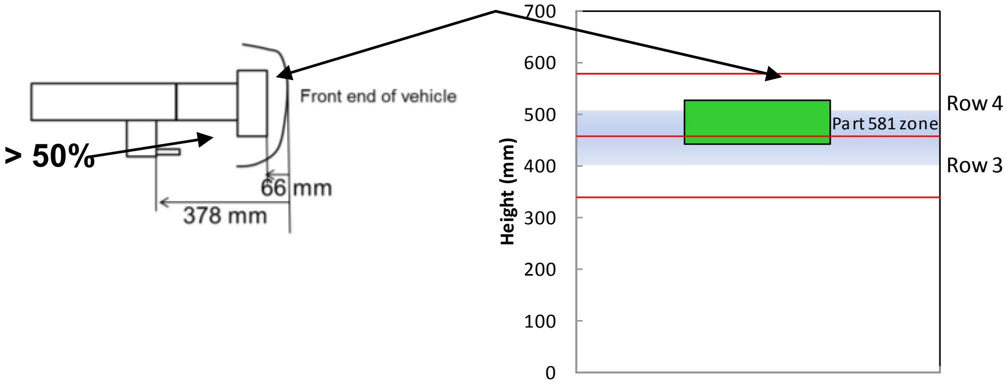


Figure 4.6: Test vehicle geometry of JAMA test.

The issues and activities described above were concerns within the FIMCAR consortium and further investigations of the SEAS and PEAS requirements for higher vehicles were conducted.

4.3.2 Accident Analyses

The real world performance of vehicles with taller structures has been part of many NHTSA projects due to the high proportion of LTV and SUV vehicles in the vehicle fleet. The Average Height of Force (AHOF) metric was developed as a potential compatibility metric to assess compatibility an update of the AHOF investigations is found in Summers et Prasad 2005. This metric has not found international acceptance and has a drawback for assessing lower structures as it assesses the entire loading profile as one force application position and does not treat the front structures separately.

The Alliance of Automotive manufacturers [Auto Alliance 2009] presented a self commitment to LTV and SUV geometry that would be implemented by 2009. Different studies have tracked the performance of vehicles to identify the benefits of the geometric requirements. The two most recent studies were conducted by IIHS [Teoh 2011] and NHTSA [Greenwall 2012]. The studies investigated the fatality risk for passengers of passenger cars struck by LTVs. In both cases the studies showed that late model LTVs that fulfilled the self commitment were performing better than corresponding model vehicles built prior to the commitment. Thus the geometric alignment of PEAS and SEAS with the part 581 zone has had benefits to traffic safety. The more crucial question is the identification of the effectiveness of the type of vehicle designs. Stage 1 vehicles comply by having a significant portion of their PEAS in line with part 581 and thus the main structures of both collision partners are in line. Stage 2 vehicles comply by positioning a lower structure under the PEAS to align in the Part 581 zone. This second option is specified in geometric requirements but has been more difficult to specify in a performance based test. The ORB [Patel 2009] is one proposed method to assess the performance of SEAS.

While both NHTSA and IIHS have identified benefits for passenger car occupants by the introduction of the geometrical alignment of structures, NHTSA has done a more thorough investigation of the different models and method (Stage 1 or Stage 2) of compliance [Greenwall 2012]. Table 6 shows the results from the NHTSA study divided by vehicle type and method of compliance.

Table 6: Effectiveness of vehicles complying to Auto Alliance Self Commitment.

	Number of reviewed models by method of compliance		
Vehicle Type	**PEAS (Stage 1)**	**SEAS (Stage 2)**	**Effectiveness**
Pickup Trucks	0	32	-4.9%
SUVs	24	15	17.5%

Communication with NHTSA indicated that the material did not allow for a separate analysis of Stage 1 or Stage 2 vehicles. It is relevant to point out that the vehicle type most dependent on Stage 2 approval (pickups) has not shown any benefit by complying to the geometric guidelines. Conversely, SUV type vehicles which predominantly have a Stage 1 approach to compliance have shown to be better than their predecessors. NHTSA points out that the benefits to car occupants is not solely due to the compliance of LTVs and SUVs to the self commitment as passenger car self protection has improved over the years and this also contributes to the reduced fatality rates. It is also important to consider that pickups are predominantly body-on-frame structures that are different from uni-body designs found on most SUVs.

The results of the accident analyses indicate that there are benefits to alignment of structures but the role of a SEAS or lower load path set behind the bumper is still not well understood. A test method to identify SEAS that is shown to be effective in car-to-car crashes is a central issue for the full width test to be proposed by FIMCAR.

4.3.3 Crash Tests and Simulation Analyses

The need of a second stage assessment and the appropriate method for evaluating was investigated by a review of previous test and simulation activities as well as new FIMCAR test and simulation results.

The ORB was proposed by industry to complement the full width test and has been evaluated by NHTSA. Patel et al. [Patel 2009] demonstrated with crash tests that vehicles fulfilling the ORB did not necessarily provide benefits in a car-to-car crash. The main reasons that can be identified:

1) The acceptance criteria are too generous. The requirement to meet a force threshold in the first 400 mm of travel can result in significant interaction of a stiff PEAS before any contribution of a SEAS with the collision partner.
2) The force measurement in a rigid load measurement system can overestimate the contribution of structures when a displacement based procedure is used.
3) The test method has no requirement for energy absorption of the structures and thus no demands are placed on the SEAS to maintain the threshold force.

An example of a vehicle with acceptable ORB performance is the GMC Silverado analysed by Patel et al [Patel 2009] and the structure is shown in Figure 4.7. The SEAS are small brackets hanging from the PEAS and fulfil the geometric requirements in the self commitment.

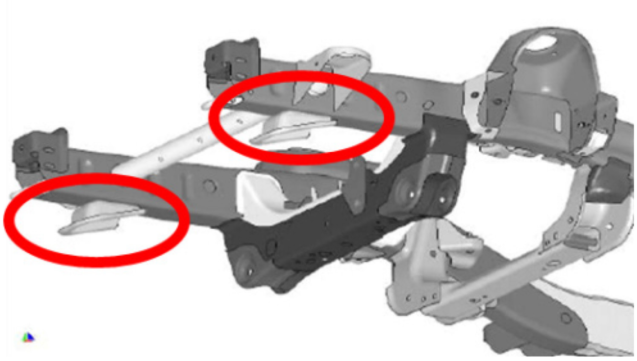


Figure 4.7: Silverado with SEAS structures.

The SEAS on the Silverado was sheared off in the ORB test but met the force requirements during the test period required. Figure 4.8 shows the test data recorded (left) and the vehicle undercarriage with the location of the SEAS bracket after the test (right).

Vehicle-to-vehicle simulations were used to assess the performance of the Silverado with and without its SEAS structure and the results showed negligible contributions of the SEAS configuration installed on the Silverado [{Patel 2009 #20}]. Although the study showed that the ORB also produced positive results for SEAS that made a contribution in a vehicle-to-vehicle crash, the false negative produced by the ORB was a point for concern.

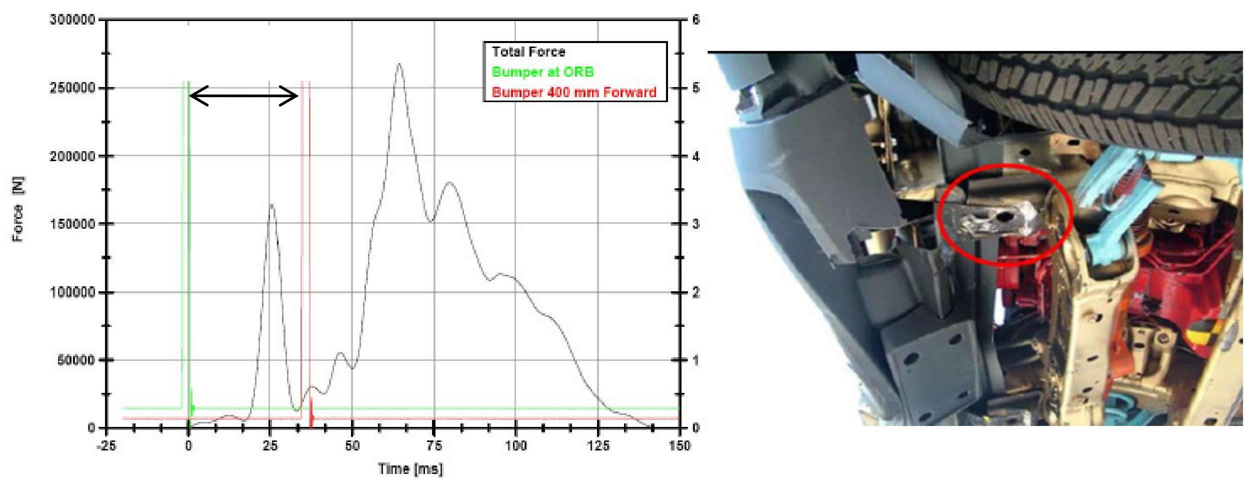


Figure 4.8: Silverado SEAS response in ORB test [Patel 2009].

Since the ORB has been designed predominantly for the large LTVs and SUVs in the US market, further simulations were conducted in FIMCAR to identify the suitability of the ORB for passenger car applications as well as the ability of the FWDB to detect SEAS. Car-to-car simulations were also explored to understand the ability of different sub-frame combinations to contribute to crash performance.

4.3.3.1 **FIMCAR Simulations with PCM Models**

Vertical load spreading and effective SEAS/lower load path structures were the focus of a FIMCAR WP6 request to WP5 to conduct computer simulations. The Parametric Car Models developed by TUB [Stein 2013/2] were used to investigate different car designs as shown in Figure 4.9. The subframe set back distance was positioned in 6 different positions (200 – 400 mm behind the bumper) to determine when the subframe is detected by the ORB. The models were then impacted against reference PCM models to identify the influence of the different subframe designs. The models were also simulated with impacts into the FWDB barrier to assess if the different subframe configurations were detected by the metric.

The PCM models were able to satisfy the ORB tests except for the case when the subframe was 400 mm behind the bumper. This was expected as the subframe must contact the ORB and deform before it can exert the 100 kN required. See Figure 4.10 where a successful test requires the curve to pass through the shaded area.

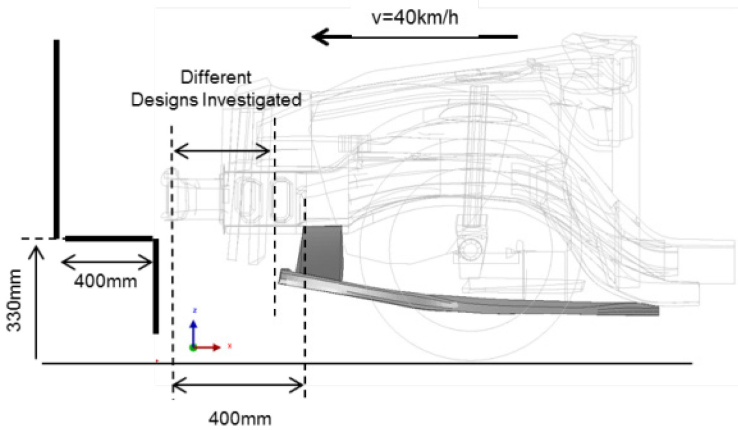


Figure 4.9: PCM model configuration with ORB.

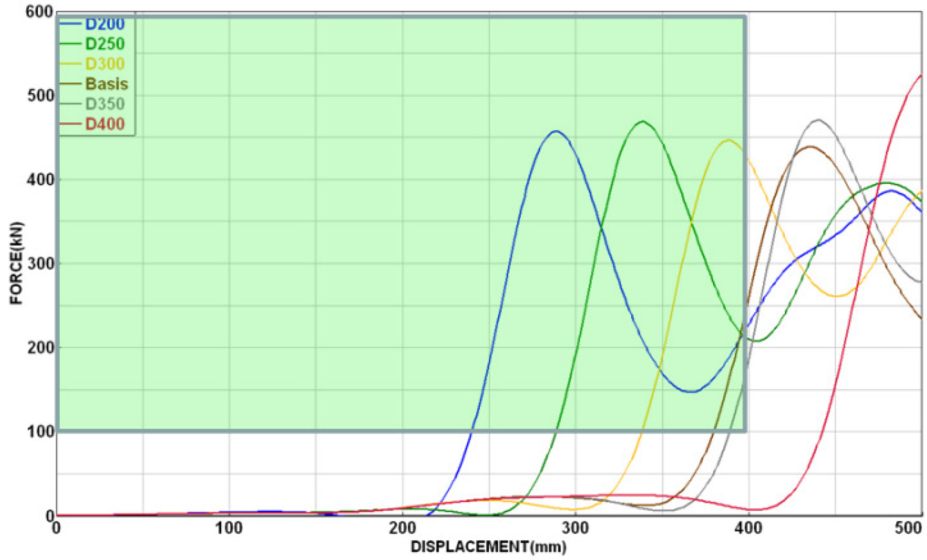
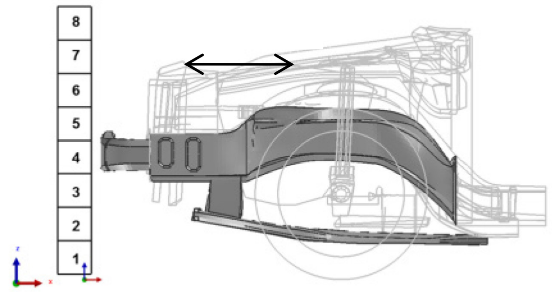


Figure 4.10: Force / PEAS displacement recorded for PCM models for ORB.

For the FWDB simulations, the vehicle was shifted vertically so that it would resemble a higher LTV or SUV (Figure 4.11, left). In all cases the lower load path was unable to create sufficient loads on the LCW so that the FWDB metric would be met. The row loads shown in Figure 4.11 show how little force is applied in Row 3.



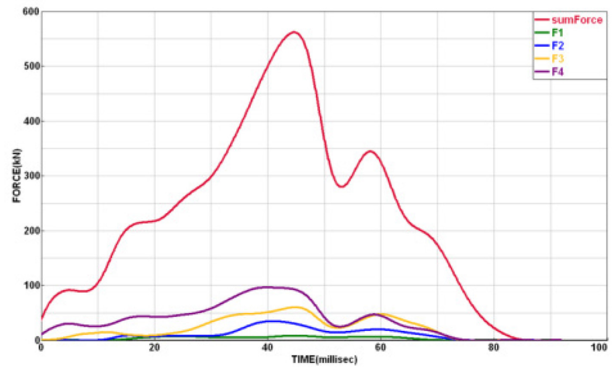


Figure 4.11: FWDB simulation configuration and sample results.

In a second series of simulations, the vehicle structure was adjusted so that the vertical connection between the PEAS and SEAS was moved forward (Option 1) and the subframe cross beam section height was also increased (Option 2) to create a larger contact surface on the deformable barrier (Figure 4.12). Even after the adjustments, the vehicle was not able to meet the FWDB criteria although there were improvements in the loads recorded on the LCW. Figure 4.13 shows the LCW results and there are noticeable improvements in Rows 2 & 3 (lower 2 curves) due to the subframe modification.

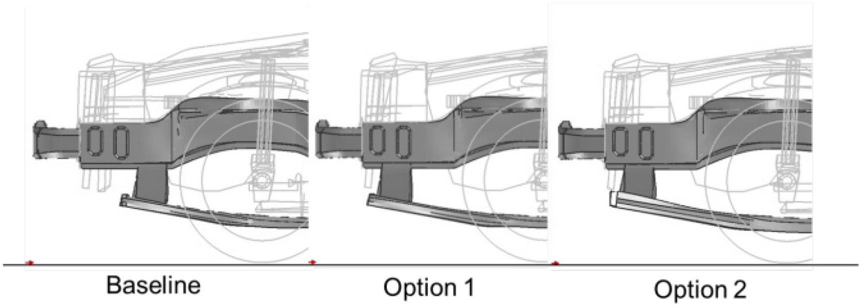


Figure 4.12: Subframes in second simulation series.

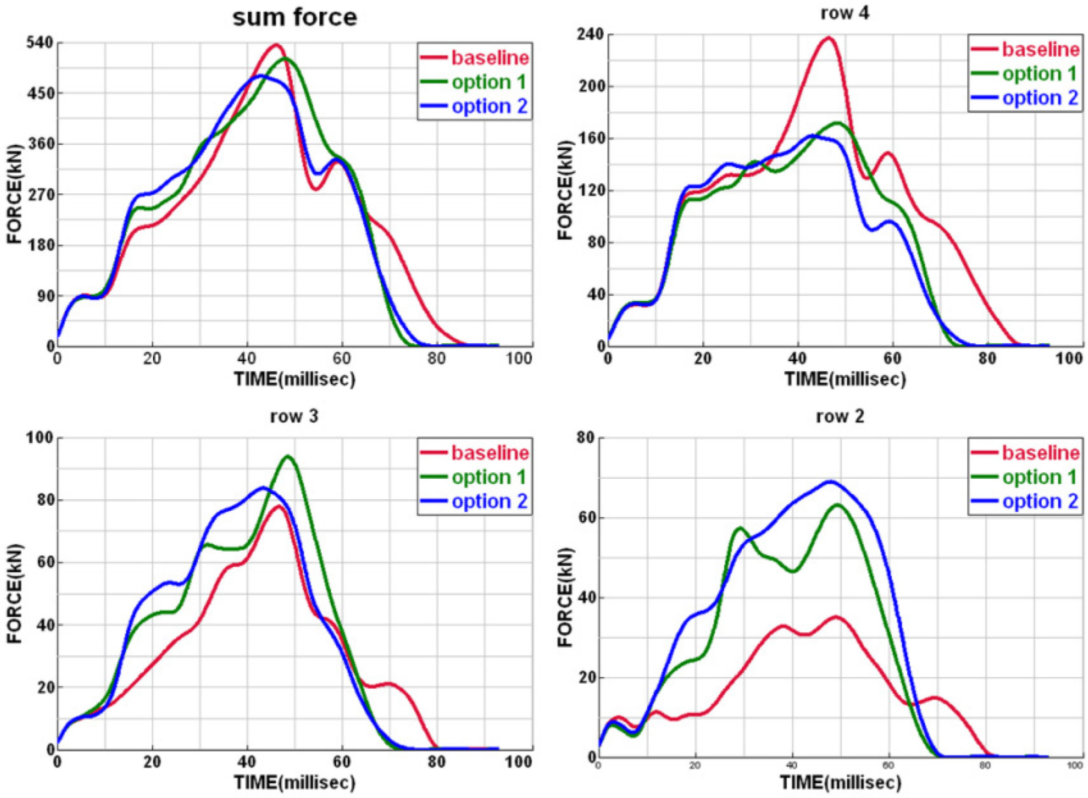


Figure 4.13: FWDB results in second series of PCM modifications.

The summary of the FWDB load cell loads processed for the proposed metric are presented in Table 7. In all cases the Row 3 loads are below 100 kN and the Row 2 loads never exceed the 70 kN needed to achieve a Limit Reduction in Row 3.

The PCM simulations for barrier impacts needed to be compared to simulations of the same vehicles impacting other vehicle models to evaluate the performance of the subframe configurations under car-car conditions. No occupants and restraint systems were modelled so only compartment intrusions and accelerations were used to compare the different simulations results. In all cases the PCMs with different subframes were positioned to be higher than the collision partner to evaluate the effectiveness of the lower load paths.

Table 7: Calculation of FWDB metric for PCM simulations in second simulation series.

Limit Reduction Metric			
	Misaligned (aligned row 4)	**Option 1** (subframe and vertical connection far forward)	**Option 2** (subframe cross section increased and vertical connection far forward)
F_{sum} [kN]	458	427	467
F_4 [kN]	190	146	155
F_3 [kN]	61	66	81
$F_3 + F_4$ [kN]	251	212	236
$0.4F_{sum\_@\_40ms}$ [kN]	183,2	170,8	186,8
$0.2F_{sum\_@\_40ms}$ [kN]	91,6	85,4	93,4
F_2 [kN]	32	46	63
LR [kN]	(-38 → 0)	(-24 → 0)	(-7 → 0)
	fail	fail	fail

The results of the first car-to-car series with the PCM investigated the reference PCM (a Large Family Car – LFC) impacts with a smaller Super Mini (SM) and a heavier Executive (Exe) car. When the intrusions were compared, no benefit for the different subframe designs could be observed. It was observed that the small section of the subframe cross beam and the rearward position of the vertical connection would allow a vertical fork effect to occur and reduce the interaction of the subframes with the partner vehicle's structures. When the second series (with better subframe designs) were analysed (see Table 7), there were improvements in the case of Option 2 compared to the baseline case (unmodified LFC against itself as shown in the lower part of the table).

Table 8: PCM car-to-car simulation results.

	Baseline	Modified car
Baseline - Misaligned	-125mm	-220mm
Baseline - Option 2	-98mm	-122mm
Reference	Baseline	Baseline
Baseline - Baseline	-163mm	-167mm

An earlier interaction of the vehicles could be observed in the acceleration vs. displacement plots presented in Figure 4.14. The red curves (with option 2) show earlier interactions than the standard vehicle accelerations (blue).

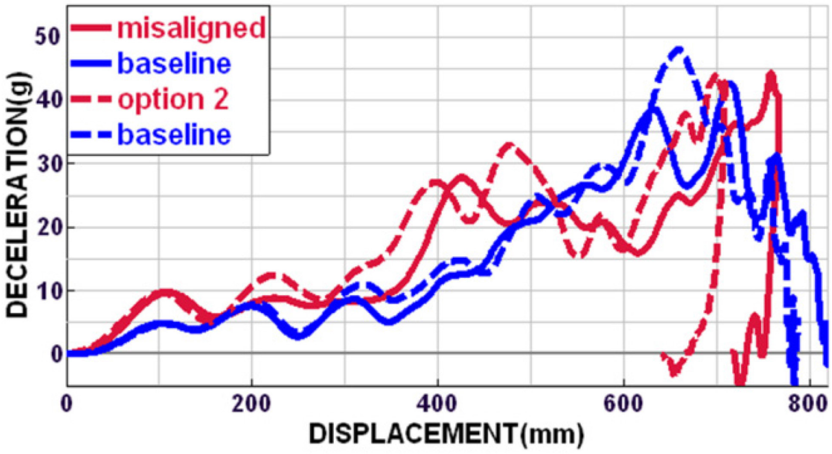


Figure 4.14: PCM simulations of reference case and best subframe configuration.

The PCM simulations should be reviewed as there is a significant simplification made when the vehicle structure was modified. Subframe geometry was modified only without balancing of the upper and lower load path stiffness's. The original PCM model was designed to have acceptable scores in the offset and full width test conditions but no optimisation of the baseline or modified vehicles were conducted. Better FWDB results would be expected in the modified cases if a more extensive engineering analysis was conducted.

As a result of the PCM simulations, the values for the Limit Reduction (LR) and allowable adjustment of Row 3 loads was reviewed. As seen in Table 7, the Row 3 loads were at 80 kN and Row 2 loads were nearing 70 kN. The limit reduction proposed earlier in this chapter was based on the test data that suggested that crash structures tended to produce more than 70 kN on a row. Given that the vertical fork effect was observed in the simulations and that 70 kN row loads were produced by vehicle structures that were giving positive results in car-to-car impacts, it was proposed that the limit reduction in Row 3 should not result in measured Row 3 loads being under 70 kN. These values are based on 56 km/h FWDB tests.

4.3.3.2 **Car-to-Car Simulations with other Vehicle Models**

Chalmers and VTI researchers had conducted an earlier study on the effect of subframe on car-to-car impacts [Park 2009, Thomson 2008]. These simulations indicated how modifications of the public FE model of a Ford Taurus affected the crash response. As part of WP6 request to WP5, the Taurus models were simulated in a FWDB impact by TUB so that the FWDB metrics could be correlated to the car-to-car crash performance. The subframe configurations investigated are shown in Figure 4.15.

The results of the car-to-car simulations were presented in [Park 2009, Thomson 2008] and are summarised in Table 9. What is significant to note is that the extended Subframe tended to improve the vehicle performance and the shortened Subframe tended to decrease the performance compared to the baseline vehicle. As seen in Figure 4.15, the basic subframe is more than 300 mm behind the bumper and the shortened Subframe is more than 400 mm.

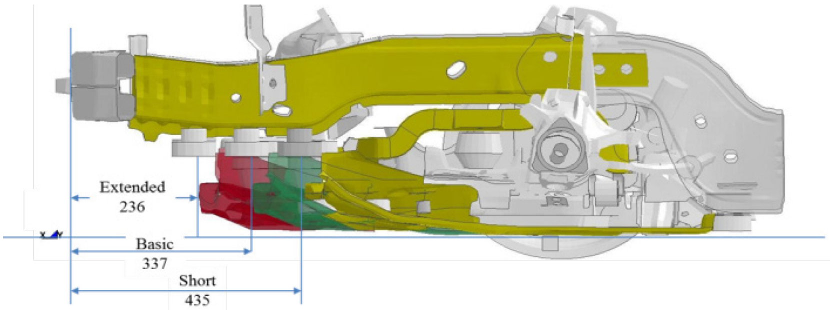


Figure 4.15: Variations of Ford Taurus subframe.

Table 9: Car-to-car of different Taurus subframes (O: Good, Δ: No better and X: Poor) [Thomson 2008].

	Cases		Difference[1] (mm) in		Vehicle [1,2]		Compatibility Performance[3]
	Horizontal Overlap	Vertical Overlap	AHOF	AHOF400	Self Protection	Partner Protection	
B2E	100%	100%	-17	-64	Δ	O	O
	60%				X	O	X
	40%				X	O	X
	100%	25%	88	41	Δ	Δ	Δ
	60%				X	O	X
	40%				X	X	X
E2B	100%	25%	122	169	Δ	X	X
	60%				O	O	O
	40%				O	O	O
B2S	100%	100%	56	25	Δ	X	X
	60%				X	X	X
	40%				Δ	X	X
	100%	25%	161	130	O	X	X
	60%				X	Δ	X
	40%				O	X	X
S2B	100%	25%	49	80	Δ	O	O
	60%				X	O	X
	40%				Δ	Δ	Δ

1. Difference is given by subtracting AHOF or AHOF400 of vehicle 1 from one of vehicle 2.
2. Self- and partner-protection of vehicle 2 is opposite of vehicle 1.
3. The results are compared with B2B under same C2C test condition.

The simulations with the FWDB show that the shortest subframe has essentially no contact with the deformable barrier at the 40 ms reference time. Figure 4.16 shows that both the basic and extended subframes are well into the first layer while the short subframe (bottom) is just starting to contact the barrier.

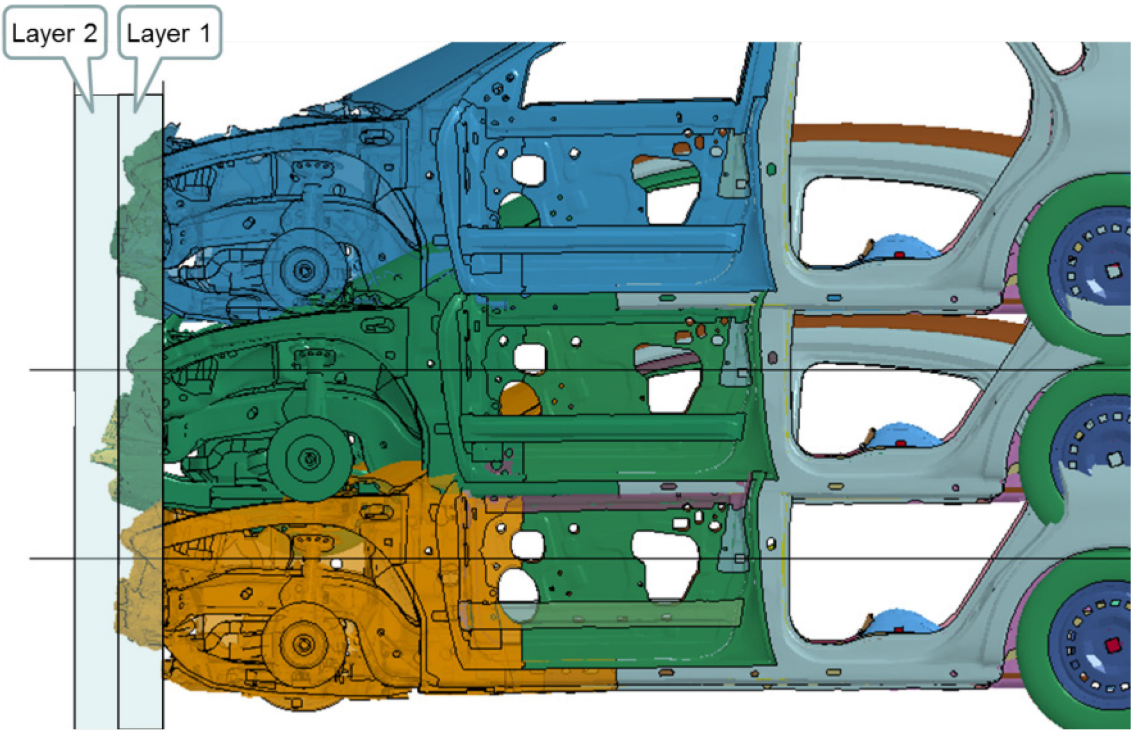


Figure 4.16: Vehicle/barrier reference dimensions at 40ms.

The FWDB tests were simulated with the Taurus in its raised conditions. The car-to-car simulations were conducted with the Taurus having a vertical offset of 25% - 25% of the vertical section height of the longitudinals were in contact. The row loads calculated for the cases are shown in Figure 4.17. All three cases meet the FWDB metric. It can be seen that the shortened subframe case just meets the 100 kN in Row 3. The raised Taurus still has some of its PEAS extending into Row 3 and this is enough to load this area of the barrier sufficiently for a positive evaluation. The Row 2 loads show significant differences for the different cases.

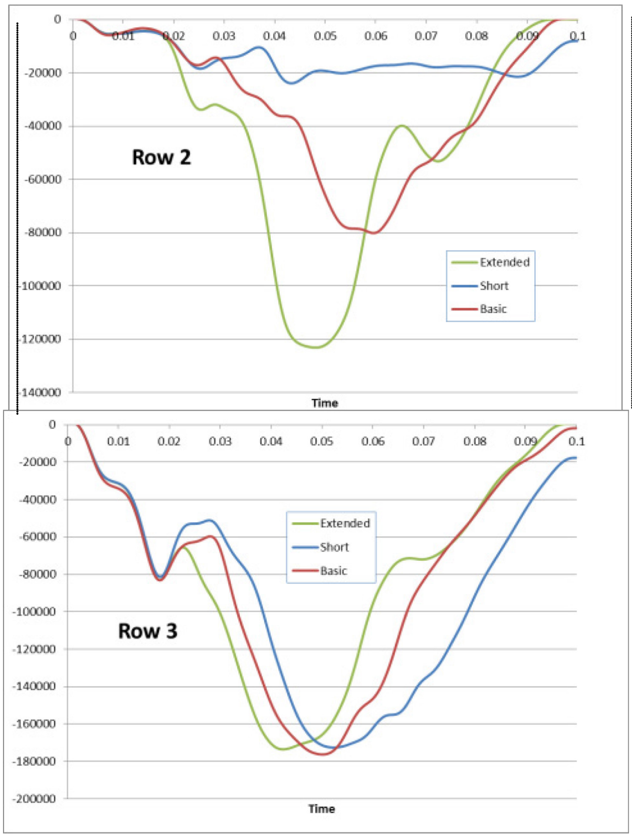


Figure 4.17: Row loads in FWDB tests with Taurus.

The results of the Taurus simulations showed that vehicles barely meeting the FWDB metric had poorer performance than those with higher loads in Row 3 and 4. The results also showed that vehicles producing Row 2 loads over 80 kN were better than those with only 40 kN. The barrier was starting to detect subframes 337 mm behind the bumper crossbeam and it was this region 300 to 400 mm that subframes could be seen to introduce differences in car-to-car crash performance.

4.3.3.3 **Other Test and Simulation Results in FIMCAR**

The influence of vertical load spreading can be inferred from the car-to-car test and simulation activities in WP6. FIMCAR Deliverable D6.1 [Sandqvist 2013] describes the results of different vehicle configurations. The results showed that the vehicles with lower load paths, i.e. better vertical load spreading, performed better than single load path vehicles. It was also shown that cases where SUV 1, in both its standard or lowered, ride height produced reasonable compatibility results in striking a smaller passenger car due to its well designed lower structures. Section III shows that the results tended to be better when the structures are aligned, but even the misaligned case could have acceptable structural interaction. This can be related to the ability of SUV 1 to produce acceptable FWDB results in its standard ride height.

A simulation and side impact study was conducted with a crossover SUV 3 and its sister vehicle in a sedan configuration. The SUV was fitted with a lower load path that could be removed for simulation and test purposed. The side impact tests are reported in Section III and showed that vertical load spreading was desirable for side impact configurations. The complementary frontal impact investigation of the SUV 3 had similar results as for SUV 1.

4.3.4 Summary for Vertical Load Spreading

The tests and simulations conducted in FIMCAR indicate that structural alignment is a high priority for frontal impact and compatibility and that vertical load spreading is an important supporting characteristic. In all cases, vehicles with vertical load spreading can be detected with the FWDB if the structures are less than 400 mm behind the bumper. Lower load paths that are detected in a FWDB by exerting more than 70 kN (in the 56 km/h test case) show a benefit for car-to-car crash performance. An FWDB metric that rewards vehicles with 70 kN in Rows 2&3 would be beneficial for vehicle safety.

4.4 Horizontal Load Spreading

4.4.1.1 **Background**

The FIMCAR project produced a list of assessment requirements and priorities which ranked load spreading as a top priority [Thomson 2013]. After the review of the candidate test procedures, the FIMCAR consortium decided to proceed with the combined FWDB and ODB tests as the best assessment approach based on the current state of the art [Thomson 2013]. Vertical load spreading is addressed in the FWDB metrics, but horizontal load spreading was not addressed in any of the final test procedures. The exclusion of the (M)PDB test in the matrix reduced the potential to assess horizontal load spreading, so FIMCAR investigated a Horizontal Load Spreading assessment using the FWDB test to increase benefit of the new test procedures

4.4.1.2 **Review of Previous Work**

Horizontal load spreading with the FWDB has been investigated in earlier projects and resulted in 3 different versions:

- **a)** Part of a global homogeneity metric “Column Homogeneity” (Hc) (beginning of VC-Compat)
- **b)** Separate “Horizontal Negative Deviation” metric (during VC-Compat)
- **c)** Horizontal Structural Interaction (HSI) metric (VC-Compat & Aprosys)

The common problems/concerns with a) and b) were that they are based on peak loads in each load cell which may occur at different times in the event and may not be physically realistic. The metrics did not show consistent results with a series of Rover 75 tests with modified bumper stiffness’s. The main issues for c) were poor repeatability observed in some APROSYS tests, no clear threshold for performance limits, and the assessment itself was seen as too complex.

4.4.1.3 **FIMCAR Approach**

A prerequisite for a horizontal load spreading metric is that the metric for an FWDB test should reflect car-to-car crash performance. The bumper beam characteristics of 3 different cars were defined based on car-to-car testing:

- VW Touareg: Stiff and narrow cross beam (Figure 4.18)
- VW Golf: Golf stiff crossbeam (Figure 4.19)
- Opel Astra: Weak crossbeam (Figure 4.20)

Figure 4.18: Front Structure of VW Touareg, left: VW Touareg versus Golf, right: VW Touareg vs. Opel Astra.

Figure 4.19: Front Structure of VW Golf, left: VW Golf versus Touareg, right: VW Golf vs. Volvo XC 90.

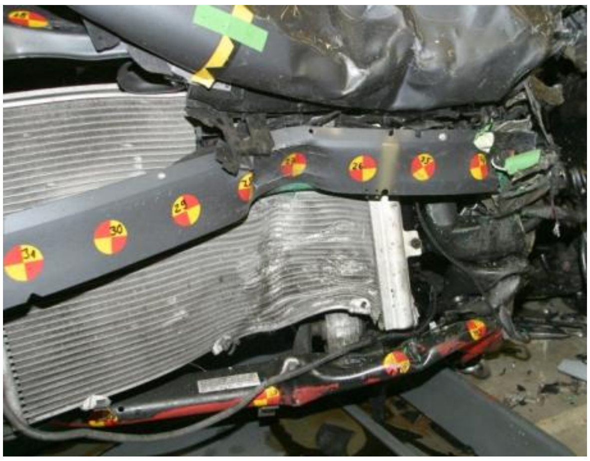


Figure 4.20 Front Structure of Opel Astra after crash test versus VW Touareg.

The bumper beam characteristics observed in car-to-car testing can also be confirmed by the footprint produced by the bumper beam in the barrier of the PDB 50% test (Figure 4.21).

Figure 4.21: PDB barriers after crash tests; Left: VW Touareg, Middle: VW Golf, Right: Opel Astra.

FWDB Testing

The results from the FWDB test of the above mentioned cars were analysed with respect to horizontal load spreading assessment. The analysis was done both by using the LCW visualization tool in the FIMCAR database and by looking at the peak forces for each column in Row 3 and 4 of the Load Cell Wall. Both analyses were done up to 40 ms (before the engine starts to load the barrier). As can be seen in Figure 4.22, the method to summarise the peak forces for each column in Row 3 and 4 does not at reflect all the result from the car-to-car testing. The VW Touareg appears to have a very weak cross beam relatively to the force from the longitudinal side members. Furthermore, the method does not seem to clearly distinguish the difference in bumper characteristics between VW Golf and Opel Astra, which, when reviewing Figure 4.22, look relatively similar even though they have different car-to-car performance.

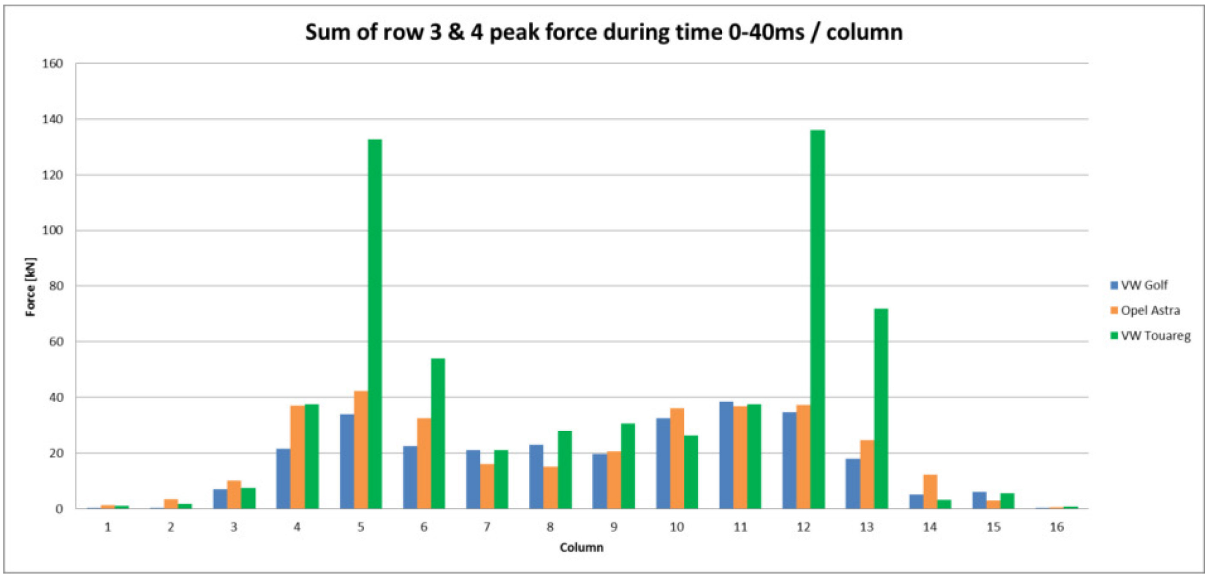


Figure 4.22: Sum of row 3 & 4 peak force during time 0-40ms / column.

By using the LCW visualization tool in the FIMCAR database, force distribution plots like Figure 4.23, Figure 4.24 and Figure 4.25 can be produced. For the VW Touareg (Figure 4.23) it is obvious that the car-to-car characteristics are not reflected in this plot and even looks more like the opposite case, the beam is very weak relative to the longitudinal side members. There is a possibility to distinguish between the bumper characteristics of the VW Golf and Opel Astra, but this approach does not discriminate between the cases as well as desired.

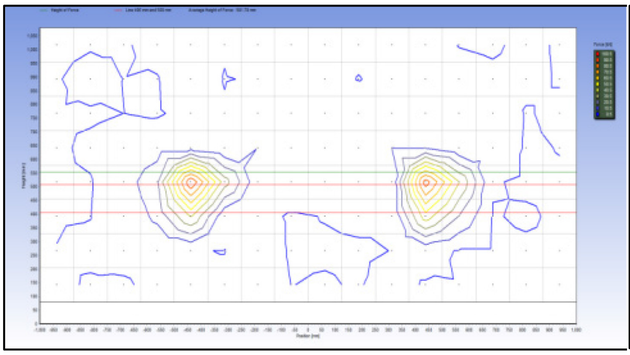


Figure 4.23: VW Touareg.

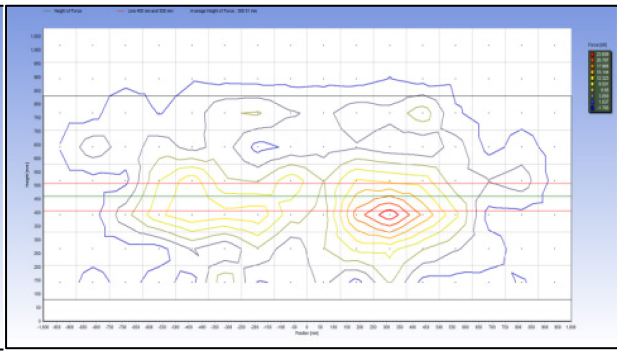


Figure 4.24: VW Golf.

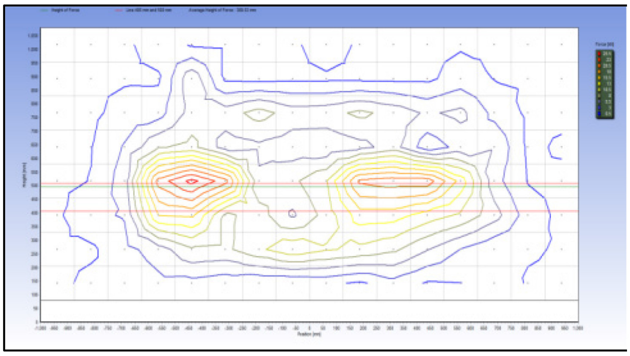


Figure 4.25: Opel Astra.

4.4.1.4 **Summary**

The FIMCAR approach to assess horizontal load spreading in the FWDB test started with two relatively simple methods to study the potential for a horizontal load spreading metric. These two methods clearly show that the potential is very low to comply with the prerequisite that the metric should reflect the characteristics proved in car-to-car testing. The results for the VW Touareg were, in particular, contradictory to what was observed in both car-to-car and PDB tests to such an extent that further attempts to develop a metric were considered pointless. It was decided to not attempt any further development of a horizontal load spreading metric for the FWDB within the FIMCAR project.

5 DEVELOPMENT OF LOAD CELL WALL CERTIFICATION AND CALIBRATION PROCEDURE

The use of an LCW for the assessment of cars requires a well defined and agreed LCW Certification procedure suitable for inclusion in regulation.

The proposed procedure was developed by Humanetics with support from other FIMCAR partners and Kistler (in this chapter referred to partners). This report presents the activities done and resulting documents.

5.1 Approach and Reference to Contents in the Report

Possible approaches for the certification of assembled walls were discussed with FIMCAR partners. Using the expertise from partner's options like wall flatness measurements, dynamic impact test using trolley with well defined impact area, load cell static calibration and load cell dynamic calibration were evaluated. Regarding the certification of installed walls it was decided to only have requirements on wall flatness included. Other options like full scale trolley tests with well defined loading surfaces are too expensive and include inaccuracies like orthogonality to the wall. In addition to the wall certification the need of a load cell specification and calibration section in the protocol was forwarded by the partners. Here options of static and dynamic calibration were discussed. As currently no proven methods exist for calibration under dynamic loading conditions it was decided to stick to static methods. Static calibration is also applied in load cell calibrations used in other tools used in the crash safety assessment of cars like Anthropomorphic Test Devices (ATD's).

5.1.1 Static Calibration of Load Cells

Static calibration is currently done for all LCW's in Europe using specifications as set by the LCW manufacturers. However, for usage in test protocols load cell specifications and performance limits are needed. Also a calibration procedure is required that includes information on items like hysteresis and non-linearity. In discussions with partners it was decided to generate a Load Cell Specification and Calibration document based on the following documents:

- SAE J2570: Performance Specifications for Anthropomorphic Test Device Transducers [SAE 2001]
- ISO 6487: Measurement techniques in impact tests – Instrumentation [ISO 2012]
- SAE J211: Instrumentation for Impact Test, Rev. 07/2007 [SAE 2007]
- DIN EN ISO 376 [DIN 2011]

Using the references mentioned above specifications and a calibration protocol were defined for the load cells. Parameter values were set based on needs for the FIMCAR metrics and manufacturers specifications of existing walls. The protocol is included in Annex A of this document.

After establishing a draft version of the protocol it was applied to a series of load cells from FIMCAR partners. Calibrations were performed to check and refine values for parameters like hysteresis and non linearity. Chapter 5.3 of this report describes the load cell calibrations done and the resulting parameter values. Final values are included in the protocol of Annex A.

5.1.2 Load Cell Wall Flatness

The wall flatness is mainly (or even only) an issue in case a barrier with deformable element is used in front of the LCW. The barrier is backed by a plate of about 2 mm thickness which spreads the loads between cells which are not aligned. Although non-alignment of cell faces can (at least partially) be compensated by adjusting the protective layers it was decided to collect flatness data from a number of existing walls and based on this define requirements for this parameter.

To define requirements for the wall flatness measurements were done on three different LCW's. Cell locations in 3-D space were measured using FARO arms. Data were then processed to reveal information on flatness of existing walls. For one of the walls the flatness information was compared against results from trolley tests with a flat impacting surface. Peak loads and loading histories were correlated with cell positions in depth direction. Results of the wall flatness analysis are included in chapter 5.4.

The resulting values for the wall flatness were used to define a LCW certification procedure as included in Annex B. Other requirements like cell size, ground clearance, cell numbering are straightforward and did not need any further investigations.

5.2 Static Load Cell Testing

To confirm parameters proposed for the Specification and Calibration document load cells available from FIMCAR partners were calibrated according to the procedures and output generated for sensitivity, non linearity and hysteresis. This chapter describes the test set-up, analysis methods and test results.

5.2.1 Test Set-Up

The load cell tests were performed on a calibrated INSTRON machine shown in Figure 5.1.

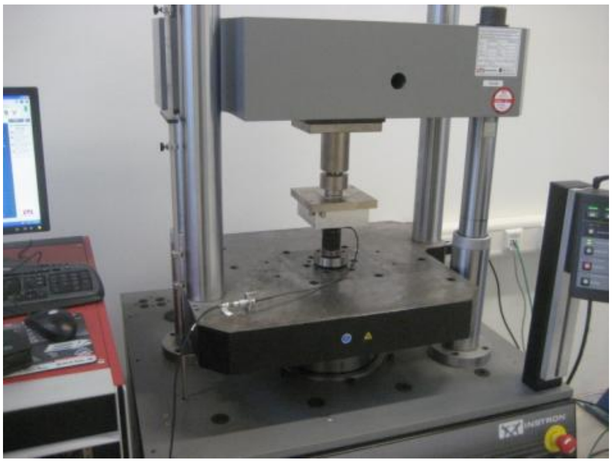


Figure 5.1: Load cell test in INSTRON machine.

The following loading sequence was applied to each cell (see Figure 5.2):

1. Three preloads up to 200 kN
2. Loading up to 200 kN increasing the load from 0 to maximum value in five steps. After each step some time to achieve stable equilibrium of the applied load level was considered. In the sequel this loading type is referred to as stable load condition.
3. Loading up to 200 kN with a continuous dynamic loop directly followed by unloading. This loading type is referred to as dynamic loop condition.

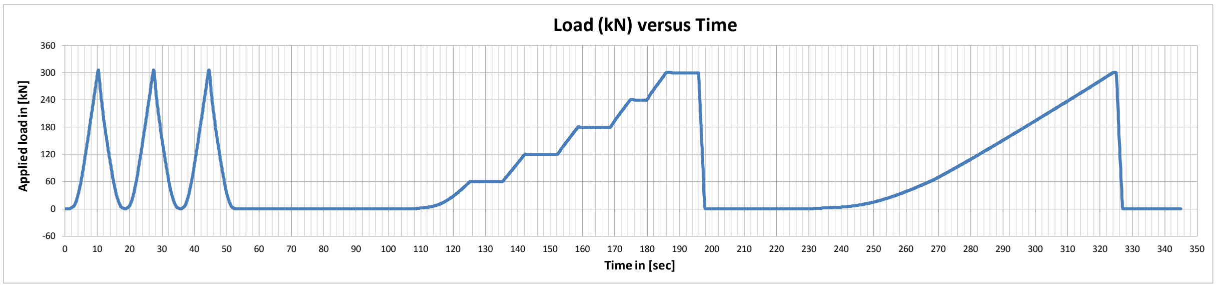


Figure 5.2: General loading sequence.

A total number of 10 load cells were subjected to the loading described above. The cells were provided by FIMCAR partners IDIADA (1 cell), BASt (2 cells), TRL (5 cells). In addition Kyowa provided 3 cells. One of the TRL cells was tested with and without protective layer.

5.2.2 Data Analysis

Through the analysis of the test data information can be obtained on the sensitivity, the non-linearity and the hysteresis. See Figure 5.3 for the definitions of these parameters. In the next sections these analyses are explained in more detail.

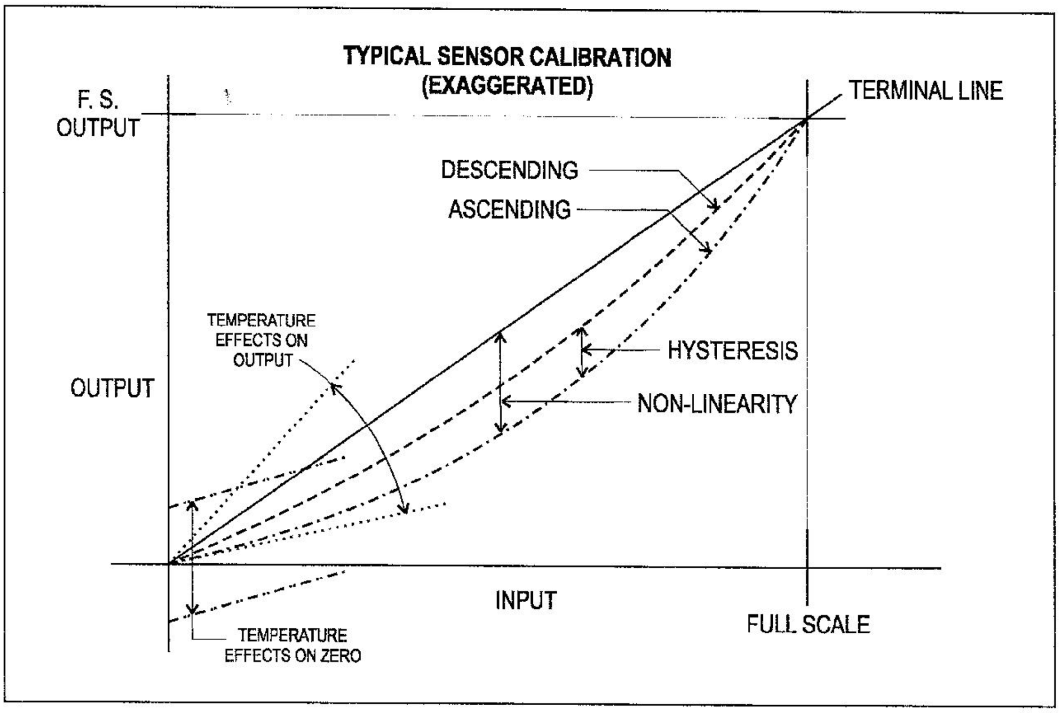


Figure 5.3: Analysis definitions according SAE J2570 standard.

5.2.2.1 **Load Cell Sensitivity**

The load cell sensitivity is defined as the output in mV/V at maximum load (full scale load level). This can be established from the stable load and the dynamic loop conditions. Hysteresis effects may cause that the sensitivity value is slight lower for the stable loop condition.

Stable load condition

At the maximum load level (step five in the stable load application) the average applied load and average load cell signal is calculated over two seconds of stable load (~20 samples). The output at maximum load level is calculated assuming a linear relation between load and output. See for example time window from 192 to 194 seconds in Figure 5.4 below:

- The measured average applied load is 299.998854 kN
- Average load cell output -1.356250 mV/V
- Resulting sensitivity at maximum load (300 kN) = 300 / 299.998854 * -1.356250 = -1.356255 mV/300 kN/V.

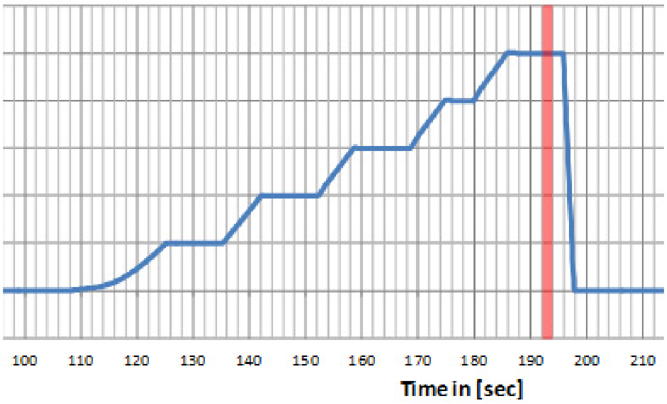


Figure 5.4: Time window of 2 seconds at full scale load level.

Dynamic loop condition

In this loading condition two data points close to the full scale load level in the loading curve of the continuous dynamic loop are taken and extrapolated to the full scale load level. See for example Figure 5.5:

- Data point 1: Applied load 297.159183 kN, Measured output -1.346150 mV/V
- Data point 2: Applied load 299.474072 kN, Measured output -1.356280 mV/V
- Sensitivity at 100 % Full Scale load level (300 kN) is -1.358581 mV/300 kN/V (extrapolated)

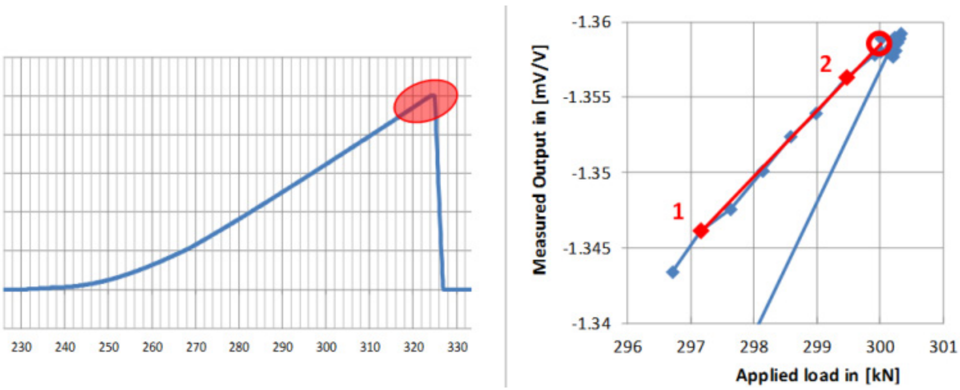


Figure 5.5: Extrapolation of measured data close to the full scale load level in the dynamic loop.

5.2.2.2 Non Linearity

The load cell non linearity as depicted in Figure 5.3 can be established in the stable load and the dynamic loop conditions. Also for this parameter hysteresis effects may introduce small differences between both loading conditions. For the non linearity the deviations of the output at 0%, 20%, 40%, 60% and 80% full scale load level is established with respect to a straight line (the so called “Terminal line”) through zero load zero output and the output at maximum load level.

Stable load condition

a. At 0%, 20%, 40%, 60%, 80% and 100% full scale load level the average applied load and average load cell signal is calculated over two seconds of stable load (about 20 samples) (see Figure 5.6).
b. These average stable load output results are scaled to the nominal values using the two adjacent average results.
c. The terminal line is the line through zero load zero output and the output at full scale load level (sensitivity)
d. At each load level is the deviation of the average stable load output results at nominal load with respect to the terminal line divided by the output at full scale load level is calculated.
e. The non linearity is the maximum deviation from the terminal line divided by output at full scale load level

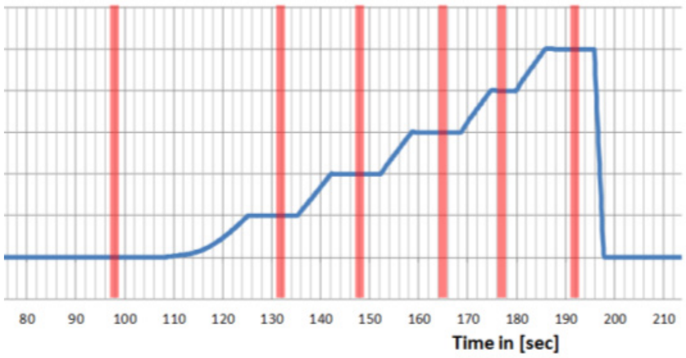


Figure 5.6: Time windows of 2 seconds at zero and 20%, 40%, 60%, 80%and 100% full scale load level.

Dynamic loop condition

See (Figure 5.7):

a. The terminal line is the line through zero load zero output and the output at full scale load level (sensitivity)
b. At each data point the deviation of the output results with respect to the terminal line divided by the output at full scale load level is calculated.
c. To stabilize the deviation the average over 40 samples is calculated
d. At 0%, 20%, 40%, 60%, 80% and 100% full scale load level the deviation is read from the averaged deviation.
e. The non linearity is the maximum deviation from the terminal line divided by output at full scale load level determined at 0%, 20%, 40%, 60%, 80% and 100% full scale load level

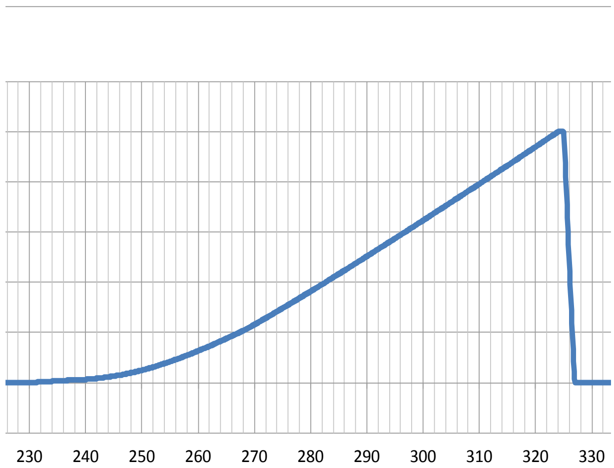


Figure 5.7: Dynamic loop signal.

5.2.2.3 **Hysteresis**

For the hysteresis the deviations of the output at 0%, 20%, 40%, 60% and 80% full scale load level between the loading and the unloading curve is established as depicted in Figure 5.3. The deviation is expressed in percentages of the output at maximum load level. This is analysis in the dynamic loop test conditions (see Figure 5.8).

a. All data points on the loading and the unloading curve are selected separately.
b. Fourth order polynomial trend line approximations of the data point on the loading and unloading curve are made separately.
c. At 0%, 20%, 40%, 60% and 80% full scale load level the deviation between both polynomial lines as calculated and divided by output at full scale load level.
d. The hysteresis is the maximum deviation between loading line and unloading polynominal approximation divided by output at full scale load level

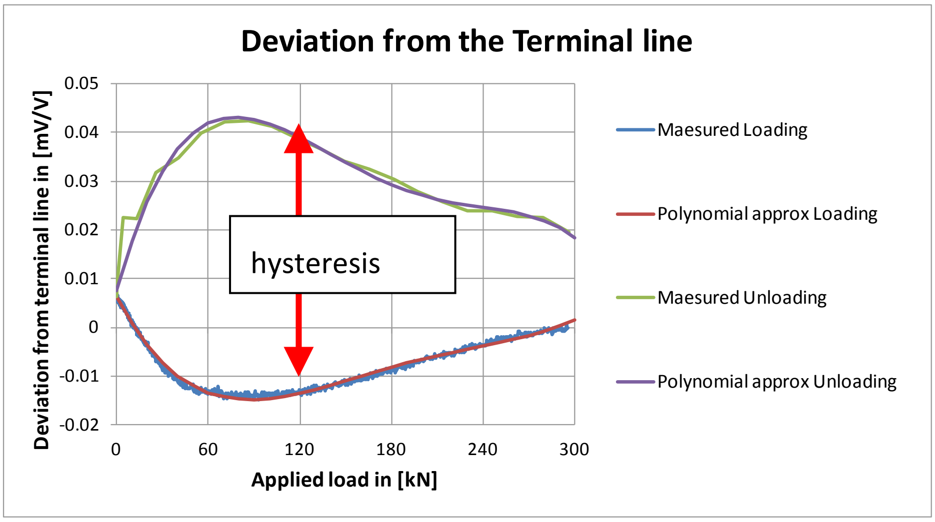


Figure 5.8: Deviation from terminal line of loading and unloading curve Measured and polynomial approximation.

5.2.3 Results

Table 10 below shows results for all load cells tested. It can be seen that the non linearity achieved over these cells is generally less than 1% as previously proposed. This value is therefore considered as achievable and included. The hysteresis however appears to be larger than the originally proposed 1%. Except for the BASt cells (in house manufactured cells) most load cells seem to be capable of reaching a hysteresis of 2%. This value is adopted in the protocol of Annex A.

Note that tests on two cells from the TRL wall were repeated. Cell unit number 912042 showed a high hysteresis value in the first test. To confirm this result test were repeated confirming the outcome. As further check the test on cell unit number 912091 was repeated to see if repeated measurements show different results. Again identical results as for the first test were found.

Finally one of the cells from TRL was tested with protective wooden layer. In this test local denting of the layer did occur directly underneath the stamp. It concerns localised deformation occurring due to the high differences in stiffness of the wooden layer and the cell itself. It is therefore recommended not to test cells including the wooden layer.

Due to the fact that no fixtures were available for cross talk and offset loading testing on the BASt and Kyowa cells these parameters were not investigated in the current study. Calibration data from load cells available from Humanetics indicate that values of about 1% are reached (both for transverse and vertical loadings). On this basis the cross talk value was set at 3% for the time being. Other parameters related to offset loading and free air resonance are to be set in future studies as indicated in Annex A.

Table 10 Sensitivity, non linearity and hysteresis of load cells tested in FIMCAR

Load Cell			**Stable load method**			**Dynamic loop method**			**Hysteresis**
									Dynamic
		Full Scale	Sensitivity		NonLinearity	Sensitivity		NonLinearity	Hysteresis
	unit	kN	mV/V @FS	mV/V/kN	max in %FS	mV/V @FS	mV/V/kN	max in %FS	max in %FS
	Draft requirement				< 1.0%			< 1.0%	< 1.0%
Kyowa	398390137	300	0.850537	0.002835	0.79	0.850848	0.002836	0.78	1.81
Kyowa	398390140	300	0.853035	0.002843	0.80	0.853620	0.002845	0.74	1.65
Kyowa	398390141	300	0.853811	0.002846	0.75	0.855314	0.002851	0.68	1.74
IDIADA	0216618	300	0.706995	0.002357	0.92	0.707790	0.002359	0.72	1.69
TRL	912009	300	-1.378615	-0.004595	0.55	-1.380067	-0.004600	0.24	1.78
TRL	912042 NW	300	*-1.356255*	*-0.004521*	*1.30*	*-1.358581*	*-0.004529*	*0.97*	*4.07*
TRL	912042 NW (2)	300	*-1.355427*	*-0.004518*	*1.36*	*-1.358709*	*-0.004529*	*1.04*	*4.19*
TRL	912091	300	-1.372614	-0.004575	0.54	-1.373373	-0.004578	0.26	1.90
TRL	912091 (2)	300	-1.368753	-0.004563	0.51	-1.368557	-0.004562	0.28	1.88
TRL	912107	300	-1.384856	-0.004616	0.72	-1.385876	-0.004620	0.79	1.78
BASt	AC-H36	50	0.670842	0.013417	0.98	0.672719	0.013454	0.93	8.55
BASt	AC-H48	50	0.673019	0.013460	0.97	0.674739	0.013495	0.91	8.71
TRL	*912042 Wood*	*300*	*-1.331751*	*-0.004439*	*1.22*	*-1.331895*	*-0.004440*	*1.23*	*1.80*

5.3 Wall Flatness

The wall flatness is mainly (or even only) an issue in case when a barrier with deformable element is used in front of the LCW. The barrier is backed by a plate of about 2 mm thick which spreads the loads between cells which are not aligned. Although non-alignment of cell faces can (at least partially) be compensated by adjusting the protective layers on the cells it was decided to collect flatness data from a number of existing walls and based on this define requirements for this parameter.

5.3.1 Approach

A protocol to measure the position of cells using the FARO arm was prepared by Humanetics. The FARO arm was suggested as it is available in most laboratories to accurately measure dummy positioning before a crash tests. It has sufficient range to cover an entire LCW from a single initial position.

The protocol was transferred into an Excel file which requires input on reference position of the FARO arm and measured positions in 3 dimensions form each cell. See Figure 5.9. Info on the cell centre and the corners was to be provided.

Three laboratories participated in this task: BASt, IDIADA and TRL. The measured data were processed by Humanetics and an analysis of the influence of the flatness on the test outcome was made using data from trolley tests done by BASt.

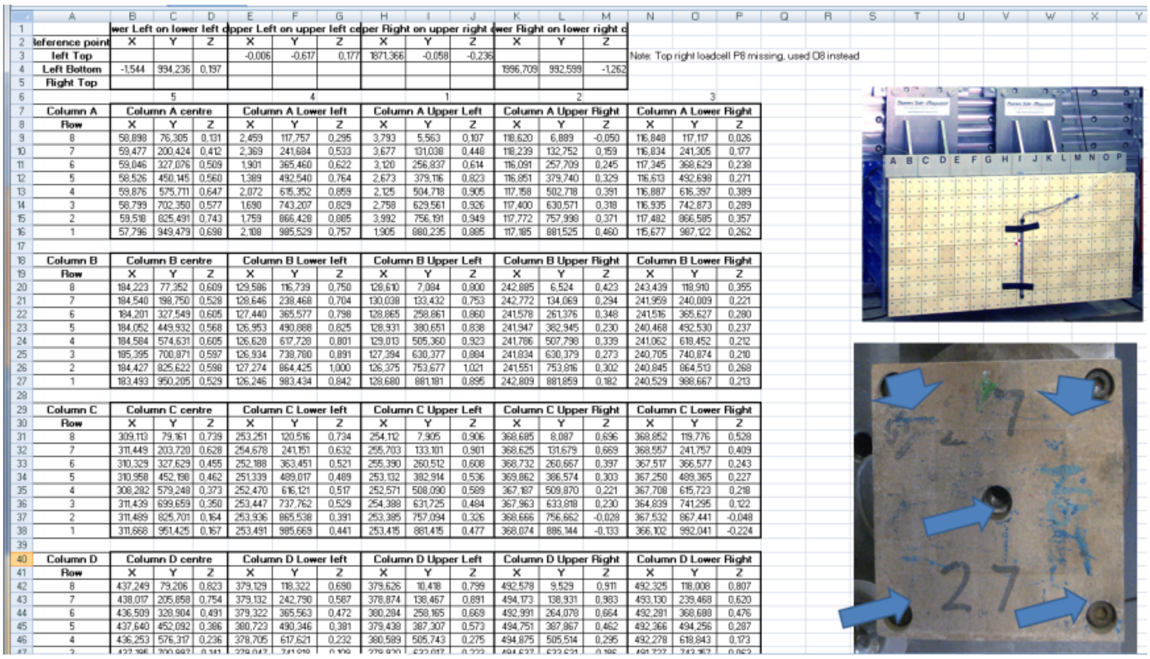


Figure 5.9: Excel file used to collect measurement data on wall flatness.

5.3.2 Wall Flatness Results

Both BASt and TRL provided multiple measurements, TRL doing three repeats on the wall itself and one measurement with protective layer. BASt did two repeats on the wall itself and one measurement with protective wooden layer on the cells. As a first step the repeated measurements were processed to give average results over the measurements. Next an average depth of the wall was computed by summing the depth position of all cells at centre location and dividing by the number of cells. This average depth was subtracted from the measured depth location at centre and corner positions to give variations over the barrier. Results for the IDIADA wall are shown in Figure 5.11. The row and column numberings used are indicated in Figure 5.10. Depth positions relative to the average plane are shown for the cell centres. The left graph plots results column wise while the right graph gives results per row. It is noted that for the columns sometimes the indication A through P is used and sometimes 01 through 16. For the final protocol it is suggested to apply the load cell numbering and indication as included in the right graph of Figure 5.10 assuming numbering 01 – 16 for the columns.

From Figure 5.11 it can be seen that cell to cell centre locations show a variation of about ±1 mm over the entire wall. In the IDIADA wall differences per column (left graph) appear to be relatively small compared to variations over the row (right graph). This is explained by the construction of the wall. The cells are mounted first on back-plates covering a column and subsequently assembled into the barrier.

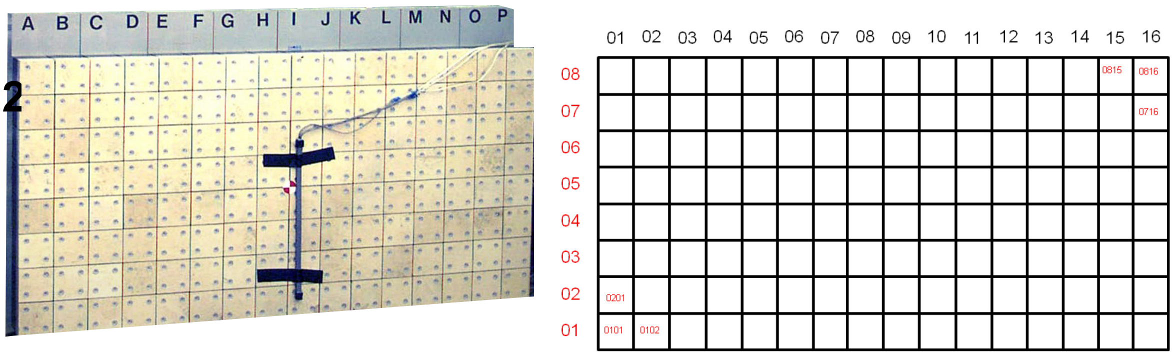


Figure 5.10: Load cell numbering (16 columns and 8 rows)): left picture of wall with columns indicated as A through P; right proposed cell numbering with columns indicated as 01 through 16. Row numbers are always indicated as 1 through 8.

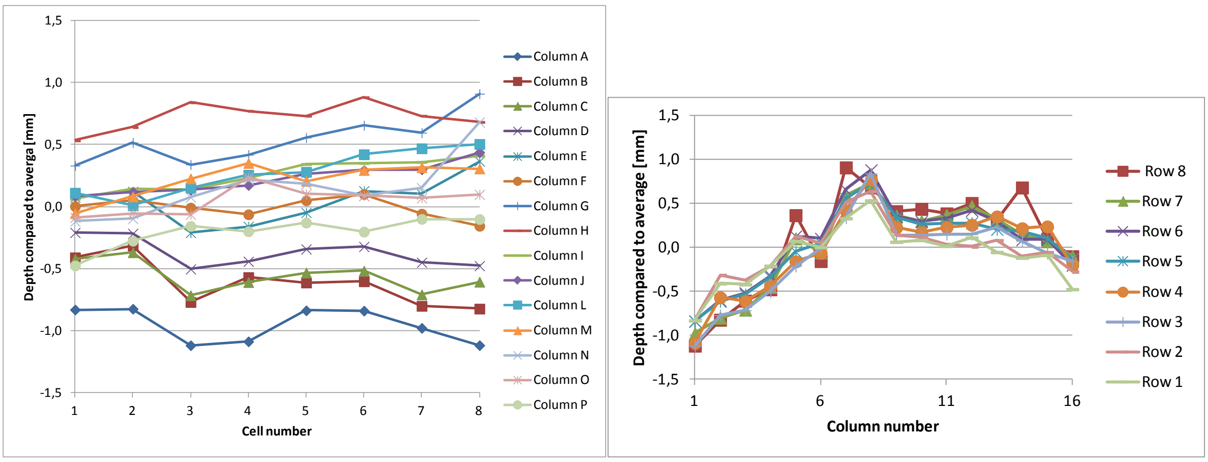
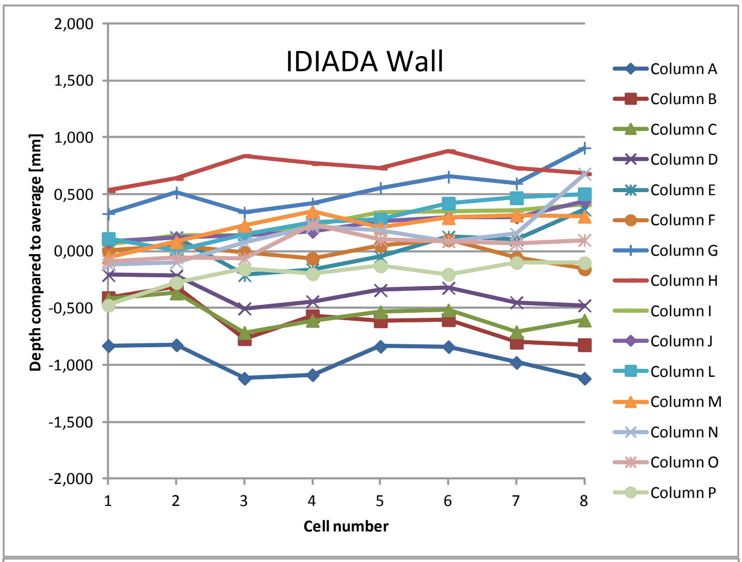
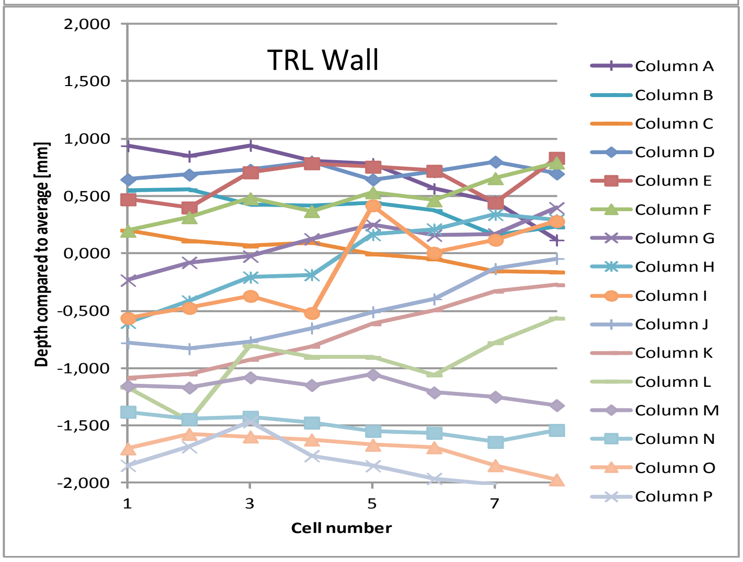


Figure 5.11: Flatness results IDIADA wall: depth position of center of all cells. Left graph shows results for each column (8 cells per column); right graph shows results for each row (16 columns).





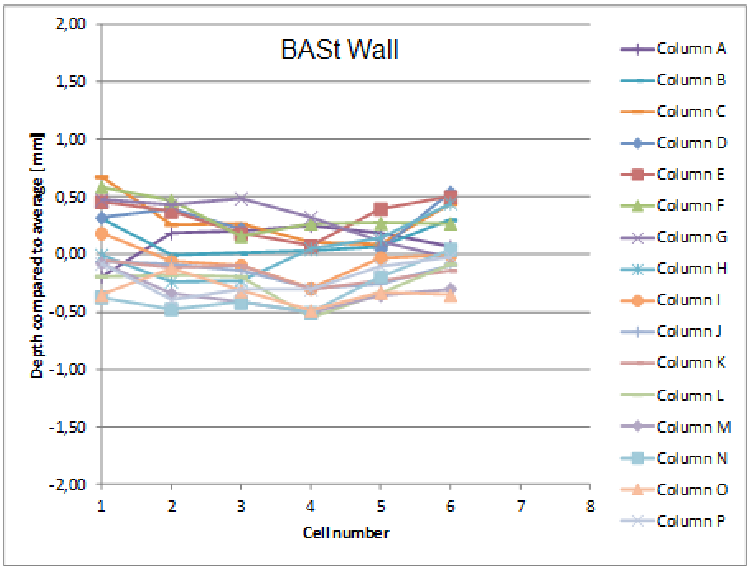


Figure 5.12: Flatness results of all three walls.

Results for all three walls measured are given in Figure 5.12. Although some variations exists between the walls all show a small variation in overall depth of less than 3 mm. Note that the BASt walls only has 6 cells over the height of each column while the TRL and IDIADA barriers have 8 cells in each column.

The influence of protective layers was measured in the TRL wall and the BASt wall. Results are shown in Figure 5.13. For the BASt wall the variations in depth increase when adding the protective wooden layer to the cells (compared to measurements on the wall itself) while for the TRL wall variations remain almost identical or even reduce somewhat. The latter is explained by the fact that TRL is minimising depth variations for full width barrier tests using protective layers from MDF of different depths.

Table 11 shows maximum differences in depth positions between adjacent cells. These differences are taken along horizontal, vertical and diagonal lines. Values are provided for centre to centre and corner to corner locations. Except for the BASt wall with protective layer the maximum variations in depth between cells appears to be around 1 mm.

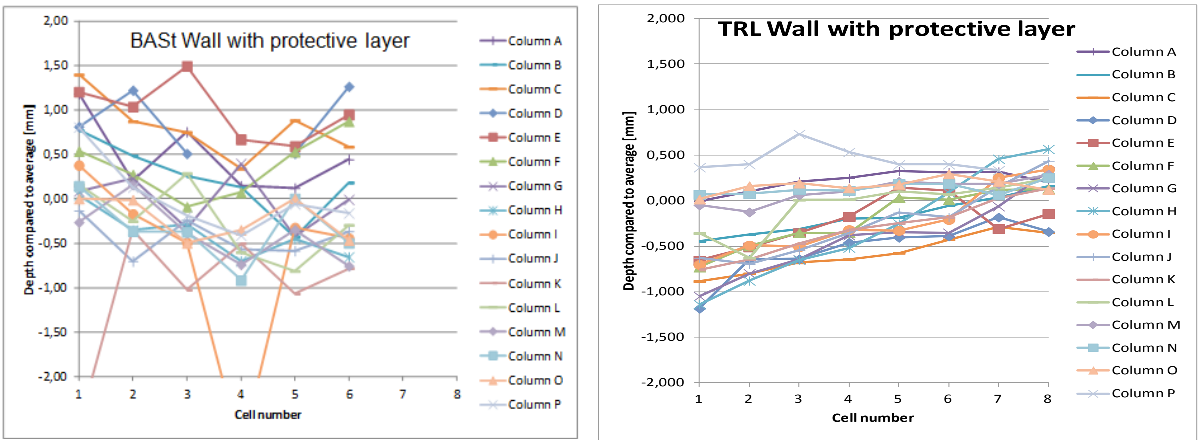


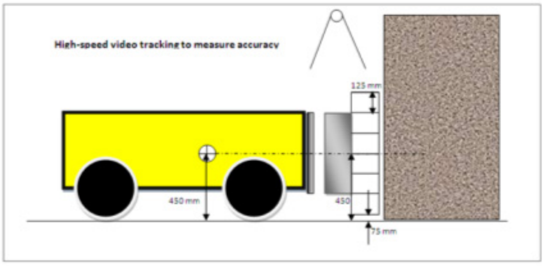
Figure 5.13: Flatness results with protective layer of BASt and TRL walls.

Table 11: Maximum differenced in depth position between adjacent cells.

	IDIADA	BASt	BASt With protective layer	TRL	TRL With protective layer
Centre-Centre	1,06	0,80	2,70	0,95	0,64
Corner - Corner	0,66	0,94	4,07	1,01	0,95

5.3.3 Analysis of Trolley Tests BASt

To analyse the influence of wall flatness FIMCAR partner BASt conducted a test using a trolley with flat loading plate. The trolley impacted a honeycomb barrier attached to the wall. The barrier was partitioned in a left side and a right side. Figure 5.14 shows the configuration. In total five tests were done. The influence of variations in cell depth position was investigated using results of a test at an impact speed of 15 km/h.



Test no.	Velocity km/h	Wood plate
FM02LC01	15	No
FM02LC02	15	No
FM02LC03	15	Yes
FM02LC04	20	Yes
FM02LC05	25	Yes

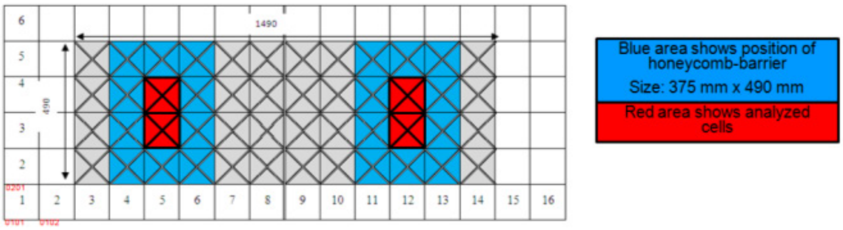


Figure 5.14: Configuration of trolley tests performed by BASt.

The two barrier partitions covered an area of 3 horizontal by 4 vertical cells each. To exclude edge effects the resulting forces of the inner cells in the left and right partition were analysed. See cells indicated with red colour in Figure 5.14.

Figure 5.15 gives force histories for the left and right barrier cells, measured depth position and peak forces. Force time histories for the cells on the left and right barrier show only very minor differences. Peak forces in the left barrier are 7.11 kN and 7.19 kN. In the right barrier slightly higher peak forces of peak forces of 7.23 kN and 7.27 kN were found. It is notable that the peak forces in the right barrier partition are higher while the cells are located more inward: -0.54 mm and -0.19 mm compared to 0.07 mm and 7.19 mm for the left barrier. This contradicting result is explained by the fact that the trolley did not approach the barrier fully orthogonal. Detailed analysis of the high speed films showed that the right side was impacting the barrier slightly before the left side, explaining the difference.

The above result shows that the load cell flatness is only a single factor in an overall measurement chain affecting the accuracy. Other parameters like approach angle and barrier flatness also influence the results. Information of the barrier flatness was requested at suppliers of these tools but not obtained.

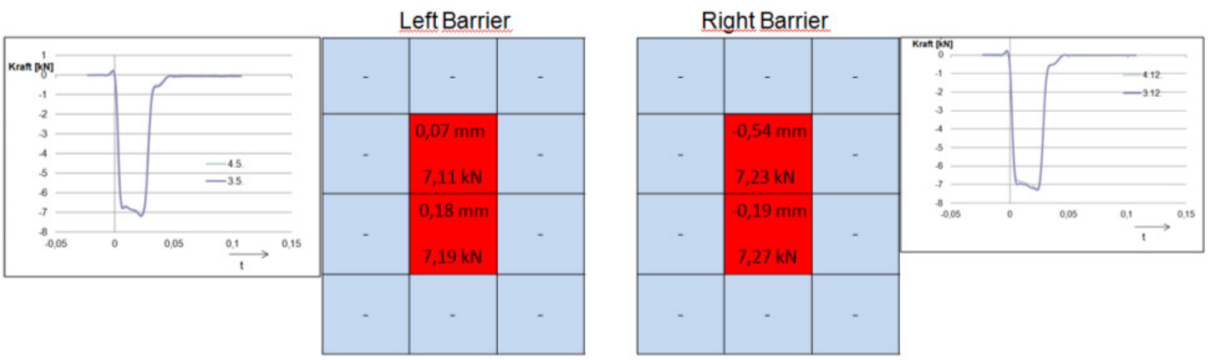


Figure 5.15: Forces in center cells of left and right barrier, peak forces and cell depth position (values indicated in cells marked in red).

5.3.4 Discussion

Measurements on various load cell walls showed that existing tools have an overall variation in depth between cells of less than 3 mm. Adjacent cells have depth variations of about 1 mm. The latter value is identical for centre to centre and corner to corner positions.

Analysis of trolley tests with a flat impacting surface showed that peak forces in the cells do not correlate with depth position of the cells. Other factors like approach angle of the impacting surface and honeycomb flatness affect results to such an extent that depth position of the cells cannot be linked to peak forces observed.

Based on the above it is decided to adopt the measured depth variations into the protocol defining the crash wall. The measured depth variations appear to be feasible / achievable and influence on measured force distribution is small compared to other factors in the test.

The definition of the load cell wall including the requirements on wall flatness is included in Annex B. Other requirements like cell size, ground clearance, cell numbering are straightforward and did not need any further investigations.

5.4 Conclusions

As part of FIMCAR Task 3.2 a Load Cell Wall (LCW) certification procedure was defined. The procedure consists of the LCW definition and certification requirements in terms of wall flatness. In addition a specification and calibration protocol was prepared for the transducers.

Parameter values for both documents were obtained from measurements and analyses on Load Cell Walls and transducers itself. Certification requirements for the wall flatness were based on measurements of three existing walls and an analysis of a trolley test done by BASt. A series of load cells was tested to check and refine values set for non-linearity and hysteresis.

The protocols are included in the Annex A and Annex B of this report.

6 VALIDATION OF FULL WIDTH DEFORMABLE BARRIER PROTOCOL

6.1 Validation of Concept

In this section the performance of cars in car-to-car tests is compared with their assessment in the FWDB test. To validate the FWDB test and proposed performance limits it is expected that if the car meets the proposed performance limits in the FWDB test then it should perform well in the car-to-car test as regards structural alignment and vice versa.

6.1.1 Supermini 1 Test Series

The Supermini 1 was tested in both FWDB tests and car-to-car tests. The objective was to validate that good/poor performance in car-to-car tests in terms of structural vertical alignment correlated with meeting/not meeting the proposed FWDB metric performance limits.

The FWDB and car-to-car tests that were performed are shown in Table 12 and Table 13. The heights of the bumper crossbeams in the Supermini 1 tests are shown in Figure 6.1.

Table 12: Supermini 1 FWDB test matrix.

Test number	Ride height test condition	Bumper crossbeam height (corrected for impact accuracy)		Nominal test speed (km/h)
		Bottom	Top	
FM04C3FW	Standard	451	530	56
FM05C3FW	Standard	449	528	56
17459	Standard	449	528	56
114601FF	Lowered	413	492	56
F114202	Raised	482	561	56

Table 13: Supermini 1 car-to-car test matrix.

Alignment	Nominal test speed (km/h)	Nominal offset (%)
Aligned structures	56	50
Misaligned structures	56	50

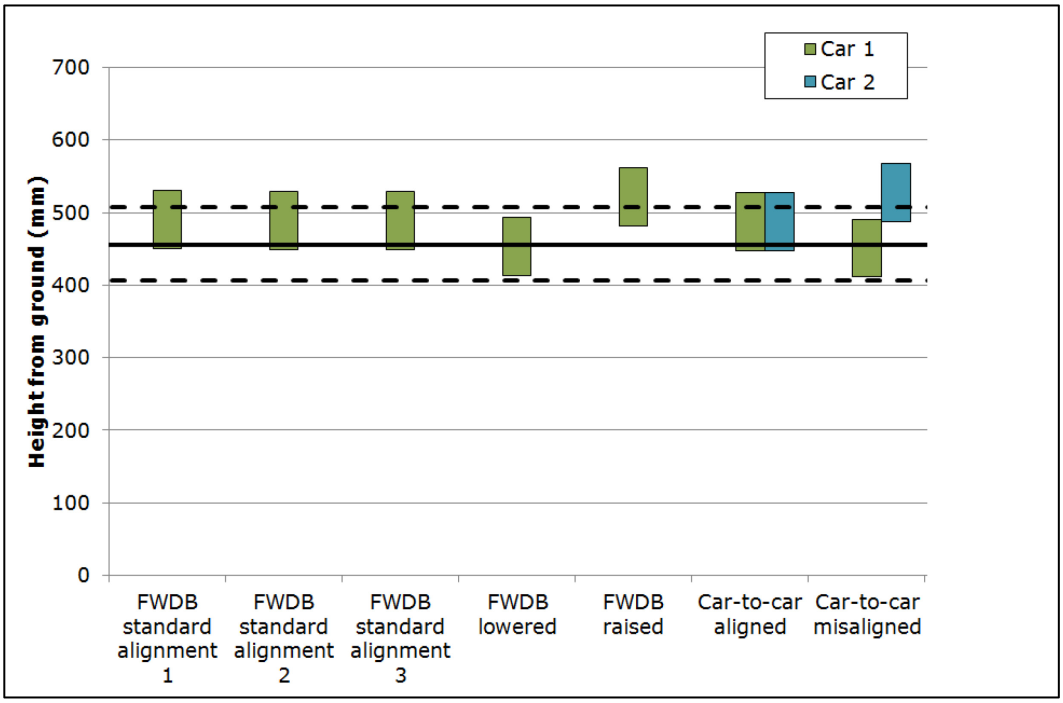


Figure 6.1: Heights of bumper crossbeams in Supermini 1 tests.

Figure 6.2: shows the intrusions in the Supermini 1 car-to-car tests.

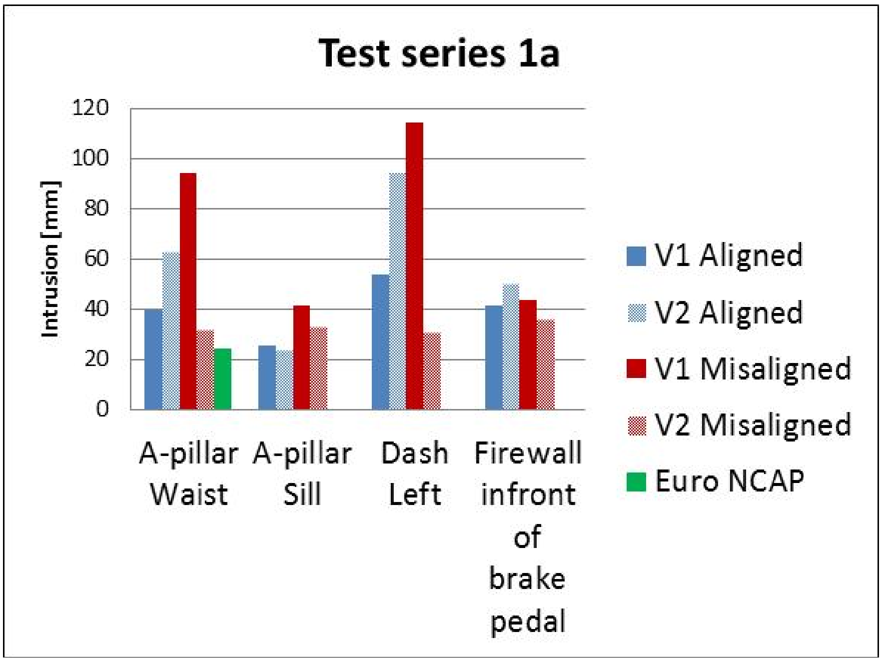


Figure 6.2: Intrusions in Supermini 1 car-to-car tests [Sandqvist 2013].

The results of this test show that the peak intrusions in the aligned test were lower than in the misaligned test at the A-pillar waist, A-pillar sill and dash, and slightly higher at the firewall in front of the brake pedal. This shows that the vehicles in the aligned test performed better than in the misaligned test.

Figure 6.3 shows the dummy injury criteria in the Supermini 1 car-to-car tests.

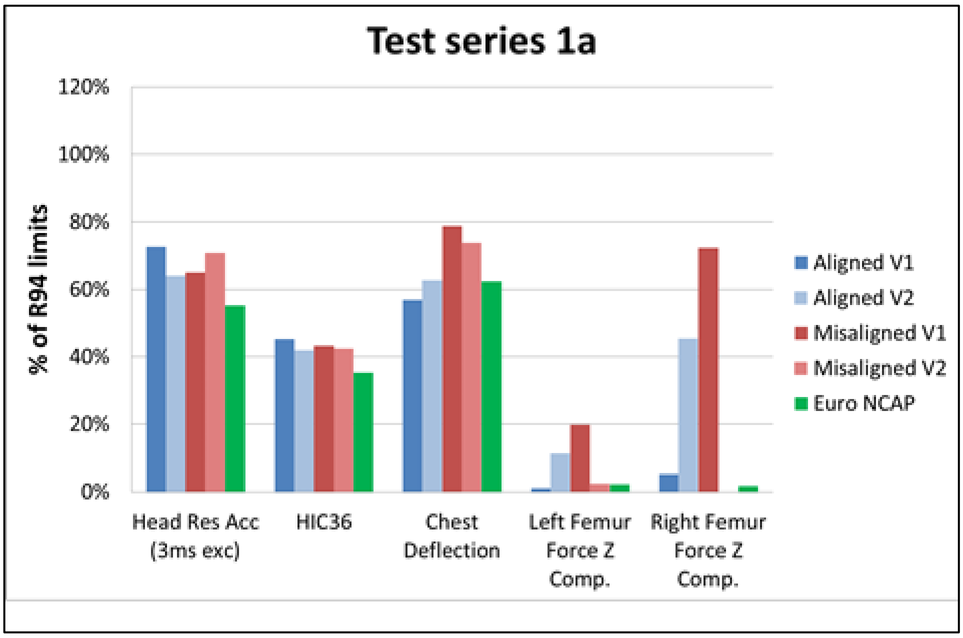


Figure 6.3: Dummy injury criteria in Supermini 1 car-to-car tests [Sandqvist 2013].

The results show that the injury criteria for the head are similar in the aligned and misaligned tests, but the chest deflection and femur forces are higher in the misaligned test. This shows that the vehicles performed better in the aligned test than in the misaligned test.

The results from a standard Supermini 1 FWDB test are shown in Table 14. The results from the lowered Supermini 1 FWDB test are shown in Table 15. The results from the raised Supermini 1 FWDB test are shown in Table 16. The standard tests and the lowered test were both performed with the vehicle frontal structures in line with the common interaction zone. The raised test was performed with the frontal structure in partial alignment with Row 4, but not in alignment with Row 3.

Table 14: Supermini 1 (standard) FWDB results.

	Supermini 1 FWDB, FM04C3FW		
	Value	**0.2*Ft40**	**OK/NOK**
F3 > MIN[100, 0.2Ft40]	104	80,4	OK
F4 > MIN[100, 0.2Ft40]	103	80,4	OK
Global	OK		

Table 15: Supermini 1 (lowered) FWDB results.

	Supermini 1 FWDB, 114601FF		
	Value	**0.2*Ft40**	**OK/NOK**
F3 > MIN[100, 0.2Ft40]	124.4	85.9	OK
F4 > MIN[100, 0.2Ft40]	112.5	85.9	OK
Global	OK		

Table 16: Supermini 1 (raised) FWDB results.

	Supermini 1 FWDB, F114202		
	Value	0.2*Ft40	OK/NOK
F3 > MIN[100, 0.2Ft40]	62.9	79.7	NOK
F4 > MIN[100, 0.2Ft40]	122.8	79.7	OK
Global	NOK		

In summary, the results show that the vehicle passes the FWDB metric in tests where the vehicle main structures (PEAS) are in line with the common interaction zone and the vehicle fails the FWDB metric when the vehicle PEAS is not in alignment with the common interaction zone. The car-to-car tests show a better performance when the vehicle main structures (PEAS) are aligned compared to when they are not aligned. These results validate the 'force in a common interaction zone' concept and with the FWDB test results show that the proposed FWDB metric can be used to enforce it.

6.1.2 Supermini 2 test series

The Supermini 2 was tested in both FWDB tests and car-to-car tests. The FWDB and car-to-car tests that were performed are shown in Table 17 and Table 18.

Table 17: Supermini 2 FWDB tests.

Test number	Ride height test condition	Bumper crossbeam height (corrected for impact accuracy)		Nominal test speed (km/h)
		Bottom	Top	
17423	Standard	401	514	56
FM08F5FW	Standard	401	514	40

Table 18: Supermini 2 car-to-car tests

Alignment	Nominal test speed (km/h)	Nominal offset (%)
Aligned structures	56	50
Misaligned structures	56	50

The results from the FWDB test at 56km/h are shown inTable 19.

Table 19: Supermini 2 56km/h FWDB results

	Supermini 2, 17423			
	Value	0.2*Ft40	MIN[100, 0.2Ft40]	OK/NOK
F3 > MIN[100, 0.2Ft40]	140.1	108.7	100	OK
F4 > MIN[100, 0.2Ft40]	148.1	108.7	100	OK
Global	OK			

The results from the FWDB test show that the Supermini 2 passes the FWDB metrics by a significant margin. This indicates that the vehicle has adequate structure in alignment with the common interaction zone. In addition the load in Row 2 is high enough to allow the limit reduction part of the metric to be invoked. This indicates that the Supermini 2 also has a good subframe load path.

Figure 6.4 shows the vehicle accelerations in the Supermini 2 car-to-car and Euro NCAP tests. Figure 6.5 shows that dummy injury criteria in the Supermini 2 car-to-car tests.

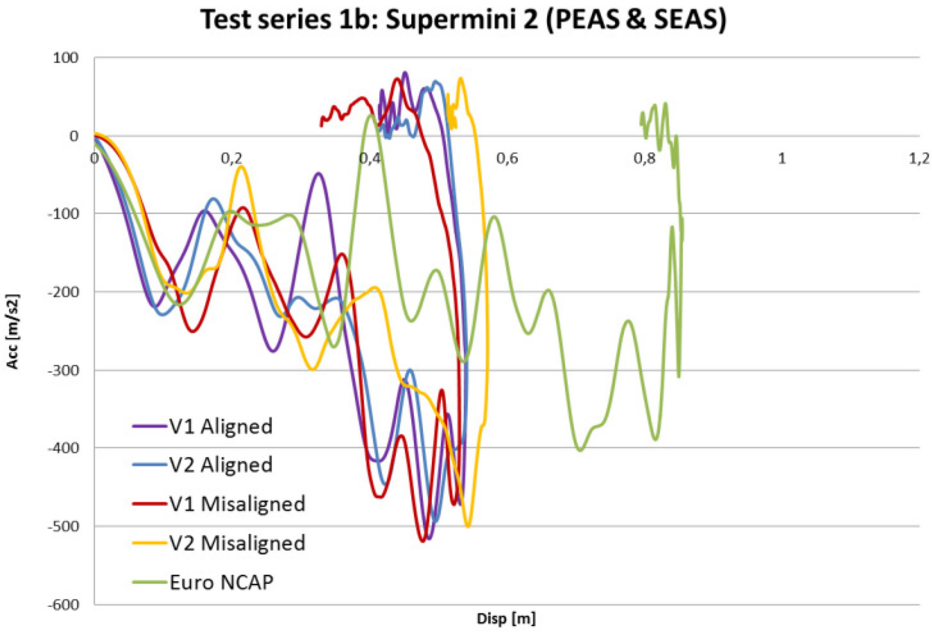


Figure 6.4: Supermini 2 vehicle accelerations in car-to-car and Euro NCAP tests.

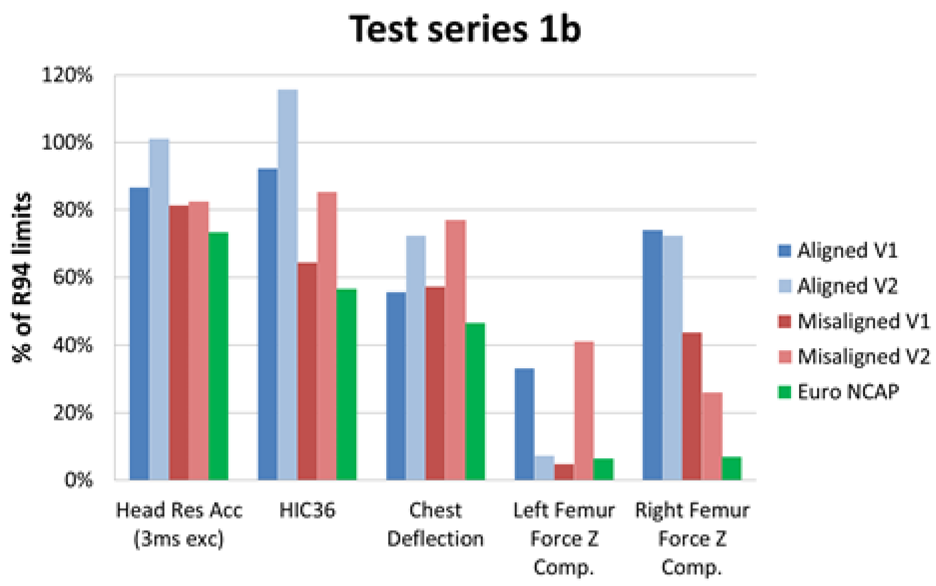


Figure 6.5: Supermini 2 dummy injury criteria.

The results show that in the car-to-car tests the vehicle accelerations were very high. This indicates that the frontal structures of the Supermini 2 are very stiff. This explains why the dummy injury criteria are higher in the aligned tests than in the misaligned tests.

If the vehicle had been designed to pass a FW test, then it is likely that the dummy numbers would have been lower in the aligned test due to improved occupant restraints and/or reduced stiffness of the frontal structures to pass the FW test.

In summary, the smaller difference in the intrusions between the aligned and misaligned tests for the Supermini 2 compared to the Supermini 1 illustrate the advantage of a design which spreads load vertically as described in greater detail in FIMCAR Deliverable D6.1 [Sandqvist 2013]. The results shown above demonstrate that the proposed FWDB metric for structural alignment correctly assesses the Supermini 2 as having structures in alignment with the common interaction zone and with the limit reduction part of the metric encourages the subframe load path which was shown to work well in the car-to-car tests.

6.1.3 SUV Test Series

In an SUV test series two different kind of SUVs were tested in car-to-car crashes against the Small Family Car 1. The objective of these test series was to show the differences between an SUV with one load path and an SUV with two load paths.

The SUV 1 was tested in both FWDB tests and car-to-car tests with a Small Family Car 1. The FWDB and car-to-car tests that were performed are shown in Table 20 and Table 21.

Table 20: SUV 1 FWDB tests.

Test number	Ride height test condition	Bumper crossbeam height (corrected for impact accuracy)		Nominal test speed (km/h)
		Bottom	Top	
B4767	Standard	522	609	56

Table 21: SUV 1 car-to-car tests.

Alignment	Impact partner	Nominal test speed	Nominal offset
Aligned structures	Small Family Car 1	56 km/h	50 %
Misaligned structures	Small Family Car 1	56 km/h	50%

The height of the main structure (PEAS) of the SUV 1 aligns with the upper part of Row 4 of the LCW, and none of it aligns with Row 3. However, the SUV 1 does have a secondary structure (SEAS) which aligns with Row 3 and lower rows. The results from the FWDB test are shown in Table 22.

Table 22: SUV 1 FWDB results.

	SUV 1, B4767			
	Value	**0.2*Ft40**	**MIN[100, 0.2Ft40]**	**OK/NOK**
F3 > MIN[100, 0.2Ft40]	151	135.4	100	OK
F4 > MIN[100, 0.2Ft40]	192	135.4	100	OK
Global	OK			

The results show that the SUV 1 at its standard ride height has sufficient structure in alignment with the common interaction zone (Rows 3 and 4) to meet the metric requirements. The intrusions and dummy injury criteria in the car-to-car tests are shown in Figure 6.6 and Figure 6.7 respectively.

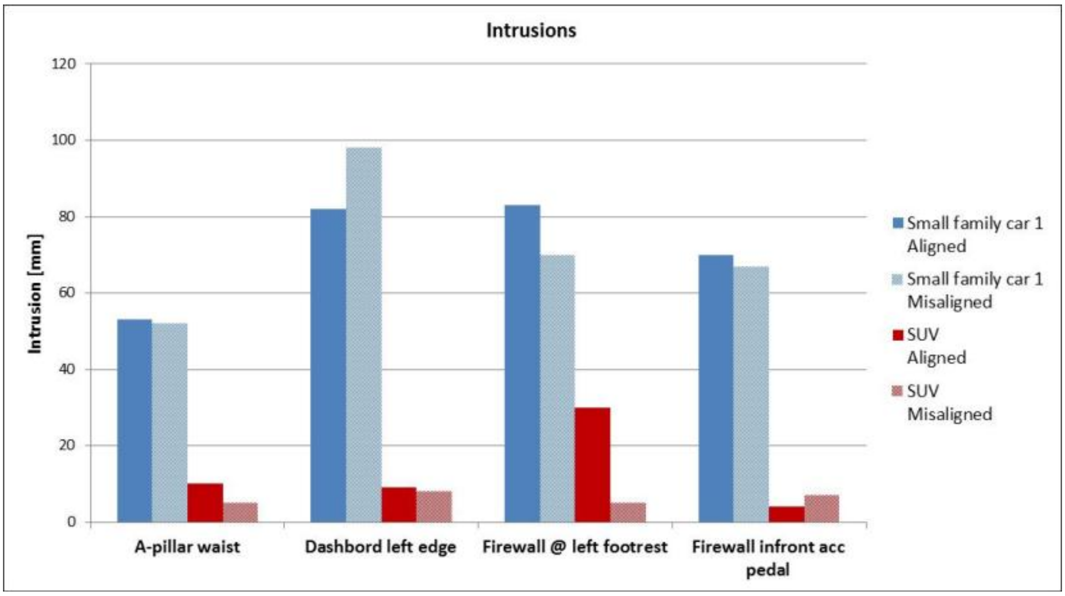


Figure 6.6: Intrusions in SUV 1 – Small Family Car 1 car-to-car tests [Sandqvist 2013].

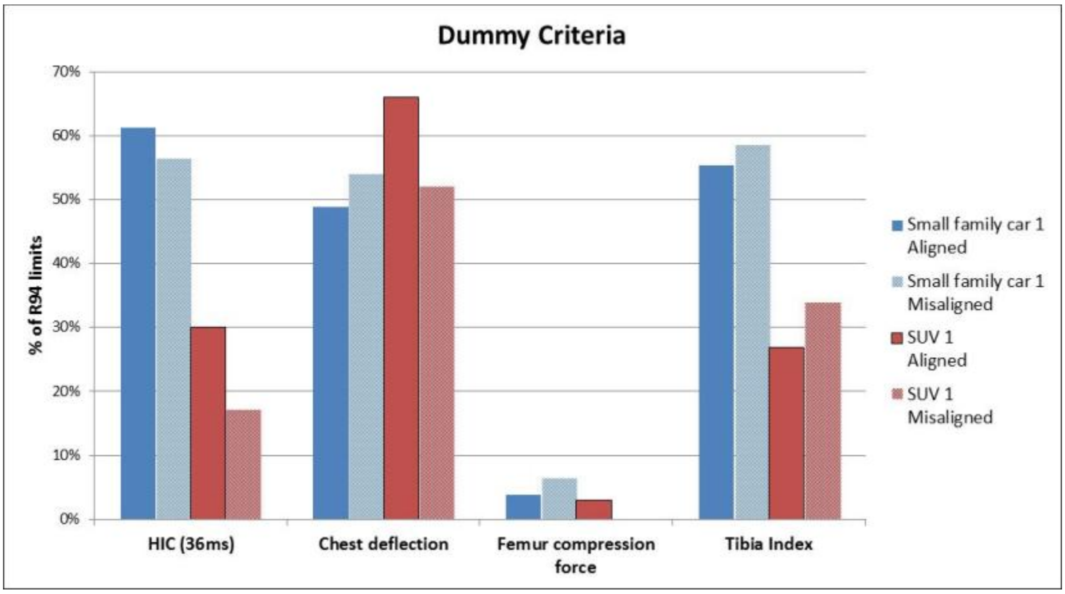


Figure 6.7: Dummy injury criteria in SUV 1 - Small Family Car 1 car-to-car tests [Sandqvist 2013].

The results show that there is a general similar level of intrusion and dummy injury criteria in both the aligned and misaligned test. This shows that the SEAS structures are strong enough to provide adequate structural interaction capability in a car-to-car impact. This agrees with the FWDB metric assessment of the SUV 1 and hence validates the proposed metric. An FWDB with a SUV 2 and car-to-car test with a SUV 2 and Small Family Car 1 were performed. The tests performed are shown in Table 22 and Table 24.

Table 23: SUV 2 FWDB test.

Test number	Ride height test condition	Bumper crossbeam height (corrected for impact accuracy)		Nominal test speed (km/h)
		Bottom	Top	
123514FF	Standard	475	-	56

Table 24: SUV 2 car-to-car test

Alignment	Impact partner	Nominal test speed	Nominal offset
Aligned structures	Small Family Car 1	56 km/h	50%
Misaligned structures	Small Family Car 1	56 km/h	50%

The SUV 2 has primary structures (PEAS) in the upper part of Row 4. The SUV 2 has no additional structures (SEAS) in Row 3 or lower. The results of the FWDB test are shown in Table 23. These results show that the SUV 2 fails the FWDB metric as the force levels in Row 3 are not sufficient.

Table 25: SUV 2 FWDB results

	SUV 2, 123514FF			
	Value	0.2*Ft40	MIN[100, 0.2Ft40]	OK/NOK
F3 > MIN[100, 0.2Ft40]	66	334.6	100	NOK
F4 > MIN[100, 0.2Ft40]	534	334.6	100	OK
Global	NOK			

In the car-to-car test the SUV 2 PEAS overrode the Small Family Car 1 and impacted the gearbox of the Small Family Car 1. This caused the gearbox to rotate which caused increased local intrusion in the footwell area. This validates the FWDB result as there was not enough suitable structure in line with the common interaction zone.

6.1.4 Effect of Test Speed on Metric

In FIMCAR most tests with the FWRB and FWDB test procedures were conducted with a speed of 56 km/h (Europe) or 55 km/h (Japan), respectively. During the project it became clear that a lower test speed with 50 km/h for AIS 3 level would be better in terms of injury mitigation to not just address the high speed impacts but also the high proportion of impacts with lower severity. This is further explained in Chapter 4.2.

Therefore it was decided that in the final test procedure 50 km/h is the test speed for FWRB and FWDB.

Nevertheless it was decided to conduct all pending full width crash tests in FIMCAR with 56 km/h in order to compare the existing test data with new test data. Simulations were conducted during the project with the PCM simulation models from TU Berlin and the GCM simulation models from CRF to investigate the differences on the metric which occur due to various test speeds. Additionally, a full scale test was conducted with a Supermini 2 at 40 km/h.

6.1.4.1 **Simulations with PCM Models**

In WP 3 the simulation request 10 was defined to investigate the test severity for FWDB by comparing FWRB pulses with 50 km/h and FWDB pulses with 56 km/h, 50 km/h and 40 km/h. Therefore simulations with the PCM models of FWRB and FWDB tests were conducted to analyse the influence on the compatibility metrics with decreased test severity.

The model taken for these simulations is shown in the Figure 6.8. The geometric alignment was chosen that the vehicle should pass based on the US voluntary agreement. The longitudinals were in the common interaction zone.

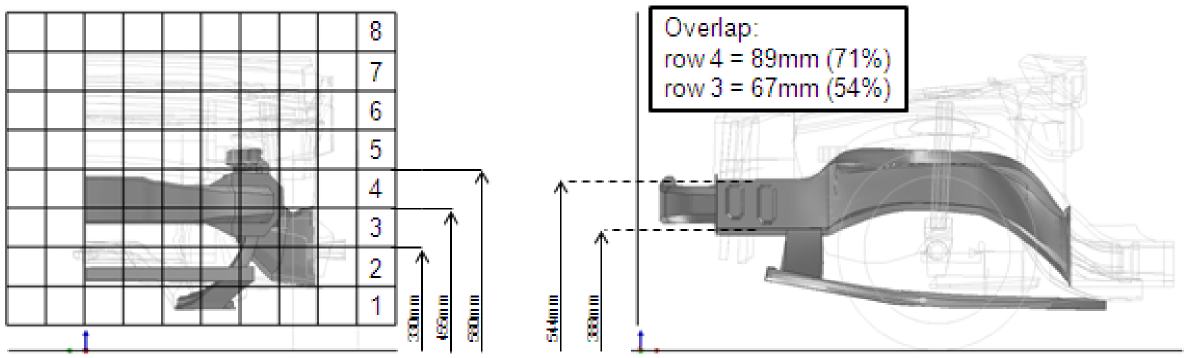


Figure 6.8: Test configuration for the simulations with different test speeds

The simulations results with the PCM model at 56, 50 and 40 km/h are displayed in the following Table 26. The forces at the LCW were calculated with the metric without Limit Reduction, see Figure 4.1.

Table 26 Results of the FWDB simulations with 56, 50 and 40 km/h

		FWDB_56	FWDB_50	FWDB_40
Metric as defined in Figure 4.1 up to 40ms	F_{t40} [kN]	**588.2**	**487.4**	**272.3**
	0.2 * F_{t40} [kN]	**117.6**	**97.5**	**54.5**
	F3 [kN]	**182.7**	**153.4**	**80.7**
	F4 [kN]	**198.2**	**149.2**	**87.5**

It is obvious that the total LCW force up to 40 ms decreases with a lower test speed. However, as this metric uses relative numbers (20% of F_{t40}) the vehicle passes the metric at all test speeds.

In the next Figure 6.9 the force distribution of Row 3 and 4 up to 40 ms in the FWDB simulations is shown in a graph. The sum forces of Row 3 and 4 of each configuration were set to 100 %. Although the main force decreases with a lower test speed, the force distribution stays on a very similar level.

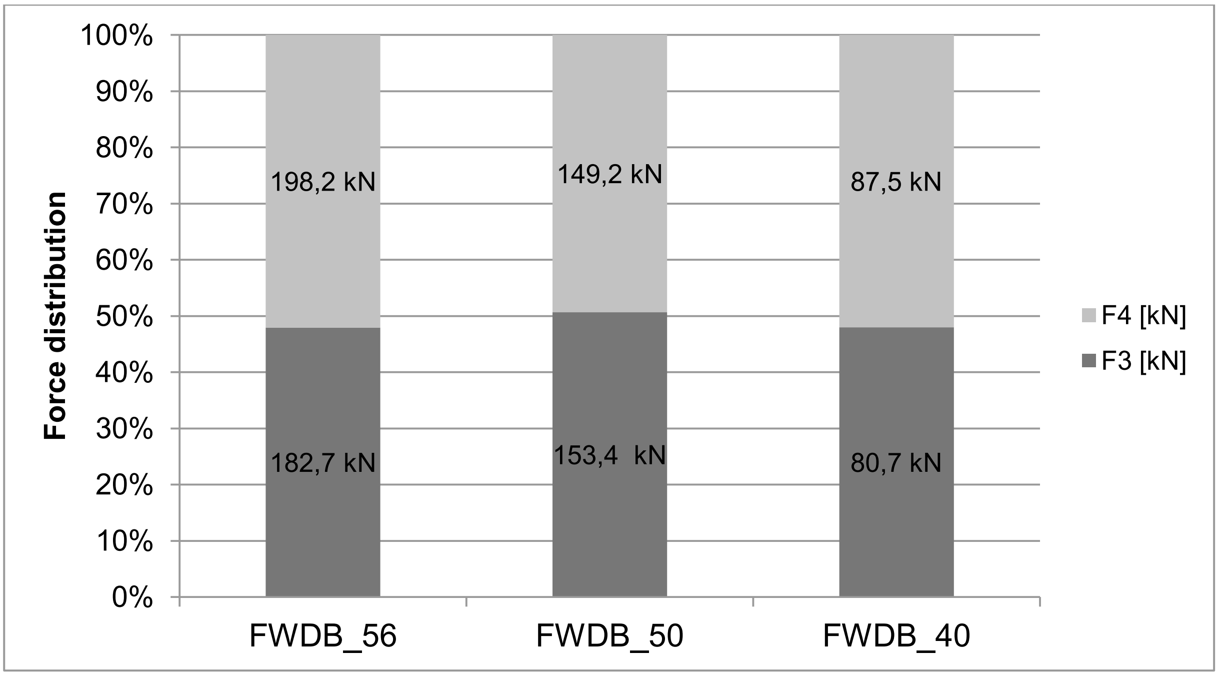


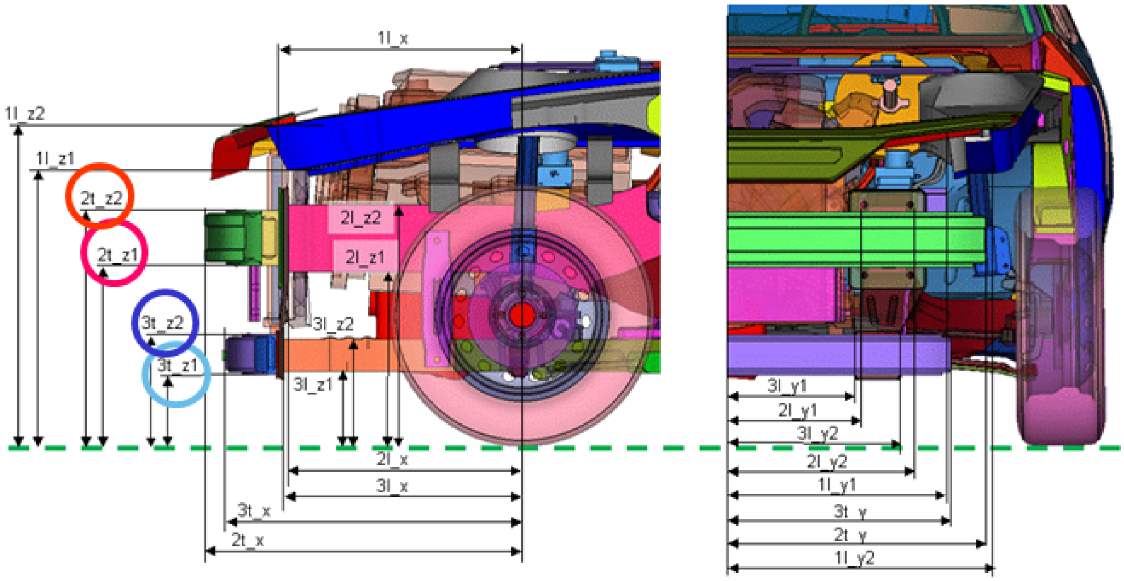
Figure 6.9: Force distribution of Row 3 and 4 up to 40 ms in FWDB simulations (sum of Row 3 and 4 of each configuration is set to 100 %).

In summary it can be concluded that the metric tends to work also for lower velocities. The LCW sum forces (F_{max}) decreases with decreasing velocity. Sum forces of Row 3 and 4 and the row forces up to 40 ms are almost the same for the different velocities.

6.1.4.2 **Simulations with GCM Models**

The same investigations were done with the GCM models from CRF. Therefore numerical simulation results of GCM1B, GCM2A and GCM3A against the FWDB barrier including the LCW were conducted at the impact speeds 40, 50 and 56 km/h. The aim was to compare the row and total load versus time curves, the maximum row loads up to 40 ms and the effect on the metric.

The following Figure 6.10 shows the geometries for the different GCM models GCM1B, GCM2A and GCM3A. All models were multiple load path designs with a PEAS structure in height of Row 3 and Row 4 and a SEAS structures in height of Row 2 and 1. In addition all models have their PEAS in alignment with the US voluntary agreement. Therefore they should pass the FWDB metric at all test speeds.



CROSSBEAMS	2t_x	3t_x	2t_y	3t_y	2t_z1	2t_z2	3t_z1	3t_z2
GCM-1A	776	X	649	X	394	498	X	X
GCM-1B	776	738	649	507	394	498	239	284
GCM-2A	750	563	607	490	442	555	172	233
GCM-2B	750	X	607	X	442	555	X	X
GCM-3	749	698	610	528	430	563	171	268

Figure 6.10: Geometries for the GCM models GCM1B, GCM2A and GCM3A.

The following Table 27 shows the results of the comparison. The maximum row loads are calculated for Rows 1, 2, 3 and 4 up to 40 ms for the impact speed 40, 50 and 56 km/h. Additionally, the maximum total LCW force up to 40 ms was calculated in order to compare the performance of the FWDB metric.

Table 27: GCMs vs. FWDB (LC) @ different impact speeds, max row loads up to 40 ms.

		Generic Car Model								
	FWDB LCW	GCM1B			GCM2A			GCM3A		
	Impact speed [kN]	40 km/h	50 km/h	56 km/h	40 km/h	50 km/h	56 km/h	40 km/h	50 km/h	56 km/h
Max Row Load Up to 40 ms [kN]	F4	82.37	97.44	148.67	128.4	170.4	185.92	164.69	194.64	214.38
	F3	104.41	129.57	161.36	100.17	115	123.83	122.42	155	163.33
	F2	78.4	92.08	90.75	49.71	61.06	96.2	81.26	113.87	122.59
	F1	27.42	30	32.45	58.31	66.87	70.34	48.88	49.45	56.03
Max Total LCW Load Up to 40 ms [kN]	F_{T40}	353.97	425.45	499.59	445.87	542.93	623.9	584.75	725.97	800.15
Metric (3)	$0.2*F_{T40}$	70.79	85.09	99.92	89.17	108.59	124.78	116.95	145.19	160.03
	Metric Reference Value	70.79	85.09	99.92	89.17	100.00	100.00	100.00	100.00	100.00

In total the results were very comparable with the results from the PCM models explained in chapter 6.1.4.1 Simulations with PCM models. The maximum row loads are decreasing when the impact speed is reduced. However, all GCM models pass the FWDB Metric at each impact speed considered. An additional results was that the total load in the first two Rows (F1+F2) is relevant. The presence of the structural lower load paths of GCMs is detected by the barrier.

In order to address the FWDB metric with Limit Reduction the PCM simulations were analysed taking into account the row loads of Row 3 and 4 but also of Row 2, see Figure 6.11. It is obvious that the share of the loads applied to Rows 2, 3 and 4 stays almost unchanged while the absolute values are dependent of the test speed.

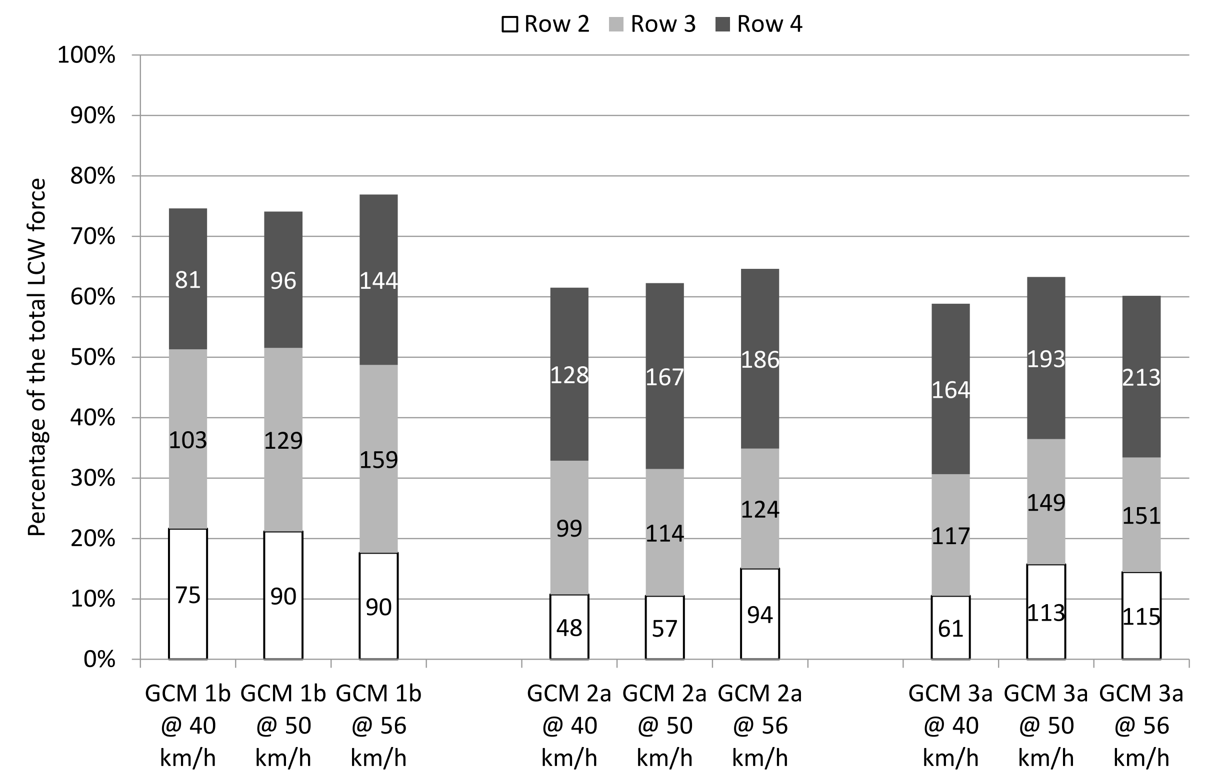


Figure 6.11: Share of loads in Rows 2, 3 and 4 dependent on test speed for GCM 1B, 2A and 3A.

6.1.4.3 **Summary**

With different simulation models it could be shown that the metric as explained in Chapter 4.1 works for test speeds in a range from 40 to 56 km/h. This is because the metric considers relative forces of the total LCW force.

An upgrade of the metric was developed at the end of the project in order to reflect forces in Row 2. This modified metric could not be tested at different impact speeds except for GCM simulation models. In general this modified metric works similar but it includes a fixed value (70 kN) which probably needs to be revised. Therefore further work is needed in order to confirm or define the fixed value with additional simulations.

6.2 Repeatability and Reproducibility

As agreed in the FIMCAR consortium each test procedure had to fulfil a number of tests to investigate the potential of the repeatability and reproducibility (R&R). By definition, repeatability means that two tests have to be performed at the same lab and reproducibility means that two tests have to be performed at different labs. In total a minimum of three tests with identical cars (two in one test lab, one in another test lab) were defined to be necessary. The whole test procedure and assessment should be repeatable and reproducible. For the full-width barrier test both test procedures, FWRB and FWDB, were checked for their R&R capabilities. This was possible because existing test data from previous projects and other parties (e.g. Japan) were made available.

6.2.1 Analysis of Data from Previous Projects

To investigate the repeatability and reproducibility (R&R) of the proposed test procedures and metrics, different full scale tests from previous projects were collected. The following Table 28 shows the available and useful test data for the **FWDB**.

Table 28: Test data for R&R analysis with the FWDB.

	Vehicle	Lab 1	Lab 2	Lab 3	Lab 4	Comment
1	Opel Astra	TRL	TRL			VC-COMPAT
2	Nissan Micra	TNO (Delft)	TNO (TTAI)			APROSYS
3	Fiat Bravo	FIAT	FIAT	IDIADA	IDIADA*	APROSYS

(* Rear seated dummies in this test)

The Opel Astra tests were performed in the European Project VC-Compat and were made available by TRL. The Nissan Micra tests came from the European project APROSYS and were made available by TNO. These test data could be used for repeatability studies. The test data from the Fiat Bravo could also be used for reproducibility analyses because three tests in two different labs were conducted (for one test at IDIADA a different number of dummies compared to the other three tests was used, the test was therefore neglected). These data came also from APROSYS.

The following Table 29 shows the available and useful test data for the **FWRB**. Although in total five tests were made available (three from the Toyota Corolla and two from the Subaru Stella) the analysis could be just used for repeatability because all tests were conducted in one laboratory. The data was supplied by Japan.

Table 29: Test data for R&R analysis with the FWRB.

Full Width Rigid Barrier			
Vehicle	**Lab 1**	**Lab 2**	**Lab 3**
Toyota Corolla	JARI	JARI	JARI
Subaru Stella R	JARI	JARI	

6.2.1.1 R&R Analyses FWDB Opel Astra

In the following Figure 6.12 the total LCW force is shown for the Opel Astra tests. The peak force in test 1 was 557 kN and in test 2 was 549 kN. The progress of both tests is quite similar and comparable. The energy absorbed was within +/- 5 % of vehicle kinetic energy for both tests.

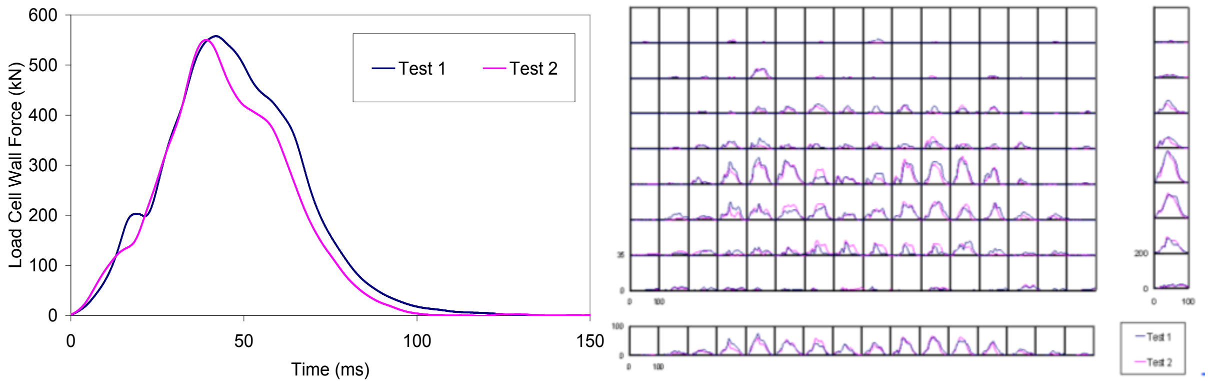


Figure 6.12 Left: Opel Astra R&R tests, total LCW force in kN versus time in ms Right: LCW forces of the individual cell forces.

In Table 30 the values for the modified metric with the Opel Astra data are demonstrated.

As the main output both vehicle passed the FWDB metric.

Table 30 Opel Astra LCW test results with the FWDB metric

Row	Test 1 Force Value KN up to 40 ms	Test 2 Force Value KN up to 40 ms	Metric Performance Limits – Test 1 kN	Metric Performance Limits – Test 2 kN
F4	182	179	100	100
F3	127	142	86 (100-14)	77 (100-23)
F4+F3	308	320	200	200
F2	84 (LR =14)	93 (LR = 23)	N/A	N/A
Total	552	550		

6.2.1.2 **R&R Analyses FWDB Nissan Micra**

Two Nissan Micra FWDB tests were performed at TNO in different facilities using the same equipment, one at TTAI in Helmond, one in Delft. The front ride had height differences up to 5 mm and the impact accuracy difference was up to 2 mm in height. In the following Figure 6.13 the forces on the LCW for the Nissan Micra tests are shown. The differences between the vehicles up to 40 ms were 9 kN in Row 3 and 8 kN in Row 4. These numbers indicate already an acceptable repeatability.

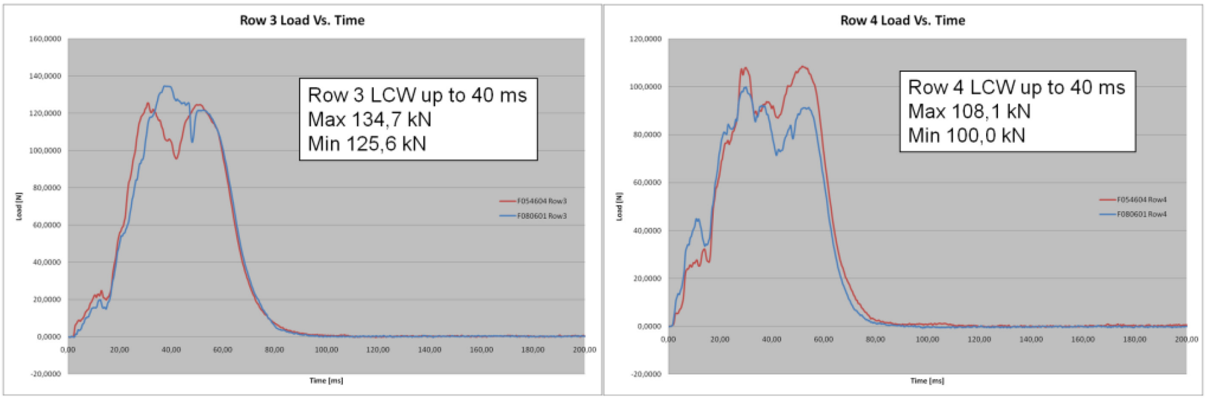


Figure 6.13: Forces on the LCW for Nissan Micra FWDB tests, left: Row 3, right: Row 4.

All tested vehicles passed the different FWDB Metrics.

6.2.1.3 **R&R Analyses FWDB Fiat Bravo**

In total four FWDB tests were performed in the project APROSYS; two at Fiat and two at IDIADA. However, in one test rear seat dummies were used and therefore the test was considered as not being useful for this R&R analyses.

The front ride height differences in these three tests were up to 13 mm and the impact accuracy unknown. In the next Figure 6.14 the LCW forces for the Rows 3 and 4 are shown. The progress of the forces between the two tests performed at FIAT is comparable. However, the Row 3 force of the test at IDIADA is slightly higher and the Row 4 force slightly lower compared to the other two tests.

This difference could be explained by the different height of the vehicles. Pictures from the barrier confirm these findings, although the ride height was not recorded.

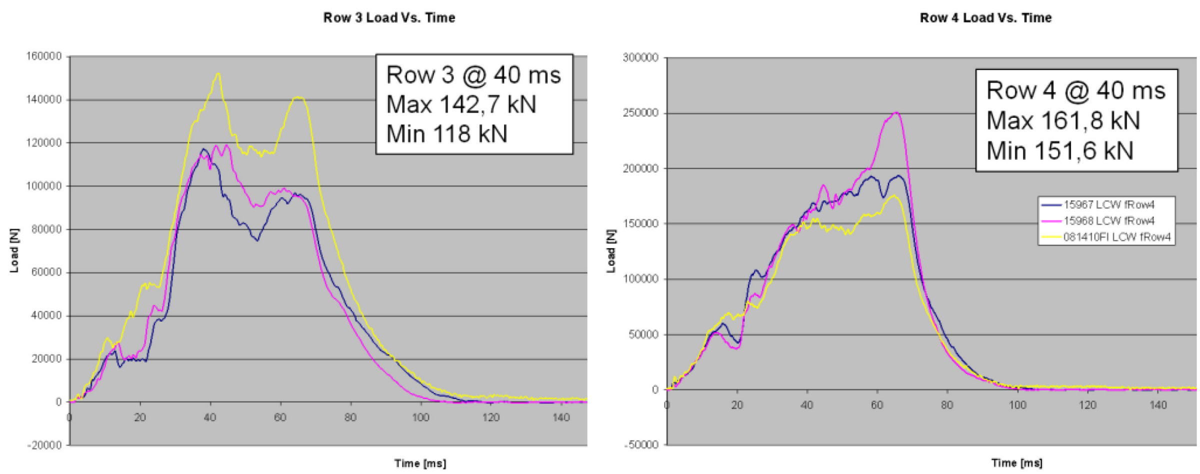


Figure 6.14: Forces on the LCW for Fiat Bravo FWDB tests, left: Row 3, right: Row 4.

The next Figure 6.15 shows the results of the three tests with the first metric for the FWDB. The numbers indicate an acceptable reproducibility.

Method B(1) FWDB: @ 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN

	FIAT FWDB test 15967		FIAT FWDB test 15968		IDIADA FWDB test 081410FI	
	Value	OK/KO	Value	OK/KO	Value	OK/KO
Time at 400kN (ms)	33.55	NA	33.05	NA	32.15	NA
F3+F4 > 180 kN (kN)	236.2	OK	235.6	OK	224.6	OK
F3 > 85 kN (kN)	97.9	OK	98.5	OK	106.4	OK
F4 > 85 kN (kN)	138.3	OK	137.1	OK	118.2	OK
Global	OK		OK		OK	

Figure 6.15: FIAT Bravo FWDB R&R analysis.

All tested vehicles passed the different FWDB Metrics.

6.2.1.4 R&R Analyses FWRB Subaru Stella

In Japan two Subaru Stella were tested against the FWRB with a test speed of 55 km/h (one in JNCAP, one at JAMA). The difference of the impact point was 10 mm. The forces for Row 3 and 4 are plotted in the next Figure 6.16. The forces and also the characteristics of the forces are very similar for both vehicles.

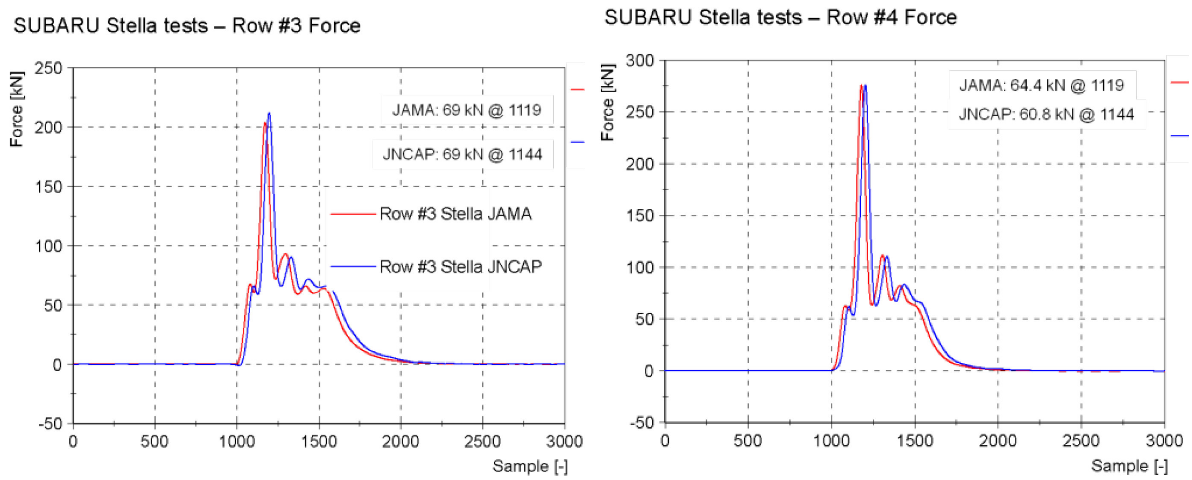


Figure 6.16: Forces on the LCW for Subaru Stella FWRB tests, left: Row 3, right: Row 4

The calculated metric for these vehicles are shown in the next table. Both vehicles would pass the initial metric and also the upgrade metric as they should.

Table 31: Subaru LCW test results with the FWRB metric.

	Current Status			Metric Upgrade				
	F3+F4 [kN]	F4/(F3+F4)	F3+F4>100 0.2<F4/(F3+F4)<0.8	LR=Min [(F2+F1-25 kN); 35 kN]	F4	F3	F4>35 kN	F3>(35 kN-LR)
JAMA	133.4	0.48	PASS	0	64.4	69	PASS	PASS
JNCAP	129.8	0.46	PASS	0	60.8	69	PASS	PASS

It could be stated that in the FWRB tests a good repeatability was seen in the LCW total Force and also for the row forces F1, F2, F3 and F4. The LCW recorded 200 kN before the engine collapsed. The current status and the upgraded FWRB Metric with the limit reduction were passed.

6.2.1.5 **R&R Analyses FWRB Toyota Corolla**

There were R&R test data available also for the Toyota Corolla. This vehicle was tested for JMLIT, JAMA and JNCAP. All vehicles were tested at 55 km/h with the same test weight. The impact point had differences up to 9 mm in the three tests. It should be noted that the undercover was not installed in the tests performed for JMLIT and JAMA.

The Figure 6.17 shows the forces on Row 3 and Row 4 for the Toyota Corolla tests. The forces are very similar up to 200 kN. The engine hits the LCW after the 200 kN. After the engine collapsed differences can be seen in the force characteristics. But some of these differences can also be due to the missing undercover.

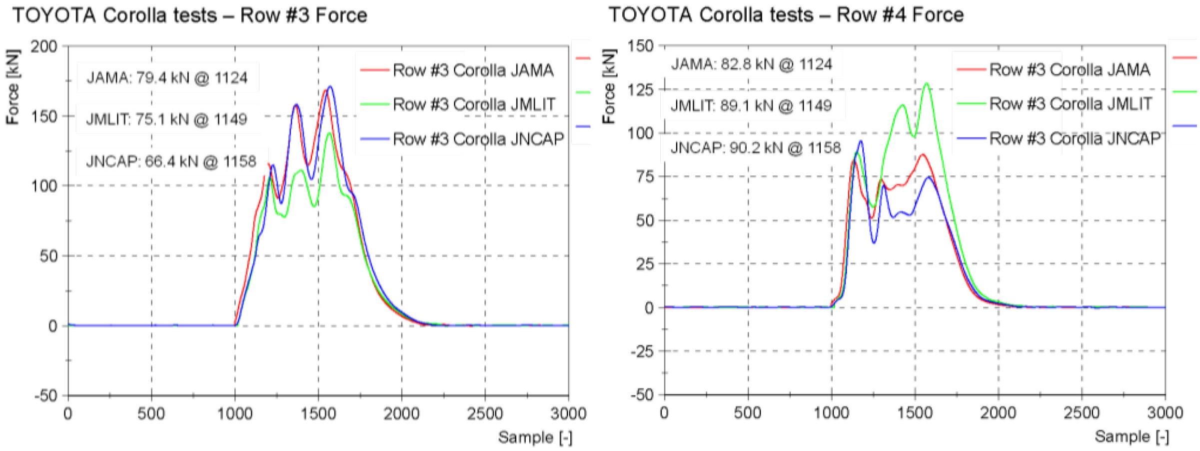


Figure 6.17: Forces on the LCW for Toyota Corolla FWRB tests, left: Row 3, right: Row 4.

The next Table 32 shows the results for the Toyota Corolla and the FWRB metric. All tested vehicles passed as they should. The differences are small and all tested vehicles have enough safety margins to pass in both metrics.

Table 32: Toyota Corolla LCW test results with the FWRB metric

	Current Status			Metric Upgrade				
	F3+F4 [kN]	F4/(F3+F4)	F3+F4>100 0.2<F4/(F3+F4)<0.8	LR=Min [(F2+F1-25 kN); 35 kN]	F4	F3	F4>35 kN	F3>(35 kN-LR)
JAMA	162.2	0.51	PASS	0	82.8	79.4	PASS	PASS
JMLIT	164.2	0.54	PASS	0	89.1	75.1	PASS	PASS
JNCAP	156.6	0.57	PASS	0	90.2	66.4	PASS	PASS

6.2.1.6 **Conclusions FWRB R&R**

The results also indicated that dummy injury for all five tests were below UN-ECE Regulation 94 limits. Good repeatability was observed in the LCW total force, in particular for F1, F3 and F4 up to 200 kN. But a mismatch in F2 for the Toyota Corolla occurred due to components modifications (Undercover effect). The LCW recorded 200 kN before the engine dumps. After the engine collapsed some discrepancies could be seen in row forces F3 and F4.

All tested vehicles passed the different FWRB Metrics.

6.2.2 Analysis of FIMCAR R&R data

To add more test data for the R&R analyses of the FWDB test procedure, three Supermini 1 FWDB tests were performed at different test labs - one at FIAT and two at BASt. The front ride height differences were up to 7 mm and the impact accuracy was up to 2 mm in height.

The LCW forces for Row 3 and Row 4 are shown in Figure 6.18. The maximum forces up to 40 ms had difference up to 23 kN in Row 3 and differences up to 40 kN in Row 4. Surprisingly one test from BASt and one test from FIAT are quite similar, but the second test at BASt showed the differences.

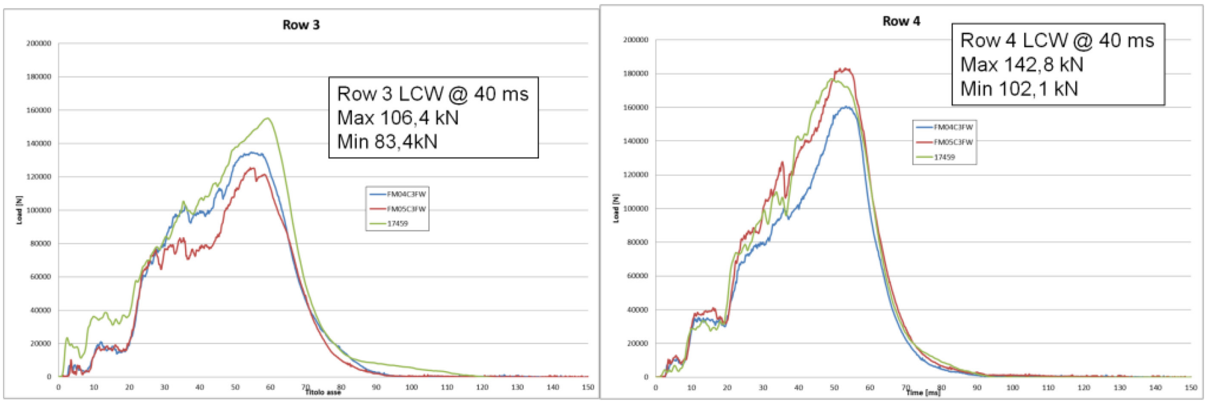


Figure 6.18: Forces on the LCW for Supermini 1 FWDB tests, left: Row 3, right: Row 4.

These differences were remarkably higher as seen in previous R&R analyses. Further examination of the vehicles and the test data showed that the bending of the structure was different. Supermini 1 is a single load path vehicle that already showed instable deformation pattern in car-to-car tests.

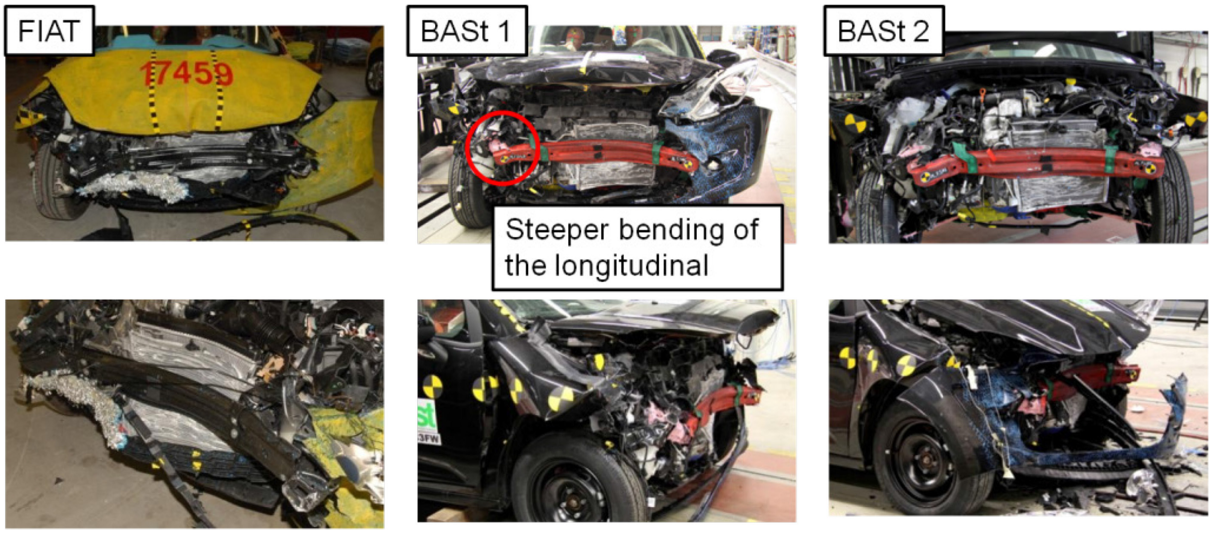


Figure 6.19: Comparison of the three Supermini 1 FWDB tests.

The deformation of the structure could partially explain the discrepancy in the force characteristics. Another explanation for the differences was the LCW used at BASt. This LCW does not fully fulfil the developed FIMCAR specifications that were finalised after scheduling the tests.

In total for the FWDB test procedure five different vehicles were tested at six different test labs. As a main conclusion all vehicles passed the metric as they should. The differences on total LCW force level are usually up to 8% and the differences on row force level were up to 15%. The exception was the Supermini 1 which had higher differences in the row forces. This was explained by different bending of the structures and the unstable rails of this vehicle, which had one load path.

6.2.3 Conclusions

Full scale crash test data analyses from previous projects and Japan were collected to analyse repeatability and reproducibility for both full width test procedures. The analyses indicate that there are reasonable results for both test procedures, the FWRB and the FWDB. However, as a final step to check the proposed test procedures three further tests in different test laboratories were conducted.

The FIMCAR consortium concluded: "Repeatability and Reproducibility is acceptable, in line with other crash tests, for cars with a stable front structure in this test mode. For further analysis of R&R the use of a stable front structure and sum forces above 500 kN is recommended (a good candidate would be Renault Mégane). Furthermore the LCW requirements as developed by FIMCAR shall be met."

6.3 Load Spreading of the Deformable Element

6.3.1 Background

In 2006 as part of the VC-Compat project, component tests were performed to investigate how the deformable barrier affected the loads measured on a Load Cell Wall (LCW) placed behind it in an FWDB test [Davies 2006]. These tests found that:

- The global force was repeatable with the total LCW force, energy and momentum balance all within ±4% of the calculated value
- The differences seen between individual load cells was greater than expected with possible reasons being differences in barrier deformation or bridging between the load cells

It was noted in VC-Compat that further investigation was required to understand better the reasons for the differences seen between individual load cells.

6.3.2 Objectives of Work

Based on the conclusions from VC-Compat the objective of the work was to:

- Determine the reasons for the unexpected differences in peak loads seen between individual load cells

This would be done by performing additional component tests to investigate whether the aluminium backing plate or the interface between the two layers affects distribution of load between cells.

6.3.3 Test Configuration

The testing was performed in the Impact Sled Facility (ISF) at TRL. The testing was the same setup as the testing in VC-Compat. The sled was fitted with a solid flat front plate. The sled impacted a section of aluminium honeycomb with FWDB specification load cells behind it to measure the force. A photograph of the setup is shown in Figure 6.20.

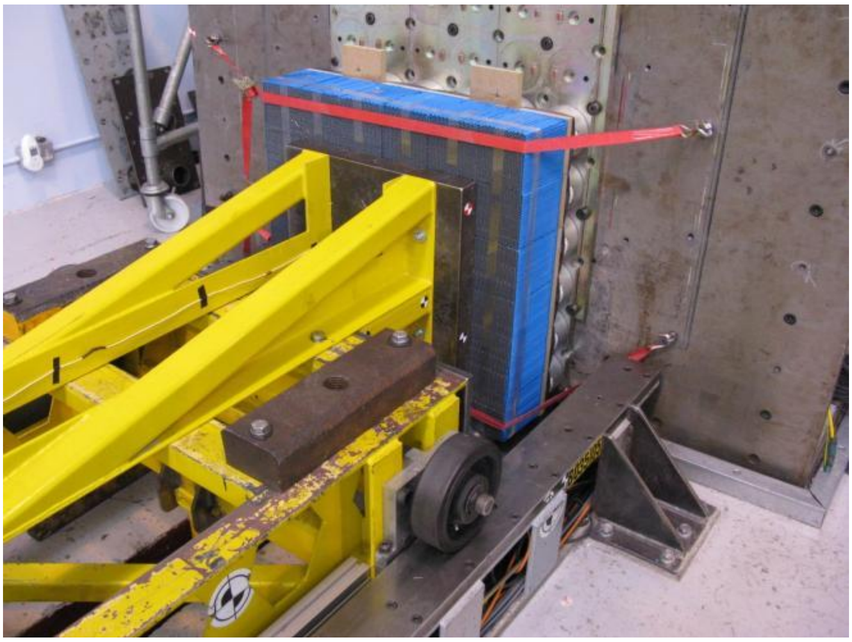


Figure 6.20: Setup of LCW component testing.

The specifications of the testing were:

- Speed: 40 km/h
- Sled mass: 762 kg
- Impactor size: 500 mm x 500 mm
- 6x6 LCW matrix covered by barrier (750 mm x 750 mm)
- Impactor aligned with central 4x4 cells

The LCW was checked for flatness in the horizontal, vertical and diagonal direction and found to be within a tolerance of ±0.5mm in all directions. When the honeycomb barrier was fitted to the wall, the segments of the honeycomb were aligned with the interfaces between the load cells.

6.3.4 Test Matrix

The test matrix for the tests performed in VC-Compat in 2006 and the tests performed in FIMCAR in 2011 are shown in Table 33.

Please note that the standard FWDB construction is as follows:

The deformable element is formed from two layers of aluminium honeycomb, with an overall depth of [300 mm], a minimum height and width of 750 mm and 2000 mm respectively.

The first layer of the deformable element has a crush strength of 0.34 MPa and is 150 mm deep, the second layer has a crush strength of 1.71 MPa and is 150 mm deep. In addition, the second layer is segmented every 125 mm in the horizontal and vertical directions starting at 125 mm from the outer edges. The two layers are joined with a muslin interlayer and there is no cladding on any faces other than the mounting face. The mounting face is clad with a 0.5 mm aluminium sheet which protrudes a set distance 40 mm from the upper and lower faces of the barrier to provide mounting flanges for attachment to the load cell wall.

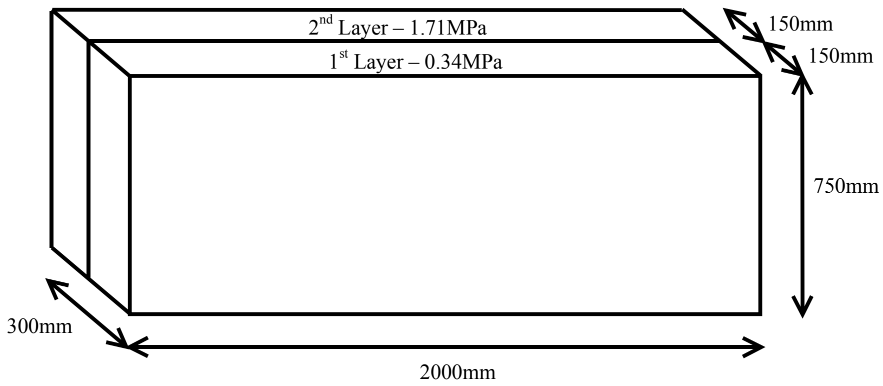


Figure 6.21: Construction of standard Full Width Deformable Barrier.

Table 33: Test matrix of LCW component tests.

2006

Test no.	Barrier	Test speed	Sled mass
1	Standard FWDB	40km/h	762kg
2	Standard FWDB	40km/h	762kg
3	'Optimised' FWDB	40km/h	762kg
4	'Optimised' FWDB	40km/h	762kg

2011

Test no.	Barrier	Test speed	Sled mass
1	Standard FWDB	40km/h	762kg
2	Standard FWDB without backplate	40km/h	762kg
3	Standard FWDB without backplate	40km/h	762kg
4	Rear section of standard FWDB without backplate	40km/h	762kg
5	Rear section of standard FWDB without backplate	40km/h	762kg

The optimisation of the FWDB in 2006 involved:

- ensuring that all the rear layer honeycomb blocks came from the same batch
- performing a cell count for each rear segment to ensure a similar number of complete cells in each block

The reasoning behind the testing in 2011 was:

- To perform a Standard FWDB test to ensure consistency between the tests performed in 2006 and the tests performed in 2011
- To perform tests with the Standard FWDB but without the aluminium backplate to investigate the effect of the backplate
- To perform tests with just the rear 1.71 MPa layer of the Standard FWDB without the backplate to investigate the effect of the interface between the layers

6.3.5 Test results

Total force against time plots for the five tests performed in 2011 and Test 1 performed in 2006 are shown in Figure 6.22.

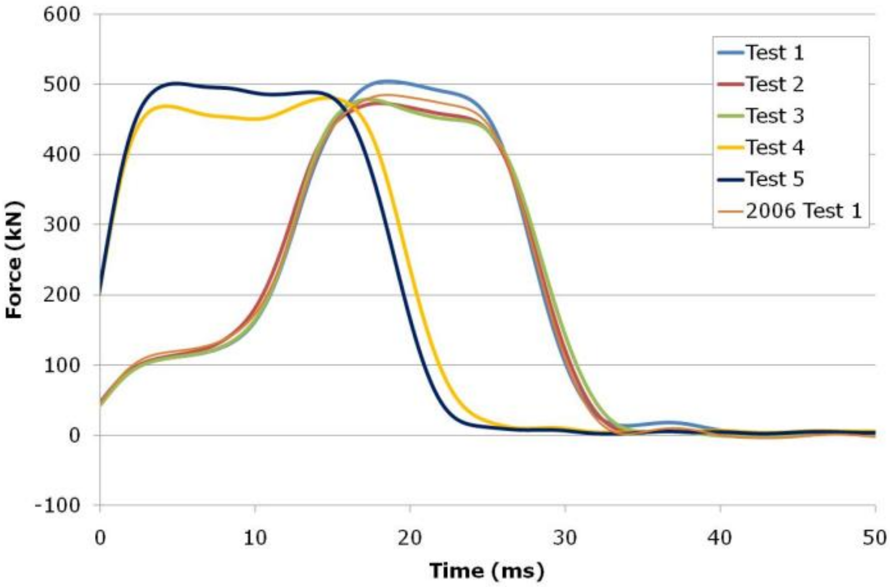


Figure 6.22: Total force against time (CFC60).

The results show a difference of up to 7% in the peak forces in these tests. It is interesting to note that the peak forces recorded were higher than the nominal static crush strength of the honeycomb. The nominal static crush strength of the honeycomb was between 385kN and 427 kN, measured dynamic crush strength approx. 450 to 500 kN. This is likely to be due to factors such as the additional force required to initiate the crush of the honeycomb and trapped air increasing its nominal static crush strength.

Figure 6.23 shows an example of the differences between forces measured by the different load cells in a single test.

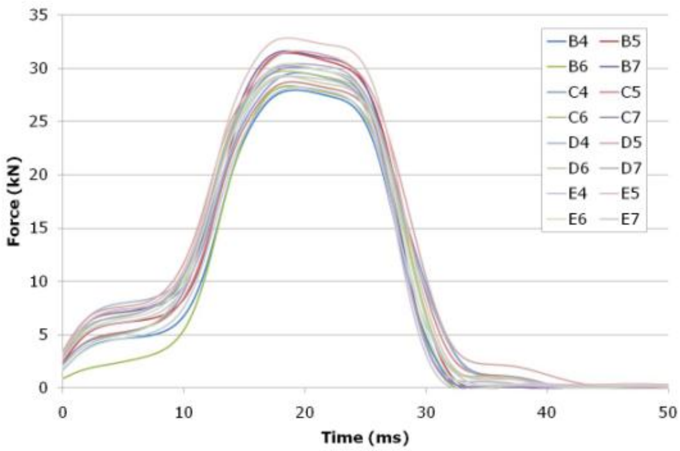


Figure 6.23: Force against time for each Load Cell in Test 1 2011.

The peak forces in each cell for 2011 Test 1 and 2006 Test 2 are shown in Figure 6.24 and Figure 6.25.

0.8	2.0	4.6	1.8	4.0	0.5
1.2	28.0	29.6	30.3	28.2	1.8
0.2	31.5	28.7	31.6	32.9	0.5
2.8	28.4	29.7	29.3	30.4	2.1
0.9	31.6	30.1	30.4	29.3	0.8
0.8	0.7	1.6	0.1	1.9	0.5

29.0
31.2
29.5
30.3

Figure 6.24: Peak cell force in 2011 Test 1 (Standard FWDB) with average centre cell row force.

1.7	2.8	3.9	4.7	1.6	1.2
0.3	25.6	27.0	27.5	25.6	0.5
2.9	30.8	29.2	29.9	29.5	4.4
0.6	27.3	27.5	35.2	28.2	0.3
0.4	28.3	28.4	30.3	31.2	0.1
1.7	2.3	0.3	0.8	1.9	0.2

26.4
29.9
29.6
29.5

Figure 6.25: Peak cell force in 2006 Test 2 (Standard FWDB) with average centre cell row force.

The results show that for the 2011 test the maximum peak cell force was 32.9 kN and the minimum peak cell force was 28.0 kN, giving a difference of 4.9 kN. For the 2006 test the maximum peak cell force was 35.2 kN and the minimum peak cell force was 25.6 kN, giving a difference of 9.6 kN.

The results for the tests without the backplate (2011 Test 2 and Test 3) are shown in Figure 6.26 and Figure 6.27.

0.2	1.9	2.4	1.7	2.1	0.2
0.8	28.2	28.7	28.5	28.2	0.6
0.5	30.6	28.1	29.2	31.1	0.5
1.3	28.7	28.2	27.7	28.2	0.9
0.6	31.0	29.8	29.0	28.6	0.2
0.0	1.1	1.4	0.1	1.2	0.1

28.4
29.8
28.2
29.6

Figure 6.26: Peak cell force in 2011 Test 2 (Standard FWDB without backplate) with average centre cell row force.

0.1	0.8	2.1	0.3	0.8	0.2
1.4	28.6	28.9	28.5	29.5	1.7
0.8	30.0	29.6	28.6	31.0	1.2
1.1	30.2	28.9	27.5	28.5	1.1
1.3	31.7	30.2	30.6	28.4	0.8
0.1	1.0	1.1	0.1	1.4	0.1

28.8
29.8
28.8
30.2

Figure 6.27: Peak cell force in 2011 Test 3 (Standard FWDB without backplate) with average centre cell row force.

For the tests without the backplate, the maximum peak cell differences are 3.4 kN and 3.5 kN respectively, compared to 4.9 kN and 9.6 kN for the Standard FWDB. This shows an improvement in peak cell force distribution. The average row force differences for the tests without the backplate are 1.6k N and 1.4 kN respectively, compared to 1.2 kN for the Standard FWDB. This shows a much smaller change.

The results for the tests without the backplate and with the rear layer of honeycomb only are shown in Figure 6.28 and Figure 6.29.

0.3	1.2	1.3	0.6	0.9	0.4		
0.2	29.5	29.6	30.9	32.2	1.1		30.6
0.1	30.0	28.5	31.6	29.8	0.7		30.0
0.1	31.2	29.2	28.9	30.5	0.7		30.0
0.2	30.9	32.6	31.4	28.3	1.4		30.8
0.1	0.2	0.2	0.1	0.2	0.2		

Figure 6.28: Peak cell force in 2011 Test 4 (FWDB without backplate, rear layer only) with average centre cell row force.

0.3	0.4	1.2	0.6	0.5	0.4		
0.3	31.9	33.0	32.7	31.5	1.7		32.3
0.2	33.7	30.8	30.2	31.0	0.8		31.4
0.3	31.6	31.6	28.9	28.4	0.8		30.1
0.2	34.7	31.3	31.7	28.8	1.5		31.6
0.1	0.4	0.4	0.1	1.1	0.1		

Figure 6.29: Peak cell force in 2011 Test 5 (FWDB without backplate, rear layer only) with average centre cell row force.

The results for the tests without the backplate, the maximum peak cell differences are 4.3 kN and 6.3 kN respectively, compared to 4.9 kN and 9.6 kN for the standard FWDB. This shows little consistent change. The average row force differences for the tests without the backplate are 0.8 kN and 2.2 kN respectively, compared to 1.2 kN for the Standard FWDB. This shows little consistent change.

Overall, there is some reduction seen in peak cell force distribution when the effect of the backplate is removed, however when the effect of the interface layer is also removed, the distribution is similar to the Standard FWDB. This may be due to increased instability of the honeycomb when the interface and backplate are removed. Little or no change in the peak row force distribution was seen.

6.3.6 Conclusions

- The causes of the 'greater than expected' differences in peak cell forces are still not understood clearly but it is likely to be a combination of factors. However it was found that neither the backplate nor interface layer are major contributors. Other contributors may include tolerance in quasi-static crush, effect of block trimming and interaction between blocks. One possible method to reduce any increase in force caused by crush initiation is to use pre-crushed honeycomb.
- When cell forces are averaged, for example across a row, the differences are reduced greatly, and therefore a metric which does this could possibly be acceptable.
- The total LCW force was found to be reasonably repeatable with differences up to approximately 7%. However the peak cell force was found to have differences of up to 15% in tests with the standard barrier, and up to 27% for the tests performed in 2006. The peak row forces were found to have differences of up to 4% with the standard barrier, and up to 12% for the tests performed in 2006.
- There was some reduction in LCW peak cell force distribution when the effect of the backplate was removed, however when the effect of the interface layer was also removed, the distribution was similar to the Standard FWDB. This may be due to increased instability of the honeycomb when the interface and backplate are removed. Little or no change in the peak row force distribution was seen

7 SUMMARY OF CONCLUSIONS

The objective of work package 3 was to develop a full overlap test procedure. Therefore the set-up of assessment criteria and their validation was needed. Performance criteria for the assessment procedure were defined based on the outcome of the FIMCAR accident analyses and the FIMCAR priorities defined.

In parallel the test and assessment procedure was developed for both configurations, the FWRB and the FWDB. In a later phase of the project the focus was settled on the FWDB test procedure, because the FIMCAR consortium agreed on this.

According to the FIMCAR priorities the main aims of the full width test were:

- Alignment with part 581 zone (initial loading is evaluated above and below the centreline)
- Not discourage a load path in alignment with Load Cell Wall Row 1 and 2 and possibly encourage

These priorities were set because structural alignment is one main pillar of compatibility. It also helps to prevent under and override which was seen in accident analyses. And it also supports the establishment of a common interaction zone.

As a result following conclusions can be made for the full width test procedure:

1. The full width test shall be performed with a deformable barrier and an LCW to measure force distribution with a test speed of 50 km/h. The full width test and assessment protocol is included in Annex C.

FWDB metric

The proposed metric with Limit Reduction which was developed based on test data with a test speed of 56 km/h, addresses the FIMCAR priorities (structural alignment in part 581 zone and encouragement of load path in alignment with Row 2) and is a good principle. However, further validation of the proposed performance limits is recommended, in particular consideration of light cars and the influence coming from the proposed change in test speed to 50 km/h is needed.

The current metric and associated performance limits which was validated for a test speed of 56 km/h is as follows

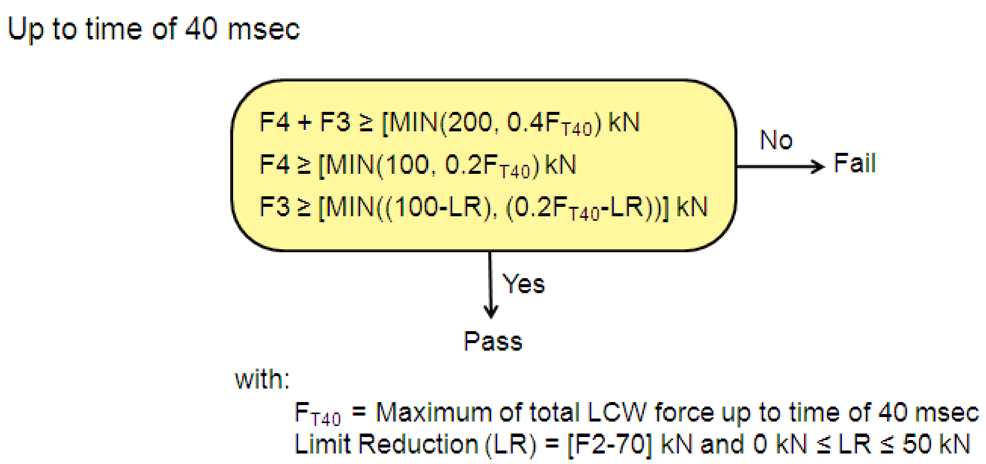


Figure 7.1: FIMCAR FWDB metric.

Lower Load Path

The tests and simulations conducted in FIMCAR indicate that structural alignment is a high priority for frontal impact and compatibility and that vertical load spreading is an important supporting characteristic. In all cases, vehicles with vertical load spreading can be detected with the FWDB if the structures are less than 400 mm behind the bumper. Lower load paths that are detected in a FWDB by exerting more than 70 kN (in the 56 km/h test case) show a benefit for car-to-car crash performance. An FWDB metric that rewards vehicles with 70 kN in Rows 2&3 would be beneficial for vehicle safety.

Over Ride Barrier

To pass the ORB test does not guarantee that the car performs well in car-to-car impacts. The FWDB is detecting structures which have a benefit in car-to-car impacts.

Test Speed

It was important to establish a test severity for the full width test procedures to ensure the candidate procedures were representative of the real world conditions. The real world data indicates that the highest risks for MAIS2+ injuries are in the range 4 to 57 km/h and that this impact severity should be used to direct future car designs. Given that a full width test delta-v usually involves a rebound velocity of approximately 10% the impact speed, a test speed of 50 km/h was selected for a full width test severity, regardless of the barrier face selected.

With all FIMCAR car models it could be shown that the metric works for test speeds in a range from 40 to 56 km/h. This is because the metric considers forces relative to the total LCW force for many vehicles. An upgrade of the metric was developed at the end of the project in order to reflect forces in Row 2. This modified metric could not be tested at different impact speeds yet. In general this modified metric works similar but it includes a fixed value (70 kN) which needs to be revised. Therefore further work is needed in order to confirm or define the fixed value with additional simulations, if the test speed of 50 km/h will be set.

Repeatability & Reproducibility

Full scale crash test data analyses from previous projects and Japan have been collected to analyse repeatability and reproducibility for both full width test procedures. The analyses indicate that there are reasonable results for both test procedures, the FWRB and the FWDB. However, as a final step to check the proposed test procedures three further tests in different test laboratories were conducted and analysed.

Based on this test data repeatability and reproducibility is acceptable, in line with other crash tests, for cars with a stable front structure in this test mode. For further analysis of R&R the use of a stable front structure and sum forces above 500 kN is recommended (a good candidate would be Renault Mégane). Furthermore the LCW requirements as developed by FIMCAR shall be met.

LCW Certification

As part of FIMCAR a Load Cell Wall (LCW) certification procedure was defined. The procedure consists of the LCW definition and certification requirements in terms of wall flatness. In addition a specification and calibration protocol was prepared for the transducers.

Parameter values for both documents were obtained from measurements and analyses on load cell walls and transducers itself. Certification requirements for the wall flatness were based on measurements of three existing walls and an analysis of a trolley test done by BASt. A series of load cells was tested to check and refine values set for non-linearity and hysteresis.

Load spreading of the deformable element

When cell forces are averaged, for example across a row, the differences are reduced greatly, and therefore a metric which does this could be acceptable.

8 ACKNOWLEDGEMENTS

The FIMCAR development of FWRB metrics was supported by JMLIT, JAMA and Nagoya University by offering test data combined with the corresponding geometrical data of the respective cars and performing some calculations.

JAMA supported the FIMCAR project with three additional FWDB tests and test data .

The development of the load cell certification and calibration procedure was supported by Kistler.

Members of the FIMCAR project thank gratefully JMLIT, Nagoya University, JAMA and Kistler for their contributions.

9 GLOSSARY

APROSYS	Integrated Project on Advanced Protection Systems APROSYS was supported in the 6th European Framework Programme
AIS	Abbreviated Injury Scale
ATD:	Anthropomorphic Test Device (crash test dummy)
CIZ:	Common Interaction Zone
ECE	Economic Commission for Europe
EEVC	European Enhanced Vehicle-safety Commission
FIMCAR	Frontal Impact and Compatibility Assessment Research
FWDB	Full Width Deformable Barrier
FWRB	Full Width Rigid Barrier
GRSP	Working Party on Passive Safety
LCW	Load Cell Wall
LTV	Light Truck Vehicle
MAIS	Maximum Abbreviated Injury Scale
MDB	Movable Deformable Barrier
NCAP	New Car Assessment Programme
PEAS	Primary Energy Absorbed Structure
RTD	Research and Technology Development
R&R	Repeatability and Reproducibility
SEAS	Secondary Energy Absorbed Structure
SUV	Sport Utility Vehicle
VC-COMPAT	Vehicle Crash Compatibility VC-Compat was a project funded under the GROWTH programme of the European Commission.
WG15	Workgroup 15 in the EEVC

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ANNEX A: LOAD CELL SPECIFICATION AND CALIBRATION

1. Objective and scope

The present guideline is general applicable for force measurements with load cells used in the application of a high resolution barrier for frontal vehicle crash testing. It is used to characterise the minimum specifications for the load cell, the calibration procedure and the estimated relative measuring uncertainty of calibration.

The guideline applies to stepwise (static) and continuous (quasi-static) loading cases during the process of calibration. In the former case, the stepwise calibration, a pure static loading will be applied. At this suitable load periods for each load step have to be sustained in order to provide for creeping effects of the unit under test. In the latter case, continuous calibration, the unit under test will be subjected to a continuously changing load. The load change during calibration has to be chosen in such a way that an adverse calibration effect by dynamic effects is precluded.

Due to the fact that the choice of calibration procedure, the exposure time and/or the rate of loading depends largely upon the force load device used for the calibration, the user of this guideline, who will be in authority of the calibration, is in charge of the suitable calibration settings.

2. Normative references

The following normative documents contain provisions which are referred to in this text. In case of any future amendments the possibility of applying the most recent editions of the normative documents should be investigated.

ISO 376:2004 Metallic materials - Calibration of force-proving instruments used for the verification of uniaxial testing machines[1].

ISO 2041:1990 Vibrational shock - Vocabulary.

ISO 6487:2002 Road vehicles - Measurement techniques in impact tests - Instrumentation.

ISO/IEC Guide 98-3:2008 Uncertainty of measurement – Part 3: Guide to expression of uncertainty in measurement (GUM:1995)

SAE J2570:2009 Performance Specifications for Anthropomorphic Test Device Transducers.

SAE J211:2007 Instrumentation for impact tests - Part 1: Electronic instrumentation.

3. Terms and definitions

3.1. Load Cell Definitions

1. A new version of DIN EN ISO 376 was expected to be published end 2011 but is not available yet. Publication should be monitored and when available reference to updated version included in this document.

3.1.1. Certification
Formal procedure by which an accredited or authorized person or agency assesses and verifies (and attests in writing by issuing a certificate) the attributes, characteristics, quality, qualification, or status of a measurement device or system, in accordance with established requirements or standards.

3.1.2. Calibration
Operation that, under specific conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.

NOTE 1 A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

NOTE 2 Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration.

NOTE 3 Often, the first step alone in the above definition is perceived as being calibration.

3.1.3. Data Channel
All of the instrumentation from and including a single transducer up to and including any analysis procedures that may alter the frequency content or the amplitude content or timing of data. It also includes all cabling and interconnections.

3.1.4. Full Scale Capacity
Full scale capacity is the maximum usable linear range of a data channel.

3.1.5. Non-Linearity (% of full scale capacity)

Linearity is defined as the closeness of the calibration curve to a specified line (source: ANSI/ISA-S37.1). Non-linearity represents the maximum deviation between ideal and actual output signal characteristics in relation to the reference in a specific measuring range. It is expressed in percentage of the range of measurement signal (full scale output).

3.1.6. Hysteresis (% of full scale capacity)
The maximum deviation between ascending and descending output readings taken at the same load point, expressed as a percentage of full scale capacity.

3.1.7. Free Air Resonance
The frequency at which a transducer resonates, when suspended freely in air by a single wire and impacted with a hard surfaced body. This test shall be done while monitoring the channel output to insure each channel’s fundamental output frequency shall be equal to or greater than the specified frequency.

3.1.8. Shear Load Sensitivity (Crosstalk)
One channel of a load cell loaded to a set loading, and the other channel(s) unloaded, the output of the unloaded channel(s) is expressed as a percentage specified of the unloaded channels full scale capacity.

3.1.9. Off-Centre Loading Error

When a force channel is loaded at a distance from the neutral axis, the error in the force channel output with respect to the output when calibrated on the neutral axis is reported as a percentage error of full scale.

3.1.10. Compensated Temperature Range

The range of temperature over which the transducer is compensated to maintain output and zero balance within specified limits.

4. Transducer Specifications

4.1. General Specifications

4.1.1. Transducer Type

Uniaxial force measurement in compression mode (x-axis).

4.1.2. Physical Dimensions

The physical dimensions of contact surface shall be nom. 125 x 125mm minus a clearance in between load cells to avoid interference between proximate transducers.

4.2. Measurement Performance Specifications for Uniaxial Loadcell

4.2.1. Full scale capacity ≥ 300 kN

4.2.2. Overload capacity ≥ 400 kN

4.2.3. Non-Linearity (% of full scale capacity [absolute value]) ≤ 1.0%.

4.2.4. Hysteresis (% of full scale capacity [absolute value]) ≤ 2.0%.

4.2.5. Free Air Resonance ≥ 5kHz [2]

4.2.6. Shear Load Sensitivity ≤ 3% under the loading condition of 50 kN for cross axis channel(s)

4.2.7. Off-Centre Loading Error ≤ 3%2

4.2.8. Temperature Range: 15°C to 30°C

5. Characteristic of the force measuring chain

5.1. Description of the force measuring chain

The force measuring chain comprises of all components from the unit under test / working standard to the indicating output instrument.

The selection and settings of all signal running components, e.g. measuring amplifier and indicating instruments, in the measuring chain of the working standard as well as the unit under test will be left to the user who will be in authority of the calibration. The characteristic function for the transfer behaviour of the signal running components has to be known and the same filter parameters have to be assured. The exchange of the signal running components by an identical component will be permitted to do as long as its systematic error of output value, due to its technical specification and the measuring uncertainty, do not have an essential influence on the calibration result.

All components of the force measuring chain (including connection cables) have to be labelled in particular and precisely.

5.2. Application of Force

[2] Final value could not be set on the basis of FIMCAR testing. For the free air resonance a value of either 4 or 5kHz was proposed. Also for the off-centre loading error a value of either 2% or 3% was proposed. Further studies are needed to set a final value for both parameters. For the time being the less strict values are listed the performance specifications.

All calibration fixtures used for calibration have to be considered as integral part of the unit under test.

5.2.1. Working Standard: Assembly following DIN EN ISO 376
5.2.2. Unit under test: To the greatest possible extent like in the field.

For the calibration with a one component force loading machine a calibration fixture with a three-sided loading base will be used for mounting of the unit under test. The position of the calibration fixture with the unit under test has to be permuted depending on each designated direction of force application (axial or transversal loads).

In the case of a three component force loading machine the unit under test will be mounted by a calibration fixture in one position in order to apply the three forces in each direction.

The application of force will be carried out by the use of a loading head, an example of which is shown in Figure A.1.

I. If the calibration force shall be applied by a 1” steel ball “sphere” a case-hardened loading head with ball joint loading points on all three sides has to be used.
II. If the calibration force shall be applied by a spherical steel stamp a plane loading head has to be used. Dependent on the geometry of the spherical steel stamp and the resultant stress in the contact area it could be necessary to use case-hardened steel plates at the stamp joint loading points

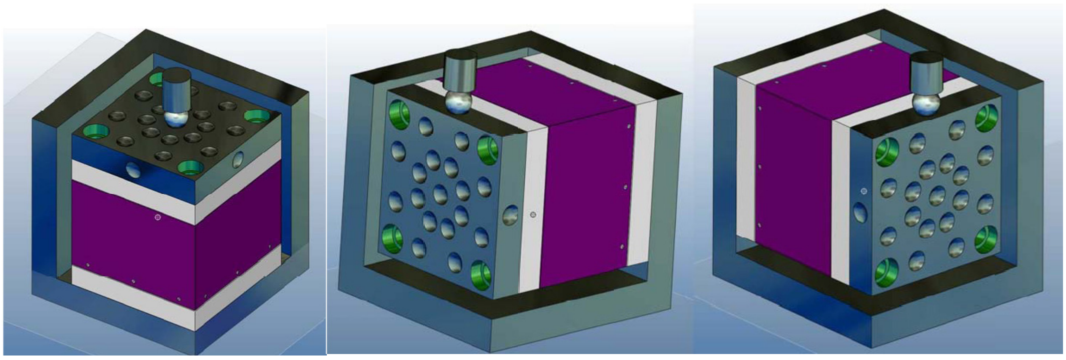


Figure A.1: Loading head with application in axial loading, cross talk Fy and cross talk Fz applications

6. Calibration of the force measuring chain
 6.1. General requirements

The calibration is done by the application of a known force into the force measuring chain. The application of force has to be done by use of a simple force load machine which is equipped with a calibrated working standard. Both the working standard – reference channel - and the unit under test are loaded at the same time. The output of the working standard as well as the unit under test has to be recorded. The measured output of the unit under test is then compared with that of the working standard.

 6.2. Calibration preparation

6.2.1.Reference and display equipment

The adjustments of the reference and display equipment must be carried out as stated in the instruction manual. For the documentation all serial numbers of the reference equipment and all variable settings must be recorded. In addition the relevant parameters of the calibration sequence have to be documented.

6.2.2.Warm-up

The unit under test must be allowed to warm-up prior to calibration. It is thus required to apply the specified supply voltage to the overall measurement chain in order to avoid warming-up errors.

6.2.3.Ambient conditions

At the beginning of the calibration the relevant ambient conditions have to be documented. The ambient temperature must be held steady within +/- 2 °C with respect to a reference temperature of 21°C.

6.3. Calibration process

The manufacturer of load cells should specify the following properties of the cells in data sheets.

6.3.1. Preloading

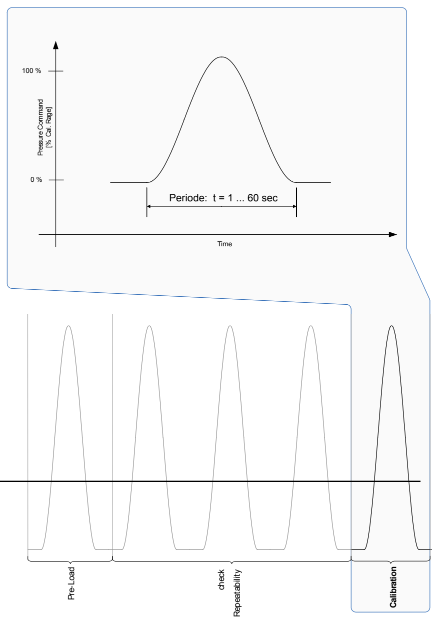
After assembly, the unit under test must be preloaded twice prior to calibration to the final value of calibration load.

6.3.2.Calibration procedure

The method applied for calibration is either a

- ⇨ Stepwise (static) procedure: The output of the unit under test is compared with that of the working standard, while discrete force values are applied from 0 to full scale and back (typical for calibration units with lever-mass system), or a
- ⇨ Continuous (quasi-static) procedure: The output of the unit under test is compared with that of the working standard, while continuously ramping the load from 0 to full scale and back (preferred procedure for piezoelectric sensors).

In case of a stepwise calibration a series of measurements in ascending order and a series of measurements in descending order is performed after the two preload cycles. A minimum of five (5) steps / force levels from zero to the final value of calibration load (FSO) have to be taken for each series. Preferably 20%, 40%, 60%, 80% and 100% of the upper limit of the effective calibration range (FSO).



In case of a continuous calibration a force progression cycle in the shape of a ramp functions with increasing and decreasing load is indicated. As the upper limit of the effective calibration range (FSO) cannot be approached definitely during the loading cycle, it is permitted to marginally exceed the upper limit of full scale calibration range.

For the acquisition of calibration data the pair of readings from the unit under test and the working standard – reference force – might be recorded time-discrete or value-discrete. The time-discrete acquisition will be done by a predetermined sampling rate. The value-discrete data acquisition will record the pairs of readings at specified load values.

6.3.3. Determination of characteristic values

Sensitivity, Non-linearity and Cross-talk are to be determined during calibration on an annual basis and in case of overloading of the transducer.

6.3.3.1. Data evaluation and interpretation

For the evaluation and interpretation of the calibration data the minimum method may be applied. In doing so the zero point of the measured characteristic line will be matched with the zero point of best fit straight line. Subsequently the slope of best fit straight line will be chosen in such a way that the deviation from the measured characteristic line meets a minimisation principle. For the minimisation principle following methods might be used:

- ⇨ The method of "least squares" that assumes that the best-fit curve of a given type is the curve through zero that has the minimal sum of the deviations squared (least square error) from a given set of measurement readings.
- ⇨ The method of "best straight line" (according to ANSI/ISA S37.1-1975) that assumes that the best-fit curve of a given type is the curve through zero that will minimize the maximum of the deviations from a given set of measurement readings.

In order to ensure the comparability of calibration results, it is necessary to declare and to document the method that was used to determine the characteristic calibration values.

The evaluation of the calibration results can be visualized in a so call difference curve by plotting the output signals of the unit under test (load cell) against the reference. The following parameters are calculated.

6.3.3.2. Sensitivity

Change in the response of a unit under test divided by the corresponding change in the value of the reference. The sensitivity is, e.g. defined as the slope of a so called Best Straight Line (BSL) through the calibration curve. The BSL is a line midway the two parallel straight lines closest together and enclosing all output versus reference values on a calibration curve. In addition, it must pass through the zero point based on the assumption that zero reference results in zero output signal.

The force application in the mean axis of the unit under test will be carried out centrically in such a way as described in detail by chapter 6.3.2.

6.3.3.3. Non-linearity

The maximum deviation of a transducer output reading from the ideal output expressed as a percentage of full scale capacity.

The ideal sensor output may be obtained by the terminal line method defined as a straight line connecting a transducer zero load reading and its full scale reading or by alternatives like the Gauss Algorithm meaning the method of least squares.

6.3.3.4. CrossTalk

Crosstalk is based on output measured in the e.g. X-direction while respectively applying a load up to 50 kN to the perpendicular Y- and Z-directions of the unit under test. With one channel of a load cell, loaded to capacity and the other channel unloaded, the output of the unloaded channel may be expressed as:

- A percentage of the unloaded channel's full scale capacity

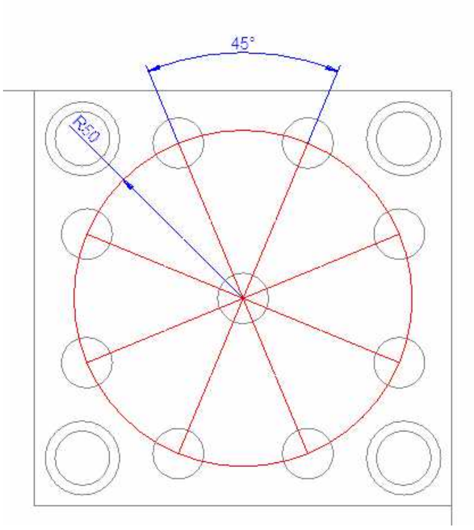
or

- A percentage of the loaded channel's full scale capacity.

or

- A percentage of the loaded channel's full scale calibration range (50 kN).

In order to ensure the comparability of calibration results, it is necessary to declare and to document the method that was used to determine the crosstalk values.



6.3.4. Determination of extended values

Extended values relate to off-centre loading error, hysteresis and free air resonance. These data are to as design verification and to be collected once per load cell design.

6.3.4.1. Off-Centre Loading Error

The off-centre loading error may be determined by applying forces in the axial direction at various eccentric application points. The area for admissible off-centre force application should be on a radius of 50 mm around the centre axis with 45° inclination between and, if possible, in the four corners of the unit under test. Maximum load should be the upper limit of the effective calibration range (FSO). The sensitivity deviation has to be calculated for each force application point and the maximum deviation shall be used to determined the maximum off-centre loading error.

Note: The identification of the off-centre loading error should be only considered as a type evaluation process. In particular a ratio of 1 to 25 units shall be considered.

6.3.4.2. Hysteresis

As defined in 3.1.6.

6.3.4.3. Free air resonance

The free air resonance may be determined by suspending the transducer freely by a single wire and impacting in the loading direction by a modal hammer. Channel output will be monitored to insure each channel's fundamental output frequency shall be equal to or greater than the specified frequency. Anti Aliasing filters and sample frequency should be chosen such to avoid Aliasing effects (see SAE J2011)

7. Classification

The calibration according to this guideline does not provide for classification.

8. Calibration Certificate

Will a calibration be executed and at that time the force measuring chain is in compliance with the requirements of this guideline, the calibration laboratory will draw up a calibration certificate with at least the following information:

- Calibration laboratory and responsible person,
- Date of the calibration,
- Specification of the calibration method and operation sequence,
- Information of the used measurement standards,
- Ambient conditions at which the calibration was performed,
- Result of calibration,
- Identification of any limit violation,
- Tabulation and/or graphical representation of the calibration results,
- Approximation function (e.g. linear equation) and its method of determination.
- Identification number of the calibration certificate, number of pages

ANNEX B: LOAD CELL WALL SPECIFICATION AND CERTIFICATION

2. Objective and scope

The present guideline is general applicable for a high resolution load cell wall used in frontal vehicle compatibility assessment. It is used to characterise the minimum specifications for the load cell wall and its certification.

3. Specifications

3.1. General Specifications

3.1.1. Physical Dimensions and positioning

The physical dimensions of the load cell wall shall be nom. 1000 x 2000mm. The ground clearance defining the height of the load cell wall above the ground shall be 80 ±2 mm.

3.1.2. Transducer dimensions

The physical dimensions of contact surface of the load cells used in the wall shall be nom. 125 x 125mm minus a clearance in between load cells to avoid interference between proximate transducers.

3.1.3. Wall flatness

3.1.3.1. Alignment of transducer centre

Transducers shall be positioned such that centre point locations of adjacent cells are aligned to have a depth variation (measured perpendicular to load cell wall) of 1 mm or less.

3.1.3.2. Alignment of transducer corners and edges

Transducers shall be positioned such that corners and edges of adjacent cells are aligned to have a depth variation (measured perpendicular to load cell wall) of 1 mm or less.

3.1.4. Transducer numbering

The transducers shall be positioned in a square grid. The numbering indication of the transducers shall be according to Figure B.1. The numbering sequence of transducers in a column starts at 01 for the lowest cell. The numbering sequence in a row starts at 01 at the left side (facing towards the barrier). A transducer number consist of its number in the column followed by its number in the row.

3.2. Measurement performance specifications

3.2.1. Sampling rate ≥ 10 kHz

3.2.2. Transducer specifications and calibrations as included in Annex A

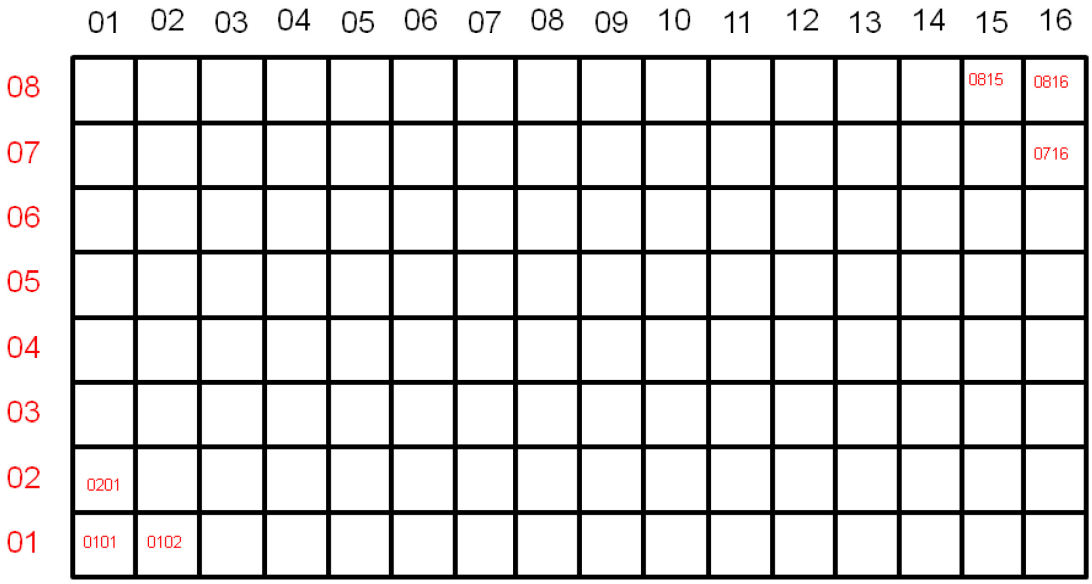


Figure B.1: Load cell numbering

4. Certification

4.1. General requirements

The certification is done by measuring the position at the centre and the corners of each transducer in a 3-Dimensional space. This has to be done by use of an adequate measuring device that has sufficient range to provide data for all transducers in the wall. Data shall be provided in metric units.

The measurement has to be done directly on the transducers. Protective layers like wooden plates have to be removed.

4.2. Position measurement

4.2.1. If applicable remove the wooden cover plates from the transducers.

4.2.2. Setup the Faro arm or alternative measurement device. If possible position the Faro arm in such a position that no frog leaps are necessary.

4.2.3. Measure on each transducer the position of the centre and corner points. For the corners measurements should be taken 5 mm from each side. See Figure B.2.

4.2.4. In case the indicated position is not applicable, for example if there is a threaded hole, take an appropriate position as close a possible.

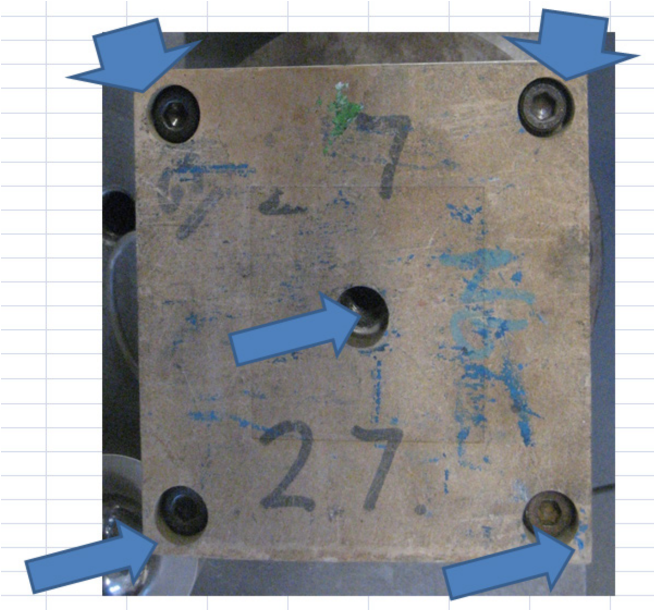


Figure B.2: Measurement locations

4.3. Determination of wall flatness

4.3.1. A reference for the transducer position in the direction perpendicular to the wall (X direction in Figure B.3) is set by summing measured positions in this direction for all transducers at centre point location. An average depth position is obtained by dividing the sum by the number of transducers.

4.3.2. Calculate depth positions (X direction in Figure B.3) for corner and centre point positions by subtracting the average depth position from the measured position in the direction perpendicular to the wall.

4.3.3. Calculate the difference of depth position between transducer centres of all adjacent cells (column wise, row wise and diagonal wise). The resulting value should meet specifications set in 2.1.3.1.

4.3.4. Calculate the difference of depth position between all adjacent transducer corners (column wise, row wise and diagonal wise). The resulting value should meet specifications set in 2.1.3.2.

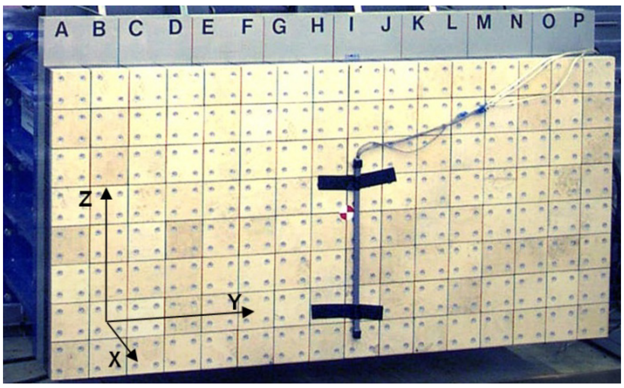


Figure B.3: Measurement locations

ANNEX C: FULL WIDTH TEST AND ASSESSMENT PROTOCOL

Table of Contents

This document describes the draft test protocol for the Full Width Deformable Barrier (FWDB) test. It must be noted that some aspects of the test protocol have yet to be defined. In such cases options have been defined, which are identified using square brackets. The main options are:

- Additional instrumentation (accelerometers) to fully evaluate compatibility for the FIMCAR project

Please note that for the tests to be performed in the FIMCAR project the high resolution Load Cell Wall (LCW) and additional instrumentation to fully evaluate compatibility should be included in all tests.

Much of the protocol is similar to the Euro NCAP v4.1 frontal impact test protocol. Those familiar with the Euro NCAP protocol should note that the main differences are in the following sections:

1.5 Suspension setting

1.6 Normal ride height

2.3.1 Optional intrusion measurements

4.2 Vehicle instrumentation – accelerometers, airbag current clamps, etc.

4.3 Load Cell Wall (LCW)

5.0 Camera Locations

9.0 Speed / Barrier Alignment / Impact Accuracy vertical

10.0 Calculation of injury parameters – additional parameters such as HIC15, Nij, etc.

11.0 Deformable Barrier specification

1 VEHICLE PREPARATION

1.1 Unladen Kerb Mass

1.1.1 The capacity of the fuel tank will be specified in the manufacturer's booklet. This volume will be referred to throughout as the "fuel tank capacity"

1.1.2 Syphon most of the fuel from the tank and then run the car until it has run out of fuel.

1.1.3 Calculate the mass of the fuel tank capacity using a density for petrol of 0.745g/ml or 0.840g/ml for diesel. Record this figure in the test details.

1.1.4 Put water, or other ballast, to this mass in the fuel tank.

1.1.5 Check the oil level and top up to its maximum level if necessary. Similarly, top up the levels of all other fluids to their maximum levels if necessary.

1.1.6 Ensure that the vehicle has its spare wheel on board along with any tools supplied with the vehicle. Nothing else should be in the car.

1.1.7 Ensure that all tyres are inflated according to the manufacturer's instructions for half load.

1.1.8 Measure the front and rear axle weights and determine the total weight of the vehicle. The total weight is the "unladen kerb mass" of the vehicle. Record this mass in the test details.

1.1.9 Measure and record the ride heights of the vehicle at all four wheels.

1.2 Reference Loads

1.2.1 Calculate 10 percent of the fuel tank capacity mass as determined in 1.13

1.2.2 Remove this mass of ballast from the fuel tank, leaving 90 percent of the mass in the tank.

1.2.3 Place both front seats in their mid-positions. If there is no notch at this position, set the seat in the nearest notch rearward (this will be done more completely in section 6).

1.2.4 Place a mass equivalent to the 50th%ile driver test dummy (including instrumentation and cables) and a 5th%ile passenger test dummy on the front seats.

1.2.5 Place 36kg in the luggage compartment of the vehicle. The normal luggage compartment should be used i.e. rear seats should not be folded to increase the luggage capacity. Spread the weights as evenly as possible over the base of the luggage compartment. If the weights cannot be evenly distributed, concentrate weights towards the centre of the compartment.

1.2.6 Roll the vehicle back and forth to “settle” the tyres and suspension with extra weight on board. Weight the front and rear axle weights of the vehicle. These loads are the “axle reference loads” and the total weight.

1.2.7 Record the axle reference loads and reference mass in the test details.

1.2.8 Record the ride heights of the vehicle at the point of the wheel arch in the same transverse plane as the wheel centres. Do this for all four wheels.

1.2.9 Remove the weights from the luggage compartment and the front and rear seats.

1.3 Vehicle width and Overlap

1.3.1 Determine the centreline of the vehicle. Mark a line along the centreline of the vehicle. This line will align with the vertical centreline of the load cell wall.

1.4 Vehicle Preparation

Care should be taken during the vehicle preparation that the ignition is not switched on with the battery or airbag disconnected. This will result in an airbag warning light coming on and the airbag system will need to be reset. The manufacturer will need to be contacted if this occurs.

1.4.1 Ensure that live battery is connected, if possible in its standard position and that the driver airbag is connected. Check that the dashboard light for the airbag circuit functions as normal. The vehicle battery may be replaced with a dummy unit and live battery placed in the luggage compartment of the vehicle. This action is at the test labs discretion, but the manufacturer must be consulted to ascertain if this is likely to cause problems with any of the vehicle's systems.

1.4.2 In the event that the engine fluids are to be drained then drain the coolant, oil, air-conditioning (air conditioning fluid, and replace with an equivalent weight of water or other ballast).

1.4.3 If the fluids are drained then measure the weights of each of these fluids, excluding the air conditioning fluid, and replace with an equivalent weight of water or other ballast.

1.4.4 Remove the luggage area carpeting, spare wheel, and any tools or jack from the car. The spare wheel should only be removed if it will not affect the crash performance of the vehicle.

1.4.5 An emergency abort braking system may be fitted to the vehicle. This is optional; the test facility may elect to test without an abort system. Where such a system is fitted its inclusion shall not influence the operation or function of any of the foot controls, in particular the brake pedal. The position and resistance to the movement of the pedals shall be the same prior to fitment of the system. Remove as little as possible of the interior trim; any mass compensation will be made when all equipment has been fitted.

1.4.6 Fit the on-board data acquisition equipment in the boot of the car. Also fit any associated cables, cabling boxes and power sources.

1.4.7 Place a weights equivalent to the 50%ile driver test dummy (including instrumentation and cables) on each of the front seats (with the seats in their mid positions).

1.4.8 Weigh the front and rear axle weights of the vehicle. Compare these weights with those determined in section 1.2.6

1.4.9 If the axle weights differ from those measured in 1.2.6 by more than 5% (of the axle reference loads) or by more than 20 kg, remove or add items which do not influence the structural crash performance of the vehicle. Similarly, if the total vehicle mass differs by more than 25 kg from the reference mass, non-structural items may be removed or added. The levels of ballast in the fuel tank (equivalent in mass to 90% capacity fuel) may also be adjusted to help achieve the desired axle weights. Any additional mass that is added to the vehicle should be securely and rigidly attached.

1.5 Suspension Settling

This activity should be performed twice; firstly to check that the normal ride attitude, as defined in section 1.6 below, is within the manufacturer tolerances and secondly to measure the ride attitude just prior to performing the test, i.e. when all dummies are in the car and the car is ready to roll back from the block for the test. Please note that target and pin to record horizontal and vertical impact accuracy (section 9.3.3) should be fixed and aligned when second set of measurements is taken.

1.5.1 Roll the vehicle forwards by a distance of at least 1 metre

1.5.2 Roll the vehicle backwards by a distance of at least 1 metre

1.5.3 Repeat steps 1.5.1 and 1.5.2 for three complete cycles.

1.5.4 Measure and record the ride heights of the vehicle at the point on the wheel arch in the same transverse plane as the wheel centres. Do this for all four wheels.

1.6 Normal Ride Attitude

1.6.1 After following the above procedures the vehicle is in its Normal Ride Attitude when the vehicle attitude is in running order positioned on the ground, with the tyres inflated to the recommended pressures, the front wheels in the straight-ahead position, with maximum capacity of all fluids necessary for operation of the vehicle, with all standard equipment as provided by the vehicle manufacturer, with a 75 kg mass placed on the driver's seat and with a 50 kg mass placed on the front passenger's seat, and with the suspension set for a driving speed of 56 km/h in normal running conditions specified by the manufacturer (especially for vehicles with an active suspension or a device for automatic levelling). The manufacturer shall specify the Normal Ride Attitude with reference to the vertical (Z) position of any marks, holes, surfaces and identification signs on the vehicle body, above the ground. These marks shall be selected such as to be able to easily check the vehicle front and rear ride heights and vehicle attitude.

1.6.2

Note: Tolerances to manufacturers design position ad procedure to follow if these are not met still need to be determined if the AE-FW test is intended to be used to take compatibility measures with a high resolution load cell wall.

1.6.3 All ride heights measured are the Normal Ride Attitude ride heights.

2 INTRUSION MEASUREMENTS

2.1 Before test

2.1.1 Determine and mark the centre of the clutch, brake and accelerator pedals.

2.1.2 Set the steering wheel to its mid-position, if it is adjustable for either rake or reach (for full description of how to do this, see section 6)

2.1.3 Remove the centre of the steering wheel or, if fitted, the airbag assembly to expose the end of the steering column. When doing this, carefully note the connections to the airbag which will need to be remade on re-assembly. Follow the manufacturer's instructions when removing the airbag and/or steering wheel assemblies.

2.1.4 Determine and mark the centre of the top of the steering-column.

2.1.5 Remove the carpet, trim and spare wheel from the luggage compartment. The plastic trim or rubber seals that might influence the latching mechanism should be re-fitted once the intrusion measurements have been recorded. This is to ensure that any opening of the rear door during the impact is not caused by the omission of some part of the trim around the latching mechanism.

2.1.6 Locate the vehicle axis reference frame (see Figure 2.1) centrally to the rear of the vehicle.

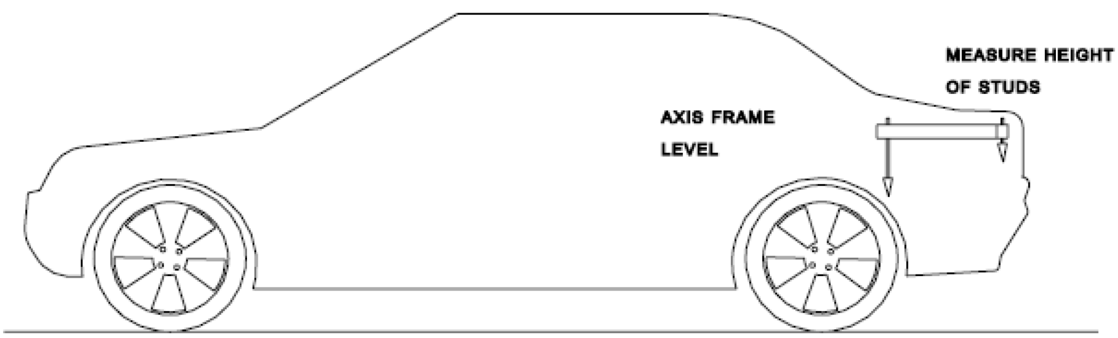


Figure 2.1: Setting up axis reference frame

2.1.7 Level the reference frame

2.1.8 Measure and record the stud heights of the reference frame. These will be used after the test to help reset the reference frame, if required.

2.1.9 If it is necessary to lean on the vehicle to reach the following points, the vehicle should be supported to maintain the ride heights during measuring.

2.1.10 Set up the vehicle co-ordinate axes in the 3D arm or similar device.

2.1.11 Mark and record the position of at least 5 datum points on the rear of the vehicle. These points should be on structures which are not expected to be deformed in the

test and should be positioned such that they have wide spaced locations in three dimensions and can all be reached with the 3D measuring system in one position.

2.1.12 Working on the passenger side of the vehicle determine and mark the positions of the B-post which are

i) at a distance of 100mm above the sill
ii) at a distance of 100 mm beneath the lowest level of the side window aperture.

2.1.13 All points should be as close as possible to the rubber sealing strip around the door aperture.

2.1.14 Measure and record the pre-impact positions of the two aperture points.

2.1.15 Working on the driver's side of the vehicle determine and mark the positions on the A and B-post which are

i) at a distance of 100mm above the sill
ii) at a distance of 100 mm beneath the lowest level of the side window aperture.

2.1.16 All points should be as close as possible to the rubber sealing strip around the door aperture.

2.1.17 Use the arm to measure the pre-impact positions of the centre of the top of the steering-column and the four door aperture points.

2.1.18 Record the position of the centre of the undepressed clutch, brake and accelerator pedals and where applicable foot operated parking brake. If the pedal is adjustable, set it to the mid position or a reasonable variation from this in accordance with the manufacturer's recommendations for the 50th percentile position.

2.1.19 Replace the steering wheel and airbag assembly. Check that all bolts are securely fastened. Ensure that all connections to the airbag are replaced and check the dashboard light to confirm the circuit is functional.

2.1.20 For optional additional intrusion measurements for compatibility please see section 2.3. Please note that these should be recorded for all FIMCAR project tests.

2.2 After test

2.2.1 Before dummy removal measure the distance between all foot pedals and a fixed point in the footwell e.g. seat runner, seat mounting bolt. If access cannot be gained remove the dummies according to section 9.6, taking care not to disturb any pedals and then record the measurement. This measurement should be re-checked before the pedals are measured with the 3D measuring system. If the pedal has moved re-position the pedal using the measurement taken previously.

2.2.2 Remove the dummies according to section 9.6 and remove the data acquisition and emergency abort equipment (if fitted) from the luggage compartment.

2.2.3 Remove the centre of the steering wheel or airbag assembly.

2.2.4 Use any 3 of the 5 datum points at the rear of the vehicle, and their pre-impact measurements, to redefine the measurement axes.

2.2.5 If the axes cannot be redefined from any 3 of the datum points relocate the axis reference frame in the same position as in section 2.1.8. Set the studs of the frame to the same heights as in section 2.2.11 (figure 2.2). The frame should now be in the same position relative to the car as it was before impact. Set up measurement axes from the frame.

2.2.6 Record the post-impact positions of the B-post points on the passenger's side of the vehicle.

2.2.7 Compare the vertical co-ordinate of the B-post sill point before (section 2.1.12) and after (section 2.2.5) the test.

2.2.8 Find the angle θ that best satisfies the following equation: $z = -x'\sin\theta + z'\cos\theta$ for the B-post sill point (where z = pre impact vertical measurement and x',z'= post-impact longitudinal and vertical).

2.2.9 Working on the driver's side of the vehicle, record the post-impact co-ordinates of the centre of the steering column, the centre of the clutch, brake and accelerator pedals, and where applicable a foot operated parking brake, with no load applied to them and in the blocked position (loaded with 200N to produce the maximum moment about the pedal pivot), the door aperture points. Prior to the 'blocked' pedal measurement, i.e. with the 200N applied, the brake fluid shall be removed to avoid the build up of hydraulic pressure. If the steering column has become detached during impact due to the operation of the shear capsules, the column should be repositioned before measurement in the upward and lateral directions so that it is in contact with whatever structure(s) last constrained it from further movement. If any of the foot pedals become detached do not take a measurement of that pedal.

2.2.10 Transform the post impact longitudinal and vertical measurement (x',z') using the following equations.

$$\begin{pmatrix} X' \\ Z' \end{pmatrix} = \begin{pmatrix} \cos \vartheta & \sin \vartheta \\ -\sin \vartheta & \cos \vartheta \end{pmatrix} \begin{pmatrix} x' \\ z' \end{pmatrix}$$

2.2.11 Where ϑ is the angle determined in Section 2.2.8. X and Z should now be in the same frame of reference as the pre-impact measurements. [1]

2.2.12 From the pre-impact and adjusted post-impact data collected, determine

i. the longitudinal, lateral and vertical movement of the centre of the top of the steering column
ii. the longitudinal and vertical movement of all of the foot operated pedals
iii. the rearward movement of the A-post at waist level
iv. the reduction in width of the door aperture at waist and sill levels.

2.2.13 Record these intrusion measurements in the test details.

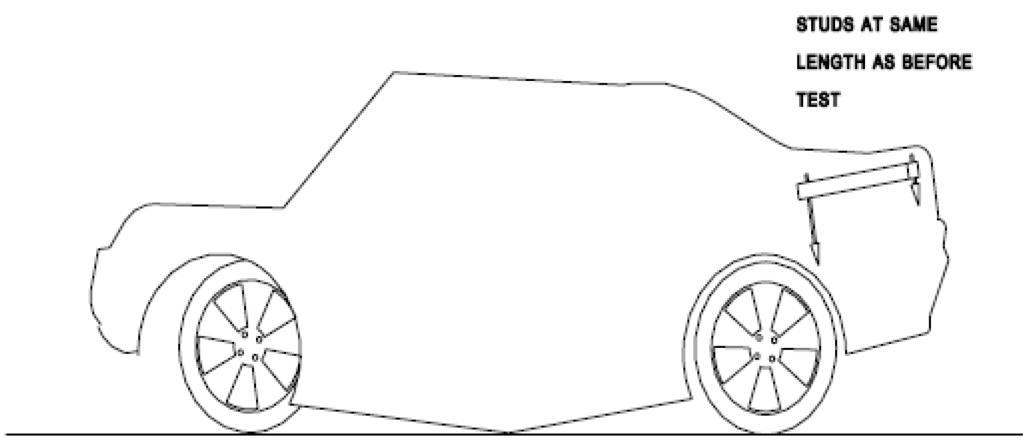


Figure 2.2: Re-setting axis reference frame after test

[1] This assumes that the point on the passenger B-post sill is not displaced vertically or laterally during the impact.

2.3 [Optional intrusion measurements]

Note: These measurements should be taken for all tests performed in the FIMCAR project.

Vehicle Pre-Test Measurements	
	Required
Door Apertures at waist and sill level	X
All Accelerometer Positions	X
Steering Wheel Centre	X
Pedal Centres	X
Pedal axis (outboard end of clutch pedal)	X
Dashboard / Footwell Points	Compatibility footwell grid and dash points (see below for details)

Compatibility Intrusion Measurements (pre- and post-test)

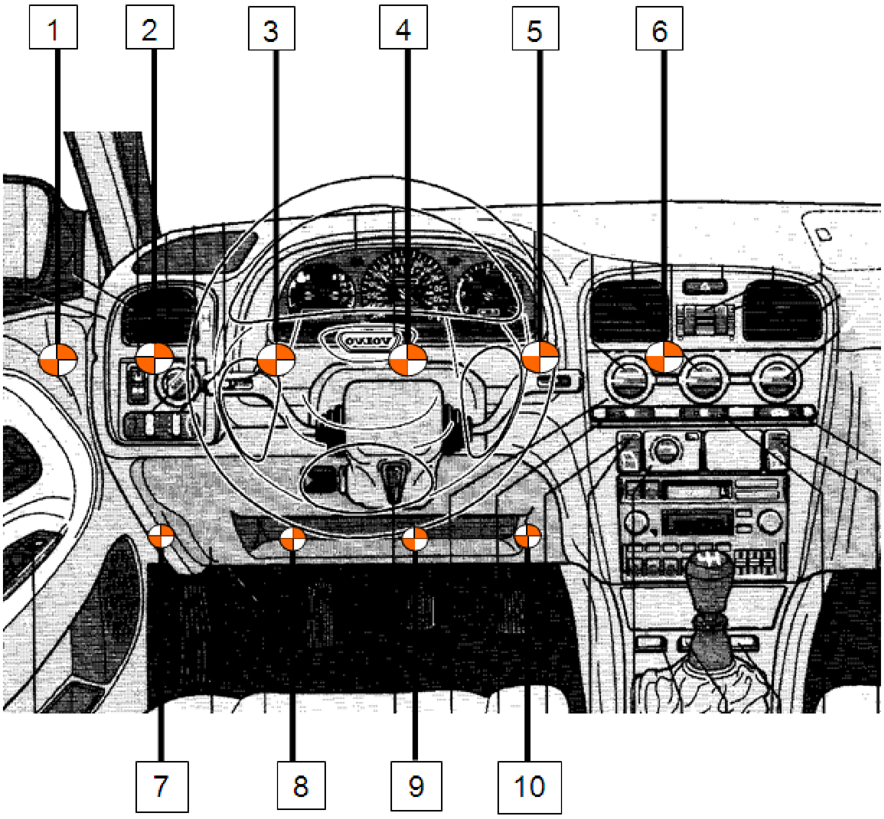
2.3.1 Instrument Panel Top (IPT)

1. Locate front lower corner of the side window in Z.
2. Locate outer edge of IP within height Z to Z+25mm and place target sticker 1.
3. Locate subsequent target stickers every 100mm (at the height defined by 2) inboard until the centreline of the vehicle. (typically 6 stickers)

Note: Z is positive in the downwards direction

2.3.2 Instrument Panel Base (IPB)

1. Locate the highest point along the centreline of the seat squab and determine height in Z and distance from vehicle centreline
2. Locate target sticker in on nearest point on the IP in the same Z height and distance from the vehicle centreline.
3. Locate target stickers every 100mm inboard and outboard along the IP until the centre console and the outer edge of the IP is reached



2.3.3 Problems with IP target location

If significant deviation is needed then best judgement is needed and the criteria that need consideration are:

1. Try to locate target stickers on major components of the instrument panel.

   Example
   Do not locate on the steering column surround as this will move independently of the majority of the IP.

2. At all times try to maintain the target stickers in the Z and X axis defined and only vary the Y axis by 100mm.

   Example

   If going below the instrument binnacle requires less deviation than proceeding around the top then place the target stickers in the former position.

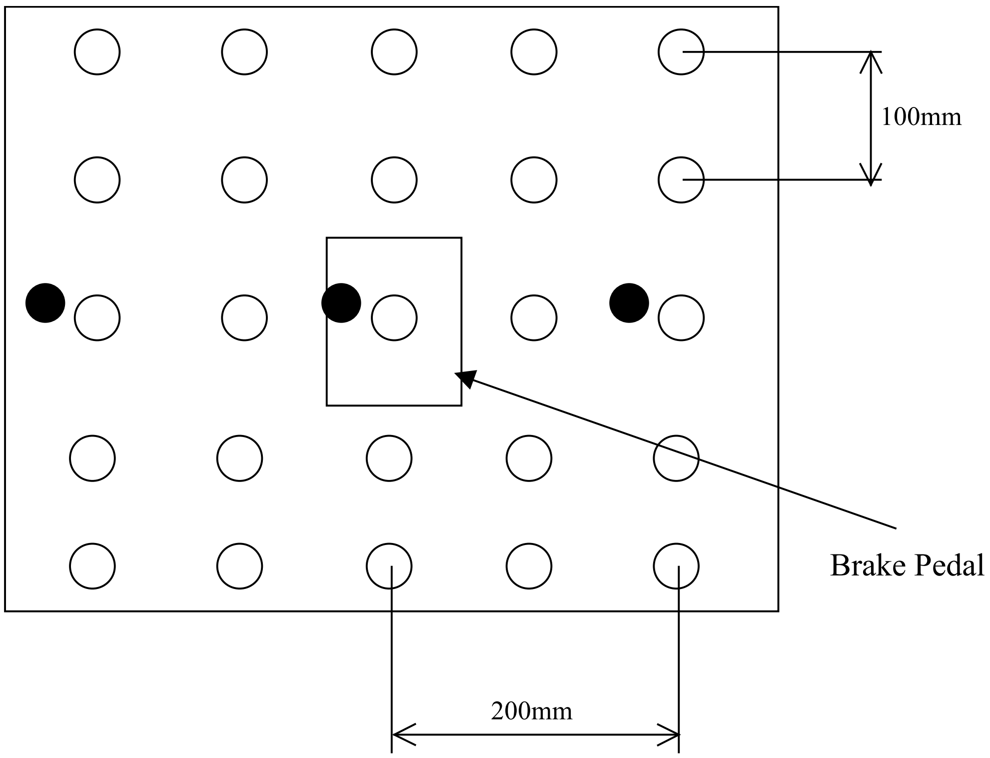
2.3.4 Footwell Intrusion

Minimum footwell intrusion measurements are the three black marked points behind the brake pedal.

If more measurements will be performed please follow the recommendations:

1. Remove all carpet from the footwell requiring measurement.
2. Locate a target sticker behind the brake pedal in the same X and Z location as that brake pedal.
3. Place a pre-cut carpet with holes spaced at 100mm in the footwell and locate one of the pre-cut holes over the target sticker defined in 2. (Carpet can follow the contours

of the footwell). If pre-cut carpet not available, use the 3D Arm to position target stickers.
4. Locate additional target stickers in the location of the pre-cut holes. Only place stickers up to a maximum of 200 mm either side of the brake pedal. Place stickers up to a maximum of 200 mm (if possible) above and 300mm below the point defined in 2.
5. If locations tie up with local features on the footwell (such as drain holes) then move target sticker the minimum distance to clear such feature.



3 DUMMY PREPARATION AND CERTIFICATION

3.1 General

3.1.1 Hybrid III test dummies should be used for the front seat driver and passenger positions. They should conform to U.S. Department of transportation, Code of Federal Regulations Part 572 Subpart E and ECE Regulation No. 94, except for modifications and additions stated later – See Section 3.3.

3.2 Dummy Certification

Full details of the certification procedure for the Hybrid-III dummy are available elsewhere (see Part 572 Subpart E of US Department of Transportation Code of Federal Regulations and Annex 10 of ECE Regulation No. 94). No manufacturer shall have access to any pre-test information regarding the test equipment to be used in the test, or be permitted to influence it selection in any way.

3.2.1 The Hybrid-III dummies should be re-certified after every THREE impact tests. With exception to the knee slider, which shall be certified to 10mm after every NINE impact tests.

3.2.2 If an injury criterion reaches or exceeds its normally accepted limit (e.g. HIC of 1000) then that part of the dummy shall be re-certified.

3.2.3 If any part of the dummy is broken in a test then the part shall be replaced with a fully certified component.

3.2.4 Copies of the dummy certification certificates will be provided as part of the full report for a test.

3.3 Additions and Modifications to the Hybrid III Dummies

3.3.1 The additions and modifications which will change the dynamic behaviour of the test dummies from Part 572E specification dummies are:

3.3.2 Ford 45 degree dorsi-flexion ankles/feet with rubber bump stops and padded heels are fitted.

3.3.3 Roller ball-bearing knees, such as those supplied by ASTC, shall be fitted.

3.3.4 Extra instrumentation is also fitted such as enhanced instrumented lower legs and a 6-axis neck. See Section 4 for a full instrumentation list.

3.3.5 Foam neck shields, such as those supplied by ASTC, must be fitted to the driver and passenger if a frontal protection airbag is present.

3.3.6 Dummy Clothing and Footwear

3.3.7 Hybrid-III dummies

3.3.8 Each dummy will be clothed with formfitting cotton stretch garments with short sleeves and pants which should not cover the dummy's knees.

3.3.9 Each dummy shall be fitted with shoes equivalent to those specified in MIL-S13192 rev P. (size XW)

3.4 Dummy Test Condition

3.4.1 Dummy Temperature

3.4.1.1 The dummy shall have a stabilised temperature in the range of 19°C to 22°C.

3.4.1.2 A stabilised temperature shall be obtained by soaking the dummy in temperatures that are within the range specified above for at least 5 hours prior to the test.

3.4.1.3 Measure the temperature of the dummy using a recording electronic thermometer placed inside the dummy's flesh. The temperature should be recorded at intervals of exceeding 10 minutes.

3.4.1.4 A printout of the temperature readings is to be supplied as part of the standard output of the test.

3.4.2 Dummy Joints

All constant friction joints should have their 'stiffness' set by the following method

3.4.2.1 Stabilise the dummy temperature by soaking in the required temperature range for at least 5 hours.

3.4.2.2 The tensioning screw or bolt which acts on the constant friction surfaces should be adjusted until the joint can just hold the adjoining limb in the horizontal. When a small downward force is applied and then removed, the limb should continue to fall.

3.4.2.3 The dummy joint stiffnesses should be set as close as possible to the time of the test and, in any case, not more than 24 hours before the test.

3.4.2.4 Maintain the dummy temperature within the range 19° to 22°C between the time of setting the limbs and up to a maximum of 10 minutes before the time of the test.

3.4.3 Dummy face painting

3.4.3.1 With the exception of the Hybrid-III face, the dummies should have masking tape placed on the areas to be painted using the size table below. The tape should be completely covered with the following coloured paints. The paint should be applied close to the time of the test to ensure that the paint will still be wet on impact.

Hybrid-IIIs

Eyebrows (left and right) Red

Nose Green

Chin Yellow

Left Knee Red

Right Knee Green

Left Tibia (top to bottom) Blue, Green, Red, Yellow

Right Tibia (top to bottom) Yellow, Red, Green, Blue

NOTE: The tape should be completely covered with the coloured paints specified.

Paint Area Sizes:

Hybrid-IIIs

Eyebrows = (25/2) x 50mm

Nose = 25 x 40mm strip, down nose centre line

Chin = 25 x 25mm square, centre line of chin

Knees = 50 x 50mm square, knee centre line with bottom edge level with top

of tibia flesh

Tibias = 25mm x 50mm, 4 adjacent areas down leg centre line with top edge

level with top of tibia flesh

front, extending to the head C of G at each side.

3.5 Post Test Dummy Inspection

3.5.1 The dummies should be visually inspected immediately after the test. Any lacerations of the skin or breakages of a dummy should be noted in the test specification. A dummy may have to be re-certified in this case. Refer to Section 3.2.

4 INSTRUMENTATION

All instrumentation shall be calibrated before the test programme. The Channel Amplitude Class (CAC) for each transducer shall be chosen to cover the Minimum Amplitude listed in the table. In order to retain sensitivity, CACs which are orders of magnitude greater than the Minimum Amplitude should not be used. A transducer shall be re-calibrated if it reaches its CAC during any test. All instrumentation shall be re-calibrated after one year, regardless of the number of tests for which it has been used. A list of instrumentation along with calibration dates should be supplied as part of the standard results of the test. The transducers are mounted according to procedures laid out in SAE J211 (1995). The sign convention used for configuring the transducers is stated in SAE J211.

4.1 Dummy Instrumentation

Hybrid-III

Location	Parameter		Minimum Amplitude	Driver No of channels	Passenger No of channels
Head	Accelerations, A_x A_y A_z		250g	3	3
Neck	Forces	F_x F_y	9kN	2	2
		F_z	14kN	1	1
	Moments, M_x M_y M_z		290Nm	3	3
Chest	Accelerations, A_x A_y A_z		150g	3	3
	Deflection, D_{chest}		100mm	1	1
Pelvis	Accelerations, A_x A_y A_z		150g	3	3
Femurs (L & R)	Forces, F_z		20kN	2	2
Knees (L & R)	Displacements, D_{knee}		19mm	2	2
Upper Tibia (L & R)	Forces, F_x F_z		12kN	4	4
	Moments, M_x M_y		400Nm	4	4
Lower Tibia[2] (L & R)	Forces, F_x F_z (F_y)		12kN	4	4
	Moments, M_x M_y		400Nm	4	4
	Total Channels per Dummy			36	36
	Total Channels			72	

[2] Note that for both dummies the measurement of F_y is at the laboratory's discretion.

4.2 Vehicle Instrumentation

4.2.1 The vehicle is to be fitted with an accelerometer on each B-post. The accelerometers are to be fitted in the fore/aft direction (Ax)

4.2.2 Remove carpet and the necessary interior trim to gain access to the sill directly below the B-post.

4.2.3 Securely attach a mounting plate for the accelerometer horizontally on to the sill, without adversely affecting seat belt retractors and/or pretensioners.

4.2.4 Fix the accelerometer to the mounting plate. Ensure the accelerometer is horizontal to a tolerance of ±1 degree and parallel to the X-axis of the vehicle.

4.2.5 Attach lightweight (<100g) seatbelt loadcells to the shoulder section of the driver and passenger seatbelts. For FIMCAR tests also attach lightweight (<100g) seatbelt loadcells to the lap section of the driver and passenger seatbelts.

VEHICLE

Location	Parameter	Minimum Amplitude	No of channels
B-Post LHS	Accelerations, A_x	150g	1
B-Post RHS	Accelerations, A_x	150g	1
Driver Seatbelt Shoulder Section	Force, $F_{diagonal}$	16kN	1
Passenger Seatbelt Shoulder Section	Force, $F_{diagonal}$	16kN	1
	Total Channels per Vehicle		4

Accelerometers for compatibility measures, note these should be included for all FIMCAR project tests

4.2.6 Additional accelerometers

Vehicle Instrumentation (Accelerometers)						
Location	X	CAC	Y	CAC	Z	CAC
RHS A-Pillar Lower	**X**	**750**				
LHS A-Pillar Lower	**X**	**750**				
RHS A-Pillar above Dash	**X**	**750**				
LHS A-Pillar above Dash	**X**	**750**				
Engine Top, Central	**X**	**2000**				
Engine Sump, Central	**X**	**2000**				
Gearbox, Central	**X**	**2000**				
RHS B-Pillar Lower	**X**	**250**				
LHS B-Pillar Lower	**X**	**250**				
Rear Cross Beam, Central	**X**	**250**	**X**	**250**	**X**	**250**
Tunnel at C of G	**X**	**250**	**X**	**250**	**X**	**250**
Tunnel at Rate Sensor	**X**	**250**	**X**	**250**	**X**	**250**
Subframe (when Present)	**X**	**2000**				
Total Channels	**19**					

Note:

To summarise and to get an overview over all used sensors, please use the following table for the documentation:

Number	Location	ISO code	Long name
001	RHS A-Pillar Lower	?3APILRILO00AC??	A-Pillar Right Lower
002	LHS A-Pillar Lower	?1APILLELO00AC??	A-Pillar Left Lower
003	RHS A-Pillar above Dash	?3APILRIMI00AC??	A-Pillar Right Middle
004	LHS A-Pillar above Dash	?1APILLEMI00AC??	A-Pillar Left Middle
005	Engine Top, Central	?0ENGNTP0000AC??	Engine Top
006	Engine Sump, Central	?0ENGNBO0000AC??	Engine Bottom
007	Gearbox, Central	?0GEAR000000AC??	Gear Box
008	RHS B-Pillar Lower	?6BPILRILO00AC??	B-Pillar Right Lower
009	LHS B-Pillar Lower	?4BPILLELO00AC??	B-Pillar Left Lower
010	Rear Cross Beam, Central	?8CRMEREMI00AC??	Cross Member Rear Middle
011	Tunnel at C of G	?5TUNNCD0000AC??	Tunnel CoG
012	Tunnel at Rate Sensor	?0CEUN000000AC??	Central Unit
013	Subframe (when Present)	??SUFR????00AC??	Sub Frame
014	Additional vehicle channel(s)		
…	Dummy channels		
…….	LCW channels		

4.2.7 Event switches

1	Time Zero Event T01
2	Time Zero Event T02
3	VEHICLE AIRBAG SENSOR TRIGGER TIME USING 2 CURRENT CLAMPS

Note: for FIMCAR project tests Time Zero Event contact should be included between barrier and car and vehicle and current clamps should be used to sense airbag trigger time for all airbags.

4.2.8 Rate Sensor

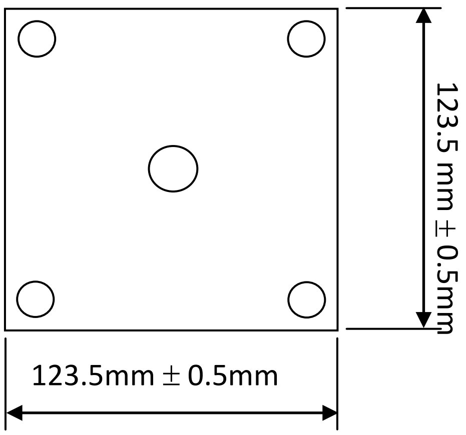
Rate sensor positioned at tunnel C. of G.

4.3 [Load Cell Wall]

4.3.1 The load cell wall is to be formed by a matrix of individual load cells with a spacing of 125 mm in the horizontal and vertical directions. The centre spacing of the load cells is 125 mm x 125 mm. The width of the load cell wall is to be equal to or greater than the width of the deformable barrier and to be exactly divisible by 250 mm. The height is to be equal to or greater than the height of the deformable element. [Width 2000 mm, height 1000 mm]. The lower edge of the load cell wall is to be parallel to the ground and at a height of 80 mm relative to the ground. The load cell wall is to be rigidly attached to the barrier with its front face in the same plane as the front face of the barrier.

Dimensions and layout

4.3.2 Each load cell tile on the load cell wall (LCW) has a nominal frontal area of 125 mm x 125 mm. However, when mounted on the LCW the load cells must have sufficient clearance between the adjacent cells to prevent interaction of the load cell tiles under maximum shear loads. The suggested external dimensions of each individual load cell face in the LCW are shown.



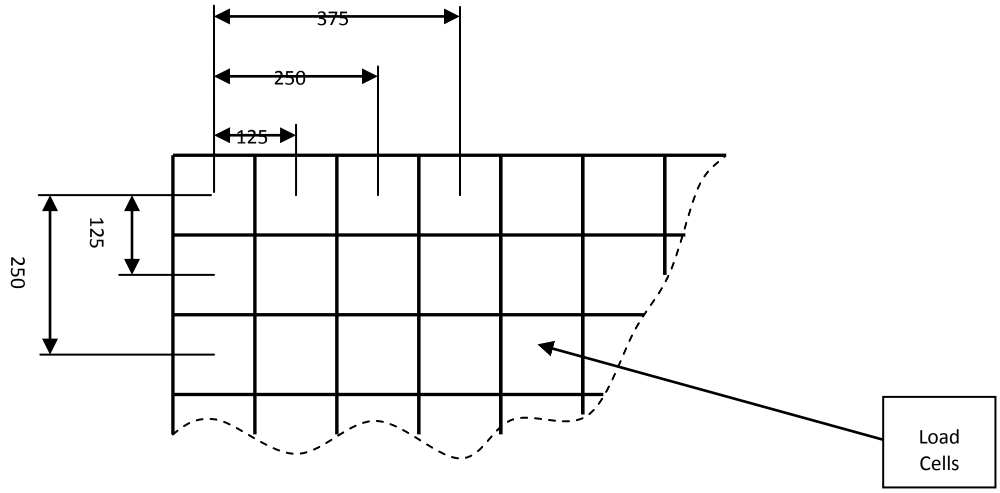
4.3.3 Each load cell shall be faced with an 18 mm thick MDF panel the same size as the load cell face. Any of these MDF facings which become damaged (e.g. dented, split, etc.) should be replaced with undamaged MDF facings.

4.3.4 Each load cell must have threaded holes on the loading face to allow the mounting of deformable barrier faces and the MDF facings. A suggested pattern of holes is shown in the previous figure.

4.3.5 The full load cell wall, for the purposes of the FWDB test, is to comprise of 128 load cells arranged in a matrix of cells 16 wide by 8 high. The full LCW should have frontal dimensions of 2000 mm wide by 1000 mm high. The height of the bottom of the LCW above ground should be adjustable. [For the FWDB test, the height of the bottom of the LCW above ground is 80 mm.]

4.3.6 The load cells shall be spaced such that the centre of each load cell is 125 mm apart in the vertical and horizontal direction. This spacing shall be measured from the centre of the uppermost corner cell on the load cell wall in order to avoid

compound errors. This can be achieved by mounting the load cells on a backplate to provide the precise location of each load cell.



4.3.7 The impact face of the load cell wall, including MDF facings, should be flat - no cell should be either recessed or protrude relative to any of its surrounding cells. The surface flatness is check by offering up a flat edge to the load cell wall – this flat edge should bridge two or more load cells. There should be no visible gap [greater than 0.5mm] between the flat edge and the surface of a load cell. If any cells are found to protrude or be recessed, remedial action should be taken to correct this.

Technical Specifications

Nominal area of each load cell impact face	125 x 125mm
Rated load	300kN
Safe overload	600kN
Shear load	100kN
Offset loading error	< 3% (300kN)
Linearity error	< 1.1% (300kN)
Compression / Shear load crosstalk	< 0.5% (300kN)
Cell Mass	< 6kg
Mass difference tolerance between load cells	± 0.2kg
Dynamic response	> 10kHz
Resonant frequency	> 5kHz
Operational temperature range	$0^{o}C$ to $+70^{o}C$

Note :- Processing of LCW data should be carried out with a filter of CFC60

5 CAMERA LOCATIONS

All cameras 1000 fps

Note: For indication of camera angles see Euro NCAP test protocol.

Camera No.	Camera Type	Shot Content
1	1000 fps high speed	Driver (tight)
2	1000 fps high speed	Driver (wide)
3	1000 fps high speed	Passenger (tight)
4	1000 fps high speed	Passenger (wide)
5	1000 fps high speed	Plan view (wide – whole car)
6	1000 fps high speed	Plan view (tight)
7	1000 fps high speed	Front view driver & passenger
8	1000 fps high speed	Driver (wide – whole car)
9	1000 fps high speed	Underside (pit) view engine bay including subframe attachment to firewall

6 PASSENGER COMPARTMENT ADJUSTMENTS

Vehicle adjustments

Adjustment	Required Setting	Notes	Methods
Seat Fore/Aft	Mid position as defined in Section 6.1	May be set to first notch rearwards of mid position if not lockable at mid position	See Section 6.1
Seat Base Tilt	Manufacturer's design position	Permissible up to Mid Position	See Section 6.1.11
Seat Height	Lowest position		
Seat Back Angle (as defined by torso angle)	Manufacturer's design position	Otherwise 25° to vertical As defined by Torso angle	See Section 7.1.1
Front Head Restraints	Highest position		
Head Restraint Tilt	Manufacturer's design Position	Otherwise mid position	
Seat Lumbar Support	Manufacturer's design position	Otherwise fully retracted	See Section 6.1.12
Steering wheel - vertical	Mid position		See Section 6.3
Steering wheel - horizontal	Mid position		See Section 6.2
Rear Head Restraints	Remove or Lowest	Unless instructed otherwise by the manufacturer	
Rear Seat Fore/Aft	Mid position		See Section 6.4.1
Rear Seat Facing	Forwards		See Section 6.4.1
Arm-rests (Front seats)	Lowered position	May be left up if dummy positioning does not allow lowering	
Arm-rests (Rear seats)	Stowed position		
Glazing	Front - Lowered Rear - Lowered or Removed	This applies to opening windows only	
Gear change lever	In the neutral position		
Pedals	Normal position of rest		
Doors	Closed, not locked		
Roof	Lowered	Where applicable	
Sun Visors	Stowed position		
Rear view mirror	Normal position of use		
Seat belt anchorage	Manufacturer's 50th percentile design position	If no design position then set to mid-position, or nearest notch upwards	

Note:- Adjustments not listed will be set to mid-positions or nearest positions rearward, lower or outboard.

6.1 Determination of and Setting the Fore/aft, Tilt and Lumbar Settings of the Seats

6.1.1 The manufacturers seat fore/aft position which corresponds to the 95th percentile male seating position will have been provided.

6.1.2 Place a mark on the moving part of seat runner close to the unmoving seat guide.

6.1.3 Move the seat to its most forward position of travel.

6.1.4 Mark the unmoving seat guide in line with the mark on the seat runner. This corresponds to the seat in its most forward position.

6.1.5 Move the seat to the position of its travel provided for the 95th percentile male.

6.1.6 Mark the unmoving seat guide in line with the mark on the seat runner. This corresponds to the 95th percentile male's seating position.

6.1.7 Measure the distance between the forwards and rearwards marks. Place a third mark on the seat guide mid-way between the forwards and rearwards marks

6.1.8 Move the seat so that the mark on the seat runner aligns with the mark on the seat guide.

6.1.9 Lock the seat at this position. Ensure that the seat is fully latched in its runners on both sides of the seat. The seat is now defined as being at its 'mid seating position'. The vehicle will be tested with the seat in this position.

6.1.10 If the seat will not lock in this position, move the seat to the first locking position that is rear of the mid seating position. The vehicle will be tested with the seat in this position.

6.1.11 If the seat base is adjustable for tilt it may be set to any angle from the flattest up to its mid position according to the manufacturer's preference. The same seat tilt setting must be used for frontal and side impact.

6.1.12 If the seat back is adjustable for lumbar support it should be set to the fully retracted position, unless the manufacturer specifies otherwise or the dummy prevents this.

6.2 Setting the Steering Wheel Horizontal Adjustment

6.2.1 Choose a part of the facia that is adjacent to the steering column and can be used as a reference.

6.2.2 Move the steering wheel to the most forward position of its travel

6.2.3 Mark the steering column in line with an unmoving part of the facia. This corresponds to the most forward travel of the steering wheel.

6.2.4 Move the steering wheel to the most rearwards position of its travel Mark the steering column in line with an unmoving part of the facia. This corresponds to the most rearwards travel of the steering wheel.

6.2.5 Measure the distance between the forwards and rearwards marks on the steering column. Place a third mark on the steering column mid-way between the forwards and rearwards marks. This corresponds to the centre of travel of the steering wheel.

6.2.6 Move the steering wheel so that the mark on the steering column aligns with the facia.

6.2.7 Lock the steering column at this position. The steering wheel is now in its mid position of travel. The vehicle will be tested with the steering wheel in this position.

6.3 Setting the Steering Wheel Vertical Adjustment

A method that is in principle the same as Section 6.2 should be used to determine and set the steering wheel vertical adjustment to the mid position. It is unlikely that the same part of the facia used during the setting procedures for the horizontal adjustments could be used for the vertical adjustment. Care should be taken to avoid unintentional adjustment of the horizontal setting during the vertical adjustment procedure.

7 DUMMY POSITIONING AND MEASUREMENTS

The table detailing the timetable for dummy position and measurements found under the section heading is replaced with the following table:-

Timetable	*When this is done*
1. Determine the H-point of the driver's seat	Day before test
2. Determine the H-point of the passenger seat	Day before test
3. Dummy installation	Test day
4. Dummy placement	
5. Dummy positioning	
6. Dummy positioning	

7.1 Determine the H-Point of front seats

The device to be used is the H-point machine as described in SAE J826. If the seat is new and has never been sat upon, a person of mass 75 ± 10kg should sit on the seat for 1 minute twice to flex the cushions. The seat shall have been at room temperature and not been loaded for at least 1 hour previous to any installation of the machine.

<u>For Driver's Seat</u>

7.1.1 Set the seat back so that the torso of the dummy is as close as possible to the manufacturers reasonable recommendations for normal use. In absence of such

recommendations, an angle of 25 degrees towards the rear from vertical will be used.

7.1.2 Place a piece of muslin cloth on the seat. Tuck the edge of the cloth into the seat pan/back join, but allow plenty of slack.

7.1.3 Place the seat and back assembly of the H-point machine on the seat at the centre line of the seat.

7.1.4 Set the thigh and lower leg segment lengths to 401 and 414mm respectively.

7.1.5 Attach lower legs to machine, ensuring that the transverse member of the T-bar is parallel to the ground.

7.1.6 Place right foot on undepressed accelerator pedal, with the heel as far forwards as allowable. The distance from the centre line of the machine should be noted.

7.1.7 Place left foot at equal distance from centre line of machine as the right leg is from centre line. Place foot flat on footwell.

7.1.8 Apply lower leg and thigh weights.

7.1.9 Tilt the back pan forwards to the end stop and draw the machine away from the seatback.

7.1.10 Apply a 10kg load twice to the back and pan assembly positioned at the intersection of the hip angle intersection to a point just above the thigh bar housing.

7.1.11 Return the machine back to the seat back.

7.1.12 Install the right and left buttock weights.

7.1.13 Apply the torso weights alternately left and right.

7.1.14 Tilt the machine back forwards to the end stop and rock the pan by 5 degrees either side of the vertical. The feet are NOT to be restrained during the rocking. After rocking the T-bar should be parallel to the ground.

7.1.15 Reposition the feet by lifting the leg and then lowering the leg so that the heel contacts the floor and the sole lies on the undepressed accelerator pedal.

7.1.16 Return the machine back to the seat back.

7.1.17 Check the lateral spirit level and if necessary apply a lateral force to the top of the machine back, sufficient to level the seat pan of the machine.

7.1.18 Adjust the seat back angle to the angle determined in 7.1.1, measured using the spirit level and torso angle gauge of the H-point machine. Ensure that the torso remains in contact with the seat back at all times. Ensure that the machine pan remains level at all times.

7.1.19 Measure and record in the test details the position of the H-point relative to some

7.1.20 easily identifiable part of the vehicle structure

For Passenger's Seat

Follow the procedure for the determination of the driver's H-point ensuring that the distance from the centre line to the legs is the same as that used in the determination of the driver's H-point. For both right and left feet, place the feet flat on the floor.

7.2 Dummy Installation

It is the intention that the dummy should not be left to sit directly on the seat for more than 2 hours prior to the test. It is acceptable for the dummy to be left in the vehicle for a longer period, provided that the dummy is not left in overnight or for a similarly lengthy period. If it is known that the dummy will be in the vehicle for a time longer than 2 hours, then the dummy should be sat on plywood boards placed over the seat. This should eliminate unrealistic compression of the seat.

7.3 Dummy Placement

Driver dummy (50th percentile Hybrid III)

7.3.1 Ensure that the seat is in the correct position as defined by Section 6.1.

7.3.2 Place the dummy in the seat with the torso against the seat back, the upper arms against the seat back and the lower arms and hands against the outside of the upper leg.

7.3.3 Carefully place the seat belt across the dummy and lock as normal.

7.3.3.1 Apply a small rearwards force to the lower torso and a small forwards force to the upper torso to flex the upper torso forwards from the seat back. Then rock the torso left and right four times, going to between 14 and 16 degrees to the vertical.

7.3.3.2 Maintaining the small rearwards force to the lower torso, apply a small rearwards force to the upper torso to return the upper torso to the seat back. Slowly remove this force.

Passenger dummy (5th percentile Hybrid III)

Follow procedure in FMVSS208 Section 16.3.3.

7.4 Front Driver Dummy Positioning

Dummy positioning should be carried out immediately before the test and the vehicle should not be moved or shaken thereafter until the test has begun. If a test run is aborted and the vehicle brought to a standstill using an emergency braking method, the dummy placement procedure should be repeated. If the dummy, after three attempts cannot be positioned within the tolerances below then it is to be placed as close to the tolerance limits as possible.

Record this in the test details.

7.4.1 H-point

The dummy's H-point shall be within 13mm in the vertical dimension and 13mm in the horizontal dimension of a point 6mm below the H-point as determined in Section. Record the position of the dummy H-point in the test details.

7.4.2 Pelvic Angle

The pelvic angle measurement gauge should read 22.5° ± 2.5° from the horizontal. Record the measured angle in the test details.

7.4.3 Head

The transverse instrumentation platform of the head shall be horizontal to within 2.5°

Levelling of the head shall be carried out in this order:

-Adjust the H-point within the limit (par. 7.5.1)

-Adjust the pelvic angle within the limits (par. 7.5.2)

-Adjust the neck bracket the minimum to ensure that the transverse instrumentation platform is level within limits. Record the measured angle in the test details.

7.4.4 Arms

The driver's upper arms shall be adjacent to the torso as far as is possible. The passenger's arms shall be adjacent to the torso and in contact with the seat back.

7.4.5 Hands

The driver dummy's hands shall have their palms placed against the steering wheel at a position of a quarter to three. The thumbs should be lightly taped to the wheel.

The passenger's hands should be placed with the palms in contact with the outside of the legs and the little finger in contact with the seat cushion.

7.4.6 Torso

The dummies' backs should be in contact with the seat back and the centre line of the dummies should be lined up with the centre line of their respective seats.

7.4.7 Legs

The upper legs of both dummies shall be in contact with the seat cushion as far as possible. The distance apart of the outside metal surfaces of the knees of each dummy shall be 270mm ± 10mm (except if the left foot is placed on a footrest in par. 7.5.8 below). The legs of the dummies should be in vertical longitudinal planes as far as is possible.

7.4.8 Feet

The driver dummy's right foot shall rest on the undepressed accelerator pedal with the heel on the floor. If the foot cannot be placed on the pedal then it should be placed as far forwards as possible with the foot perpendicular to the lower tibia, in line with the centre line of the pedal. The left foot should be placed as flat as possible on the toe-board parallel to the centre line of the vehicle. If any part of the left foot is in contact with a foot-rest or wheel arch when in this position then place the foot fully on this rest providing a normal seating position can still be achieved. Keep the legs in the same vertical longitudinal plane. The knee gap requirement of 270mm ± 10mm may be ignored in this case. Note the knee gap in the test details.

The passenger dummy's feet shall be placed with the heel as far forwards as possible and the feet as flat as possible. Both feet shall be parallel to the centre line of the vehicle.

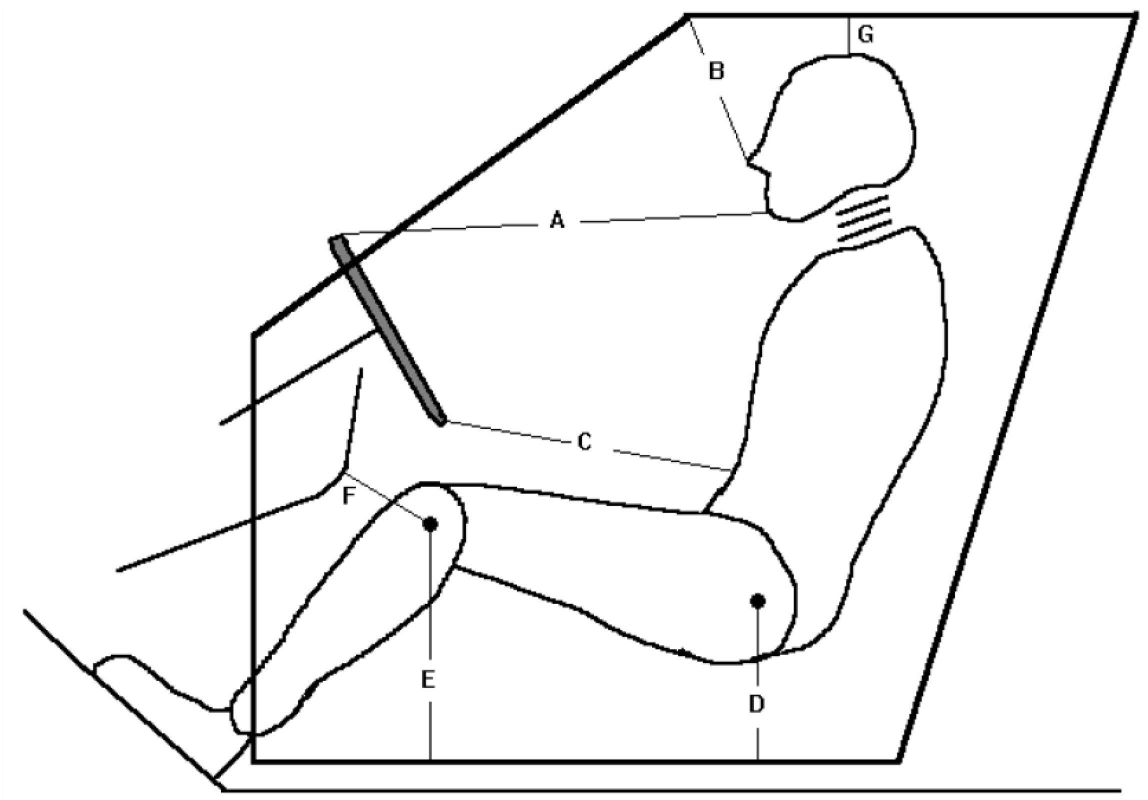
7.5 Front Passenger Dummy Positioning

Follow procedure in FMVSS208 Section 16.3.3.

7.6 Dummy Measurements

The following measurements are to be recorded prior to the test after the dummy settling and positioning procedures have been carried out.

<u>Front Seated Dummies</u>



Recording dummy position – Pre-test

Driver's Side		Passenger's Side	
A	Chin to top of rim	A	Chin to facia
B	Nose to top edge of glass	B	Nose to top edge of glass
C	Stomach to rim	C	Stomach to facia*
D	H-point to top of sill	D	H-point to top of sill
E	Knee bolt to top edge of sill	E	Knee bolt to top edge of sill
F	Knee bolt to top edge of bolster	F	Knee bolt to top edge of bolster*
G	Head to roof surface	G	Head to roof surface
θ	Neck Angle	θ	Neck Angle
	H-Point Co-ordinates (to vehicle)		H-Point Co-ordinates (to vehicle)
α	Seat back angle (as defined by torso angle)	α	Seat back angle (as defined by torso angle)

* Shortest distance

8 STILL PHOTOGRAPHY

The following photographs will be taken pre and post-test unless otherwise indicated. Pre-test photographs will be taken with the dummies in their final positions.

1 Front view of barrier.

2 Side view of barrier.

3 Side view of barrier at 45 degrees to front.

4 Side view of barrier with vehicle.

5 Car RHS, with camera centred on junction of B-post waist, showing full car.

6 Car RHS, with camera centred on B-post waist, showing rear passenger compartment.

7 Car RHS, with camera aimed at waist height, showing driver's compartment.

8 Car RHS at 45 degrees to front.

9 Front view of car.

10 Car LHS at 45 degrees to front.

11 Car LHS, with camera aimed at waist height, showing front passenger's compartment.

12 Car LHS, with camera centred on B-post waist, showing rear passenger compartment.

13 Car LHS, with camera centred on B-post waist, showing full car.

14 Driver and seat to show driver compartment and position of seat relative to the sill.

15 To show area immediately in front of driver.

16 To show driver's footwell area and location of dummy's feet and pedals.

17 Passenger and seat to show compartment and position of seat relative to sill.

18 To show area immediately in front of passenger.

19 To show passenger footwell area and dummy's feet.

20 *Overall view of where the car has come to rest after impact (including barrier).]

21 *To show position of all door latches and/or open doors.

22 *To show driver knee contacts with facia (airbag should be lifted if obscuring view).

23 *To show passenger knee contacts with facia (airbag should be lifted if obscuring view).

After Dummy Removal

24 Passenger compartment from rear window.

25 LHS interior from RHS of car.

26 RHS interior from LHS of car.

27 LHS front door area.

28 RHS front door area.

29 Facia.

30 Passenger footwell.

31 Driver footwell.

32 Steering wheel taken perpendicular to driver's side.

33 Driver right knee impact point.

34 Driver left knee impact point.

35 Passenger knee impact area.

36 Positions of all accelerometers

37 Position of rate sensor

Note: The above photos are for a RHD car, for a LHD car camera locations will switch sides.

9 TEST PARAMETERS

9.1 Load Cell Wall and Deformable Barrier

9.1.1 A high resolution Load Cell Wall as described in section 4.3 is included in the protocol as an option. Please note that for all APROSYS project tests the LCW should be included in all tests.

9.1.2 A deformable barrier as described in section 11 is included in the protocol as an option. Please note that for APROSYS project tests the deformable barrier should be included in appropriate tests.

9.2 Speed

9.2.1 Measure the speed of the vehicle as near as possible to the point of impact.

9.2.2 This speed should be 56km/h +/-1km/h. Record the test speed in the test details.

TARGET SPEED = 50km/h ± 1km/h

9.3 Alignment of vehicle to barrier

The fore/aft centre line of the vehicle is to be aligned with the vertical centre line of the deformable element facing the barrier.

9.3.1 Alignment of the load cell wall

The lower edge of the load cell wall is to be parallel to the ground and at a height of 80 mm relative to the ground. The load cell wall is to be rigidly attached to the barrier with its front face in the same plane as the front face of the barrier. The load cell wall must not overlap the edges of the barrier.

9.3.2 Alignment of deformable element

The lower edge of the deformable element, excluding the mounting flanges, is to be aligned with the lower edge of the load cell wall. The vertical centreline of the deformable element is to be aligned with the vertical centre line of the load cell wall. In order to attach the deformable element to the load cell wall, the MDF facings on the lower row of load cells are to extend below the lower edge of the load cells. The barrier is fixed to the load cell wall by means of a clamping plate along the upper edge and along the lower edge.]

9.3.3 Record the horizontal and vertical accuracy

TARGET OVERLAP = 100%

9.4 Door Opening Forces

9.4.1 Check that none of the doors have locked during the test

9.4.2 Try to open each of the doors (front doors followed by rear doors) using a spring-pull attached to the external handle. The opening force should be applied perpendicular to the door, in a horizontal plane, unless this is not possible. The manufacturer may specify a reasonable variation in the angle of the applied force. Gradually increase the force on the spring-pull, up to a maximum of 500N, until the door unlatches. If the door does not open record this then try to unlatch the door using the internal handle. Again attempt to open the door using the spring-pull attached to the external handle. Record the forces required to unlatch the door and to open it to 45° in the test details.

9.4.3 If a door does not open with a force of 500N then try the adjacent door on the same side of the vehicle. If this door then opens normally, retry the first door.

9.4.4 If the door still does not open, record in the test details whether the door could be opened using extreme hand force or if tools were needed.

Note: In the event that sliding doors are fitted, the force required to open the door sufficiently enough for an adult to escape should be recorded in place of the 45^{o} opening force.

9.5 Dummy Removal

9.5.1 Do not move the driver or passenger seats. Try to remove the dummies.

9.5.2 If the dummies cannot be removed with the seats in their original positions, recline the seat back and try again. Note any entrapment of the dummy.

9.5.3 If the dummies can still not be removed, try to slide the seats back on their runners.

9.5.4 If the dummies can still not be moved, the seats can be cut out of the car.

9.5.5 Record the method used to remove the dummies.

9.6 Intrusion Measurements

Take the vehicle intrusion measurements. See Section 2.2 for a full description of how to do this.

10 CALCULATION OF INJURY PARAMETERS

This section of the Euro NCAP frontal impact testing protocol is replaced by the following. The following table lists all of the channels which are to be measured and the Channel Frequency Class at which they are to be filtered. Traces should be plotted of all of these channels. The injury calculation column lists the parameters which will be calculated for each location. If the injury parameter is not a simple peak value and involves some further calculation, details are given subsequently. Peak levels of head or neck parameters occurring from impacts after the dummy head rebounds from an initial contact are not considered when calculating maximum levels of injury parameters.

Location	Parameter	CFC[3]	Injury Calculation
Head	Accelerations, A_x A_y A_z	1000	Peak Resultant acceleration HIC_{36} HIC_{15} Resultant 3msec exceedence
Neck	Forces, F_x F_y F_z	1000	Tension (+F_z) continuous exceedence Shear (F_x) continuous exceedence Peak Extension (M_y)I Nij for US FMVSS208 SNPRM
	Moments, M_x M_y M_z	600	
Chest	Accelerations, A_x A_y A_z	180	Peak resultant acceleration Resultant 3 msec exceedence Peak deflection Viscous Criterion
	Deflection, D	180	
Pelvis	Accelerations, A_x A_y A_z	180	Peak resultant acceleration Resultant 3 msec exceedence
Femurs	Forces, F_z	600	Compressive Axial Force (-F_z)

(L & R)			Continuous exceedence
Knees (L & R)	Displacements, D	180	Peak displacement
Upper Tibia (L & R)	Forces, F_x F_z	600	Peak displacement
	Moments, M_x M_y	600	Peak Tibia Compression ($-F_z$) Tibia Index
Lower Tibia (L & R)	Forces, F_x F_z	600	Peak Tibia Compression ($-F_z$) Tibia Index
	Moments, M_x M_y	600	

[3] All CFCs taken from SAE J211

Using the above channels, dummy injury parameters can be calculated according to the following procedures:

10.1 Head

10.1.1 Calculate the resultant head acceleration AR from the three components Ax, Ay and Az after they have been filtered and determine the maximum value of AR

$$A_R = \sqrt{A_X^2 + A_Y^2 + A_Z^2}$$

10.1.2 Determine the highest value of the resultant head acceleration

10.1.3 Calculate the Head Injury Criterion (HIC) according to

$$HIC = (t_2 - t_1)\left[\frac{\int_{t1}^{t2} A_R.dt}{(t_2 - t_1)}\right]^{2,5}$$

where AR is expressed in multiples of g. Maximise HIC for any time ‘window’ (t2 – t1) up to 36 milliseconds.

10.1.4 Determine the acceleration level which AR exceeds for a cumulative time period of three milliseconds i.e. the head 3msec exceedence.

10.2 Neck

10.2.1 Calculate the neck extension bending moment from

$$(M_y)i = M_y - fx.d$$

Where My and Fx are bending moment and shear force respectively measured at the transducer and d is the distance from the transducer to the interface

(d=0.01778). See (SAEJ1733).

10.2.2 Determine the 'continuous exceedence' of both the neck tension (Fz positive) and neck shear (Fx) forces.

$$C_{(t)} = \frac{D_{(t)}}{0{,}229}$$

10.3 Chest

V is the velocity of deflection and is calculated as the differential of the deflection with respect to time:

$$V_{(t)} = \frac{8 * \left[D_{(t+1)} - D_{(t-1)}\right] - \left[D_{(t+2)} - D_{(t-2)}\right]}{12\delta t}$$

where δt is the time interval between successive digital samples of D(t). Calculate V(t)*C(t) continuously with time and determine its greatest value.

10.4 Femurs

10.4.1 For each of the femurs, calculate the continuous exceedence in compression (Fz negative)

10.5 Knees

10.5.1 For each of the knees, determine the greatest value of the knee displacement D

10.6 Tibia

10.6.1 At the upper and lower of both the left and the right tibias, calculate the resultant bending moment MR from Mx and My after they have been filtered.

$$M_{R(t)} = \sqrt{M_{X(t)}^2 + M_{Y(t)}^2}$$

10.6.2 Calculate the Tibia Index (TI) at the upper and lower tibia of each leg according to the equation

$$TI_{(t)} = \left|\frac{M_{R(t)}}{(M_R)_C}\right| + \left|\frac{F_{Z(t)}}{(F_Z)_C}\right|$$

TI(t) is the instantaneous value of the Tibia Index at time t. (MR)C is the critical value of the bending moment = 225Nm and (FZ)C is the critical value of the axial force = 35.9kN. The vertical lines indicate that the modulus should be taken.

10.6.3 Determine the highest value of the Tibia Index.

10.6.4 Determine the highest value of the axial compressive force measured at either the upper or lower tibia.

11 DEFORMABLE BARRIER SPECIFICATION

The external dimensions of the barrier are illustrated in Figure C.1. The deformable element is formed from two layers of aluminium honeycomb, with an overall depth of 300 mm, a height of 1000 mm and a width of 2000 mm. [For larger vehicles the height and the width of the deformable element should be increased in 125 mm increments vertically and 250 mm *increments horizontally to ensure that no part of the vehicle directly impacts the LCW.]*

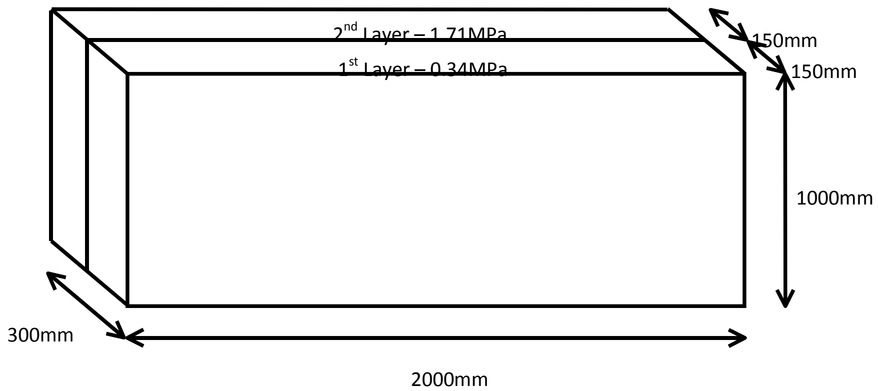


Figure C.1: Full Width Deformable Barrier external dimensions (not to scale).

The first (front) layer of the deformable element has a crush strength of 0.34 MPa and is 150 mm deep, the second (rear) layer has a crush strength of 1.71 MPa and is 150 mm deep. In addition, the second layer is segmented every 125 mm in the horizontal and vertical directions starting at 125 mm from the outer edges. The position of each of the slots is to be measured from the outer edge of the barrier to prevent compound errors. The two layers are joined with a muslin interlayer and there is to be no cladding on any faces other than the mounting face. The mounting face is the rear face of the 1.71 MPa layer. The mounting face is to be clad with a 0.5 mm aluminium sheet which protrudes a set distance of 40 mm from the upper and lower faces of the barrier to provide mounting flanges for attachment to the load cell wall.

Front honeycomb layer

Height: 1000 mm (in direction of honeycomb ribbon axis)

Width: 2000 mm

Depth: 150 mm (in direction of honeycomb cell axes)

Material: Aluminium 3003 (ISO 209, part 1)

Foil thickness: 0.076 mm

Cell size: 19.14 mm

Density: 28.6 kg/m3

Crush strength: 0.342 MPa +0% -10%

Rear honeycomb layer

Height: 1000 mm [□2.5 mm] (in direction of honeycomb ribbon axis)

Width: 2000 mm [□2.5 mm]

Depth: 150 mm [□1 mm] (in direction of honeycomb cell axes)

Material: Aluminium 3003 (ISO 209, part 1)

Foil thickness: 0.076 mm

Cell size: 6.4 mm

Density: 82.6 kg/ m3

Crush strength: 1.711 MPa +0% -10%

Backing sheet

Height: 1080 mm □ 2.5 mm

Width: 2000 mm □ 2.5 mm

Thickness: 0.5 mm □ 0.1 mm

Material: Aluminium 5251

Deformable Barrier Face Construction

The rear honeycomb layer is segmented every 125 mm in the horizontal and vertical directions starting at 125 mm from the outer edges. The position of each of the segmentation slots is to be measured from the outer edge of the barrier to prevent compound errors. [The slot size is to be less than 5 mm wide.]

The rear honeycomb layer shall be bonded to the backing sheet with adhesive such that the cell axes are perpendicular to the sheet.

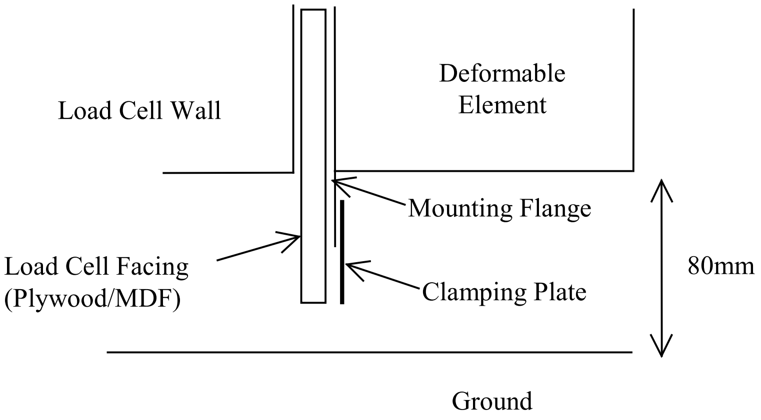
The front honeycomb layer shall be adhesively bonded to the rear honeycomb layer by means of a muslin interlayer sheet, such that the cell axes are perpendicular to the sheet. The deformable element is formed from two layers of aluminium honeycomb, with an overall depth of 300 mm, a minimum height and width of 1000 mm and 2000 mm respectively. [For larger vehicles the height and the width of the deformable element should be increased in 125mm increments vertically and 250 mm increments horizontally to ensure that no part of the vehicle directly impacts the LCW.]

The certification procedure that should be followed for the materials in the Full Width Deformable Barrier is described in Annex 9 Paragraph 2 of Regulation 94, these materials having a crush strength of 0.342 MPa and 1.711 MPa respectively.

The adhesive to be used throughout should be a two-part polyurethane (such as Ciba-Geigy XB5090/1 resin with XB5304 hardener, or equivalent). The adhesive bonding procedure that should be followed for materials in the Full Width Deformable Barrier is described in Annex 9 Paragraph 3 of Regulation 94.

Deformable Barrier Face Mounting

The lower edge of the deformable element, excluding the mounting flanges, is to be aligned with the lower edge of the load cell wall. The vertical centreline of the deformable element is to be aligned with the vertical centre line of the load cell wall. In order to attach the deformable element to the load cell wall, the MDF facings on the lower row of load cells are to extend below the lower edge of the load cells. The barrier is fixed to the load cell wall by means of a clamping plate along the upper edge and along the lower edge. The bolts used to attach the clamping plate must not pass through the mounting flange.



[If the impact area of the test vehicle were likely to exceed the upper edge of the deformable element when at the minimum height of 1000 mm, an alternative option to increasing the height of the deformable element would be to increase the height of the LCW relative to the ground. This is provided that the lower edge of the impact area is a minimum of 125 mm further from the ground level in the vertical direction than the lower edge of the deformable element when in the new position. The proposed increase in height would be in 125 mm steps beginning at 80 mm relative to the ground.]

12 COMPATIBILITY METRIC

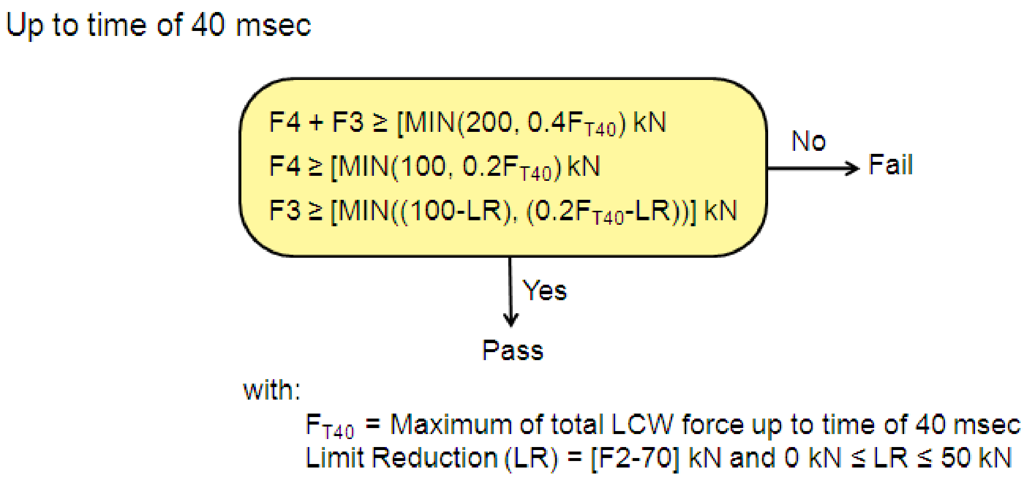


Figure C.2: FWDB Metric with Limit Reduction

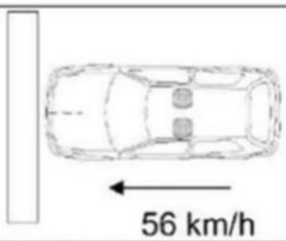
ANNEX D: FULL WIDTH TEST REPORTS

Table of Contents

SUPERMINI 1 FWDB 56 KM/H (1) @ BAST

FWDB Supermini 1

Test Date	05/02/2012
Location	BASt
Topic	Full Width test
Test Number	FM05C3FW
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1		Barrier:	Full Width
Brand/type	Supermini 1		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	56 km/h		Segmented
Overlap:	100%	Impact accuracy	8 mm left
Test mass:	1301 kg		0 mm
Dummy:	LHS - Hybrid III 50th RHS - Hybrid III 5th	LCW ground clearance	80 mm
		LCW / barrier dimensions	2000 mm wide 750 mm high

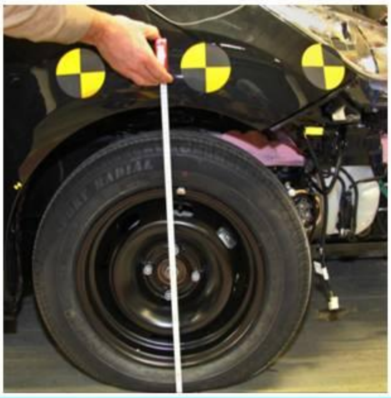
Test parameters

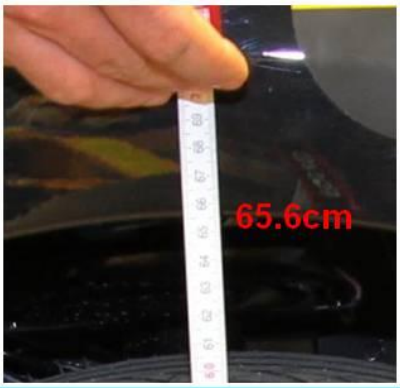
- **Vehicle data: Supermini 1, LHD**
- **Engine / Transmission: 1.4 l diesel / 5 gear**
- **Test speed: 56.02 km/h**
- **Test weight: F 757 kg / R 544kg Total 1301 kg**
- **Test impact accuracy: 8 mm left, 0 mm up**

- **Test vehicle status:**
  - **Not raised (references see next slides)**

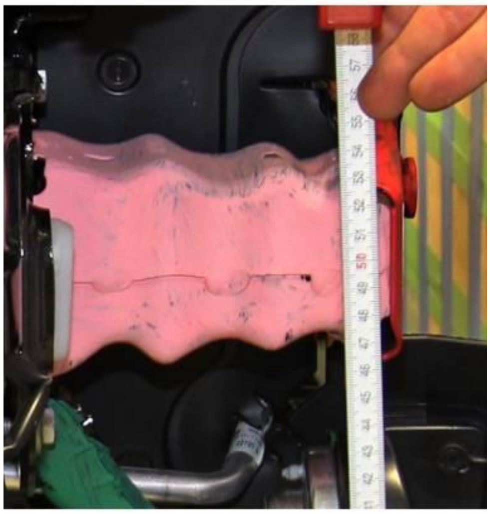
Car hight

Ride heights (wing edge to floor distance) [mm]		
	Left side	Right side
Front	650	654
Rear	635	643





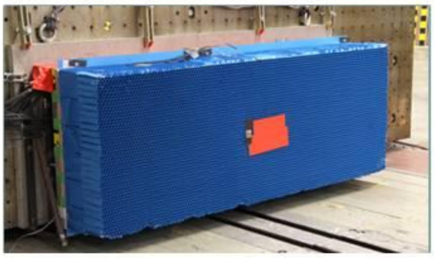
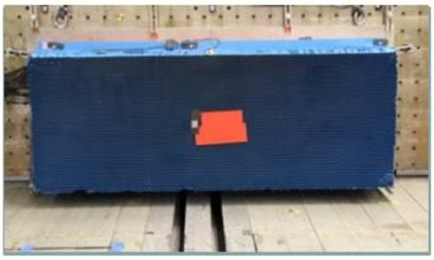
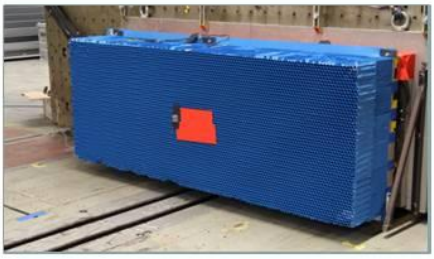
Car hight



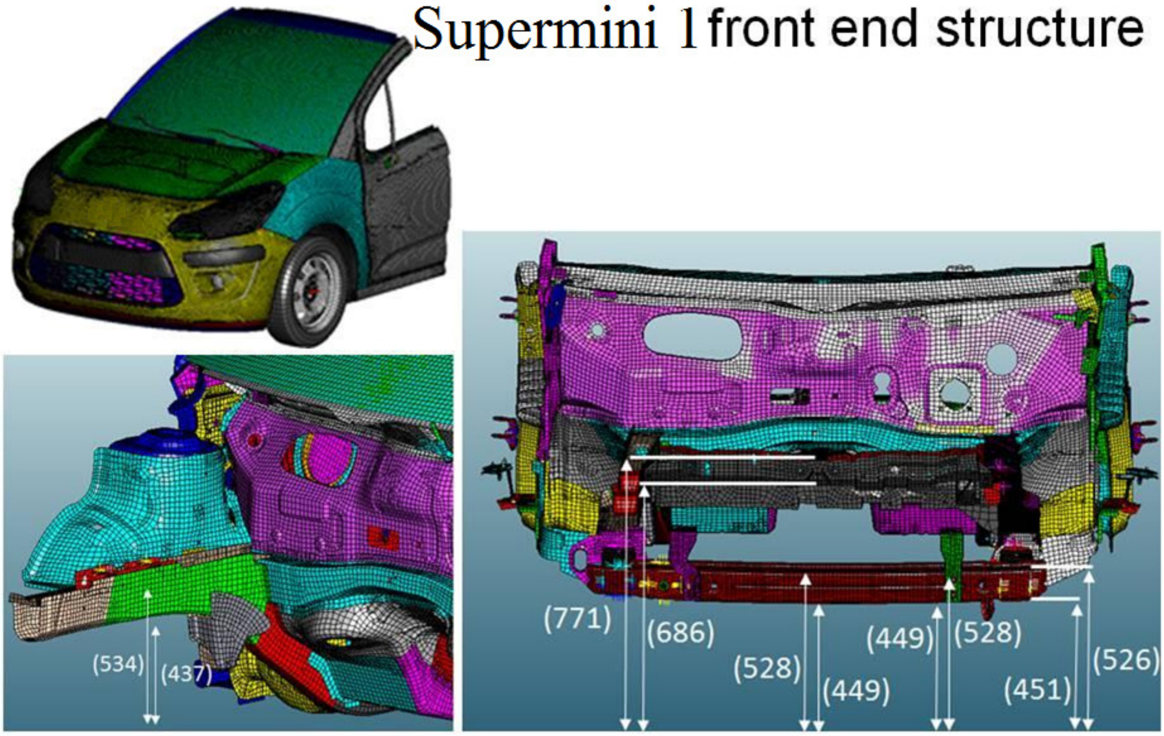
Pre-test Pictures



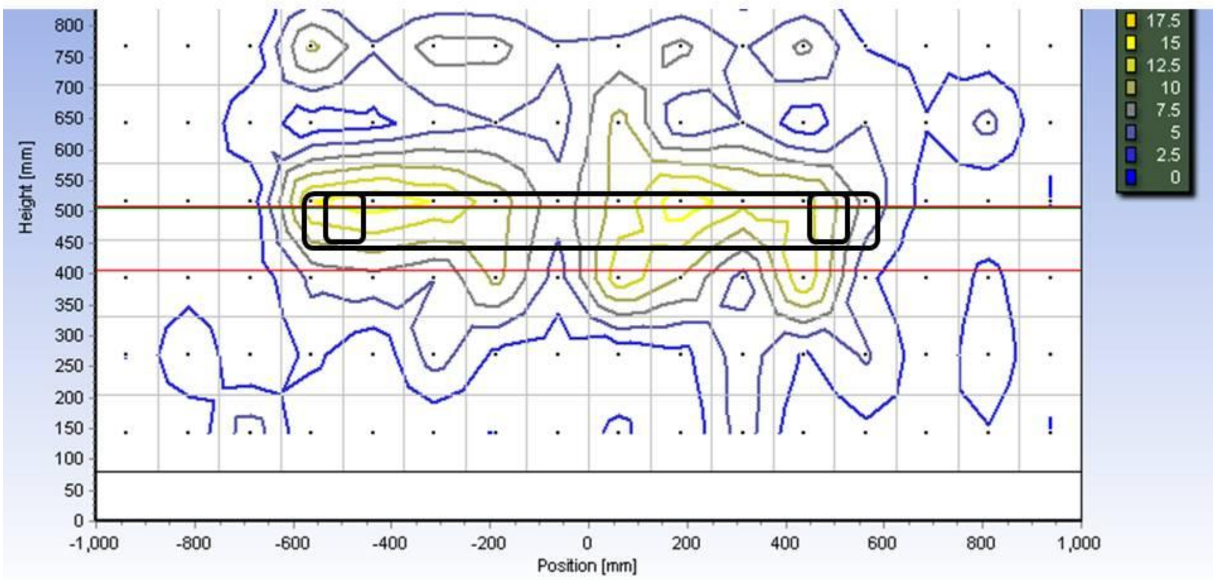

Pre-test Pictures
Barrier

Supermini 1 front end structure



Alignment of Vehicle Structure with LCW



LCW Forces at 40 ms

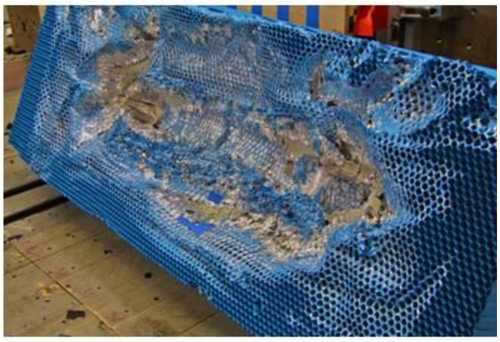
40.00 ms	-687.50	-562.50	-437.50	-312.50	-187.50	-62.50	62.50	187.50	312.50	437.50	562.50	687.50	812.50	937.50	Sum Rows
1017.50 [mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
892.50 [mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
767.50 [mm]	0.93	10.64	5.32	8.54	8.28	5.34	5.76	8.15	4.67	8.16	2.46	1.80	0.86	0.19	72.26
642.50 [mm]	4.23	0.94	1.77	3.82	4.92	3.86	10.94	3.08	4.98	0.88	4.99	2.62	5.80	0.02	53.10
517.50 [mm]	0.89	14.99	16.60	14.85	11.33	6.10	11.08	16.72	13.40	13.74	6.89	1.40	0.21	-0.01	131.04
392.50 [mm]	0.38	5.62	6.64	5.01	10.65	3.79	14.06	9.83	3.98	14.69	3.00	0.25	3.27	0.10	82.67
267.50 [mm]	0.05	3.19	0.22	6.30	1.90	0.91	0.27	1.57	6.40	2.14	5.37	0.77	4.23	0.31	38.48
142.50 [mm]	6.50	0.10	0.23	0.02	0.00	0.84	3.13	0.00	6.31	0.14	1.88	2.02	2.30	-0.08	24.31
Sum Columns	12.98	35.48	30.78	38.54	37.08	20.84	45.24	39.35	39.74	39.75	24.59	8.86	16.67	0.53	401.86

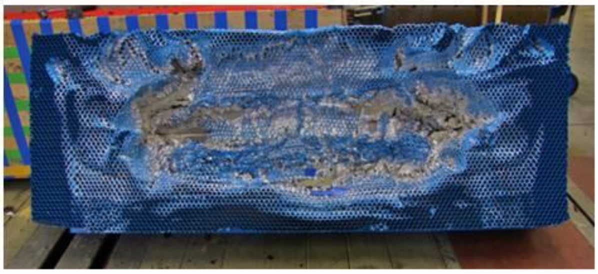
Post-test Pictures
Vehicle 1



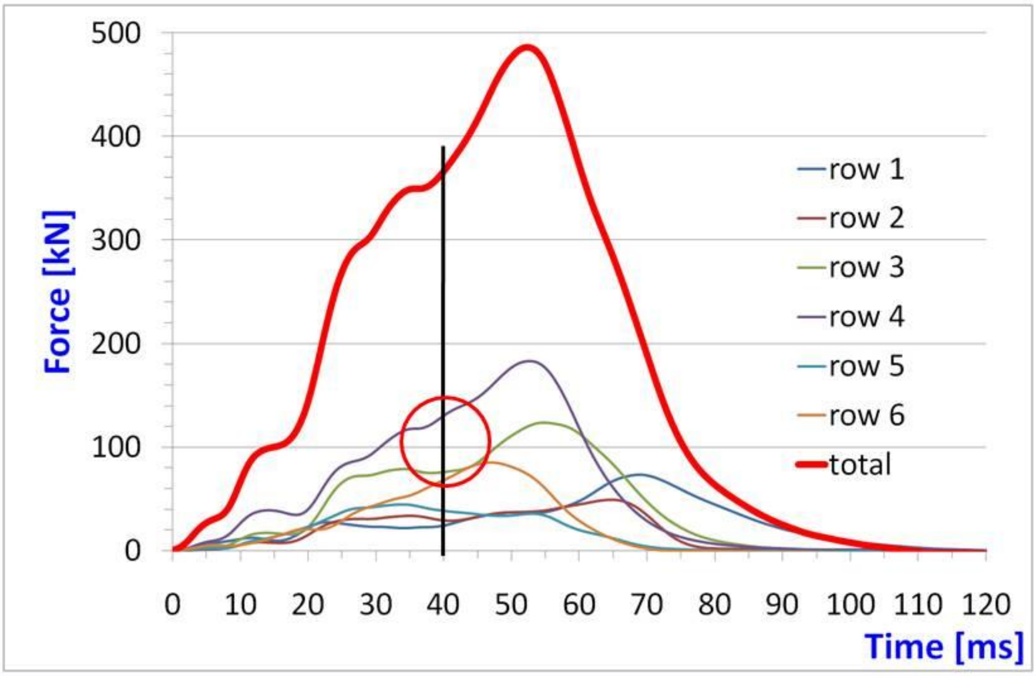

Post-test Pictures

Barrier

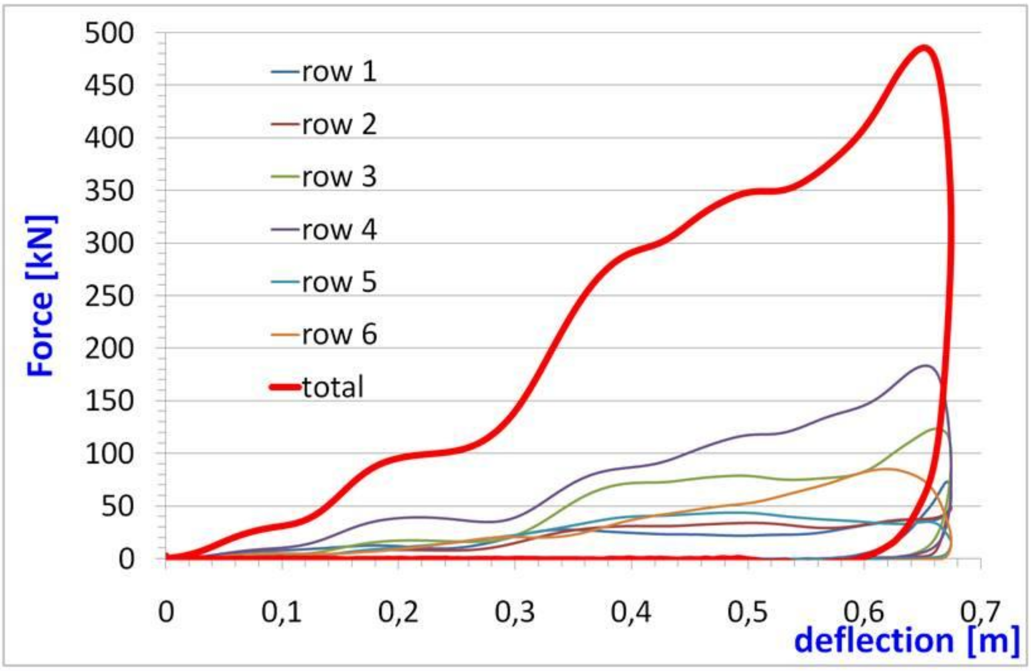




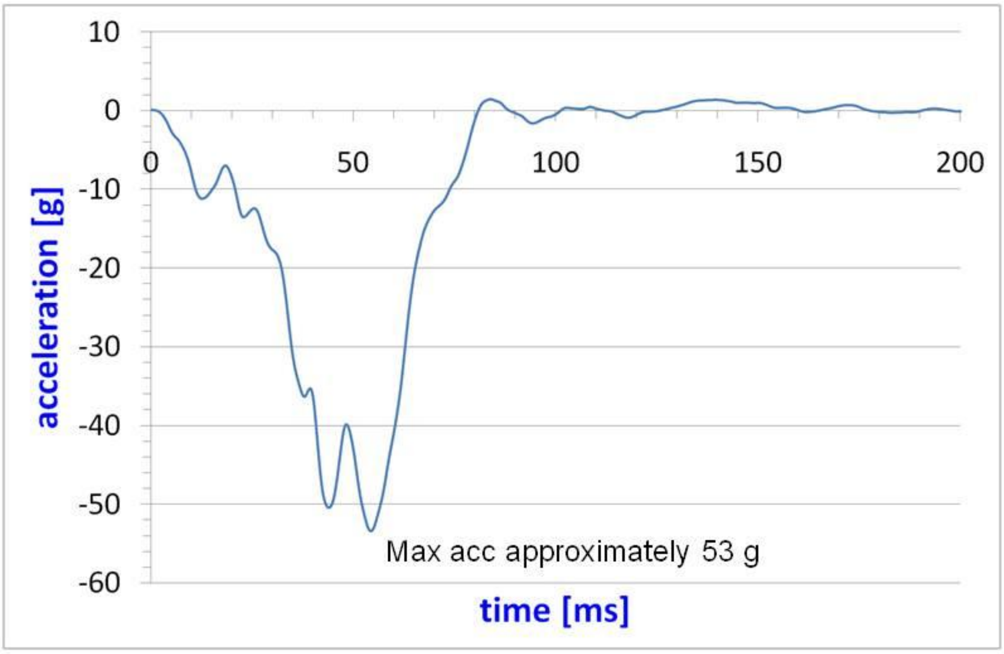
Plot: row forces over time



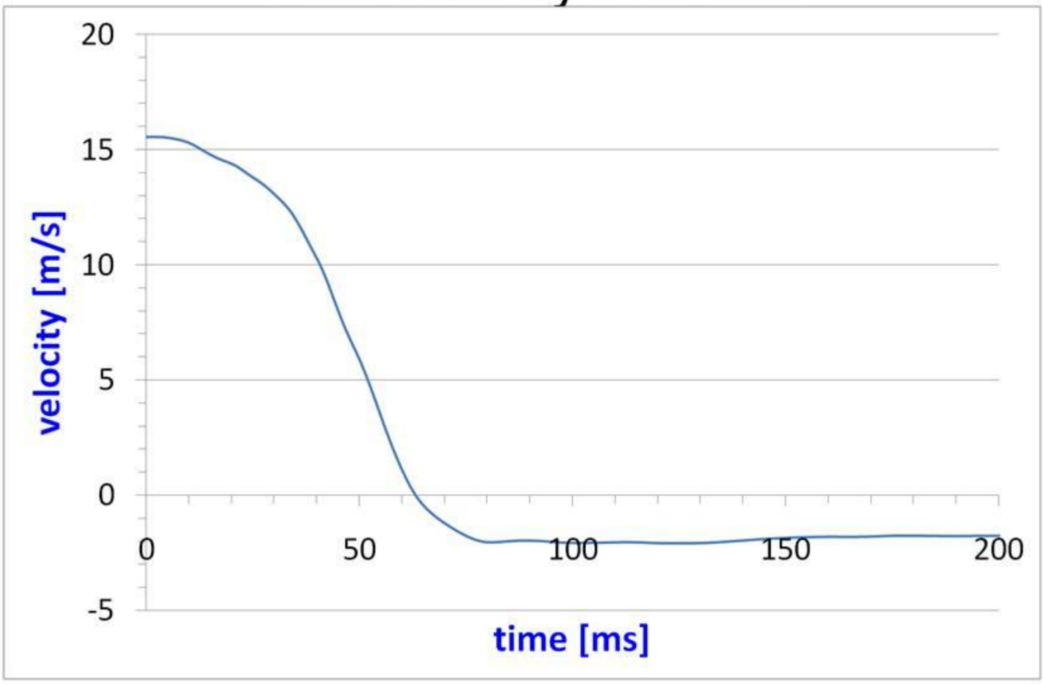
Plot: Row forces over deflection



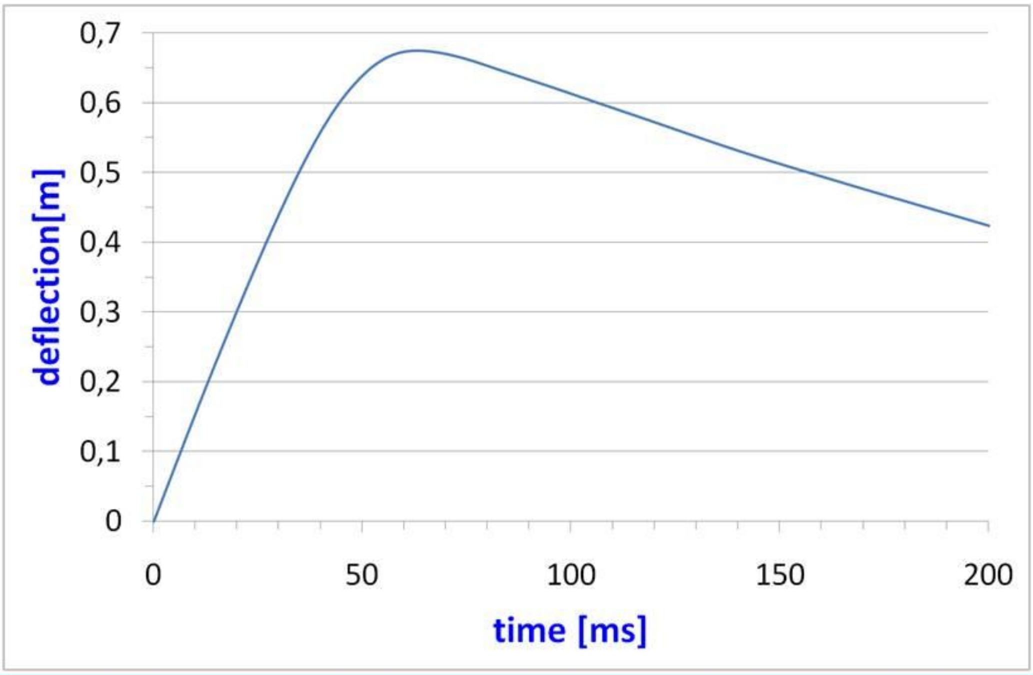
Plot: Vehicle acceleration (a+b pillar)



Plot: Velocity over time



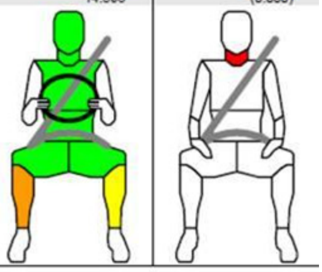
Plot: Deflection over time



Dummy values FW Test

FM05C3FW		Supermini 1 vs. FWDB
FM05C3FW	Type of Test	Frontal Impact
2012-03-05	Regulation	Euro NCAP

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (HF)		
Head & Neck			4.000			0.000
Head						
HIC 36	707.83			912.82		
Acceleration Resultant	72.31	g	4.000	84.98	g	
3ms cumulative	71.23	g		84.43	g	
Neck						
Shear Force Fx+	0.65	kN	4.000	0.10	kN	0.000
Shear Force Fx-	-0.27	kN	4.000	-0.35	kN	0.000
Tensile Force Fz+	1.48	kN	4.000	1.36	kN	0.000
Extension My-	-10.63	Nm	4.000	-35.09	Nm	
Chest			4.000			
Deflection	-0.11	mm	4.000	-27.55	mm	
VC max	0.25	m/s	4.000	0.14	m/s	
belt at upper diagonal belt Force	5.32	kN		4.69	kN	
Femur & Knee			4.000			
Left						
Femur Force Fz-	-0.29	kN	4.000			
Knee Slider Displacement	-0.34	mm	4.000			
Right						
Femur Force Fz-	-1.64	kN	4.000			
Knee Slider Displacement	-0.45	mm	4.000			
Tibia			2.596			
Left						
Compression Upper Fz-	-1.90	kN	4.000	-0.75	kN	
Compression Lower Fz-	-2.62	kN	3.585	-1.04	kN	
Tibia Index Upper	0.69		2.712	0.86		
Tibia Index Lower	0.32		4.000	0.62		
Right						
Compression Upper Fz-	-1.86	kN	4.000	-0.66	kN	
Compression Lower Fz-	-2.77	kN	3.488	-0.84	kN	
Tibia Index Upper	0.72		2.596	0.59		
Tibia Index Lower	0.44		3.823	0.32		
Sum			14.596			(0.000)



Rating without modifiers

Points
- 4.000
- 2.670 - 3.999
- 1.330 - 2.669
- 0.001 - 1.329
- 0.000

Citroen C3 56.02 km/h 1300 kg Driver Left	Load Cell Wall Fimcar 0.0 km/h 0 kg	**Results Passengers** Front Vehicle 1

Dummy values Euro NCAP Test

Driver Passenger

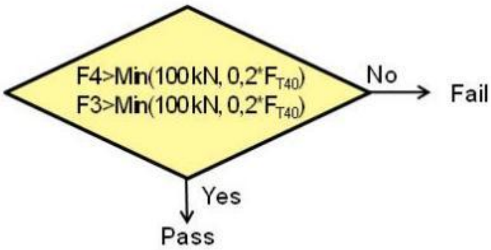
	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	44,93	4,000	42,97	4,000
HIC_{36}	350,03		333,44	
Resultant Acc. 3 msec exeedence - g	44,38		41,89	
Unstable airbag contact, Bottoming out or Hazardous deployment		0,000		0,000
Steering wheel displacement (-1) mm	-4	0,000		
Incorrect airbag deployment		0,000		0,000
Head Assessment		4,000		4,000
NECK				
Shear level exceeded - kN	0,42	4,000	0,37	4,000
duration of exceedence - ms	0		0,00	
Tension level exceeded - kN	1,40	4,000	1,26	4,000
duration of exceedence - ms	0		0,00	
Extension - Nm	18,40	4,000	27,80	4,000
Neck Assessment		4,000		4,000
Head and Neck Assessment		4,000		4,000
CHEST				
Compression - mm	31,16	2,691	29,24	2,966
Viscous criterion - m/s	0,13	4,000	0,11	4,000
Steering wheel contact (-1)		0,000		
A-Pillar displacement (-2) mm	-24	0,000		
Unstable passenger compartment (-1)		0,000		
Shoulder belt load - kN	5,33		4,98	
Chest Incorrect Airbag Deployment Modifier		0,000		0,000
Chest Assessment		2,691		2,966
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0,0	4,000	0,0	4,000
Left Femur Compression level exceeded - kN	0,21	4,000	0,1	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Left Knee, Femur and Pelvis Assessment		4,000		4,000
Right Knee Slide - mm	0,0	4,000	0,0	4,000
Right Femur Compression level exceeded - kN	0,16	4,000	0,2	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Right Knee, Femur and Pelvis Assessment		4,000		4,000

	Driver		Passenger	
Knee, Femur and Pelvis assessment		4,000		4,000
LOWER LEG				
Left compression - kN	2,14	3,907	1,55	4,000
Left Upper Tibia Index	0,47	3,689	0,38	4,000
Left Lower Tibia Index	0,26	4,000	0,23	4,000
Brake pedal vertical (-1) mm	-49	0,000		
Left Lower Leg assessment		3,689		4,000
Right compression - kN	0,92	4,000	1,42	4,000
Right Upper Tibia Index	0,42	3,911	0,39	4,000
Right Lower Tibia Index	0,29	4,000	0,22	4,000
Brake pedal vertical (-1) mm	-49	0,000		
Right Lower Leg assessment		3,911		4,000
FOOT and ANKLE				
Clutch pedal horizontal displacement - mm	-96	4,000		
Footwell Rupture (-1)		0,000		
Pedal Blocking (-1)	0	0,000		
Foot and Ankle assessment		4,000		
Lower Leg, Foot and Ankle assessment		3,689		4,000
SUMMARY				
Head and Neck assessment		4,000		4,000
Chest assessment		2,691		2,966
Knee, Femur and Pelvis assessment		4,000		4,000
Lower Leg, Foot and Ankle Assessment		3,689		4,000
TOTAL		14,380		14,966

TOTAL FRONTAL 14,380

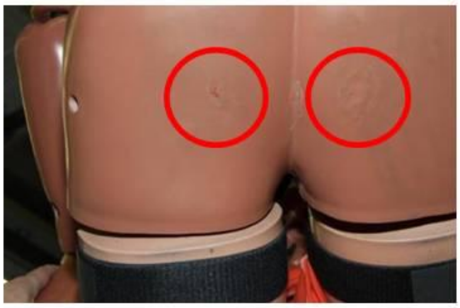
Metrics evaluation

	Supermini 1 FWDB, FM05C3FW		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	83	80,4	OK
F4 > MIN[100, 0.2Ft40]	131	80,4	OK
Global	OK		



Other findings

- Dummy pelvis were loaded due to seat pan structure



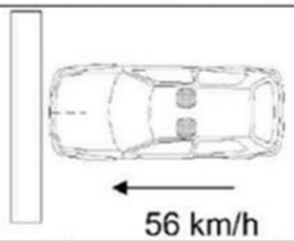
Conclusions

- Supermini 1 test with 56 km/h FWDB
- Max vehicle acceleration: 53 g
- High head and neck loading on the passenger dummy
- Vehicle has one load path, the longitudinals are located in the part 581 zone and they are in agreement with US voluntary agreement.
- Forces on row 3 are lower and forces on row 4 are higher compared to the previous test at BASt
- However, the vehicle will pass the metric but is close to fail

SUPERMINI 1 FWDB 56 KM/H (2) @ BAST

FWDB Supermini 1

Test Date	28/02/2012
Location	BASt
Topic	Full Width test
Test Number	FM04C3FW
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1:		Barrier:	Full Width
Brand/type	Supermini 1		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	56 km/h		Segmented
Overlap:	100%	Impact accuracy	18 mm left 2 mm up
Test mass:	1300 kg	LCW ground clearance	80 mm
Dummy:	LHS - Hybrid III 50th RHS - Hybrid III 5th	LCW / barrier dimensions	2000 mm wide 750 mm high

Test objectives:

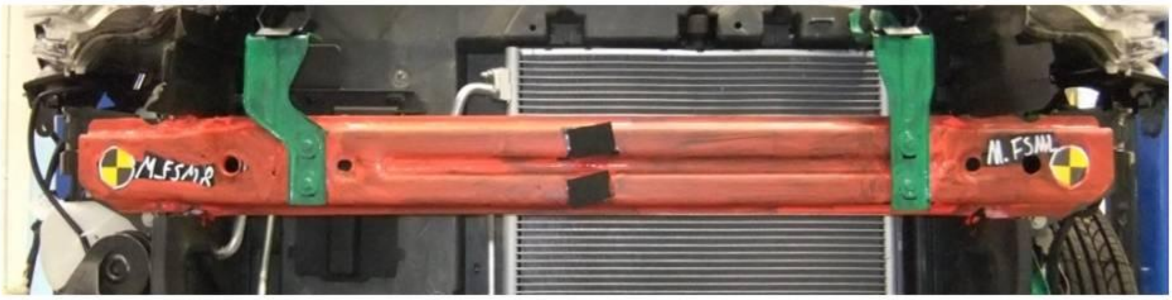
Test parameters

- Vehicle data: Supermini 1, LHD
- Engine / Transmission: 1.4 l diesel / 5 gear
- Test speed: 56.02 km/h
- Test weight: F 759 kg / R 541 kg Total 1300 kg
- Test impact accuracy: 18 mm left, 2 mm up

- Test vehicle status:
  - Not raised (references see next slides)

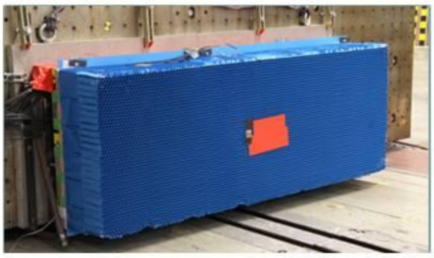
Car hight

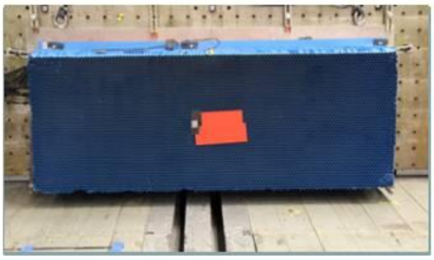
Ride heights (wing edge to floor distance) [mm]		
	Left side	Right side
Front	648	653
Rear	638	643

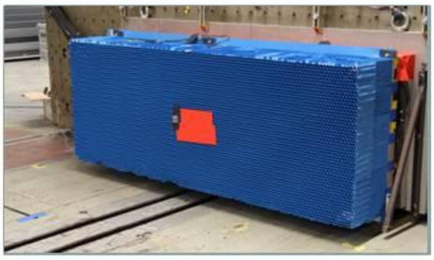


Pre-test Pictures

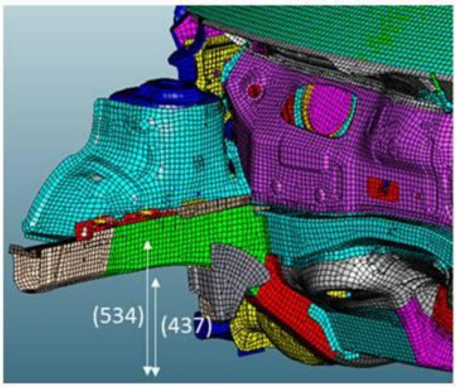
Pre-test Pictures
Barrier

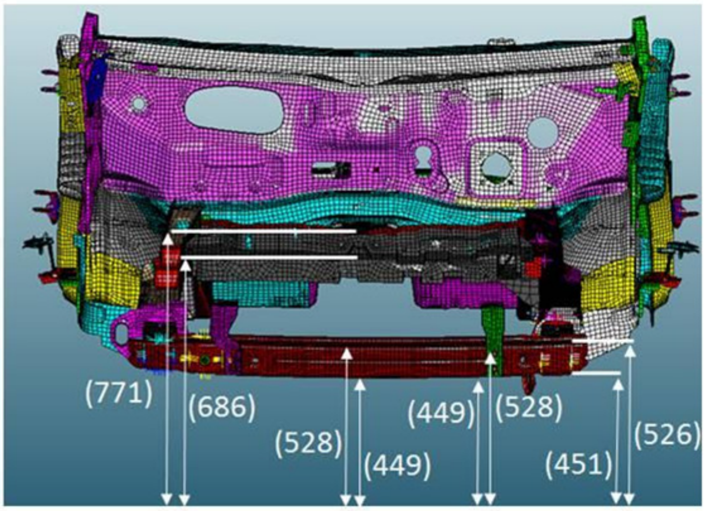




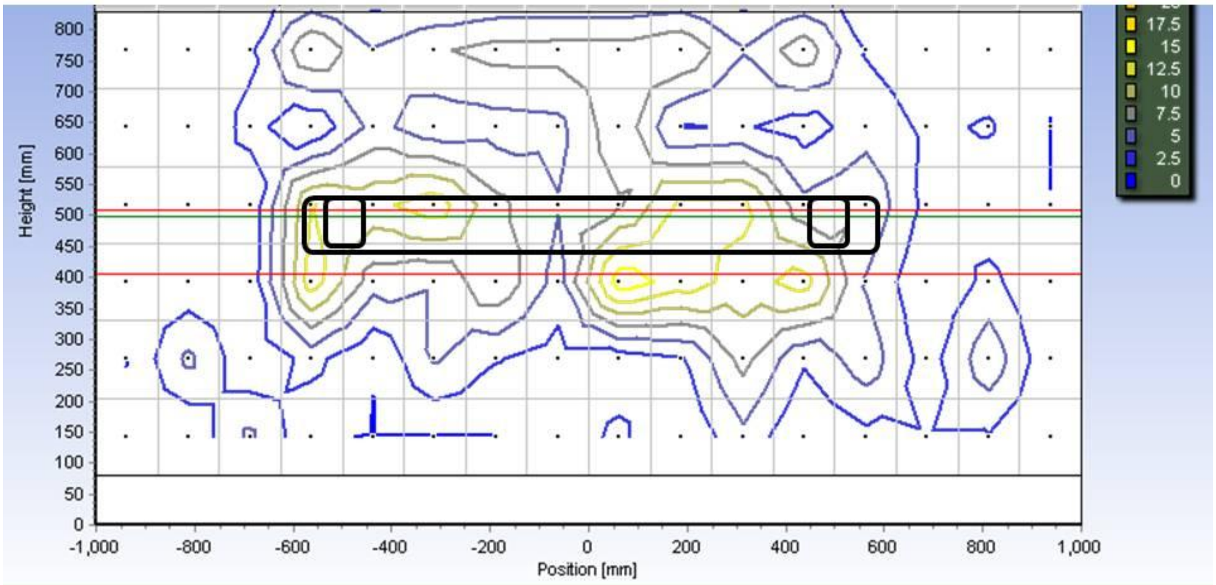


Supermini 1 front end structure





Vehicle Structure with LCW



LCW Forces at 40 ms

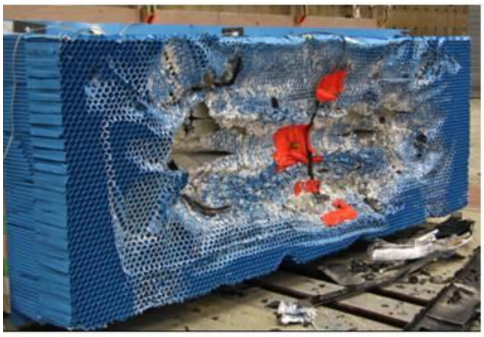
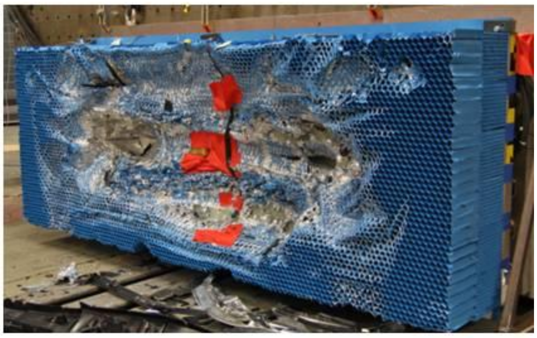
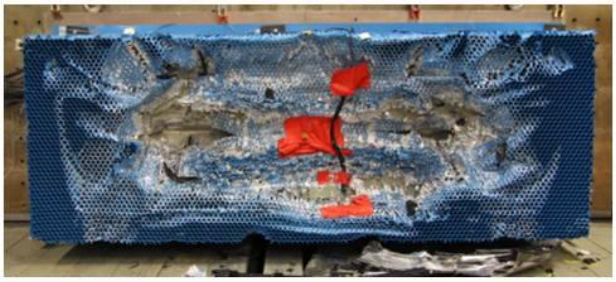
40.00 ms	-687.50	-562.50	-437.50	-312.50	-187.50	-62.50	62.50	187.50	312.50	437.50	562.50	687.50	812.50	937.50	Sum Rows
1017.50 [mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
892.50 [mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
767.50 [mm]	1.97	9.90	5.13	7.16	8.44	8.51	8.49	9.83	5.15	9.09	2.30	0.99	0.76	0.15	79.52
642.50 [mm]	3.34	0.41	5.86	3.38	3.94	4.26	9.39	2.29	2.78	1.33	3.92	2.01	2.76	-0.02	45.93
517.50 [mm]	0.55	12.57	11.70	13.98	8.16	5.14	7.19	13.04	13.26	5.65	7.15	1.74	0.66	0.01	103.25
392.50 [mm]	0.56	13.86	6.03	5.24	9.75	4.08	16.52	13.86	11.36	13.52	4.75	0.22	3.24	0.08	104.10
267.50 [mm]	0.34	3.36	0.08	5.30	2.67	1.22	0.99	2.11	8.39	2.85	6.57	1.30	6.74	0.43	47.92
142.50 [mm]	5.52	0.21	-0.09	-0.07	-0.03	1.12	3.03	0.05	4.36	-0.01	1.86	2.36	2.35	0.11	21.20
Sum Columns	12.28	40.31	28.71	34.99	32.93	24.33	45.61	41.18	45.30	32.43	26.55	8.62	16.51	0.76	401.92

Post-test Pictures
Vehicle 1

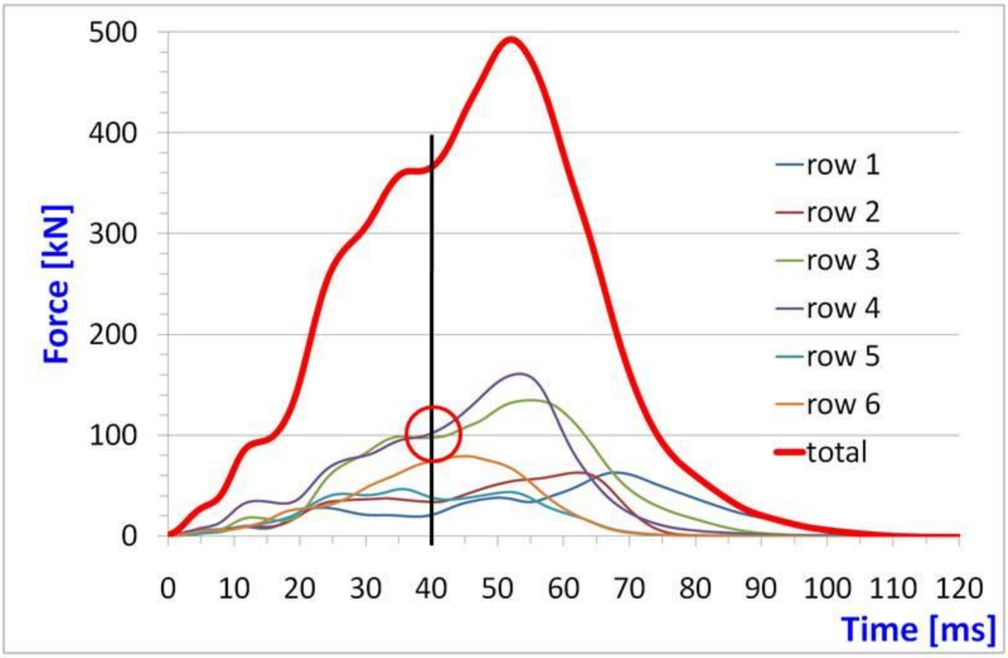



b

Post-test Pictures
Barrier

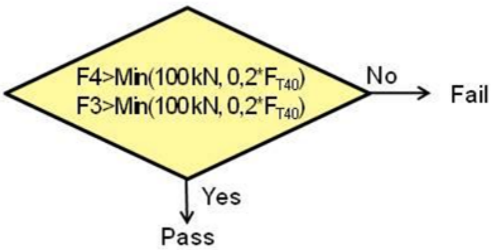




Plots: Row forces over time

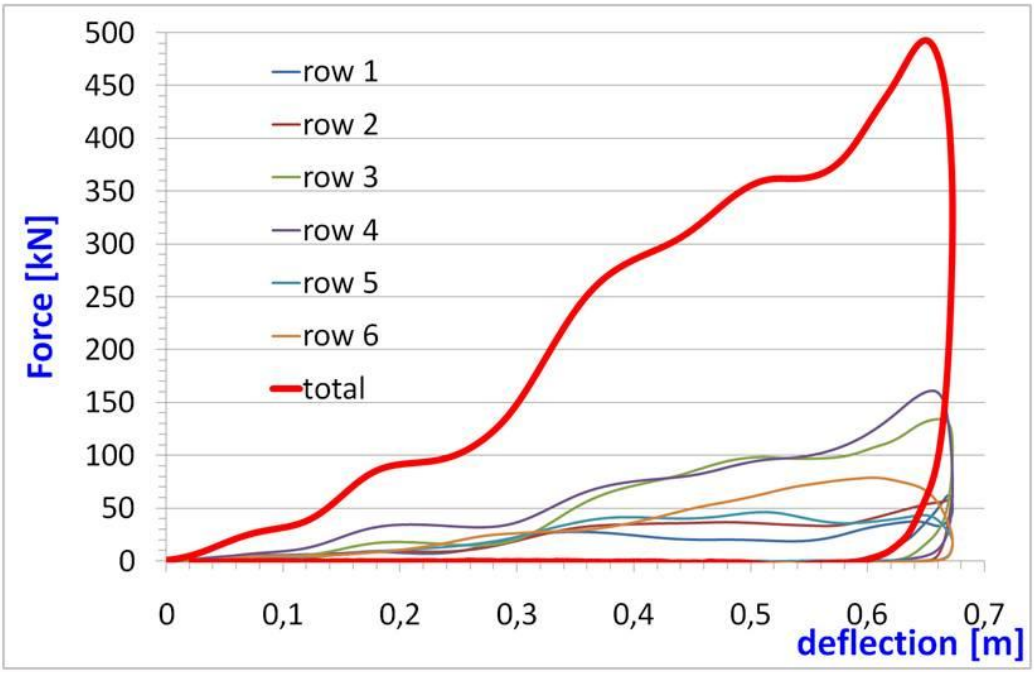


Metrics evaluation

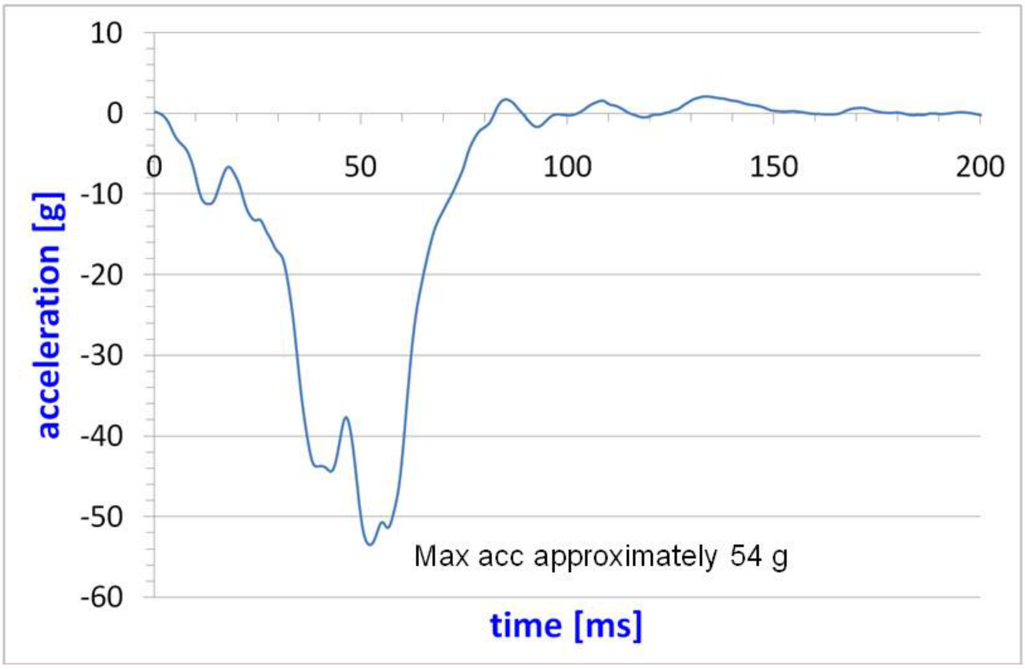
	Supermini 1 FWDB, FM04C3FW		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	104	80,4	OK
F4 > MIN[100, 0.2Ft40]	103	80,4	OK
Global	OK		



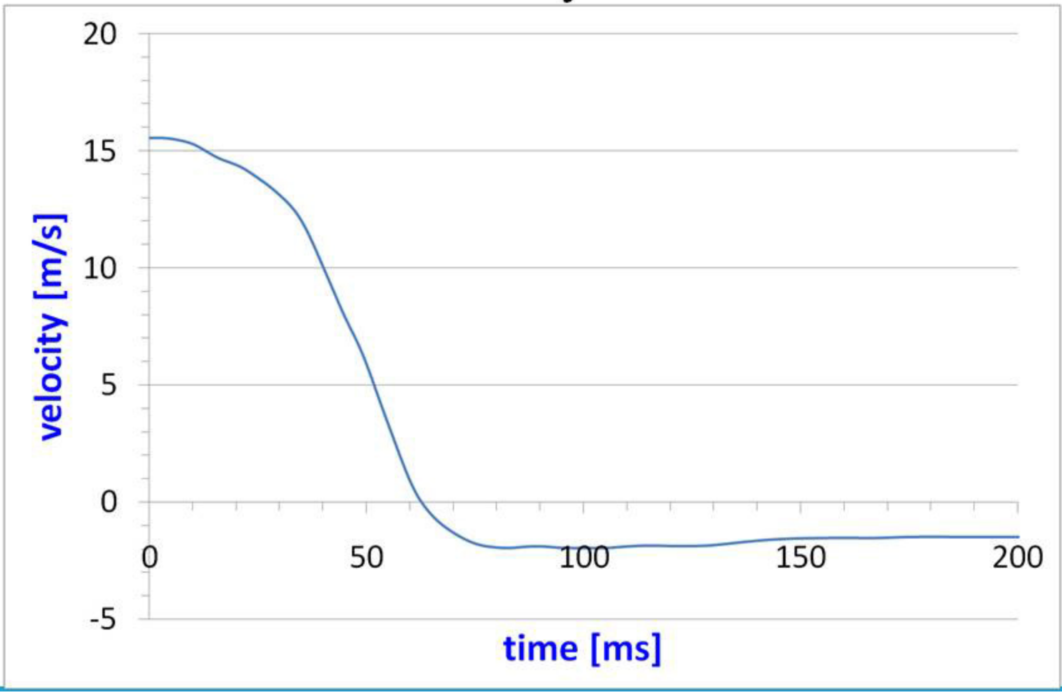
Plot: Row forces over deflection



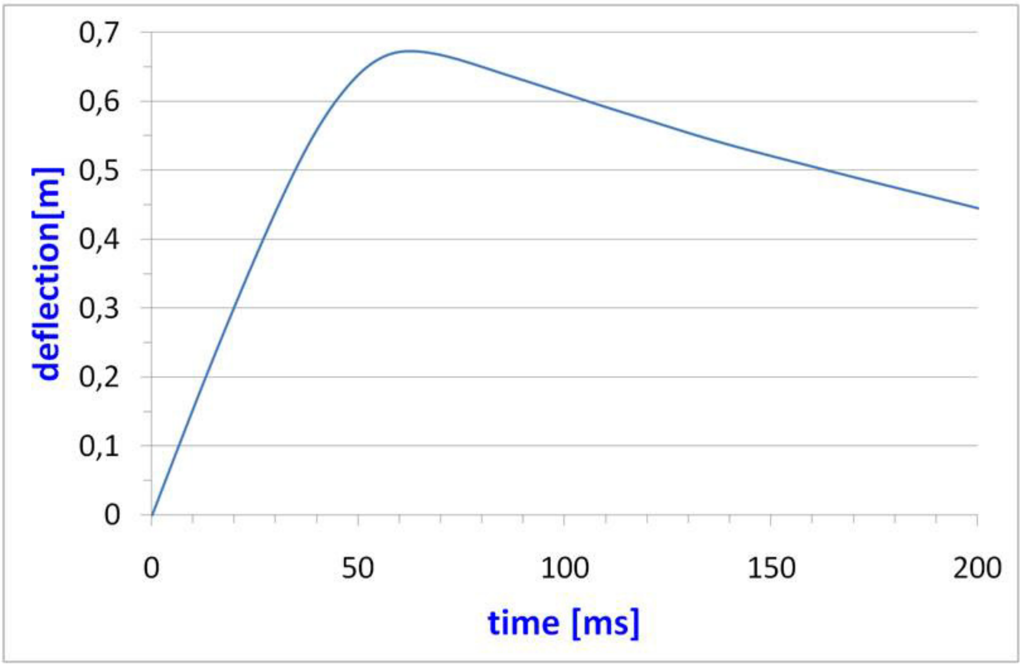
Plot: Vehicle acceleration (a+b pillar)



Plot: Velocity over time



Plot: Deflection over time



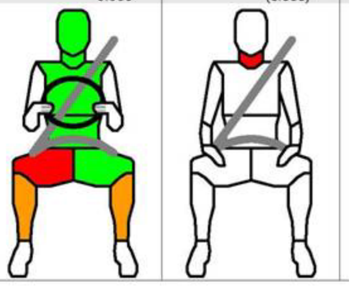
Dummy values FW Test

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (HF)		
Head & Neck			4.000 *			0.000 *
Head						
HIC 36	545.85			1089.92		
Acceleration Resultant	65.76	g	4.000 *	88.45		
3ms cumulative	63.75	g		87.33	g	
Neck						
Shear Force Fx+	0.77	kN	4.000 *	0.15	kN	0.000 *
Shear Force Fx-	-0.37	kN	4.000 *	-0.30	kN	0.000 *
Tensile Force Fz+	1.56	kN	4.000 *	1.25	kN	0.000 *
Extension My-	-14.17	Nm	4.000 *	-48.05	Nm	
Chest			4.000 *			
Deflection	-0.08	mm	4.000 *	-24.94	mm	
VC max	0.27	m/s	4.000 *	0.12	m/s	
belt at upper diagonal belt Force	5.44	kN		4.52	kN	
Femur & Knee			0.000 *			
Left						
Femur Force Fz-	-0.29	kN	4.000 *			
Knee Slider Displacement	-0.40	mm	4.000 *			
Right						
Femur Force Fz-	-20.90	kN	0.000 *			
Knee Slider Displacement	-0.51	mm	4.000 *			

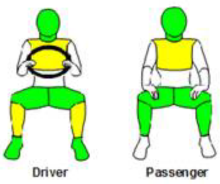
Tibia			1.955 *		
Left					
Compression Upper Fz-	-2.64	kN	3.572 *	-0.75	kN
Compression Lower Fz-	-3.16	kN	3.229 *	-1.00	kN
Tibia Index Upper	0.86		1.955 *	0.80	
Tibia Index Lower	0.29		4.000 *	0.55	
Right					
Compression Upper Fz-	-1.68	kN	4.000 *	-0.70	kN
Compression Lower Fz-	-2.46	kN	3.696 *	-0.93	kN
Tibia Index Upper	0.76		2.397 *	0.61	
Tibia Index Lower	0.51		3.509 *	0.35	
Sum			9.955		(0.000)

Rating without modifiers

Points
- * 4.000
- * 2.670 - 3.999
- * 1.330 - 2.669
- * 0.001 - 1.329
- * 0.000



Dummy values Euro NCAP Test



	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	44,93	4,000	42,97	4,000
HIC_{36}	350,03		333,44	
Resultant Acc. 3 msec exeedence - g	44,38		41,89	
Unstable airbag contact, Bottoming out or Hazardous deployment		0,000		0,000
Steering wheel displacement (-1) mm	-4	0,000		
Incorrect airbag deployment		0,000		0,000
Head Assessment		4,000		4,000
NECK				
Shear level exceeded - kN	0,42	4,000	0,37	4,000
duration of exceedence - ms	0		0,00	
Tension level exceeded - kN	1,40	4,000	1,26	4,000
duration of exceedence - ms	0		0,00	
Extension - Nm	18,40	4,000	27,80	4,000
Neck Assessment		4,000		4,000
Head and Neck Assessment		4,000		4,000
CHEST				
Compression - mm	31,16	2,691	29,24	2,966
Viscous criterion - m/s	0,13	4,000	0,11	4,000
Steering wheel contact (-1)		0,000		
A-Pillar displacement (-2) mm	-24	0,000		
Unstable passenger compartment (-1)		0,000		
Shoulder belt load - kN	5,33		4,98	
Chest Incorrect Airbag Deployment Modifier		0,000		0,000
Chest Assessment		2,691		2,966
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0,0	4,000	0,0	4,000
Left Femur Compression level exceeded - kN	0,21	4,000	0,1	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Left Knee, Femur and Pelvis Assessment		4,000		4,000
Right Knee Slide - mm	0,0	4,000	0,0	4,000
Right Femur Compression level exceeded - kN	0,16	4,000	0,2	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Right Knee, Femur and Pelvis Assessment		4,000		4,000

	Driver		Passenger	
Knee, Femur and Pelvis assessment		4,000		4,000
LOWER LEG				
Left compression - kN	2,14	3,907	1,55	4,000
Left Upper Tibia Index	0,47	3,689	0,38	4,000
Left Lower Tibia Index	0,26	4,000	0,23	4,000
Brake pedal vertical (-1) mm	-49	0,000		
Left Lower Leg assessment		3,689		4,000
Right compression - kN	0,92	4,000	1,42	4,000
Right Upper Tibia Index	0,42	3,911	0,39	4,000
Right Lower Tibia Index	0,29	4,000	0,22	4,000
Brake pedal vertical (-1) mm	-49	0,000		
Right Lower Leg assessment		3,911		4,000
FOOT and ANKLE				
Clutch pedal horizontal displacement - mm	-96	4,000		
Footwell Rupture (-1)		0,000		
Pedal Blocking (-1)	0	0,000		
Foot and Ankle assessment		4,000		
Lower Leg, Foot and Ankle assessment		3,689		4,000
SUMMARY				
Head and Neck assessment		4,000		4,000
Chest assessment		2,691		2,966
Knee, Femur and Pelvis assessment		4,000		4,000
Lower Leg, Foot and Ankle Assessment		3,689		4,000
TOTAL		14,380		14,966

TOTAL FRONTAL **14,380**

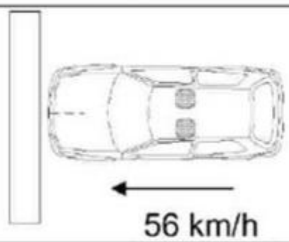
Conclusions

- Supermini 1 test with 56 km/h FWDB
- Max vehicle acceleration: 54 g
- High dummy values for the HIII 5^{th} Dummy on front seat passenger side (head and neck)
- Vehicle has one load path, the longitudinals are located in the part 581 zone and they are in agreement with US voluntary agreement.
- According to the LCW forces calculated, the Vehicle passes the FWDB metric

SUPERMINI 1 FWDB 56 KM/H (3) @ FIAT

FWDB Supermini 1

Test Date	10/11/2011
Location	FIAT Safety Center
Topic	Full Width test
Mass Ratio	N/A
Test Number	17459
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1:	Small car	Barrier:	Full Width
Brand/type	Supermini 1		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	56.39 km/h		Segmented
Overlap:	100%	Impact accuracy	10 mm left 0 mm
Test mass:	1289 kg	LCW ground clearance	80 mm
Dummy:	LHS - Hybrid III 50th RHS - Hybrid III 5th	LCW / barrier dimensions	2 m wide 0.75 m high

Test objectives:

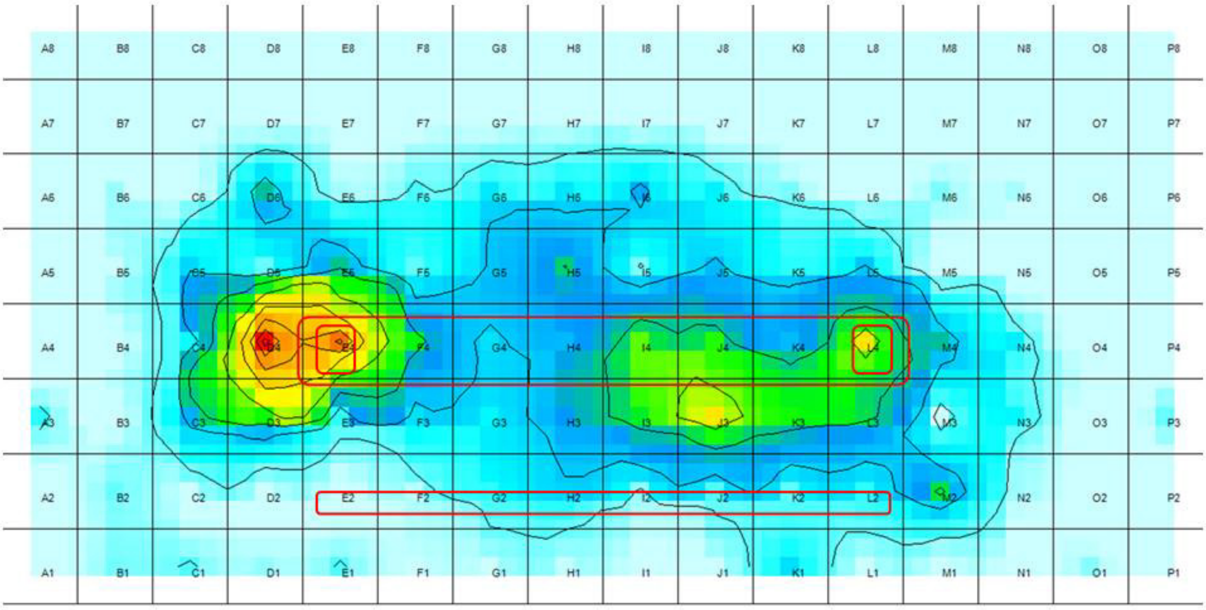
Test parameters

- **Vehicle data: Supermini 1 LHD**
- **Engine / Transmission: 1.4 HDi / Manual**
- **Test speed: 56.39 kph**
- **Test weight: F 755 kg / R 534 kg Total 1289 kg**
- **Test impact accuracy: 10mm left, 0mm up**
- **Test vehicle status:**
  - **Standard ride heights:**
  - **Fender height R F 647**
    Fender height L F 649
    Fender height R R 616
    Fender height L R 620

Pre-test Pictures
Vehicle 1

Pre-test Pictures
Barrier

Alignment of Vehicle Structure with LCW



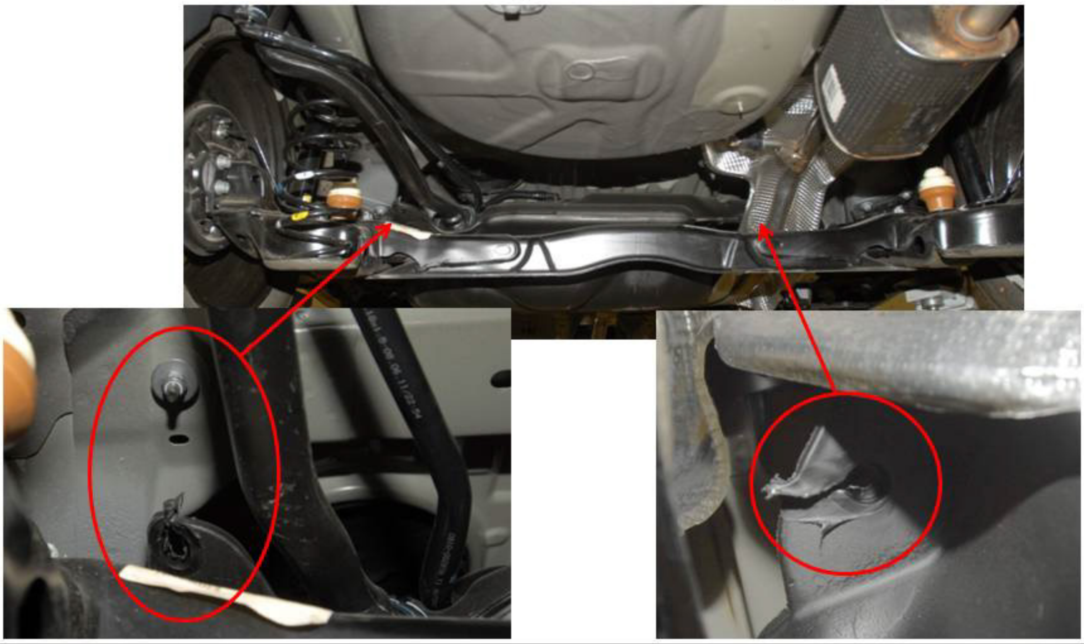
Post-test Pictures
Vehicle 1

Post-test Pictures
Barrier

Additional pictures (1/2)

Separation between crossmember and CB/longitudinal

Additional pictures (2/2)



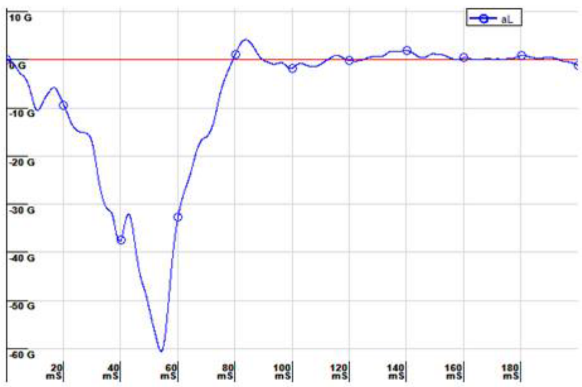
Failure of rear fuel tank fixages

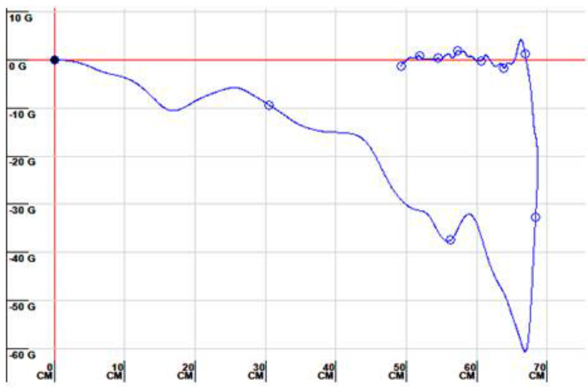
Static measurements

Frontal Impact	Rearw. Steering wheel displacment	Upward Steering wheel displacement	Lateral Steering wheel displacement	Rearw. A pillar displacement	Rearward pedal fixation displacement
Remarks	(mm)	(mm)	(mm)	(mm)	(mm)
FWDB - 56kph - 17459	-36	-72	0	5	35
	Occupant compartment stability	Footwell Ruptures	Rearw. Pedals displacement	Upward. Pedals displacement	G max SAE 60
			(mm)	(mm)	(g)
FWDB - 56kph - 17459	Yes	No	20 (accel)	-22 (accel)	61

Car Accelerations vs.

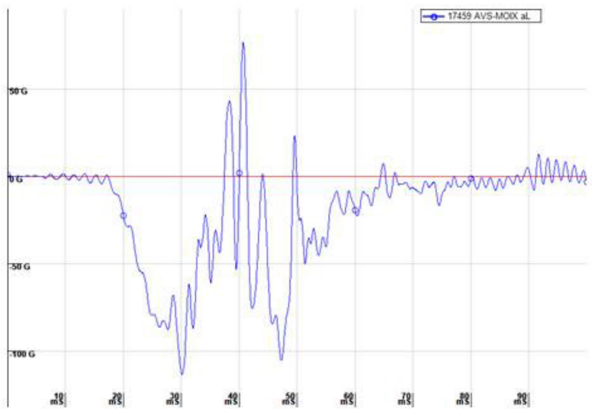
Time / Displacement

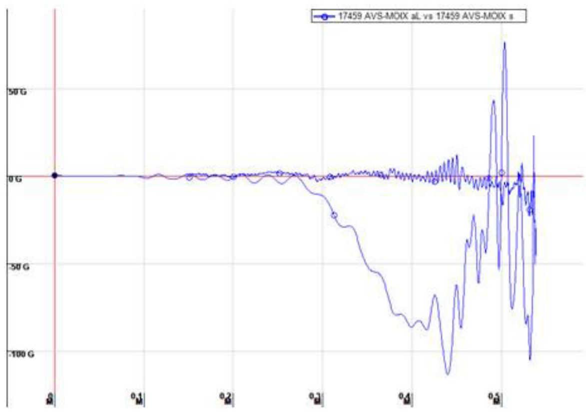




Engine acceleration vs.

Time / Displacement





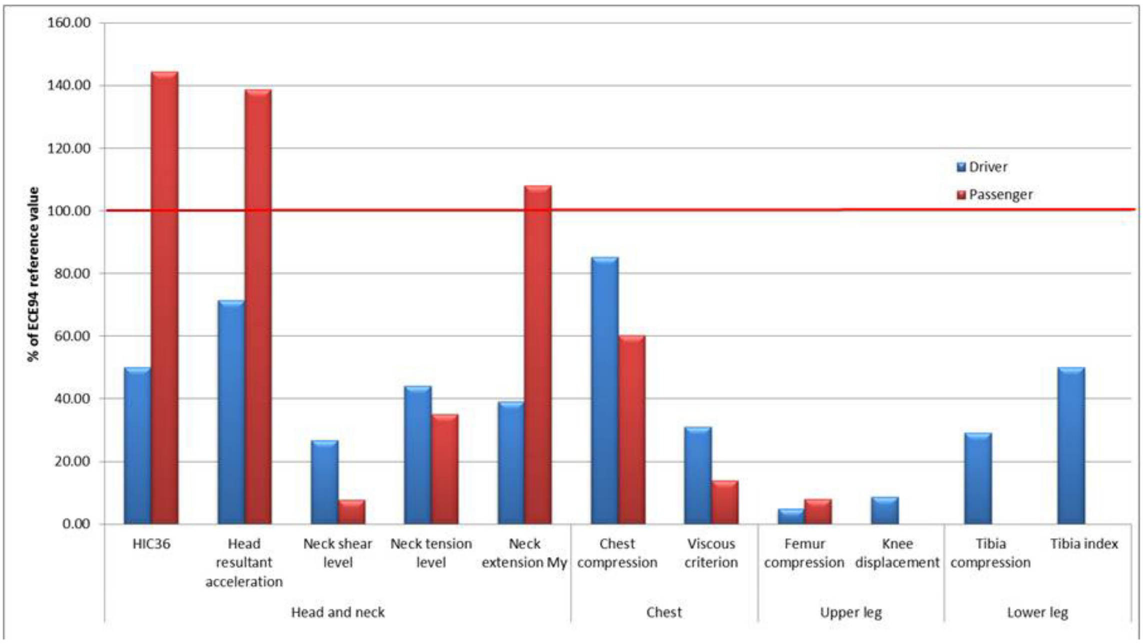
Dummy criteria comparison. - Standard FIMCAR database output

	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	57.20	4.000	110.94	0.000
HIC_{36}	502.24		1443.94	
Resultant Acc. 3 msec exceedence - g	55.45		104.78	
Head Assessment		4.000		0.000
NECK				
Shear level exceeded - kN	0.83	4.000	0.24	4.000
duration of exceedence - ms	0		0.00	
Tension level exceeded - kN	1.46	4.000	1.18	4.000
duration of exceedence - ms	0		0.00	
Extension - Nm	22.37	4.000	81.57	0.000
Neck Assessment		4.000		0.000
Head and Neck Assessment		4.000		0.000
CHEST				
Compression - mm	42.80	1.057	30.20	2.829
Viscous criterion - m/s	0.31	4.000	0.14	4.000
Shoulder belt load - kN	5.51		4.80	
Chest Assessment		1.057		2.829
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	1.3	4.000	0.0	4.000
Left Femur Compression level exceeded - kN	0.24	4.000	0.8	4.000
duration of exceedence - ms	0		0.0	
Left Knee, Femur and Pelvis Assessment		4.000		4.000
Right Knee Slide - mm	1.2	4.000	0.0	4.000
Right Femur Compression level exceeded - kN	0.50	4.000	0.2	4.000
duration of exceedence - ms	0		0.0	
Right Knee, Femur and Pelvis Assessment		4.000		4.000
Knee, Femur and Pelvis assessment		4.000		4.000

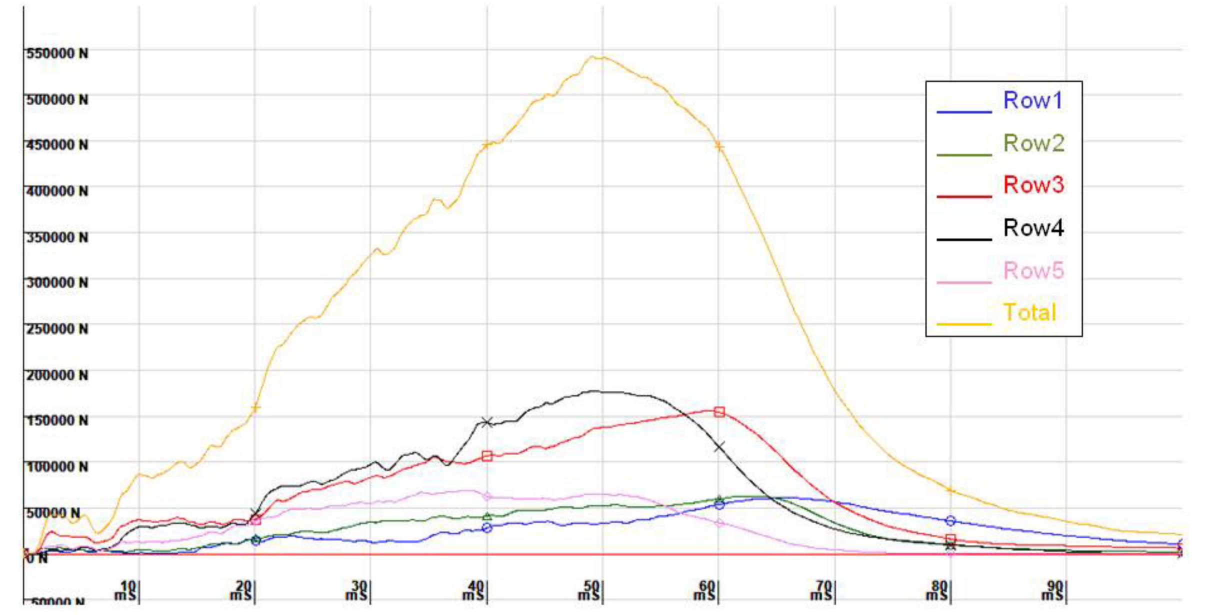
	Driver	Points	Passenger	Points
LOWER LEG				
Left compression - kN	2.34	3.773	0.00	4.000
Left Upper Tibia Index	0.85	2.889	0.00	4.000
Left Lower Tibia Index	0.35	4.000	0.00	4.000
pedal vertical (-1) mm	0	0.000		
Left Lower Leg assessment		2.889		4.000
Right compression - kN	2.33	3.780	0.00	4.000
Right Upper Tibia Index	0.59	3.158	0.00	4.000
Right Lower Tibia Index	0.44	3.822	0.00	4.000
pedal vertical (-1) mm	0	0.000		
Right Lower Leg assessment		3.158		4.000
FOOT and ANKLE				
pedal horizontal deplacement - mm	0	4.000		
Footwell Rupture (-1)		0.000		
Pedal Blocking (-1)	0	0.000		
Foot and Ankle assessment		4.000		
Lower Leg, Foot and Ankle assessment		2.889		4.000
SUMMARY				
Head and Neck assessment		4.000		0.000
Chest assessment		1.057		2.829
Knee, Femur and Pelvis assessment		4.000		4.000
Lower Leg, Foot and Ankle Assessment		2.889		4.000
TOTAL		11.946		10.829

Restraint	Time-to-fire (movie analysis)
Retractor	19 ms
DAB	29 ms
PAB	39 ms

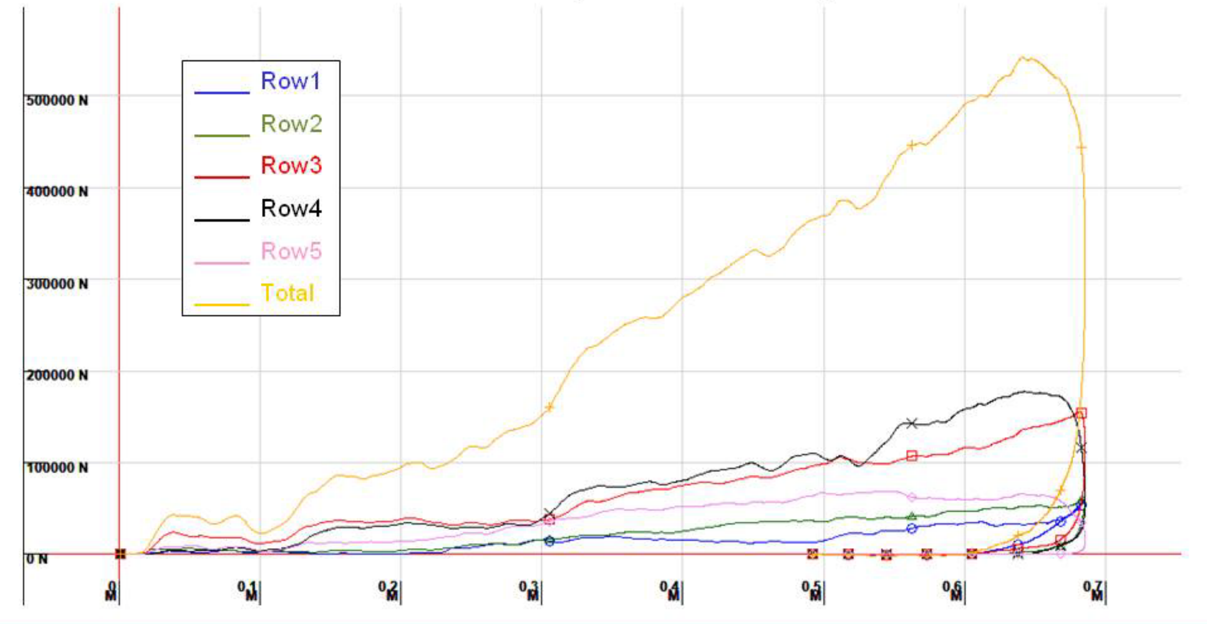
Dummy Criteria Comparison - % of Reference Value (Reg 94)



LCW force vs time



LCW force vs B-pillar displacement



Metrics evaluation

Method B(1) FWDB: up to 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN

	Supermini 1 FWDB	
	Value	OK/KO
Time at 400kN (ms)	37.8	NA
F3+F4 > 180 kN (kN)	221.1	OK
F3 > 85 kN (kN)	105.3	OK
F4 > 85 kN (kN)	115.8	OK
Global	OK	

Method B(2) FWDB: up to 40 ms → F3 > 75 kN AND F4 > 75 kN

	Supermini 1 FWDB	
	Value	OK/KO
Up to 40 ms, F3 > 75 kN (kN)	106.4	OK
Up to 40 ms, F4 > 75 kN (kN)	142.8	OK
Global	OK	

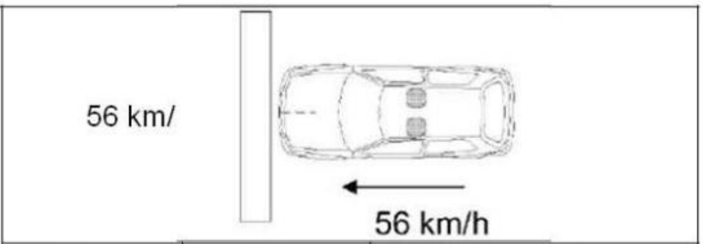
Upgrade1 FWDB: up to 40 ms → F3 > [MIN(100, 0.2Ft40)] AND F4 > [MIN(100, 0.2Ft40)]

	Supermini 1 FWDB		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	106.4	89.0	OK
F4 > MIN[100, 0.2Ft40]	142.8	89.0	OK
Global	OK		

SUPERMINI 1 FWDB 56 KM/H (LOWERED) @ IDIADA

Supermini 1 (lowered) FWDB test

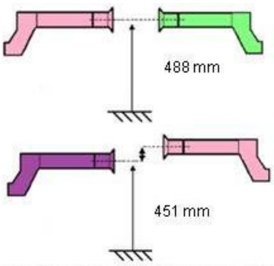
Test Date	Nov. 14, 2011
Location	IDIADA
Topic	FWDB
Mass Ratio	NA
Test Number	114601FF
Test Protocol	FIMCAR



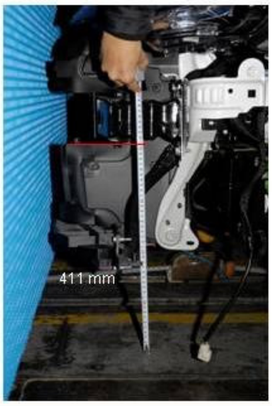
Vehicle 1:	Small family	Ride height measured at wheel arch:
Brand/type	Supermini 1	
Impact side:	Front	Front left: 618 mm
Speed:	56 km/h	Front right: 619 mm
Overlap:	100 %	
Test mass:	1337.0 kg	Rear left: 621 mm
Dummy:	LHS - Hybrid III 50th RHS - Hybrid III 50th	Rear right: 621 mm

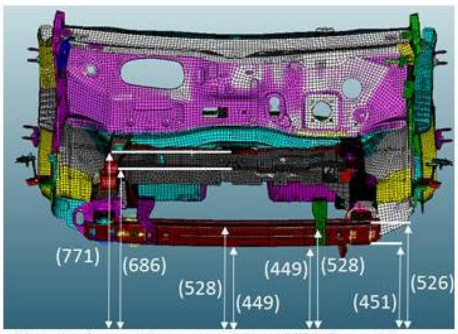
Test objective: Car to FWDB test with lowered vehicle, 37 mm to the nominal position.

Full Frontal FWDB impact test on Supermini 1 (lowered)
Structural analysis
IDIADA test no. 114601FF
Vehicle: Supermini 1
Ground clearance: 413 mm to bumper beam CTR bottom



Lowered adjustment to achieve according UTAC report 488 – 451 = 37 mm





Nominal conditions according UTAC report

Full Frontal FWDB impact test on Supermini 1 (lowered)

Test conditions

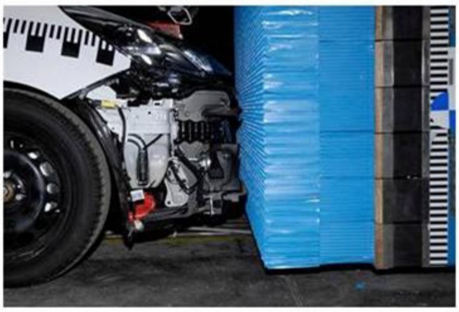
IDIADA test no. 114601FF

Vehicle: Supermini 1

Test Vehicle Mass: 1337.0 kg

Test velocity: 56.33 km/h

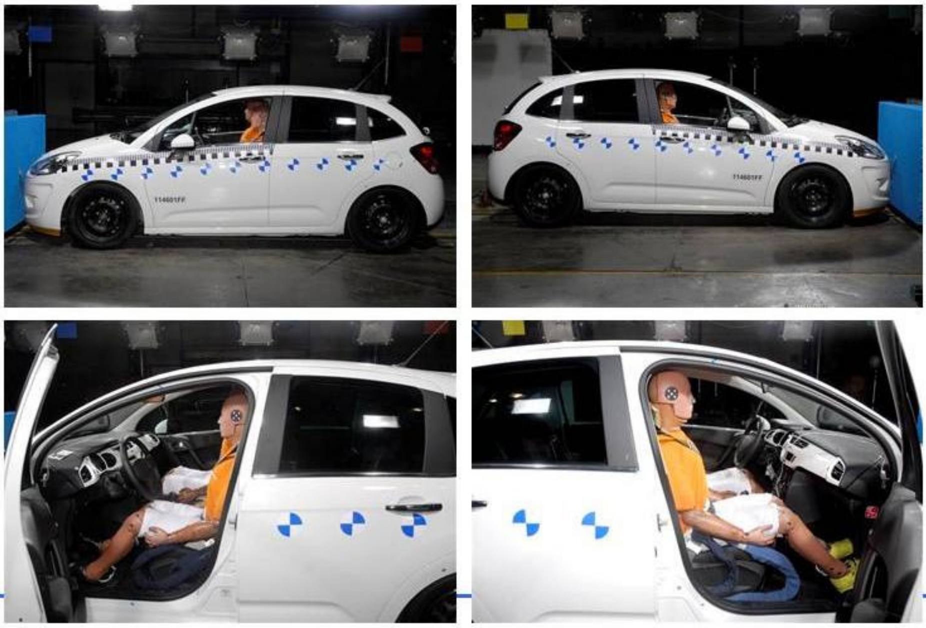
Ground clearance: 413 mm to bumper beam CTR bottom



SUMMARY		
Head and Neck assessment	4.000	1.850
Chest assessment	2.643	1.716
Knee, Femur and Pelvis assessment	4.000	4.000
Lower Leg, Foot and Ankle Assessment	2.844	3.644
TOTAL	13.487	11.210
Door Opening	0.00	
TOTAL FRONTAL	**10.410**	

Supermini 1 (lowered) FWDB Impact

Pre-Test photos



Supermini 1 (lowered) FWDB Impact
Static measurement results

- No door opening during the test.
- No door opening after the test.

Supermini 1

STATIC MEASUREMENTS

+ve= up,aft,left

STEERING WHEEL	
Fore/aft displacement - mm	-9
Vertical displacement - mm	-3
Lateral displacement - mm	4

A PILLAR	
Waistline displacement - mm	5

PEDAL DISPLACEMENTS	
Brake Vertical displacement - mm	-33
Brake Horizontal displacement - mm	15
Clutch Vertical displacement - mm	-32
Clutch Horizontal displacement - mm	6
Accel Vertical displacement - mm	-29
Accel Horizontal displacement - mm	20
MAXIMUM PEDAL MOVEMENT	
vertical displacement - mm	-29
horizontal displacement - mm	20

DOOR APERTURE	
Waist level collapse - mm	-6
Sill level collapse - mm	-1

Supermini 1 (lowered) FWDB Impact
Dummy results

Citroën C3

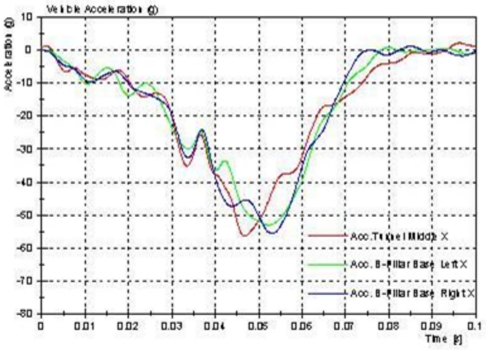
	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	78.52	4.000	81.67	1.850
HIC_{36}	648.33		822.06	
Resultant Acc. 3 msec exeedence - g	68.45		80.60	
Unstable airbag contact, Bottoming out or Hazardous deployment (-		0.000		0.000
Steering wheel displacement (-1) mm	4	0.000		
Incorrect airbag deployment		0.000		0.000
Head Assessment		4.000		1.850
NECK				
Shear level exceeded - kN	0.30	4.000	0.47	4.000
duration of exceedence - ms	0		0.00	
Tension level exceeded - kN	1.32	4.000	2.21	4.000
duration of exceedence - ms	0		0.00	
Extension - Nm	24.22	4.000	42.94	3.749
Neck Assessment		4.000		3.749
Head and Neck Assessment		4.000		1.850
CHEST				
Compression - mm	31.50	2.643	37.99	1.716
Viscous criterion - m/s	0.16	4.000	0.26	4.000
Steering wheel contact (-1)		0.000		
A-Pillar displacement (-2) mm	5	0.000		
Unstable passenger compartment (-1)		0.000		
Shoulder belt load - kN	0.00		0.00	
Chest Incorrect Airbag Deployment Modifier		0.000		0.000
Chest Assessment		2.643		1.716

	Driver	Points	Passenger	Points
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	1.0	4.000	0.4	4.000
Left Femur Compression level exceeded - kN	0.23	4.000	0.2	4.000
duration of exceedence - ms	0		0.0	
Variable contact (-1)		0.000		0.000
Concentrated loading (-1)		0.000		0.000
Incorrect airbag deployment		0.000		0.000
Left Knee, Femur and Pelvis Assessment		4.000		4.000
Right Knee Slide - mm	0.4	4.000	0.1	4.000
Right Femur Compression level exceeded - kN	0.52	4.000	0.1	4.000
duration of exceedence - ms	0		0.0	
Variable contact (-1)		0.000		0.000
Concentrated loading (-1)		0.000		0.000
Incorrect airbag deployment		0.000		0.000
Right Knee, Femur and Pelvis Assessment		4.000		4.000
Knee, Femur and Pelvis assessment		4.000		4.000
LOWER LEG				
Left compression - kN	2.86	3.427	2.06	3.960
Left Upper Tibia Index	0.58	3.200	0.44	3.822
Left Lower Tibia Index	0.66	2.844	0.28	4.000
pedal vertical (-1)mm	-29	0.000		
Left Lower Leg assessment		2.844		3.822
Right compression - kN	2.90	3.400	1.94	4.000
Right Upper Tibia Index	0.58	3.200	0.48	3.644
Right Lower Tibia Index	0.34	4.000	0.28	4.000
pedal vertical (-1)mm	-29	0.000		
Right Lower Leg assessment		3.200		3.644
FOOT and ANKLE				
pedal horizontal displacement - mm	20	4.000		
Footwell Rupture (-1)		0.000		
Pedal Blocking (-1)	-67	0.000		
Foot and Ankle assessment		4.000		
Lower Leg, Foot and Ankle assessment		2.844		3.644

Supermini 1 (lowered) FWDB Impact
Vehicle pulse

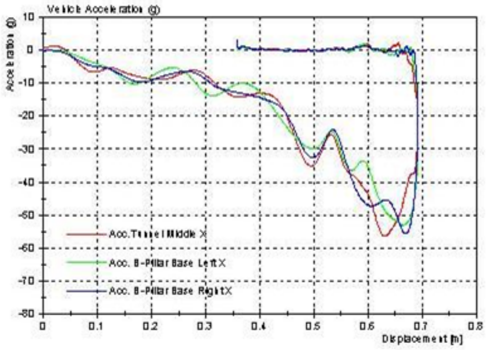
Time

B–Pillar Left side

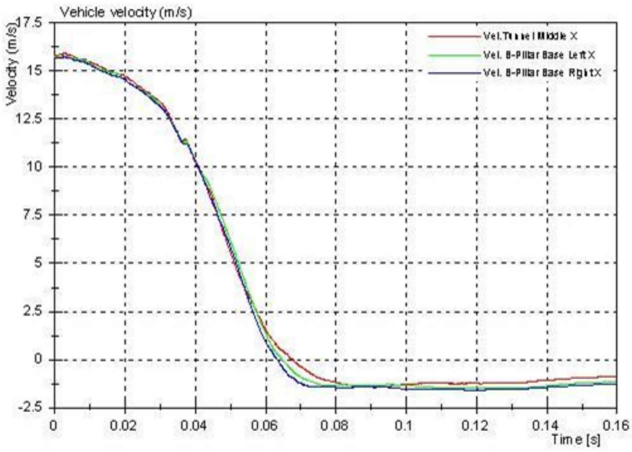


Displacement

B–Pillar Left side

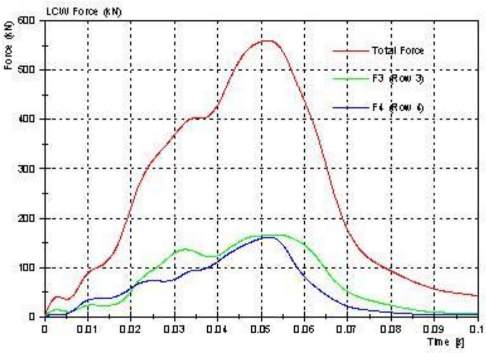


Supermini 1 (lowered) FWDB Impact
Vehicle velocity



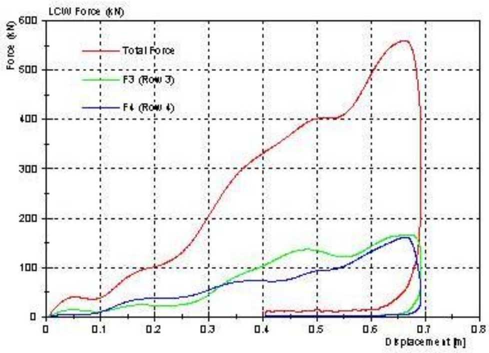
Supermini 1 (lowered) FWDB Impact
LCW Force

Time

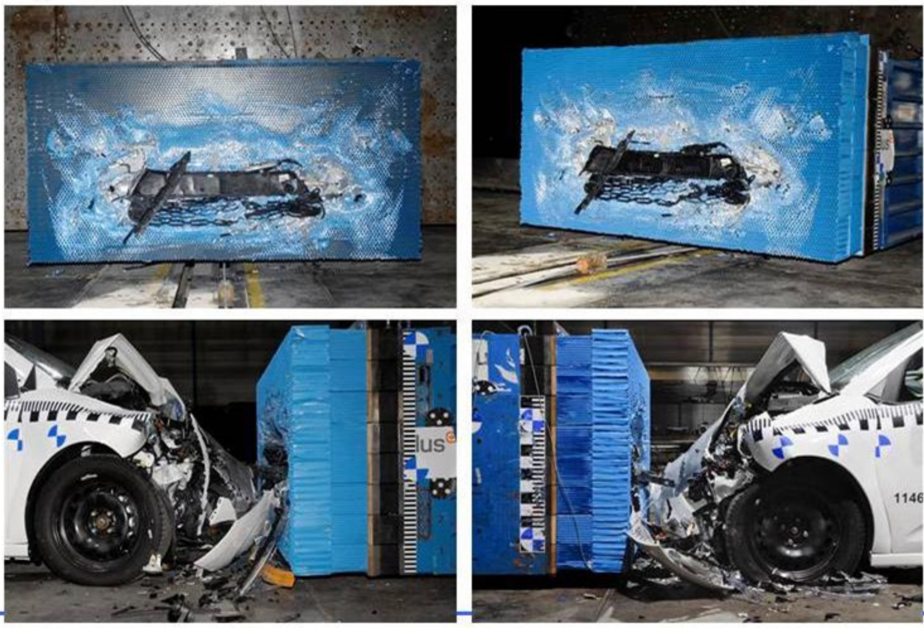


Displacement

B–Pillar Left side



Supermini 1 (lowered) FWDB Impact
Post-test photos



Supermini 1 (lowered) FWDB Impact
Metrics

- Metric 1

- Stage 1 Metric @ total LCW force 400 kN

F3+F4>[180 (160)] kN	F3+F4= 228.0 kN	PASS
F3>[85 (75)] kN	F3=135.8 kN	PASS
F4>[85 (75)] kN	F4=92.2 kN	PASS

Note: Limits in brackets are for vehicles for which the total LCW force is less than 400 kN

- Stage 2 (if stage 1 not met and eligibility met)

Metric up to time of 40 ms

F3>[100] kN	F3= 124.4 kN
F4>[100] kN	F4= 112.5 kN

- Metric 2 "upgrade"

Metric up to time of 40 ms

F3≥[MIN(100, 0.2xFT40) kN	F3=124.4 kN; 0.2xFT40=85.9 kN	PASS
F4≥[MIN(100, 0.2xFT40] kN	F4=112.5 kN; 0.2xFT40=85.9 kN	PASS

FT40=Maximum of total LCW force up to time of 40 ms

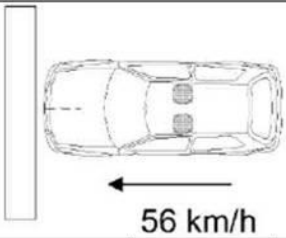
Supermini 1 (lowered) FWDB Impact
Conclusions

- Dummy injury bellow R94 limits
- The Supermini 1 (lowered) passes the FWDB Original an Upgrade Metrics

SUPERMINI 1 FWDB 56 KM/H (RAISED) @ PSA

FWDB Supermini 1 raised +39mm

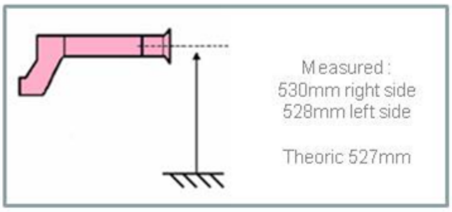
Test Date	31/10/2011
Location	TNO Safety Center
Topic	Full Width test
Test Number	F114202
Test Protocol	Draft FWDB protocol



Vehicle 1:	Small car	Barrier:	Full Width
Brand/type	Supermini 1, LHD		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	55.8 km/h		Segmented
Overlap:	100%	Impact accuracy	6mm below
Test mass:	1315 g		
Dummy:	Left - HIII 50th	LCW ground clearance	80 mm
	Right HIII 50th	LCW / barrier dimensions	2 m wide 1 m high

Test parameters

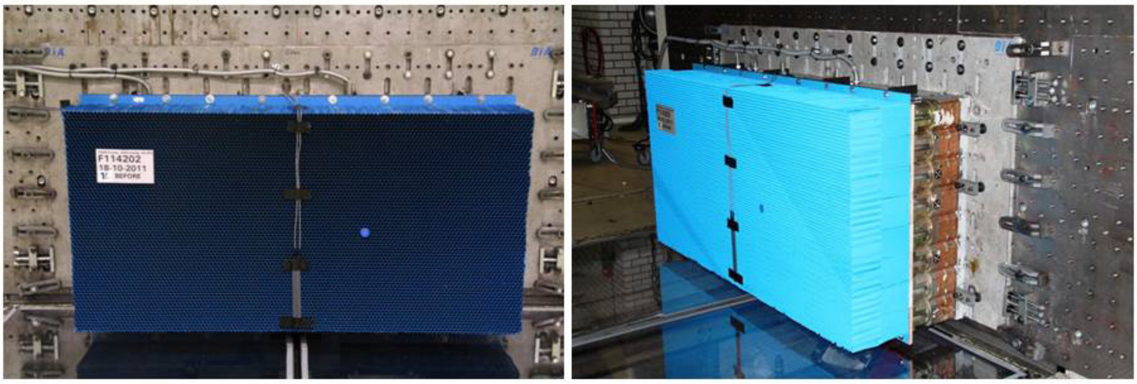
- **Vehicle data: Supermini 1**
- **Test number F114202**
- **Engine / Transmission: 1.4 HDi / Manual 5+R**
- **Test speed: 55.8 kph**
- **Test weight: F 787.5 kg / R 527.5 kg Total 1315 kg**
- **Test impact accuracy: 6mm below**
- **Test vehicle status:**
  - **Raised front and rear ride heights *+39mm***
  - **Fender height R F 685**
    Fender height L F 681
    Fender height R R 654
    Fender height L R 651



Pre-test Pictures
Vehicle 1 (raised +39mm)

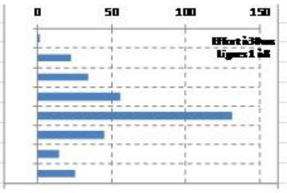
Pre-test Pictures
Barrier

FWDB Cellbond 2000x1000x300mm
2 stages of cells : **0.34MPa** / 1.7MPa

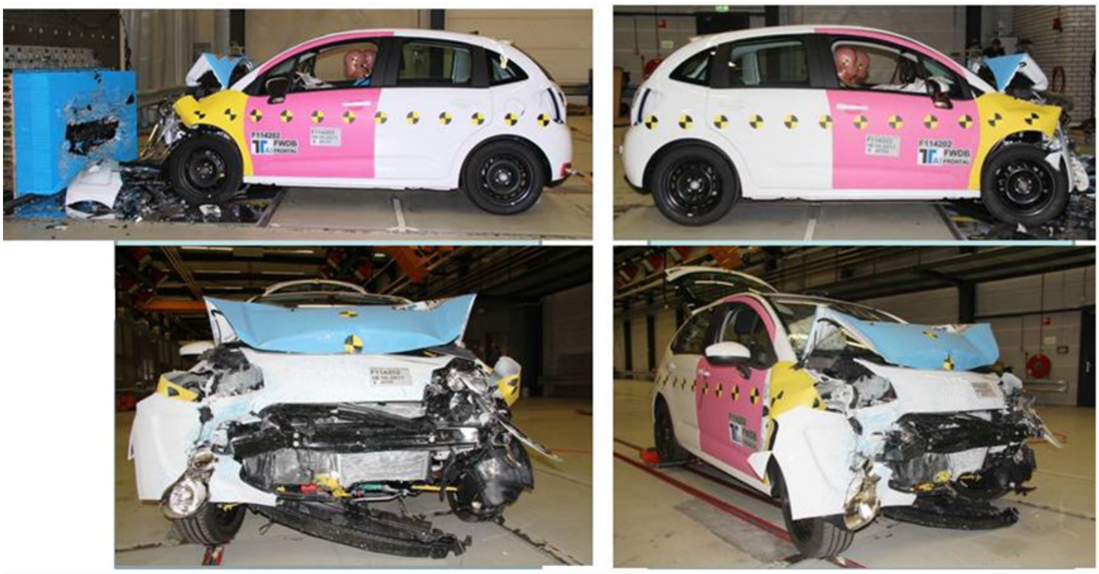


Alignment of Vehicle Structure with LCW

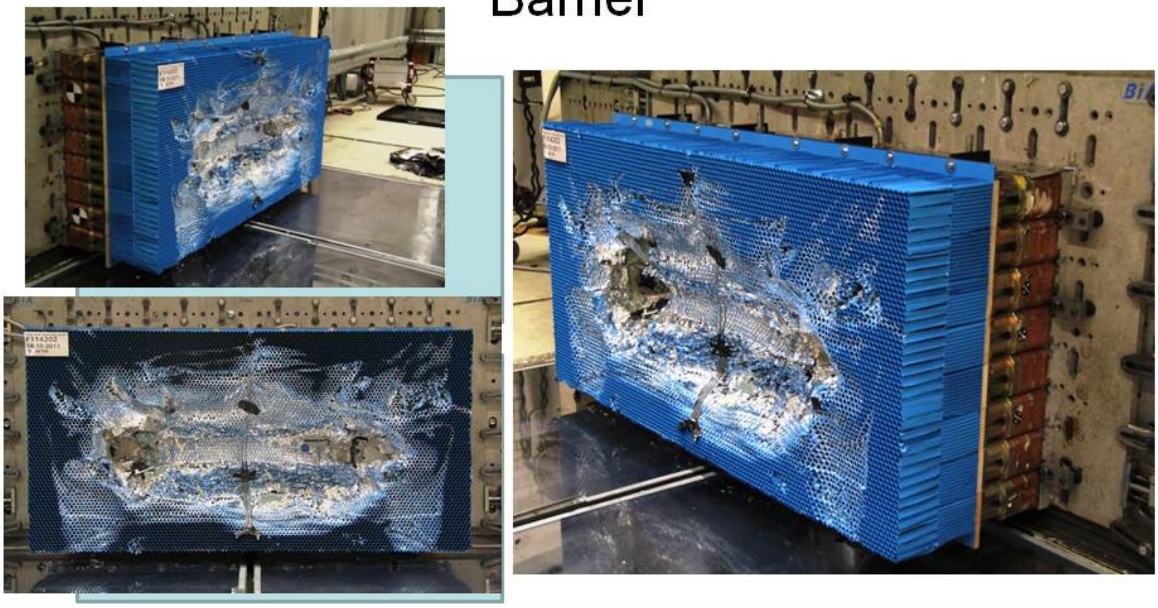
30 ms																	
-11	-58	-43	20	19	139	88	1307	258	16	-43	-13	-44	301	-23	-128	1%	2
30	-35	14	3480	-10	2288	266	5247	298	26	10218	-44	47	10	952	-68	7%	23
-34	-38	52	8139	575	4472	1584	4738	9940	313	3569	700	2	196	217	161	10%	35
-49	1	602	7398	1614	10005	1007	10041	3817	7187	3334	1465	5922	1027	2466	-106	17%	56
692	-3	3105	7688	27824	9764	5477	6500	9057	12355	21448	21736	4930	434	-5	366	40%	131
12	8	228	781	5148	2568	3163	6465	4362	4934	6436	8074	2371	-20	-65	381	14%	45
-163	-105	-21	-69	27	6261	-21	2519	2008	1476	2071	540	-5	6	-59	-60	4%	14
-99	-114	4796	-77	3140	66	1978	18	2837	3182	579	5538	-45	3635	-41	10	8%	25



Post-test Pictures
Vehicle 1



Post-test Pictures
Barrier



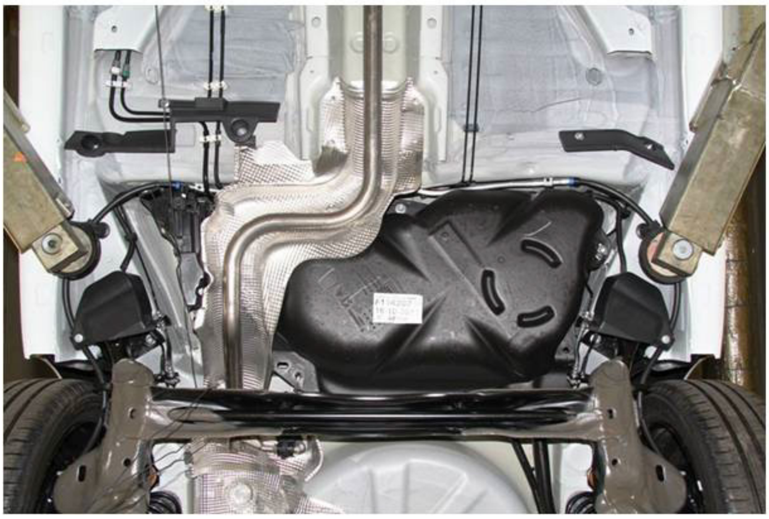
Additional pictures (1/3)

LEFT : Failure between front member and crash box, partial collapsing of the crash box
RIGHT : No failure between front member and crash box, no collapsing of the crash box (bending and side displacement), but beginning of failure on the front cross member (see orange mark)

Additional pictures (2/3)

Beginning of crushing of the 2 windscreen pillars, more important on right side
This appear between 60 and 65ms.

Additional pictures (2/3)



2 attachments of the rear fuel tank has been broken
No leakage observed.

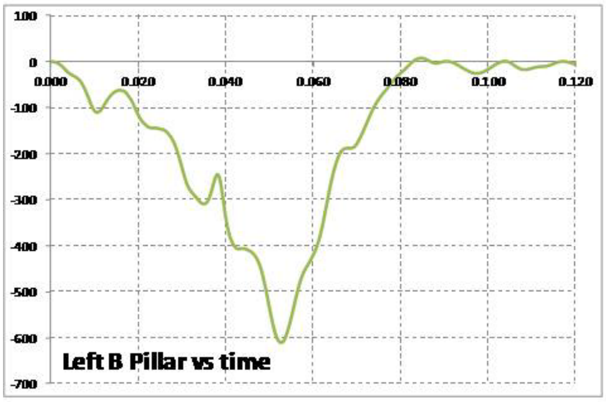
Static measurements

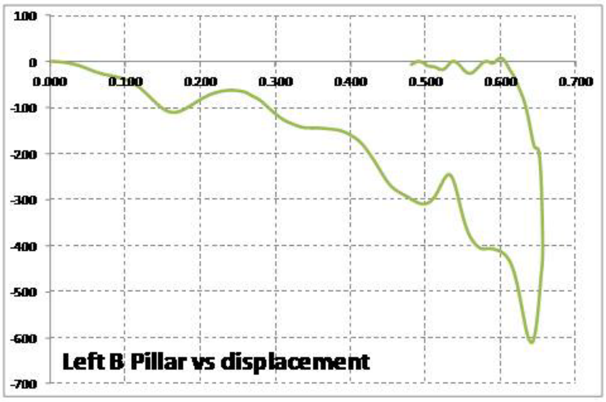
(raised +39mm)

FRONTAL IMPACT	Rearward steering wheel displacement (mm)	Upward steering wheel displacement (mm)	Lateral steering wheel displacement (mm)	Rearward A pillar displacement (mm)	
	-50	-30	-3	9	
	Occupant compartmernt stability	Footwell failures	Rearward pedals displacement (mm)	Upward pedals displacement (mm)	G max CFC60 (g)
	Yes	No	16	-23	62.3

Supermini 1 raised +39mm car accelerations vs.

Time Displacement





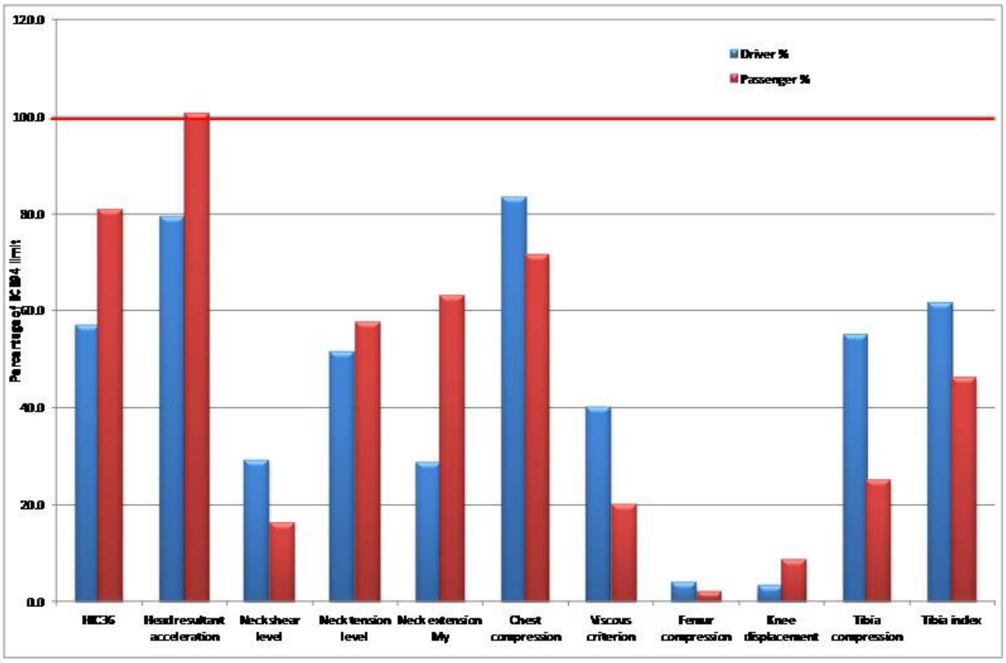
Dummy criteria comparison. - Standard FIMCAR database output

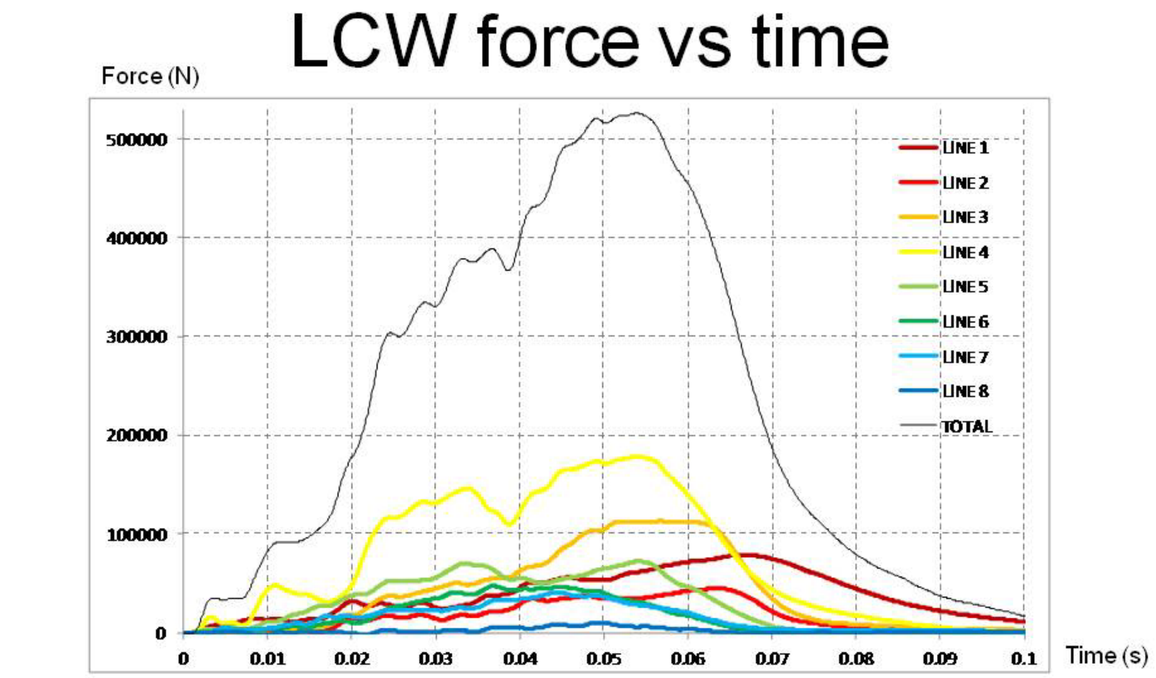
Raised vehicle	DRIVER		CO-DRIVER	
	Value	Points	Value	Points
HEAD				
HIC 36ms	570.00	4.000	808.00	2.194
Acceleration 3ms (g)	63.50	4.000	80.50	1.875
		4.000		1.875
NECK				
Shear Fx (kN)	0.87	4.000	0.49	4.000
Tension Fz (kN)	1.73	4.000	1.85	4.000
My Extension (N.m)	16.30	4.000	57.00	0.000
		4.000		0.000
CHEST				
Compression (mm)	41.70	1.186	35.80	2.029
Viscous criterion (m/s)	0.37	4.000	0.20	4.000
		1.186		2.029
KNEE & FEMUR				
Let Femur Compression (kN)	0.42	4.000	0.24	4.000
Let Knee Slide (mm)	0.49	4.000	1.26	4.000
		4.000		4.000
Right Femur Compression (kN)	0.40	4.000	0.10	4.000
Right Knee Slide (mm)	0.25	4.000	0.06	4.000
		4.000		4.000
INF MEMBERS				
Let Compression tibia Upper (kN)	2.15	3.900	1.98	4.000
Let compression tibiaLower (kN)	1.64	4.000	1.91	4.000
Let TI upper	0.37	4.000	0.60	3.111
Let TI lower	0.56	3.289	0.37	4.000
		3.289		3.111
Right compression tibia upper (kN)	3.07	3.287	1.57	4.000
Right compression tibia lower (kN)	4.39	2.407	1.79	4.000
Right TI upper	0.82	2.133	0.46	3.733
Right TI lower	0.41	3.956	0.29	4.000
		2.133		3.733

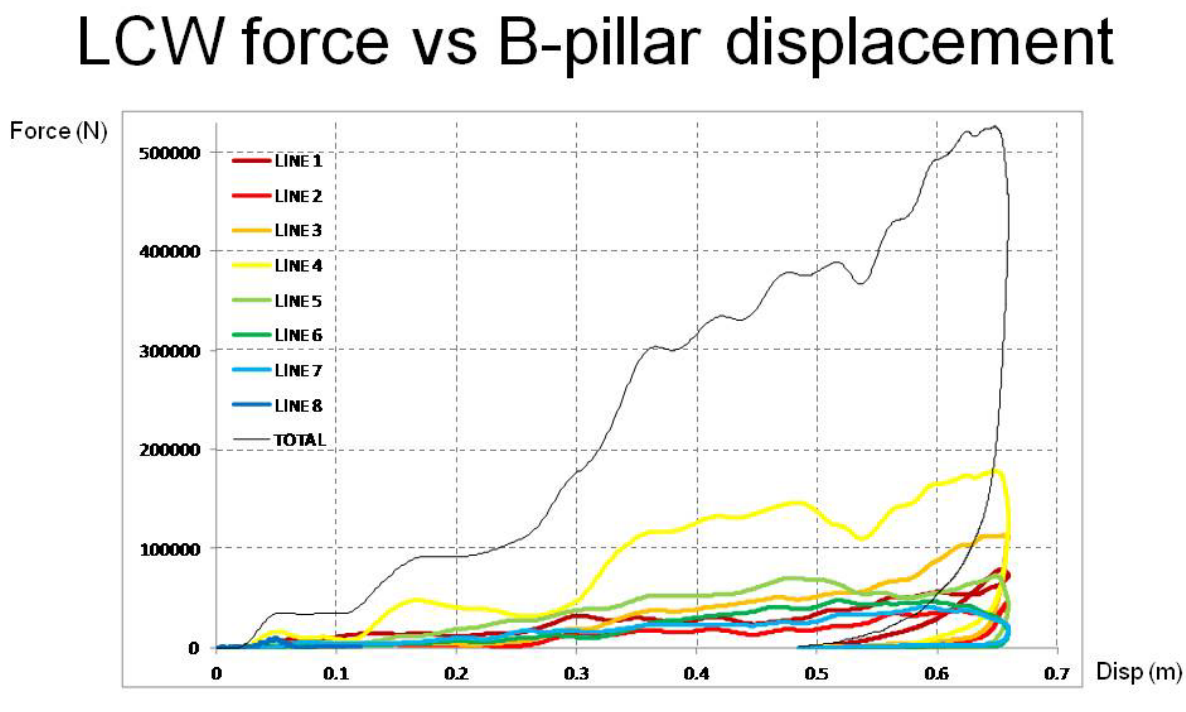
	DRIVER	CO-DRIVER
HEAD & NECK	4.000	0.000
CHEST	1.186	2.029
KNEE & FEMUR	4.000	4.000
INF MEMBERS	2.133	3.111
TOTAL	11.32	9.140

Restraint	Time-to-fire (movie analysis)
Retractor	18 ms
DAB	26 ms
PAB	39 ms

Dummy Criteria Comparison - % of Reference Value (Reg 94)




LCW force vs time
Force (N)
500000
400000
300000
200000
100000
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Time (s)
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
LINE 6
LINE 7
LINE 8
TOTAL


LCW force vs B-pillar displacement
Force (N)
500000
400000
300000
200000
100000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Disp (m)
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
LINE 6
LINE 7
LINE 8
TOTAL

Compatibility criteria (raised +39mm)

Method B(1) FWDB: up to 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN

	Supermini 1 FWDB raised	
	Value	OK/KO
Time at 400kN (ms)	40.0	NA
F3+F4 > 180 kN (kN)	185.7	OK
F3 > 85 kN (kN)	62.9	KO
F4 > 85 kN (kN)	122.8	OK
Global	KO	

Method B(2) FWDB: up to 40 ms → F3 > 75 kN AND F4 > 75 kN

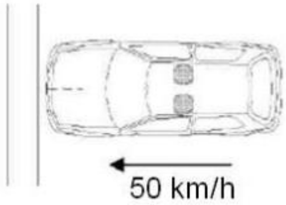
	Supermini 1 FWDB raised	
	Value	OK/KO
Up to 40 ms, F3 > 75 kN (kN)	62.9	KO
Up to 40 ms, F4 > 75 kN (kN)	122.8	OK
Global	KO	

Upgrade1 FWDB: up to 40 ms → F3 > [MIN(100, 0.2Ft40)] AND F4 > [MIN(100, 0.2Ft40)]

	Supermini 1 FWDB raised +39mm		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	62.9	79.7	KO
F4 > MIN[100, 0.2Ft40]	122.8	79.7	OK
Global	KO		

SUPERMINI 2 FWRB 50 KM/H @ IDIADA

Test Date	Jul. 18, 2011
Location	IDIADA
Topic	FWRB
Mass Ratio	NA
Test Number	112901FF
Test Protocol	FIMCAR



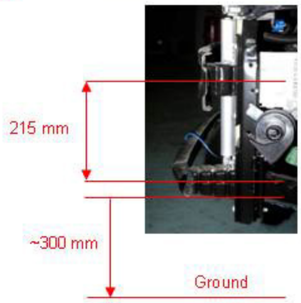
Vehicle 1:	Super-mini	Ride height measured at wheel arch:
Brand/type	Supermini 2	
Impact side:	Front	Front left: 620 mm
Speed:	50 km/h	Front right: 623 mm
Overlap:	100%	
Test mass:	1159 kg	Rear left: 614 mm
Dummy:	LHS - HIII 50% RHS - HIII 5%	Rear right: 624 mm

Test object

- **Vehicle 1 data: Supermini 2**
- **Engine / Transmission: 1.2 / Manual**
- **Test weight: F 648.5_kg / R 474.5_kg Total 1159_kg**

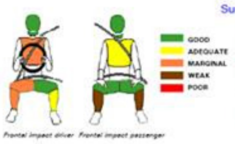
- **Test vehicle status:**
  Normal vehicle conditions
- **SEAS 215 mm below PEAS, SEAS well connected to the subframe which is 400 mm behind.**

Structure analysis



Dummy criteria comparison. - Standard FIMCAR database output

Supermini 2 FWRB



Summary.

Head and Neck Assessment	4.000
Chest Assessment	2.173
Knee, Femur and pelvis Assessment	1.938
Lower leg, Foot and Ankle Assessment	0.356

TBA: Modifiers to be assessed

Overall Frontal Assessment 8.467

Note: Score controlled by Driver results, Passenger HIII 5%tile can not be directly compared to the Euro NCAP result

EURONCAP

Adult occupant protection

Front: 15.1

		Front impact driver. ()			Front impact passenger. ()		
Head	Peak resultant.		76.41 g	(4.000)		73.97 g	(4.000)
	HIC_36		778.56	--		821.06	--
	Acc resultant (3 ms.)		75.33 g	--		72.31 g	--
	Head bottoming out. (-1)			TBA			TBA
	Unstable airbag contact. (-1)			TBA			TBA
	Steering wheel displacement. (-1)			TBA			
Head Assessment:		4.000			4.000		
Neck	Shear level exceed.		0.52 kN			0.73 kN	
	duration of exceedence		0.00 ms	(4.000)		0.00 ms	(4.000)
	Tension level exceed.		1.64 kN			0.78 kN	
	duration of exceedence		0.00 ms	(4.000)		0.00 ms	(4.000)
	Extension Nm.		-22.89 Nm	(4.000)		-16.71 Nm	(4.000)
Neck Assessment:		4.000			4.000		
Head and Neck Assessment:		4.000			4.000		
Chest	Compresion.		-34.79 mm	(2.173)		-30.49 mm	(2.787)
	Viscous criterion.		0.33 m/s	(4.000)		0.37 m/s	(4.000)
	Steering wheel contact.(-1)			TBA			
	A-Pillar displacement.(-2)			TBA			
	Unstable passenger compartment. (-1)			TBA			
Chest Assessment:		2.173			2.787		
Knee, Femur and Pelvis.							
	Left knee slide.		-0.49 mm	(4.000)		-0.01 mm	(4.000)
	Left femur compresion exceed.		-0.39 kN			-1.07 kN	
	duration of exceedence		0.00 ms	(4.000)		0.00 ms	(4.000)
	Variable contact(-1)			TBA			TBA
	Concentrate loading.(-1)			TBA			TBA
Left Knee, Femur and Pelvis Assessment:		4.000			4.000		
	Right knee slide.		-10.64 mm	(1.938)		0.00 mm	(4.000)
	Right femur compresion exceed.		-6.29 kN			-0.43 kN	
	duration of exceedence		0.00 ms	(2.092)		0.00 ms	(4.000)
	Variable contact(-1)			TBA			TBA
	Concentrate loading.(-1)			TBA			TBA
Right Knee, Femur and Pelvis Assessment:		1.938			4.000		
Lower leg. Left.							
	Left compresion.		-2.04 kN	(3.973)		-1.89 kN	(4.000)
	Left upper tibia index.		0.46	(3.733)		1.03	(1.200)
	Left lower tibia index.		0.24	(4.000)		1.11	(0.844)
	Pedal vertical (-1)			TBA			
Left Lower Leg Assessment:		3.733			0.844		
Right.	Right compresion.		-5.90 kN	(1.400)		-2.37 kN	(3.753)
	Right upper tibia index.		0.51	(3.511)		1.22	(0.356)
	Right lower tibia index.		0.40	(4.000)		0.84	(2.044)
	Pedal vertical (-1)			TBA			
Right Lower Leg Assessment:		1.400			0.356		
Foot and Ankle.							
	Pedal horizontal displacement.			TBA			
	Footwell rupture (-1).			TBA			
	Pedal blocking			TBA			
Foot and Ankle Assessment:		Evaluation based on static measurement (TBA)					
Lower leg, Foot and Ankle Assessment:		1.400			0.356		

Dummy and restraint analysis

Vehicle equipped with seatbelt pretensioners, driver and passenger head airbag and driver knee airbag.

The driver's knee were protected by the airbag, during the restraint the right femur was loaded up to 6.31 kN, the knee slider was of 10.64 mm.

Structure analysis

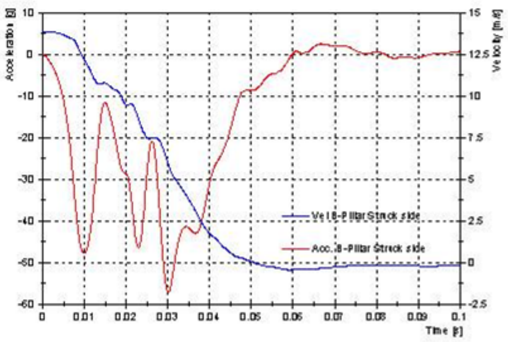
Euro NCAP positions measured in the FWRB test

Location	Before (mm)			After (mm)			Difference (mm)		
	X	Y	Z	X	Y	Z	X	Y	Z
A-Pillar Left Top	472,5	-684,9	602,2	473,1	-686,2	603,3	0,6	-1,4	1,2
A-Pillar Left Bottom	474,4	-687,0	170,9	474,5	-688,7	174,8	0,0	-1,7	3,8
B-Pillar Left Top	1570,3	-659,6	658,6	1570,7	-660,8	658,4	0,4	-1,2	-0,2
B-Pillar Right Top	1572,7	677,1	670,2	1571,8	677,3	669,8	-0,9	0,2	-0,4
B-Pillar Left Bottom	1513,8	-700,6	189,7	1514,4	-701,2	189,5	0,6	-0,6	-0,2
B-Pillar Right Bottom	1520,4	720,5	196,6	1521,2	721,3	195,7	0,9	0,8	-0,9
Steering Wheel	725,1	-327,2	662,8	709,7	-325,0	670,9	-15,4	2,2	8,1
Accelerator pedal	355,2	-159,3	183,8	373,6	-163,0	191,0	18,4	-3,8	7,2
Brake pedal	369,2	-268,6	220,4	385,3	-264,2	220,7	16,1	4,4	0,3
Clutch pedal	366,3	-385,9	222,3	332,3	-384,2	201,1	-34,0	1,6	-21,2

Supermini 2 FWRB Accelerations

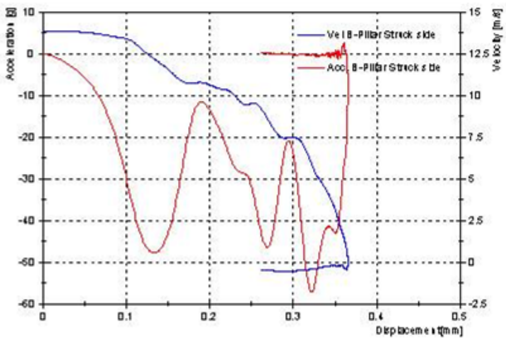
Time

B–Pillar Left side



Displacement

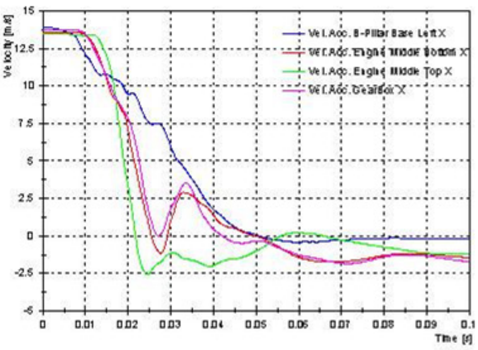
B–Pillar Left side



Supermini 2 FWRB Engine Analysis

Time

B–Pillar Left side

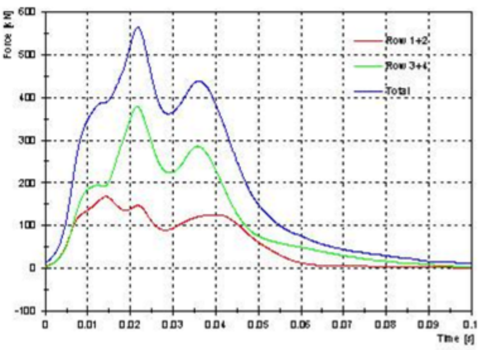


The velocities of engine and gear box drop from 15 to 27 ms. At 27 ms both are stopped due to the contact with the rigid wall.

Supermini 2 FWRB Load Cell Wall

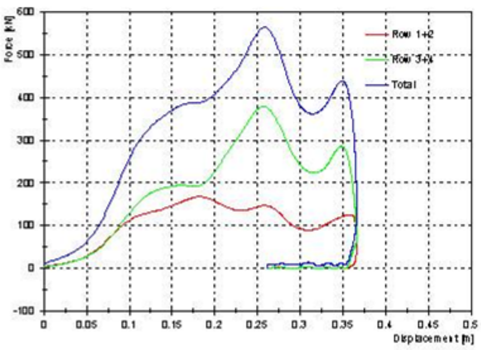
Time

B–Pillar Left side



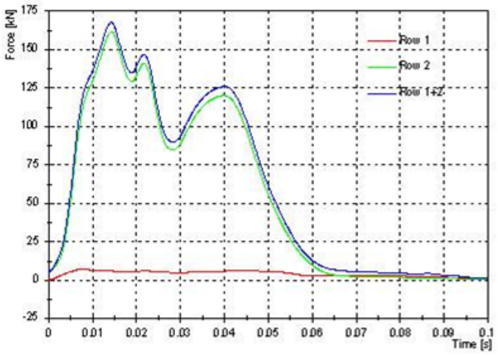
Displacement

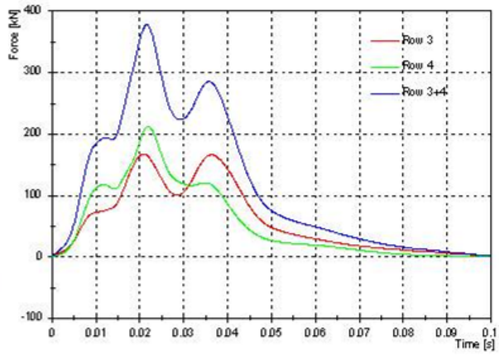
B–Pillar Left side



Total: 202 kN @ 6.9ms Row 1+2: 94 kN @ 6.9ms Row 3+4: 98 kN @ 6.9ms

Supermini 2 FWRB Load Cell Wall





Row 1+2: 94 kN @ 6.9ms

Row 1: 7 kN @ 6.9ms

Row 2: 87 kN @ 6.9ms

Row 3+4: 98 kN @ 6.9ms

Row 3: 44 kN @ 6.9ms

Row 4: 54 kN @ 6.9ms

FWRB Metric

- Current status

Metric @ total LCW force 200 kN

F3+F4>80 kN	F3+F4=98 kN	PASS
0.2<(F4/(F4+F3)<0.8	F4/(F4+F3)=0.55	PASS

- Metric upgrade

Metric @ total LCW force 200 kN

F3+F4>(100 kN-LR)	LR=35; F3+F4=98 kN	PASS
F4>35 kN	F4=54 kN	PASS
F3>(35 kN-LR)	F3=44 kN	PASS

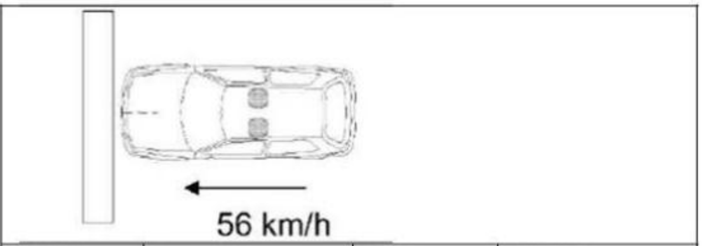
Limit Reduction = Min [(F2+F1-25 kN); 35 kN]

Conclusions

- Dummy injury bellow R94 limits, however, high loading in femurs and lower legs were observed
- LCW recorded 200 kN at 6.9 ms, before engine dumps, which starts at 15 ms
- Current status and Metric Upgrade of FWRB PASS

CITYCAR 1 FWDB 56 KM/H @ RENAULT

Test Date	21/12/11
Location	UTAC
Topic	Full Width test
Mass Ratio	N/A
Test Number	AFFSEP1102988
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1:	Super-mini	Barrier:	Full Width
Brand/type	City Car 1		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	56 km/h		Segmented
Overlap:	100%	Impact accuracy	5 mm left 5 mm up
Test mass:	1174 kg	LCW ground clearance	80 mm
Dummy:	LHS - Hybrid III 50th RHS - Hybrid III 5th	LCW / barrier dimensions	2m wide 1m high

Test objectives: Test performed with FIMCAR WP3 configurations in order to check City Car 1 with WP3 criteria.

Test parameters

- **Vehicle data: City Car 1**
- **Engine / Transmission: Petrol / Manual gearbox**
- **Test speed: 56kph**
- **Test weight: F 675 kg / R 499 kg Total 1174 kg**
- **Test impact accuracy: lateral and vertical**
- **Test vehicle status:**
  - **Test mass as Euro NCAP test**

FIMCAR frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

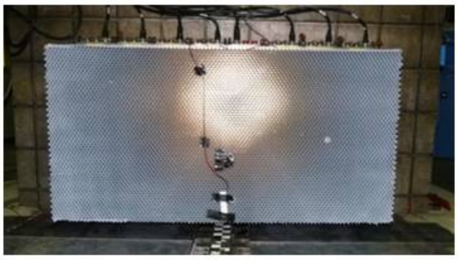
Pre-test Pictures
Vehicle




SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures
Barrier



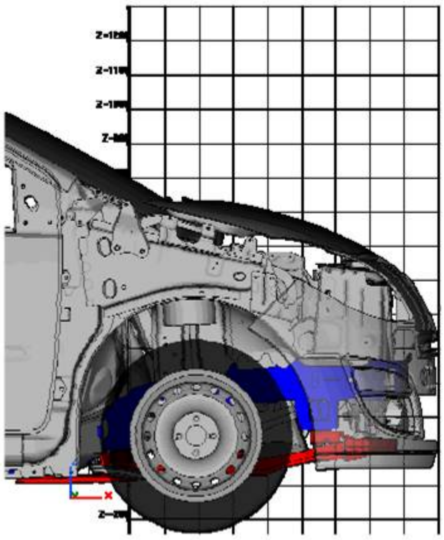


SEVENTH FRAMEWORK PROGRAMME

Description of front-end structure

Pictures / description of front-end structure:

City Car 1 front end structure composed of two load path (crossbeam and advanced subframe), with vertical connections between both.



Description of front-end structure

City car 1 front end structure is composed of two load paths (crossbeam and advanced subframe), with 2 vertical connections between both.

The advanced subframe is stiffer than the crossbeam

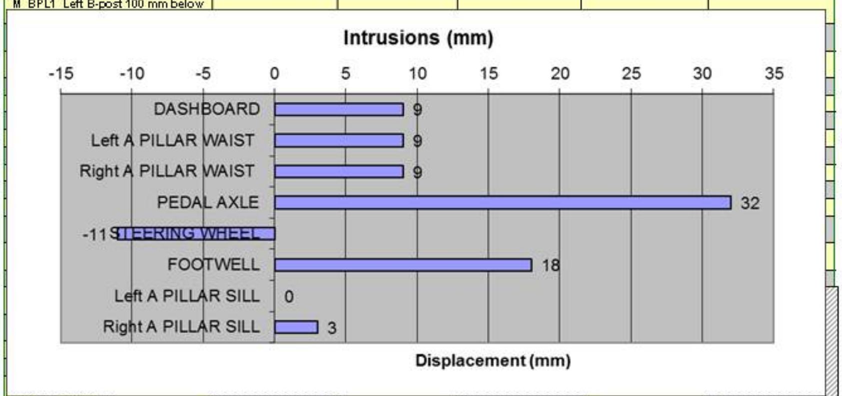
Post-test Pictures
Vehicle

Post-test Pictures
Barrier

Additional pictures to show detailed deformation of car or barrier

Example: Static deformations in x-direction, y and z also collected.

Vehicle: Test Number: Test type: Velocity / Comments:	x xxxxxx EuNCAP ODB 40 mph	x yyyyyy C2C V1 35 mph	x yyyyyy C2C V1 Dx-EuNCAP dx	x yyyyyy C2C V2 35 mph	x yyyyyy C2C V2 Dx-EuNCAP dx
	dX	dX	dX	dX	dX
M_APL1 Left A-post 100 mm below window					
M_BPL1 Left B-post 100 mm below					
M_EMSR Engine low Right - at mount to subframe					



First 13 rows are EuNCAP positions, Brake Pedal Axle defined by UTAC for PDB tests, last 6 rows are for structural interaction analysis.

Structural results

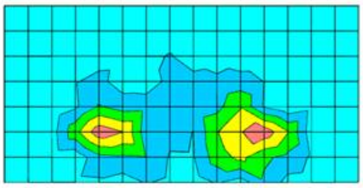
- Vehicle 1

Good general comportement of the occupant space.

Barrier

Deformation permits to well see the position of cross beam and subframe.

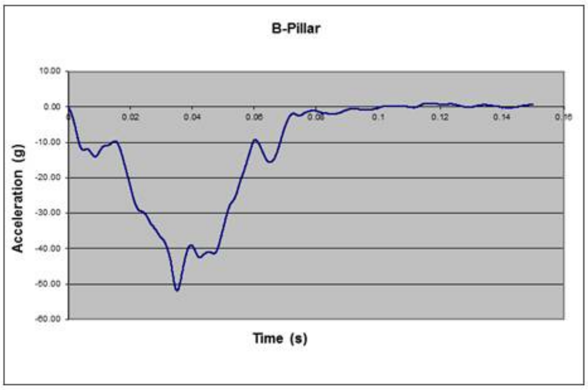
Deformation from subframe are at least as important thant those from crossbeam

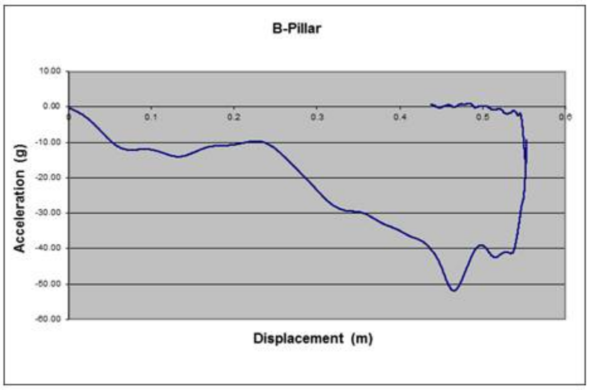


Car Accelerations vs.

Time

Displacement

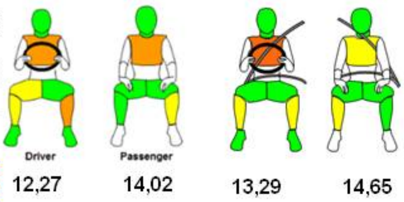




Dummy criteria comparison

FWDB (without modifiers)

EuroNCAP frontal assessment	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	84.40	4.000	70.80	4.000
HIC36	598		855.00	
Resultant Acc. 3 msec exceedence - g	83.30		63.30	
Unstable airbag contact, Bottoming out (-1)		0.000		0.000
Steering wheel displacement (-1) mm	0	0.000		
Incorrect airbag deployment		0.000		0.000
NECK				
Shear level exceeded - kN	0.38	4.000	0.84	4.000
duration of exceedence - ms	0		0.00	
Tension level exceeded - kN	1.97	4.000	1.35	4.000
duration of exceedence - ms	0		0.00	
Extension - Nm	7.41	4.000	19.74	4.000
CHEST				
Compression - mm	35.10	2.129	34.30	2.757
Viscous criterion - m/s	0.27	4.000	0.32	4.000
Steering wheel contact (-1)		0.000		
A-Pillar displacement (-2) mm	0	0.000		
Unstable passenger compartment (-1)		0.000		
Shoulder belt load - kN	4.43		4.35	
Chest Incorrect Airbag Deployment Modifier		0.000		0.000
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0.0	4.000	0.2	4.000
Left Femur Compression level exceeded - kN	2.24	4.000	1.8	4.000
duration of exceedence - ms	0		0.0	
Variable contact (-1)		0.000		0.000
Concentrated loading (-1)		0.000		0.000
Incorrect airbag deployment		0.000		0.000
Right Knee Slide - mm	3.3	4.000	0.2	4.000
Right Femur Compression level exceeded - kN	4.28	3.851	2.3	4.000
duration of exceedence - ms	0		0.0	
Variable contact (-1)		0.000		0.000
Concentrated loading (-1)		0.000		0.000
Incorrect airbag deployment		0.000		0.000
LOWER LEG				
Left compression - kN	2.55	3.833	0.73	4.000
Left Upper Tibia Index	0.45	3.773	0.49	3.387
Left Lower Tibia Index	0.74	2.439	0.40	4.000
pedal vertical (-1) mm	0	0.000		
Right compression - kN	3.03	3.279	1.55	4.000
Right Upper Tibia Index	0.81	3.087	0.39	4.000
Right Lower Tibia Index	0.53	4.000	0.22	4.000
pedal vertical (-1) mm	0	0.000		
FOOT and ANKLE				
pedal horizontal displacement - mm	0	4.000		
Footwell Rupture (-1)		0.000		
Pedal Blocking (-1)	0	0.000		
SUMMARY				
Head and Neck assessment		4.000		4.000
Chest assessment		2.129		2.757
Knee, Femur and Pelvis assessment		3.851		4.000
Lower Leg, Foot and Ankle Assessment		2.439		3.387



EURONCAP (without modifiers)

EuroNCAP frontal assessment	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	53.20	4.000	45.51	4.000
HIC36	351		213.22	
Resultant Acc. 3 msec exceedence - g	57.50		42.33	
Unstable airbag contact, Bottoming out (-1)		0.000		
Steering wheel displacement (-1) mm	12	0.000		0.000
NECK				
Shear level exceeded - kN	0.50	4.000	0.87	4.000
duration of exceedence - ms	0		0.00	
Tension level exceeded - kN	1.33	4.000	1.13	4.000
duration of exceedence - ms	0		0.00	
Extension - Nm	38.80	4.000	3.30	4.000
CHEST				
Compression - mm	33.50	2.380	29.00	3.000
Viscous criterion - m/s	0.75	4.000	0.09	4.000
Steering wheel contact (-1)		0.000		
A-Pillar displacement (-2) mm	-31	0.000		
Unstable passenger compartment (-1)		0.000		
Shoulder belt load - kN	5.00		4.32	
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0.4	4.000	0.2	4.000
Left Femur Compression level exceeded - kN	0.31	4.000	1.7	4.000
duration of exceedence - ms	0		0.0	
Variable contact (-1)		0.000		0.000
Concentrated loading (-1)		0.000		0.000
Right Knee Slide - mm	1.0	4.000	0.3	4.000
Right Femur Compression level exceeded - kN	2.53	4.000	0.2	4.000
duration of exceedence - ms	0		0.0	
Variable contact (-1)		0.000		0.000
Concentrated loading (-1)		0.000		0.000
LOWER LEG				
Left compression - kN	1.35	4.000	0.28	4.000
Left Upper Tibia Index	0.35	4.000	0.21	4.000
Left Lower Tibia Index	0.84	2.930	0.18	4.000
Brake pedal vertical (-1) mm	-43	0.000		
Right compression - kN	2.78	3.300	2.18	3.300
Right Upper Tibia Index	0.43	3.850	0.43	3.850
Right Lower Tibia Index	0.30	4.000	0.30	4.000
Brake pedal vertical (-1) mm	-43	0.000		
FOOT and ANKLE				
Brake pedal horizontal displacement - mm	75	4.000		
Footwell Rupture (-1)		0.000		
Pedal Blocking (-1)	47	0.000		
SUMMARY				
Head and Neck assessment		4.000		4.000
Chest assessment		2.380		3.000
Knee, Femur and Pelvis assessment		4.000		4.000
Lower Leg, Foot and Ankle Assessment		2.930		3.850

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Dummy and restraint analysis

- Restraint fire time,
  - Seat belt at 10ms for both front passenger,
  - Airbag at 16ms for both front passenger

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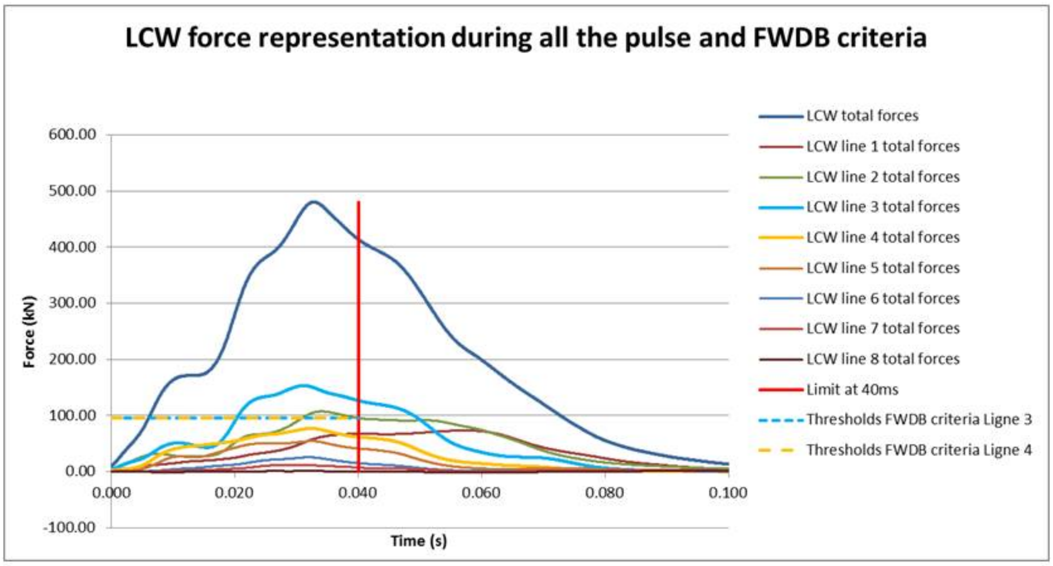
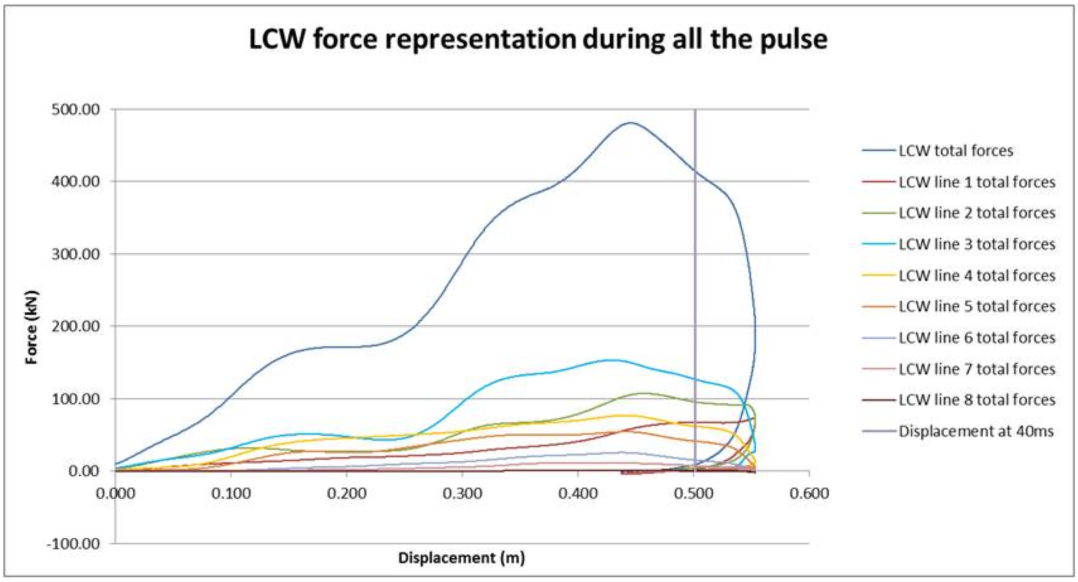
LCW force vs time



LCW force vs B-pillar displacement



Metrics evaluation

Method B(1) FWDB: up to 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN

	City car 1 FWDB	
	Value	OK/KO
Time at 400kN (ms)	27.1	NA
F3+F4 > 180 kN (kN)	206.72	OK
F3 > 85 kN (kN)	138.93	OK
F4 > 85 kN (kN)	67.79	KO
Global	KO	

Method B(1) FWDB: up to 40 ms → F3 > 75 kN AND F4 > 75 kN

	City car 1 FWDB	
	Value	OK/KO
Up to 40 ms, F3 > 75 kN (kN)	126.55	OK
Up to 40 ms, F4 > 75 kN (kN)	61.67	KO
Global	KO	

Upgrade1 FWDB: up to 40 ms → F3 > [MIN(100, 0.2Ft40)] AND F4 > [MIN(100, 0.2Ft40)]

	City car 1 FWDB		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	153.01	96.15	OK
F4 > MIN[100, 0.2Ft40]	76.79	96.15	KO
Global	KO		

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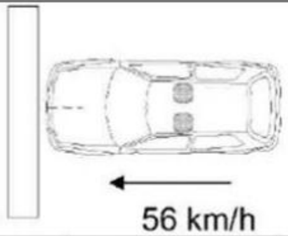
Conclusions

- City car 1 has higher dummy valuse compared to the Euro NCAP test
- The vehicle has its PEAS beneath the common alignment zone.
- LCW forces in row 4 are low, thus it does not fulfill the metric

MINICAR 2 FWDB 56 KM/H @ FIAT

Test Date	26/09/2011
Location	FIAT Safety Center
Topic	Full Width test
Mass Ratio	N/A
Test Number	17423
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1:	Super-mini	Barrier:	Full Width
Brand/type	Supermini 2		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	56.49 km/h		Segmented
Overlap:	100 %	Impact accuracy	5 mm left 4 mm up
Test mass:	1106 kg	LCW ground clearance	80 mm
Dummy:	LHS – Hybrid III 50th RHS – Hybrid III 5th	LCW / barrier dimensions	2000 mm wide 750 mm high

Test objectives:

Test parameters

- **Vehicle data: Supermini 2 LHD**
- **Engine / Transmission: 1.2 Petrol / Manual**
- **Test speed: 56.49**
- **Test weight: F 666 kg / R 440 kg Total 1106 kg**
- **Test impact accuracy: 5 mm left, 4 mm up**
- **Test vehicle status:**
  - **Standard ride heights:**
  - **Fender height R F 628**
    Fender height L F 627
    Fender height R R 636
    Fender height L R 634

Pre-test Pictures
Vehicle 1

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Pre-test Pictures
Barrier



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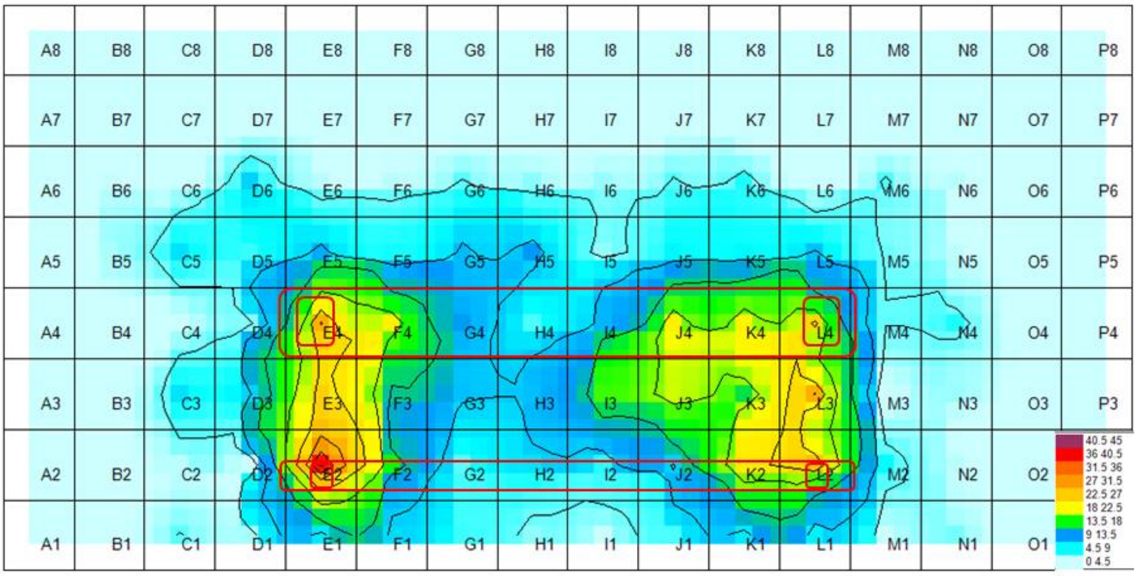
Alignment of Vehicle Structure with LCW



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Post-test Pictures
Vehicle 1

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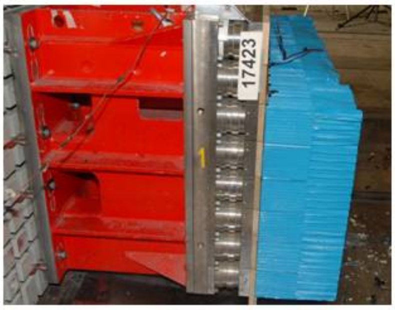
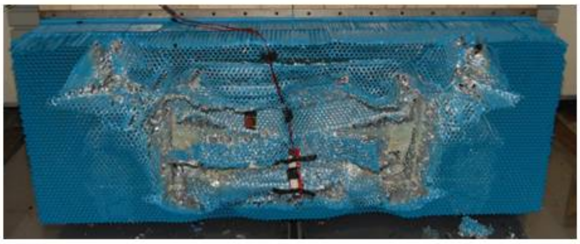
Post-test Pictures
Barrier





Additional pictures (1/2)

Additional pictures (2/2)

Structural results

- Supermini 2: main rails and third load paths folded, good stability of passenger compartment and door rings.

Static measurements

Frontal Impact	Rearw. Steering wheel displacment	Upward Steering wheel displacement	Lateral Steering wheel displacement	Rearw. A pillar displacement	Rearward pedal fixation displacement
Remarks	(mm)	(mm)	(mm)	(mm)	(mm)
FWDB - 56kph - 17423	-23	8	4	1.7	22
	Occupant compartment stability	Footwell Ruptures	Rearw. Pedals displacement	Upward. Pedals displacement	G max SAE 60
			(mm)	(mm)	(g)
FWDB - 56kph - 17423	Yes	No	5 (accel)	0 (clutch)	62

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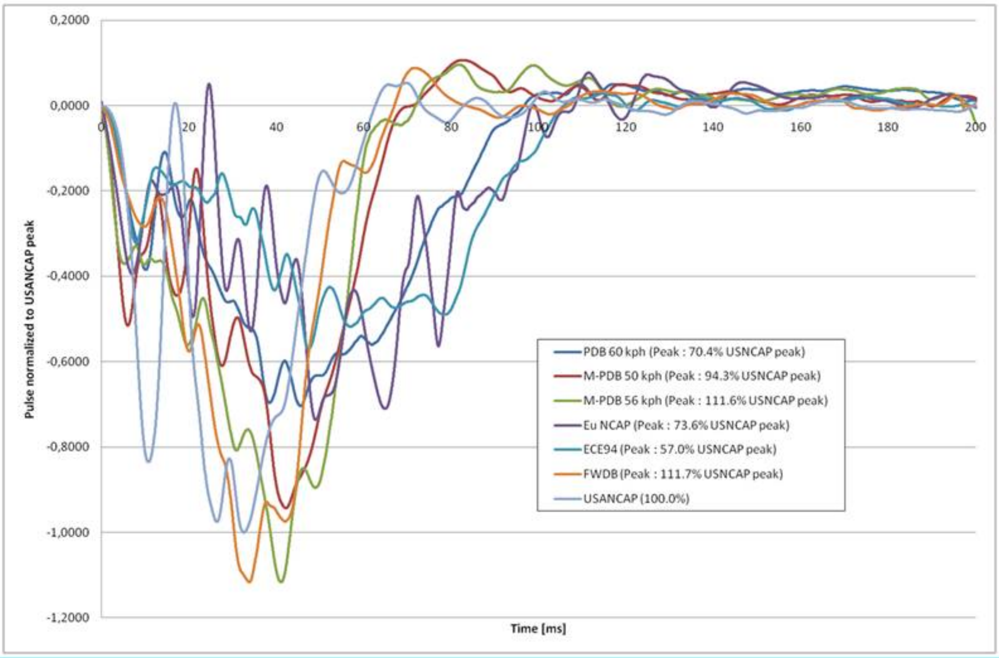
Normalized acceleration Vs. time



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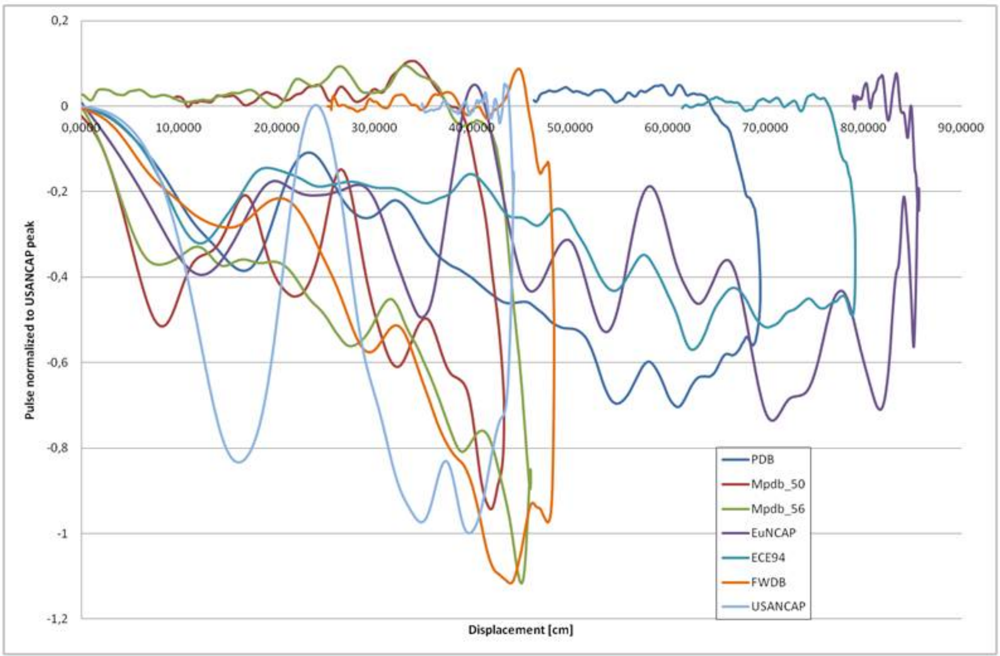
Normalized acceleration Vs. displacement



Dummy criteria comparison

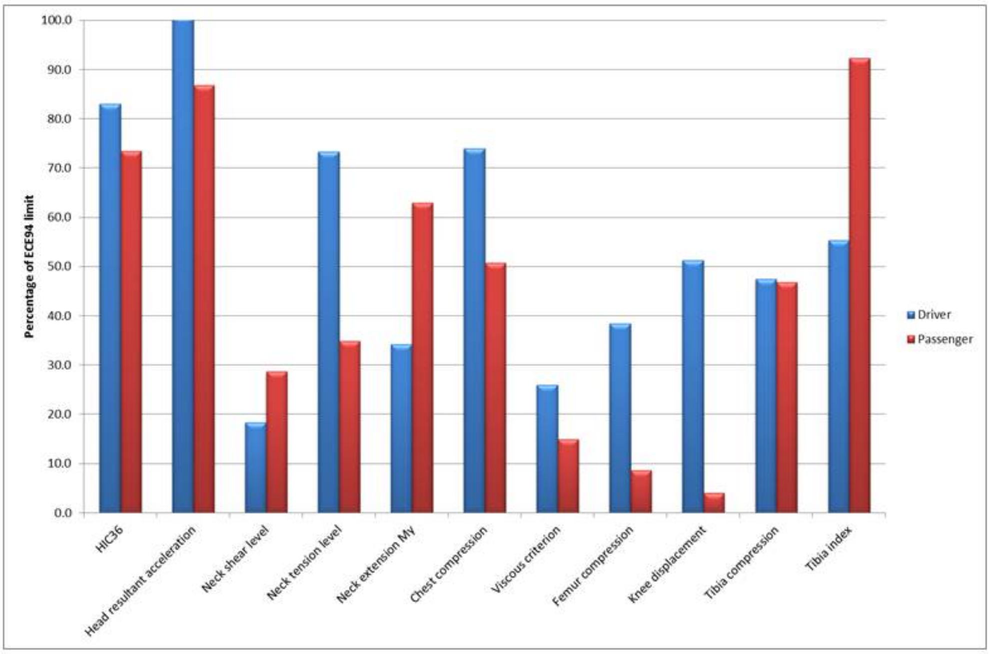
FWDB

	Driver		Passenger	
HEAD	Value	Points Scored	Value	Points Scored
Peak resultant acceleration - g	80.74	1.934	69.42	4.000
HIC [illegible]	830.78		734.90	4.000
Resultant Acc. 3 msec exeedence - g	78.74		68.43	4.000
Head Assessment		1.934		4.000
NECK				
Shear level exceeded - kN	0.57	4.000	0.89	4.000
Tension level exceeded - kN	2.42	4.000	1.15	4.000
Extension - Nm	19.53	4.000	35.85	4.000
Neck Assessment		4.000		4.000
Head and Neck Assessment		1.934		4.000
CHEST				
Compression - mm	37.00	1.857	25.40	3.514
Viscous criterion - m/s	0.26	4.000	0.15	4.000
Shoulder belt load - kN	3.59		3.71	
Chest Assessment		1.857		3.514
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	1.4	4.000	0.4	4.000
Left Femur Compression level exceeded - kN	0.48	4.000	0.53	4.000
duration of exceedence - ms	0		0	
Left Knee, Femur and Pelvis Assessment		4.000		4.000
Right Knee Slide - mm	7.7	3.262	0.6	4.000
Right Femur Compression level exceeded - kN	3.84	3.970	0.86	4.000
duration of exceedence - ms	0		0	
Right Knee, Femur and Pelvis Assessment		3.262		4.000
Knee, Femur and Pelvis assessment		3.262		4.000
LOWER LEG				
Left compression - kN	3.43	3.047	3.75	2.833
Left Upper Tibia Index	0.58	3.200	0.48	3.644
Left Lower Tibia Index	0.41	3.956	0.61	3.067
Left Lower Leg assessment		3.047		2.833
Right compression - kN	3.80	2.800	3.22	3.187
Right Upper Tibia Index	0.72	2.578	1.20	0.444
Right Lower Tibia Index	0.61	3.067	0.99	1.378
Right Lower Leg assessment		2.578		0.444
Lower Leg, Foot and Ankle assessment		2.578		0.444
SUMMARY				
Head and Neck assessment		1.934		4.000
Chest assessment		1.857		3.514
Knee, Femur and Pelvis assessment		3.262		4.000
Lower Leg, Foot and Ankle Assessment		2.578		0.444
TOTAL DRIVER FRONTAL		9.631		11.958

EU-NCAP

	Driver		Passenger	
HEAD	Value	Points Scored	Value	Points Scored
Peak resultant acceleration - g	58.98	4.000	45.56	4.000
HIC [illegible]	562.75	4.000	356.68	4.000
Resultant Acc. 3 msec exeedence - g	58.71	4.000	44.63	4.000
Head Assessment		4.000		4.000
NECK				
Shear level exceeded - kN	0.67	4.000	0.28	4.000
Tension level exceeded - kN	1.72	4.000	0.67	4.000
Extension - Nm	18.85	4.000	18.38	4.000
Neck Assessment		4.000		4.000
Head and Neck Assessment		4.000		4.000
CHEST				
Compression - mm	23.27	3.820	22.43	3.940
Viscous criterion - m/s	0.08	4.000	0.10	4.000
Shoulder belt load - kN	3.77		3.24	
Chest Assessment		3.820		3.940
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0.6	4.000	0.5	4.000
Left Femur Compression level exceeded - kN	0.52	4.000	0.28	4.000
Variable contact		0.000		0.000
Left Knee, Femur and Pelvis Assessment		4.000		4.000
Right Knee Slide - mm	2.6	4.000	0.3	4.000
Right Femur Compression level exceeded - kN	0.59	4.000	0.30	4.000
Variable contact		0.000		0.000
Right Knee, Femur and Pelvis Assessment		4.000		4.000
Knee, Femur and Pelvis assessment		4.000		4.000
LOWER LEG				
Left compression - kN	3.07	3.290	2.24	3.840
Left Upper Tibia Index	0.47	3.690	0.35	4.000
Left Lower Tibia Index	0.52	3.470	0.22	4.000
Left Lower Leg assessment		3.290		3.840
Right compression - kN	2.36	3.760	1.27	4.000
Right Upper Tibia Index	0.43	3.870	0.35	4.000
Right Lower Tibia Index	0.39	4.000	0.42	3.910
Right Lower Leg assessment		3.760		3.910
Lower Leg, Foot and Ankle assessment		3.290		3.840
SUMMARY				
Head and Neck assessment		4.000		4.00
Chest assessment		3.820		3.94
Knee, Femur and Pelvis assessment		4.000		4.00
Lower Leg, Foot and Ankle Assessment		3.290		3.84
TOTAL FRONTAL		15.110		15.780

Dummy Criteria Comparison - % of Reference Value (Reg 94)



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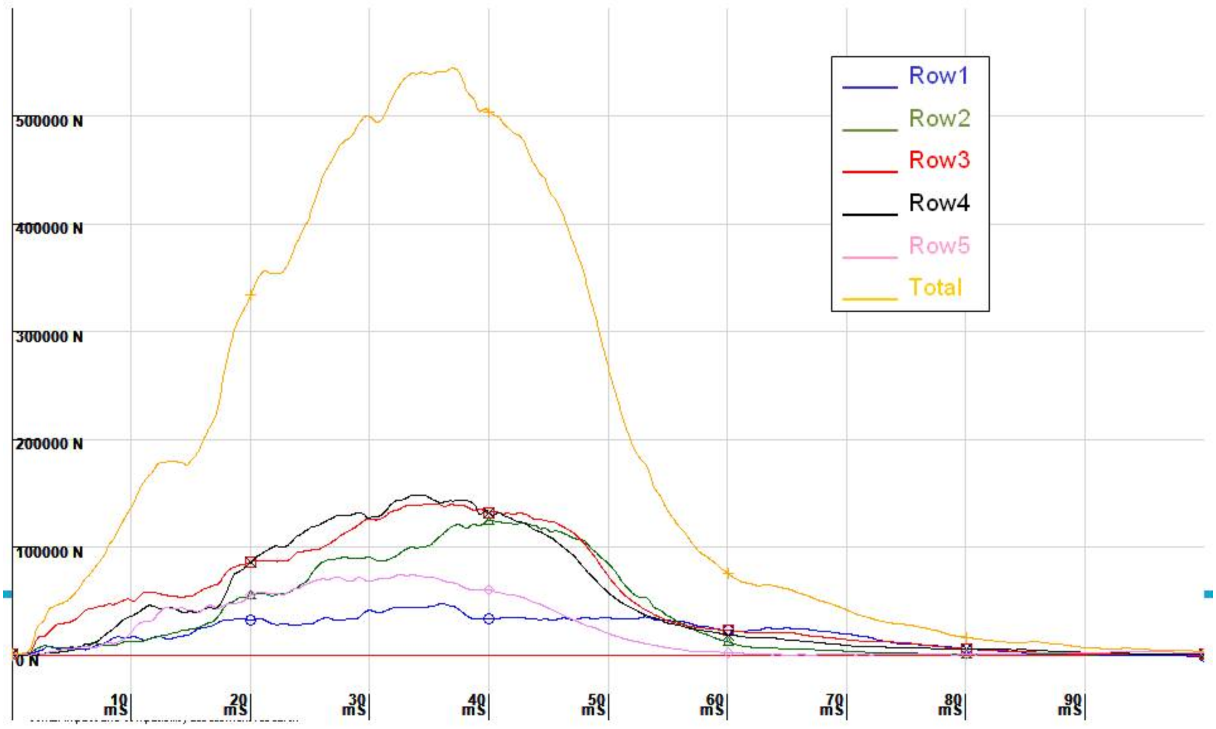
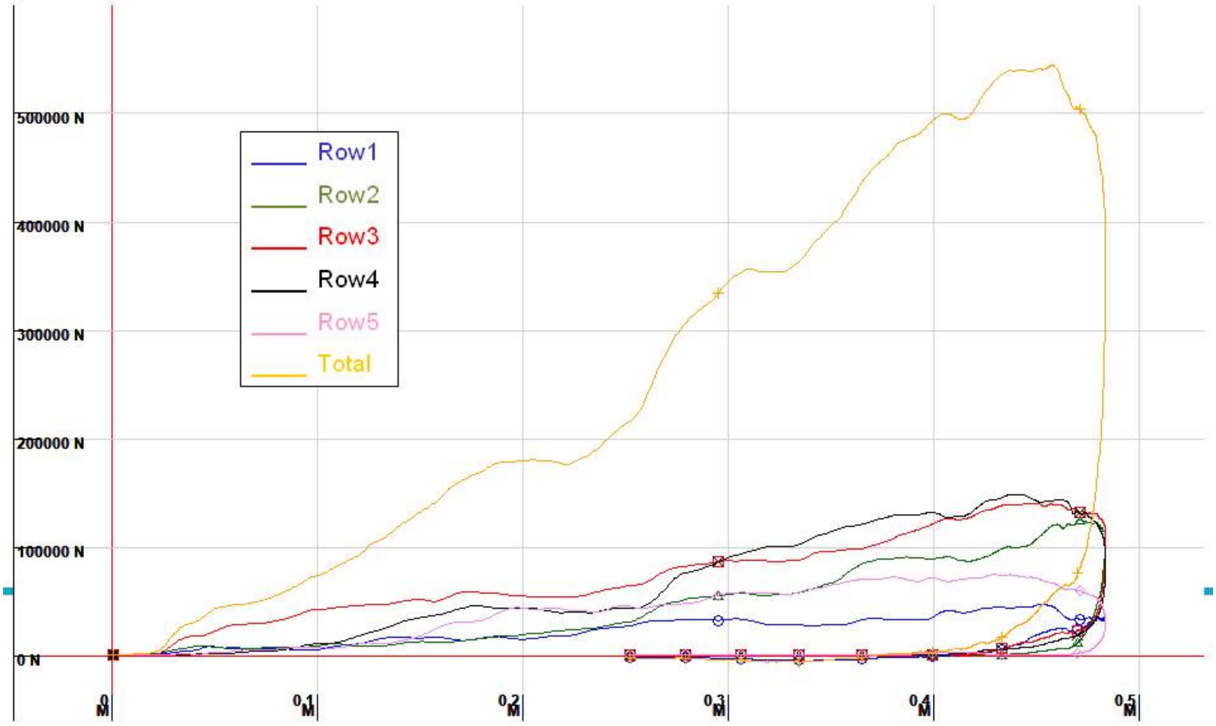
SEVENTH FRAMEWORK PROGRAMME

LCW force vs time



LCW force vs B-pillar displacement



Metrics evaluation

Method B(1) FWDB: up to 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN

	Supermini 2 FWDB	
	Value	OK/KO
Time at 400kN (ms)	24.7	NA
F3+F4 > 180 kN (kN)	211.7	OK
F3 > 85 kN (kN)	96.1	OK
F4 > 85 kN (kN)	115.5	OK
Global	OK	

Method B(2) FWDB: up to 40 ms → F3 > 75 kN AND F4 > 75 kN

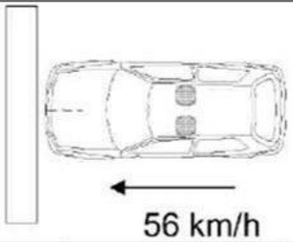
	Supermini 2 FWDB	
	Value	OK/KO
Up to 40 ms, F3 > 75 kN (kN)	140.1	OK
Up to 40 ms, F4 > 75 kN (kN)	148.1	OK
Global	OK	

Upgrade1 FWDB: up to 40 ms → F3 > [MIN(100, 0.2Ft40)] AND F4 > [MIN(100, 0.2Ft40)]

	Supermini 2 FWDB		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	140.1	108.7	OK
F4 > MIN[100, 0.2Ft40]	148.1	108.7	OK
Global	OK		

SUV 1 FWDB 56 KM/H @ TRL

Test Date	23/03/12
Location	TRL
Topic	Full Width test
Mass Ratio	N/A
Test Number	B4767
Test Protocol	Draft FWDB protocol v1.doc



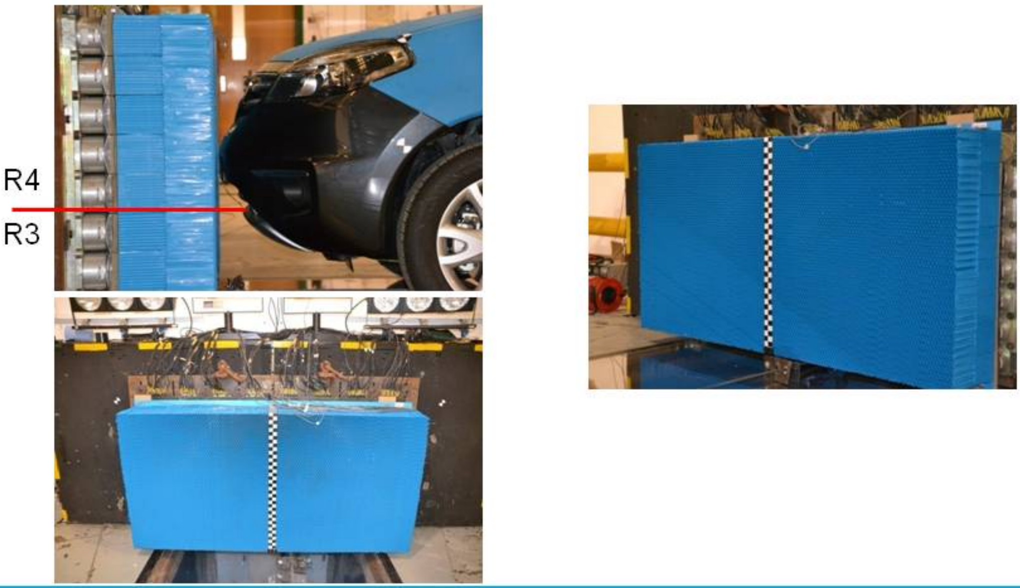
Vehicle 1:		Barrier:	Full Width
Brand/type	SUV 1		150 mm 0.34 MPa
Impact side:	Front		150 mm 1.71 MPa
Speed:	56 km/h		Segmented
Overlap:	100 %	Impact accuracy	Lost in test
Test mass:	1961kg		
Dummy:	LHS – Hybrid III 50th RHS – Hybrid III 5th both with RibEye chest deflection	LCW ground clearance	80 mm
		LCW barrier dimensions	2m wide 1m high

Test parameters

- **Vehicle data: SUV 1**
- **Engine / Transmission: 2.0L DCi / Manual 4WD**
- **Test speed: 55.8km/h**
- **Test weight: F 1147kg / R 814 kg Total 1961 kg**
- **Test impact accuracy: Lost in test**
- **Test vehicle status:**
-
  - **Standard ride height**
-
  - **FL = 760mm FR = 758mm**
  - **RL = 757mm RR = 755mm**

Pre-test Pictures
SUV 1

Pre-test Pictures
Barrier

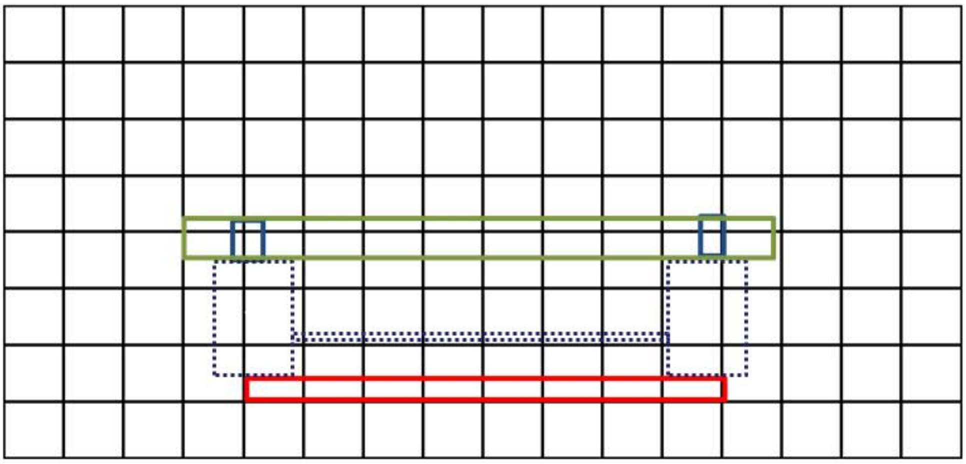


Description of front-end structure

Two main longitudinal rails, each with cross-sectional area (y)59mm x (z)94mm. Bumper crossbeam connecting the two rails horizontally. A hanger from each side of the rails connects to a subframe 26mm rearwards and 209mm below the rails.

SEVENTH FRAMEWORK PROGRAMME

Alignment of Vehicle Structure with LCW



SEVENTH FRAMEWORK PROGRAMME

Post-test Pictures
Vehicle 1

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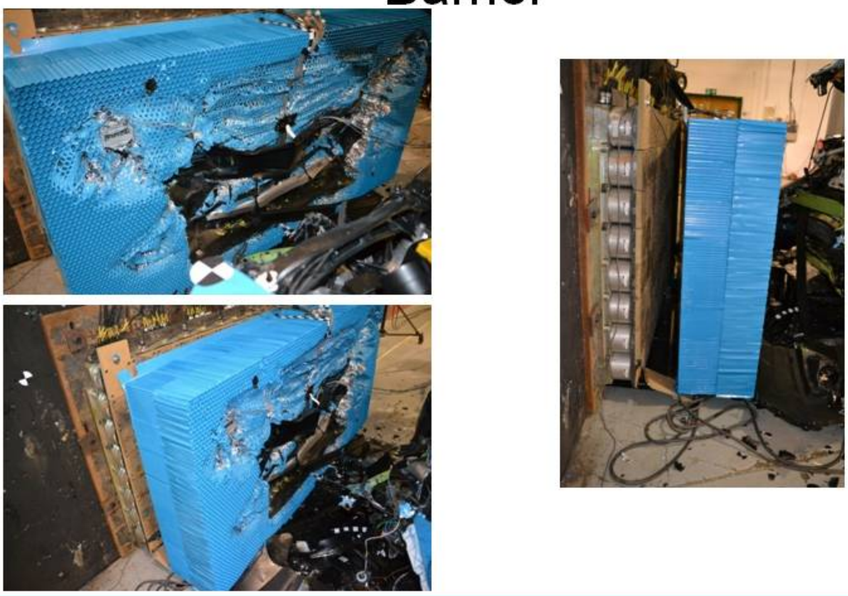
SEVENTH FRAMEWORK PROGRAMME

Post-test Pictures
Barrier



FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Deformation measurements

SUV 1

Vehicle:	Renault Koleos
Test Number:	B4767
Test type:	FWDB
Velocity / Comments:	56km/h
	dX (mm)
M_APL1 Left A-post 100 mm below window	-2
M_BPL1 Left B-post 100 mm below window	-1
M_APL3 Left A-post 100 mm above sill	0
M_BPL3 Left B-post 100 mm above sill	0
M_SCT Top of steering column	38
M_AP Accelerator pedal	-12
M_AP2 Accelerator pedal 200N	18
M_BP Brake pedal	56
M_BP2 Brake pedal 200 N	148
M_CP Clutch pedal	106
M_CPA Brake Pedal Axle (hinge)	-
M_CP2 Clutch pedal 200 N	110
M_BPR1 Right B-post 100 mm below window	-1
M_APR3 Right B-post 100 mm above sill	-2
M_FSML Left front end of side member	-
M_FSMR Right front end of side member	-
M_SFL Subframe left front side	-
M_SFR Subframe right front side	-
M_EMSL Engine low Left - at mount to subframe	-
M_EMSR Engine low Right - at mount to subframe	-

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SEVENTH FRAMEWORK PROGRAMME

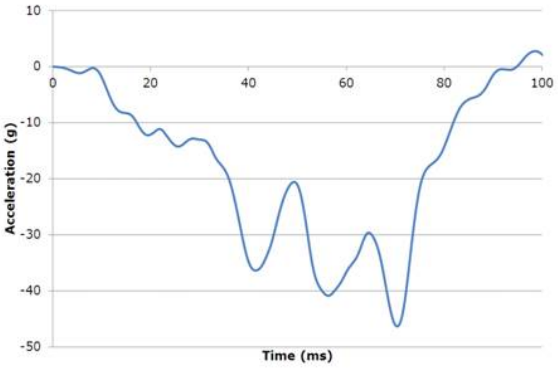
Structural results

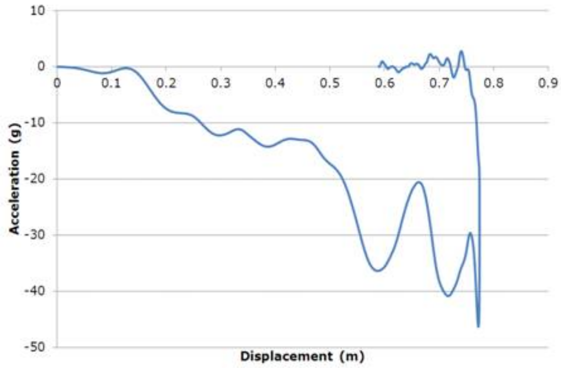
- Vehicle
  - Crumpling and bending of main rails with much greater deformation of RHS rail compared to LHS rail.
  - Bending of bumper crossbeam in middle
- Barrier
  - Barrier deformation as expected for large vehicle with significant deformation in areas of vehicle with structure
  - Barrier bottomed out in locations of longitudinal rails

FIMCAR frontal impact and compatibility assessment research

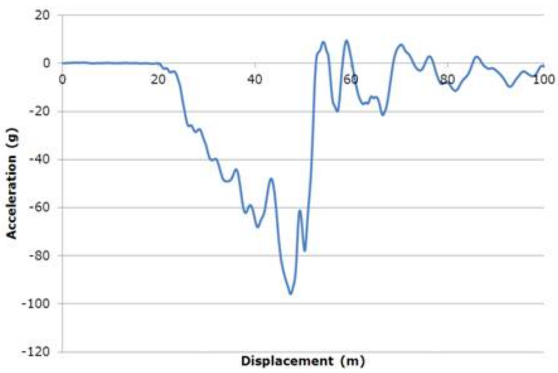
SEVENTH FRAMEWORK PROGRAMME

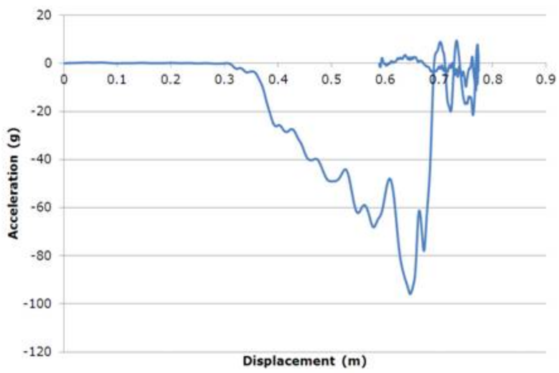
Car Accelerations
vs.
Time Displacement



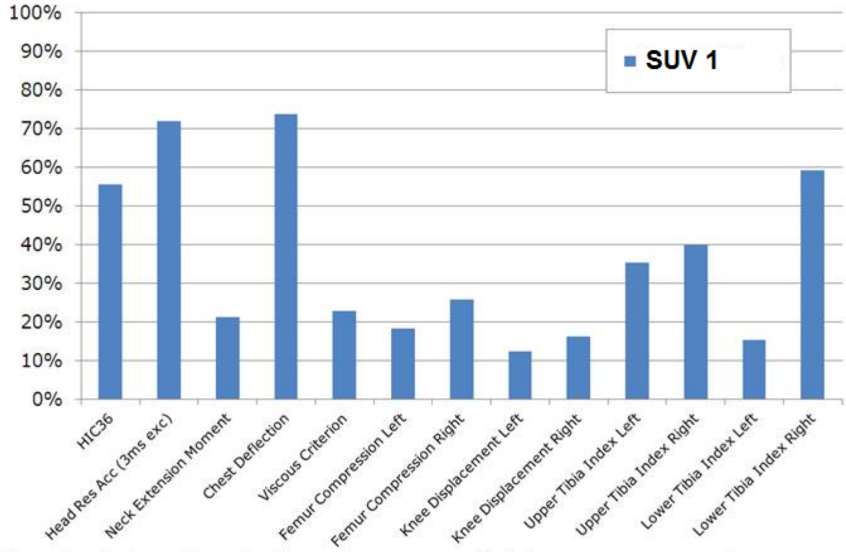


Engine acceleration
vs.
Time Vehicle displacement





Driver Dummy Criteria Comparison - % of Reg 94 limits

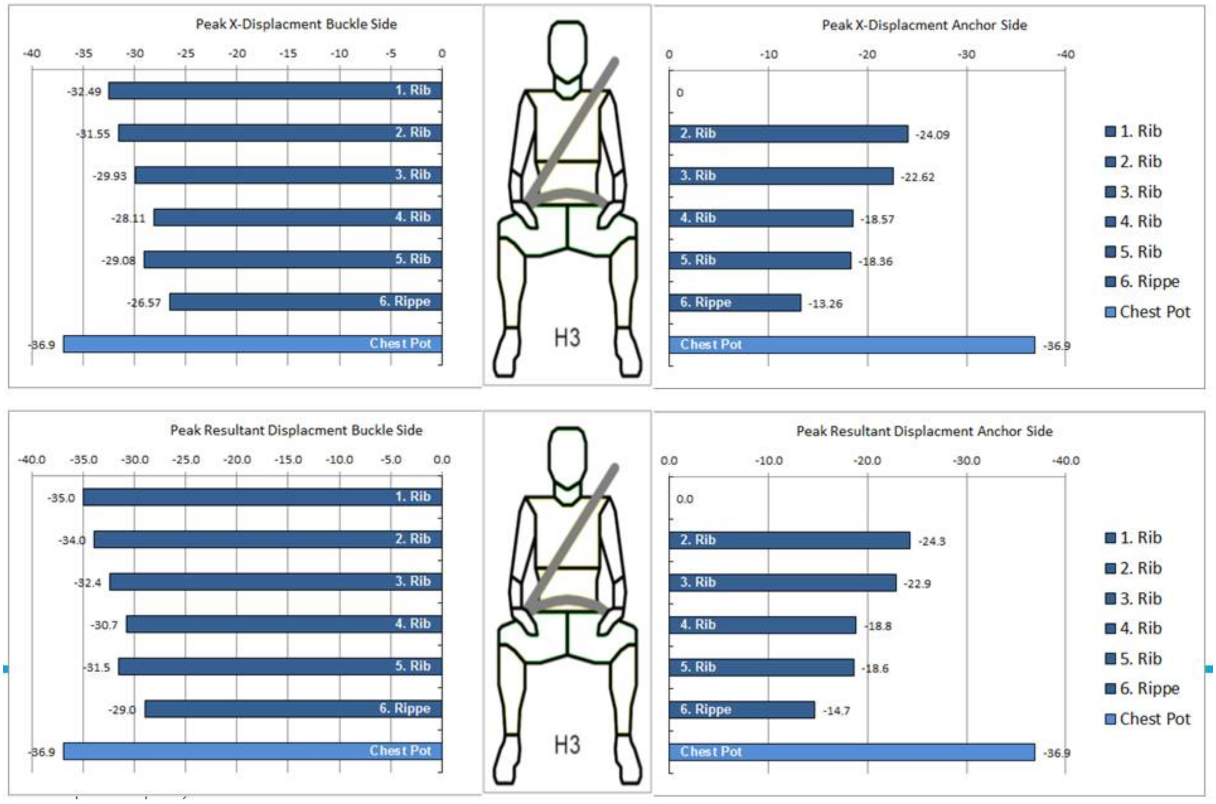


Note: After test shoulder belt anchorage point for passenger dummy could move ~ 2 cm up/down in a manner which indicated that height adjustment mechanism was broken

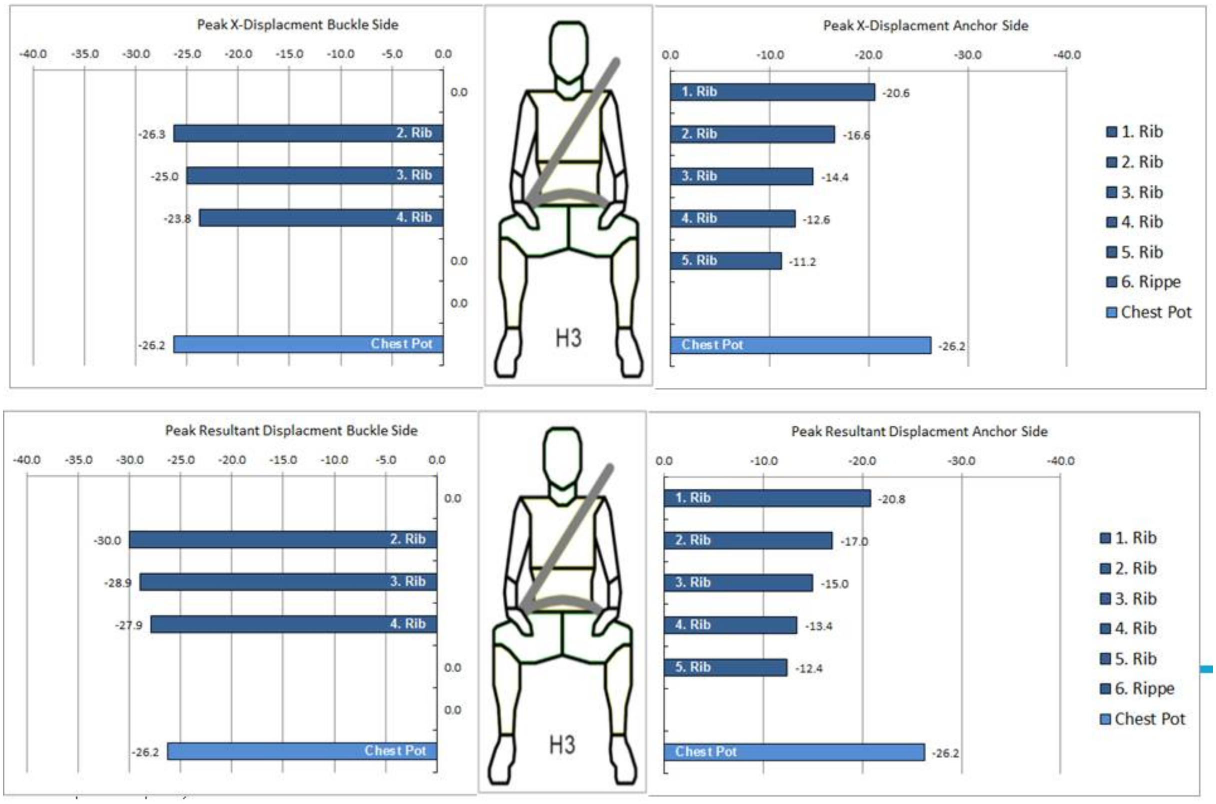
Dummy and restraint analysis – airbag firing times

Driver	Passenger
17ms	17ms

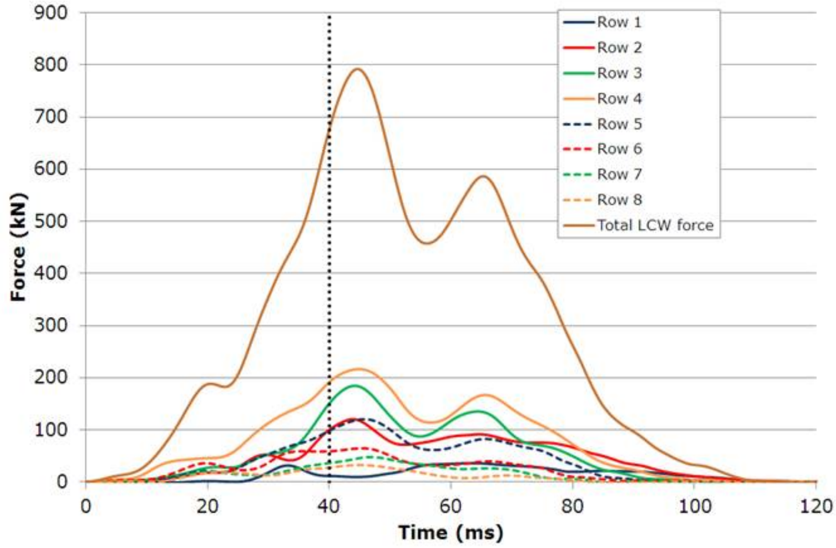
RibEye analysis - driver



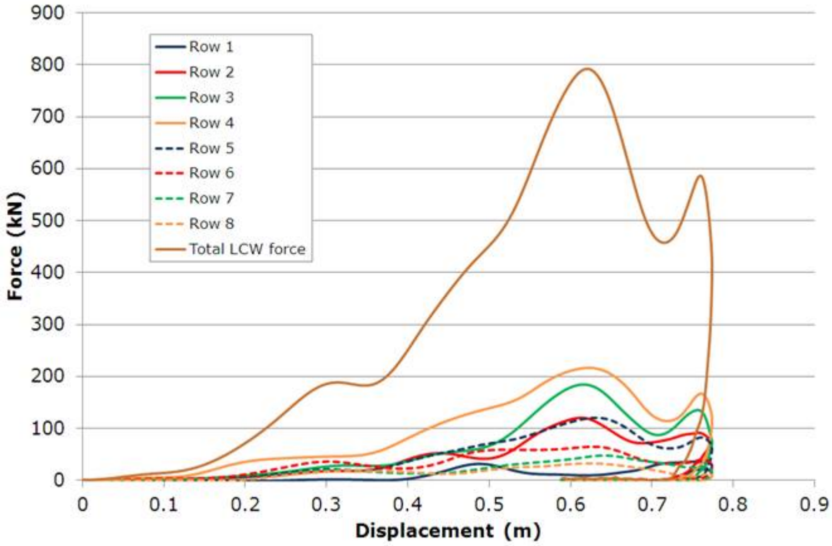
RibEye analysis – front seat passenger



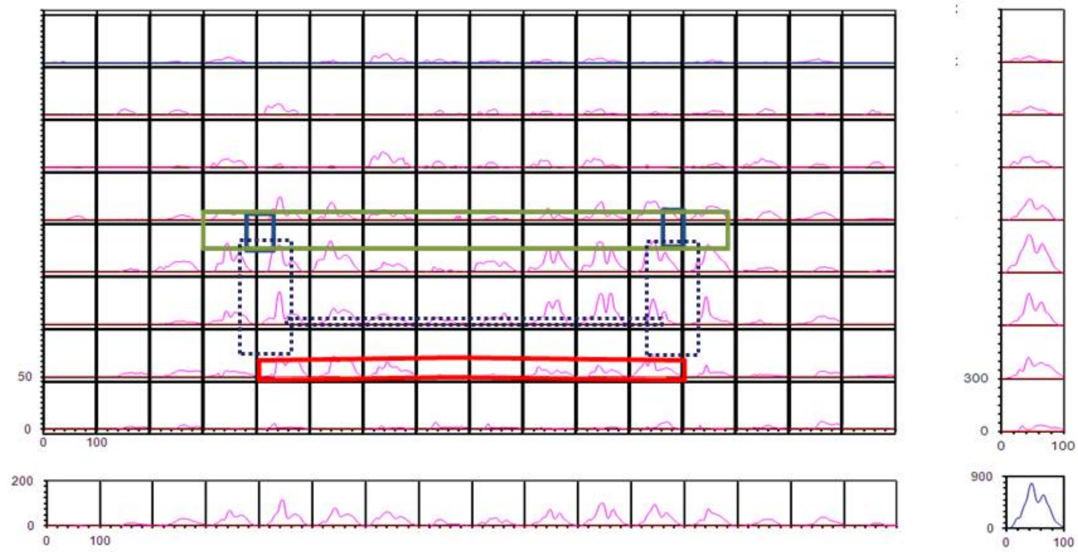
LCW force vs time



LCW force vs B-pillar displacement



LCW cell forces



Metrics evaluation

Method B(1) FWDB: up to 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN

	SUV 1 FWDB	
	Value	OK/KO
Time at 400kN (ms)	31.8	NA
F3+F4 > 180 kN (kN)	182.6	OK
F3 > 85 kN (kN)	56.8	NO
F4 > 85 kN (kN)	125.8	OK
Global	OK	

Method B(1) FWDB: up to 40 ms → F3 > 75 kN AND F4 > 75 kN

	SUV 1 FWDB	
	Value	OK/KO
Up to 40 ms, F3 > 75 kN (kN)	151	OK
Up to 40 ms, F4 > 75 kN (kN)	192	OK
Global	OK	

Upgrade1 FWDB: up to 40 ms → F3 > [MIN(100, 0.2Ft40)] AND F4 > [MIN(100, 0.2Ft40)]

	SUV 1 FWDB		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	151	135.4	OK
F4 > MIN[100, 0.2Ft40]	192	135.4	OK
Global	OK		

Conclusions

- LCW
  - Likely that hanger structure between rails and subframe contributed significantly to load on row 3 because of its large frontal area
- LCW metrics
  - SUV 1 met:
    - Up to 40 ms F3 > [MIN(100, 0.2Ft40)] AND F4 > [MIN(100, 0.2Ft40)
    - Up to 40 ms → F3 > 75 kN AND F4 > 75 kN
  - SUV 1 did not meet:
    - Up to 400 kN → F3 + F4 > 180 kN AND F3 > 85 kN AND F4 > 85 kN
- Dummy results
  - All driver dummy values less than 73% of current R94 performance limits

SUV 2 FWDB 56 KM/H @ IDIADA

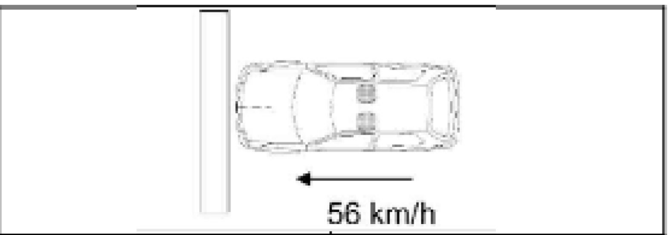
WP3 testing activities

SUV 2

FWDB at IDIADA

SUV 2 FWDB test

Test Date	Aug. 31, 2012
Location	IDIADA
Topic	FWDB
Mass Ratio	NA
Test Number	123514FF
Test Protocol	FIMCAR



Vehicle 1:	4x4	Ride height measured at wheel arch:
Brand/type	SUV 2	
Impact side:	Front	
Speed:	56 km/h	Front left: 742 mm
Overlap:	100 %	Front right: 748 mm
Test mass:	1846.0 kg	
Dummy:	LHS – HIII 50%	Rear left: 750 mm
	RHS – HIII 5% Female	Rear right: 746 mm

Test objective: Car to FWDB test.

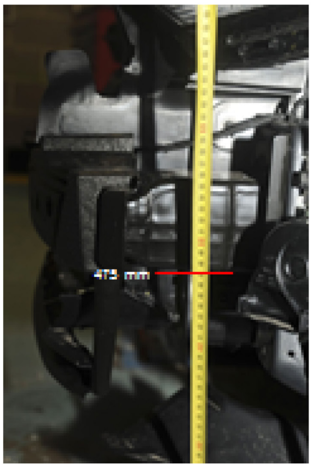
Full Frontal FWDB impact test on SUV 2

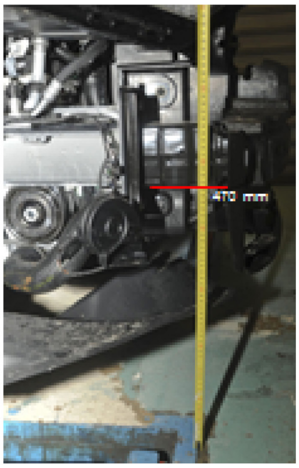
Structural analysis

IDIADA test no. 123514FF

Vehicle: SUV 2

Ground clearance: 475 mm to bumper beam CTR bottom





Full Frontal FWDB impact test on SUV 2

Test conditions

IDIADA test no. 123514FF

Vehicle: SUV 2

Test Vehicle Mass: 1846.0 kg

Test velocity: 56.54 km/h

Ground clearance: 475 mm to bumper beam CTR bottom

SUMMARY		
Head and Neck assessment	4,000	4,000
Chest assessment	2,840	2,349
Knee, Femur and Pelvis assessment	3,924	1,673
Lower Leg, Foot and Ankle Assessment	2,889	2,922
TOTAL	13,653	10,944
Door Opening	0,00	
TOTAL FRONTAL	10,944	

SUV 2 FWDB Impact
Pre-Test photos

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

SUV 2 FWDB Impact
Static measurement results

- No door opening during the test.
- No door opening after the test.

A-Pillar Left Top	3.2
A-Pillar Left Bottom	-1.0
B-Pillar Left Top	-3.8
B-Pillar Left Bottom	-2.2
A-Pillar Right Top	0.6
A-Pillar Right Bottom	-1.1
B-Pillar Right Top	3.7
B-Pillar Right Bottom	1.7
Steering Wheel	-63.3
Accelerator pedal	3.0
Brake pedal	0.5
Clutch pedal	-134.8

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SEVENTH FRAMEWORK PROGRAMME

SUV 2 FWDB Impact
Dummy results

SUV 2

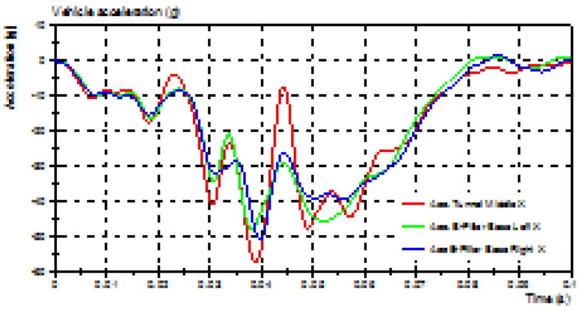
	Value	Points	Value	Points
HEAD				
Peak resultant acceleration - g	70,44	4,000	66,65	4,000
HIC_{15}	751,34		566,88	
Resultant Acc. 3 msec exceedance - g	66,63		67,46	
Unstable airbag contact, Bottoming out or Hazardous depl		0,000		0,000
Steering wheel displacement (-1) mm	-1	0,000		
Incorrect airbag deployment		0,000		0,000
Head Assessment		4,000		4,000
NECK				
Shear level exceeded - kN	0,37	4,000	0,39	4,000
duration of exceedence - ms	0		0,00	
Tension level exceeded - kN	1,75	4,000	1,07	4,000
duration of exceedence - ms	0		0,00	
Extension - Nm	36,40	4,000	36,88	4,000
Neck Assessment		4,000		4,000
Head and Neck Assessment		4,000		4,000
CHEST				
Compression - mm	30,12	2,640	30,36	2,349
Viscous criterion - m/s	0,14	4,000	0,36	4,000
Steering wheel contact (-1)		0,000		
A-Pillar displacement (-2) mm		0,000		
Unstable passenger compartment (-1)		0,000		
Shoulder belt load - kN	4,79		4,80	
Chest Incorrect Airbag Deployment Modifier		0,000		0,000
Chest Assessment		2,010		2,349

	Value	Points	Value	Points
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	1,4	4,000	0,1	4,000
Left Femur Compression level exceeded - kN	0,71	4,000	1,1	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Left Knee, Femur and Pelvis Assessment		4,000		4,000
Right Knee Slide - mm	6,2	3,908	0,0	4,000
Right Femur Compression level exceeded - kN	2,76	4,000	6,5	1,975
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Right Knee, Femur and Pelvis Assessment		3,908		1,975
Knee, Femur and Pelvis assessment		3,954		1,975
LOWER LEG				
Left compression - kN	2,54	3,640	2,15	3,800
Left Upper Tibia Index	0,65	3,688	0,91	3,511
Left Lower Tibia Index	0,35	4,000	0,57	3,344
Brake pedal vertical (-1) mm	-63	0,000		
Left Lower Leg assessment		3,688		3,344
Right compression - kN	1,90	4,000	2,39	3,467
Right Upper Tibia Index	0,37	4,000	0,71	2,922
Right Lower Tibia Index	0,41	3,926	0,71	2,922
Brake pedal vertical (-1) mm	-63	0,000		
Right Lower Leg assessment		3,926		2,922
FOOT and ANKLE				
Brake pedal horizontal displacement - mm	-68	4,000		
Footwell Rupture (-1)		0,000		
Pedal Blocking (-1)	22	0,000		
Foot and Ankle assessment		4,000		
Lower Leg Foot and Ankle assessment		3,009		2,922

SUV 2 FWDB Impact
Vehicle pulse

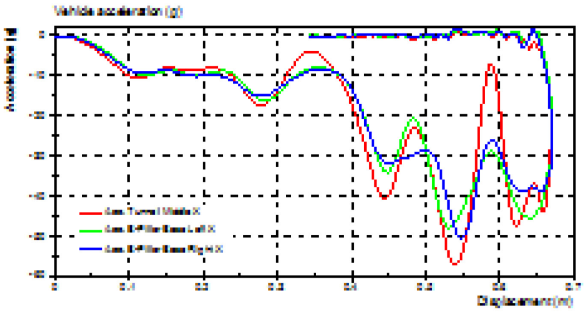
Time

B-Pillar Left side

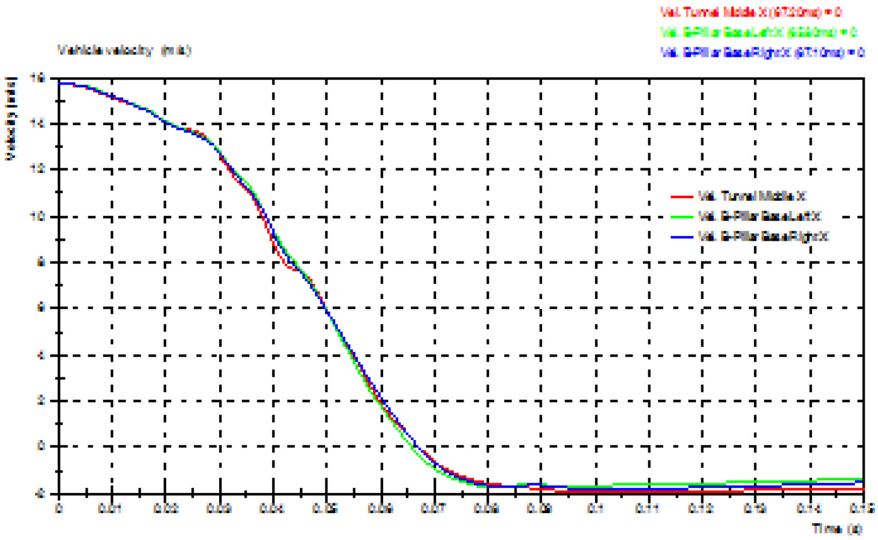


Displacement

B-Pillar Left side

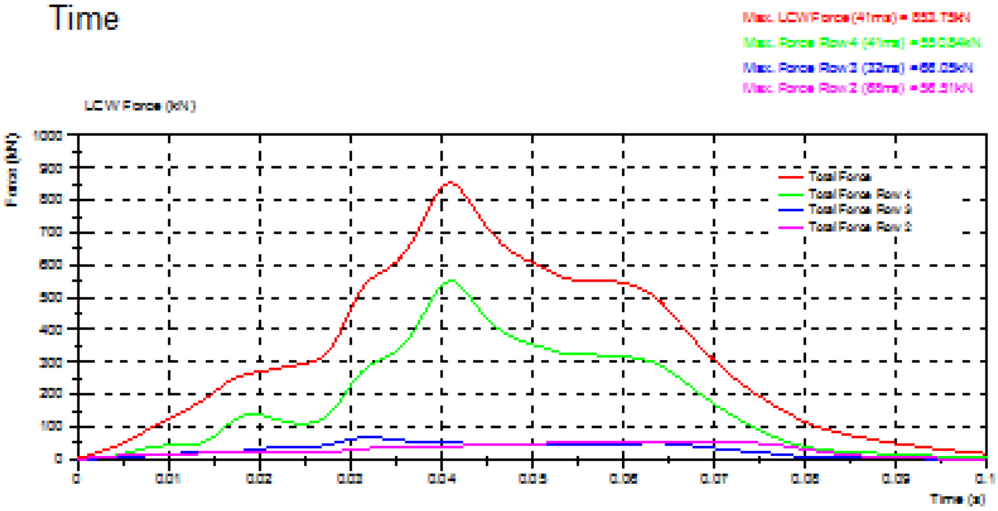


SUV 2 FWDB Impact
Vehicle velocity



SUV 2 FWDB Impact
LCW Force

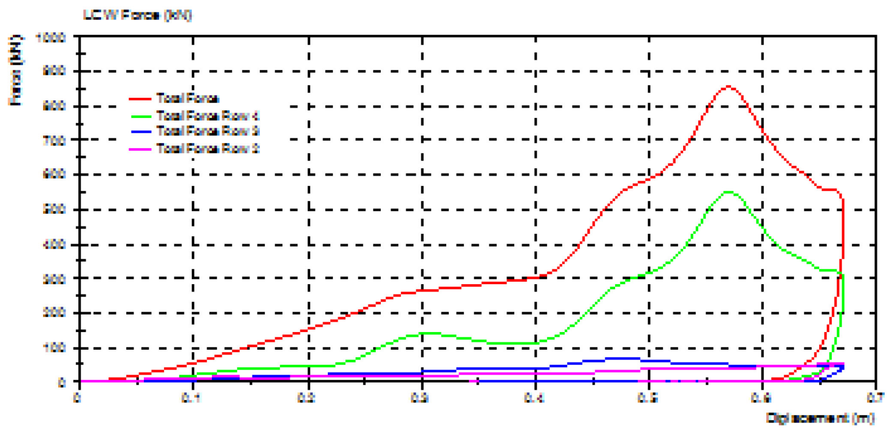
Time



SUV 2 FWDB Impact
LCW Force

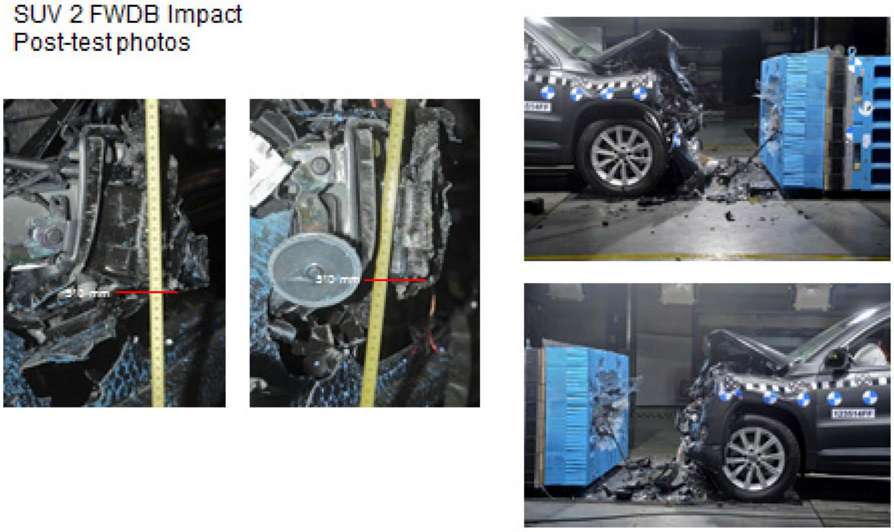
Displacement

B-Pillar Left side



SUV 2 FWDB Impact
Post-test photos

SUV 2 FWDB Impact
Post-test photos



SUV 2 FWDB Impact Metrics

LCW forces at time of 40 ms
FT = 836.57 kN
F2 = 39.02 kN
F3 = 50.23 kN (6.0%)
F4 = 534.44 kN (63.8%)
F5 = 102.40 kN

Metric up to time of 40 ms
0.2 x FT40 = 334.62 kN

F3 = 66.05 kN	**FAIL**
F4 = 534.44 kN	**PASS**

Limit Reduction
F2 = 56.51 kN Below 70 kN

Modified Metric

- Up to time of 40 msec
  - $F4 + F3 \geq [MIN(200, 0.4F_{T40})$ kN
  - $F4 \geq [MIN(100, 0.2F_{T40})$ kN
  - $F3 \geq [MIN((100-LR), (0.2F_{T40}-LR))$ kN
  - where:
    - F_{T40} = Maximum of total LCW force up to time of 40 msec
    - Limit Reduction (LR) = [F2-70] kN and 0 kN ≤ LR ≤ 50 kN

SUV 2 FWDB Impact Conclusions

- SUV 2 FWDB impact with 56 km/h in standard configuration (not raised)
- The rails were in alignment with row 4 and produces there the main amount of forces at the LCW (more than 50 %)
- The SUV 2 was in standard configuration, however it does not fulfill the geometric requirement of stage of the US voluntary agreement (rails too high)
- The SUV 2 failed the FWDB metrics as it should
- Dummy injury values were below R94 limits, maximum acceleration 55 g

SMALL FAMILY CAR 1 FWDB 56 KM/H @ BAST

Small Family Car 1
FWDB 56 km/h
Test No. FM07RMFW

Thorsten Adolph
Tobias Langner

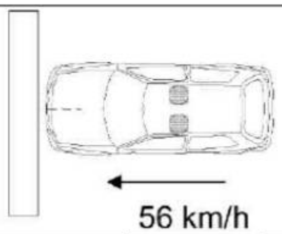
FIMCAR WP 3, 24th September 2012

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

FWDB Small Family Car 1

Test Date	15/06/2012
Location	BASt
Topic	FWDB Test
Test Number	**FM07RMFW**
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1:	Small Family Cars 1	Barrier:	FWDB barrier (750mm)
Brand/type	(silver)		
Impact side:	Front		
Speed:	56,02 km/h		
Overlap:	100 %	Impact accuracy	8 mm left 0 mm
Test mass:	1441 kg		
Dummy:	LHS – Hybrid III 50th RHS – Hybrid III 5th	Barrier ground clearance	80 mm
		LCW / barrier dimensions	2000 mm wide 750 mm high 300 mm deep

Test objectives: To complete the test data set for the FWDB approach; to add additional data and compare with previous tests (e.g. Renault Megane vs. Renault Koleos)

FIMCAR frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Test parameters

- Vehicle data: Small Family Car 1(Left hand drive)
- Vehicle identification no (VIN):
- Engine / Transmission: Diesel, manual transmission
- Test speed: 56,02 km/h
- Test weight: 1441 kg
- Test impact accuracy: 0 mm, 10 mm up

- Test vehicle status:
  - No changes in ride height

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Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures Vehicle

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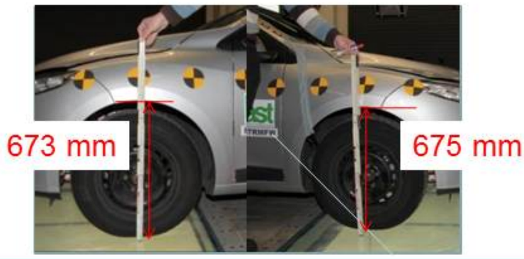
Small Family Car 1, FWDB 56 km/h, FM07RMFW

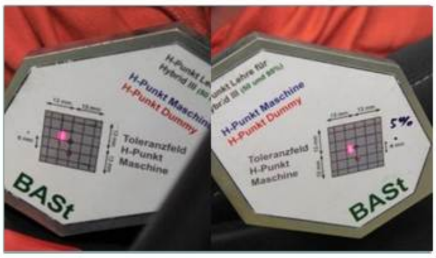
SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures Vehicle



Small Family Car 1, FWDB 56 km/h, FM07RMFW

Pre-test Pictures Dummy



Small Family Car 1, FWDB 56 km/h, FM07RMFW

Pre-test Pictures
Barrier / Trolley

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Small Family Car 1, FWDB 56 km/h, FM07RMFW

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Post-test Pictures
Vehicle Overview

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Small Family Car 1, FWDB 56 km/h, FM07RMFW

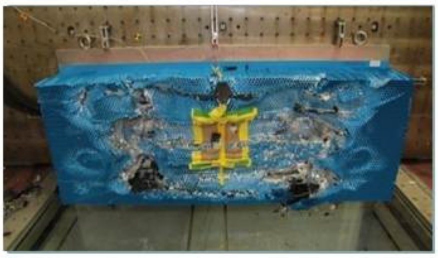
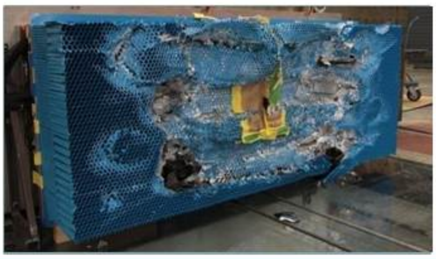
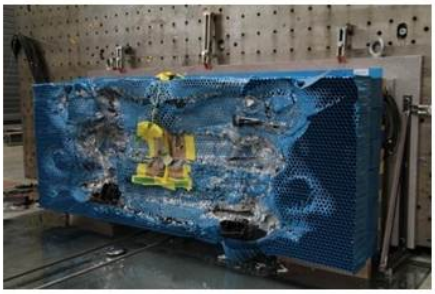
SEVENTH FRAMEWORK PROGRAMME

Post-test Pictures
Vehicle Structure




Small Family Car 1, FWDB 56 km/h, FM07RMFW

Post-test Pictures
Barrier

Small Family Car 1, FWDB 56 km/h, FM07RMFW

Post-test Pictures Dummy



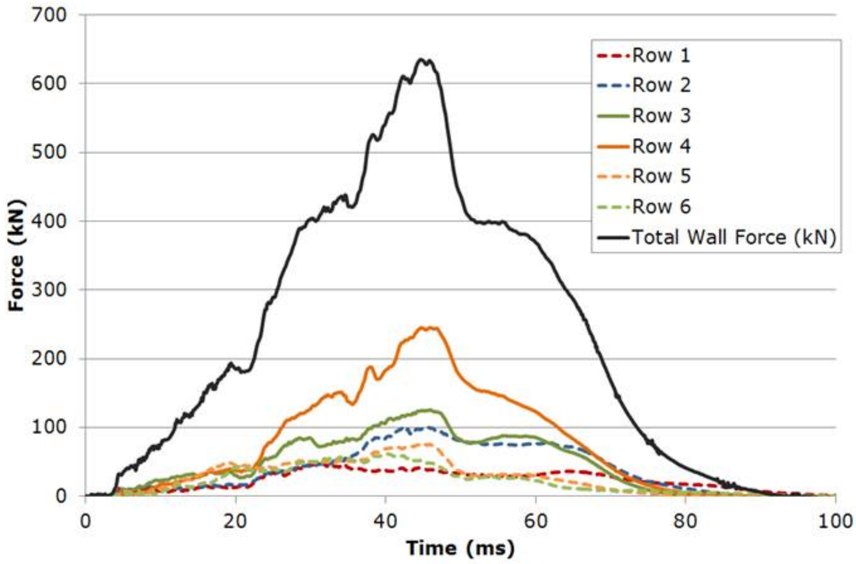

Small Family Car 1, FWDB 56 km/h, FM07RMFW

Small Family Car 1 front end structure

HIGHER CROSSBEAM				LOWER CROSSBEAM (middle plane)				CRUSH CAN	
Top height	Bottom height	Depth	Distance from the wheel axis centre	Top height	Bottom height	Depth	Distance from the wheel axis centre	Bottom height	Top Height
503	411	40	627	277	232	54	588	227	278

Small Family Car 1, FWDB 56 km/h, FM07RMFW

Plot: Row forces over time



FIMCAR frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

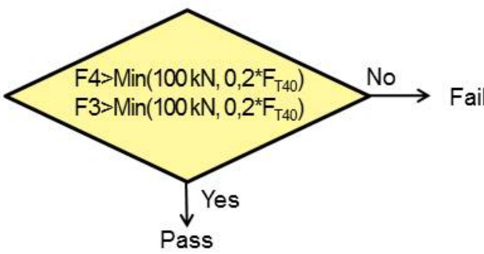
Metrics evaluation

Upgrade1 FWDB: up to 40 ms

→F3 > [MIN(100, 0.2Ft40)] AND

→F4 > [MIN(100, 0.2Ft40)]

	Megane FWDB		
	Value kN	0.2*Ft40	OK/NO
F3 > MIN[100, 0.2Ft40]	107	109	OK
F4 > MIN[100, 0.2Ft40]	188	109	OK
Global	OK		
LR [F2-70kN]	F2 = 85.3kN; LR = 15,3 kN		



Modified Metric

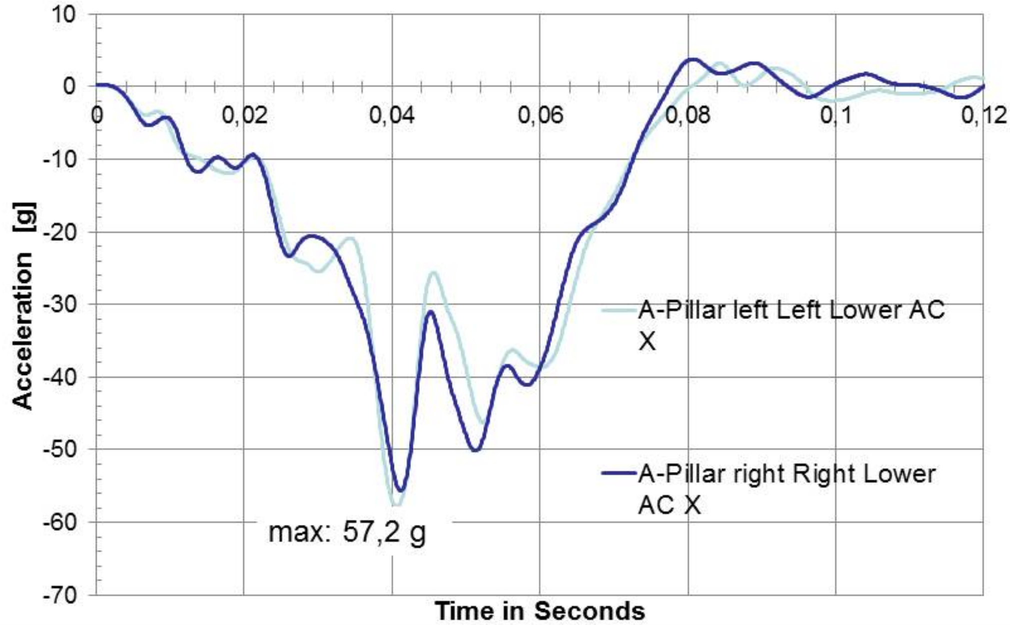
- Up to time of 40 msec
  - $F4 + F3 \geq [MIN(200, 0.4F_{T40})$ kN
  - $F4 \geq [MIN(100, 0.2F_{T40})$ kN
  - $F3 \geq [MIN((100-LR), (0.2F_{T40}-LR))$ kN
  - where:
    - F_{T40} = Maximum of total LCW force up to time of 40 msec
    - Limit Reduction (LR) = [F2-70] kN and 0 kN ≤ LR ≤ 50 kN

FIMCAR frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Plot: Vehicle acceleration (x, a pillar)



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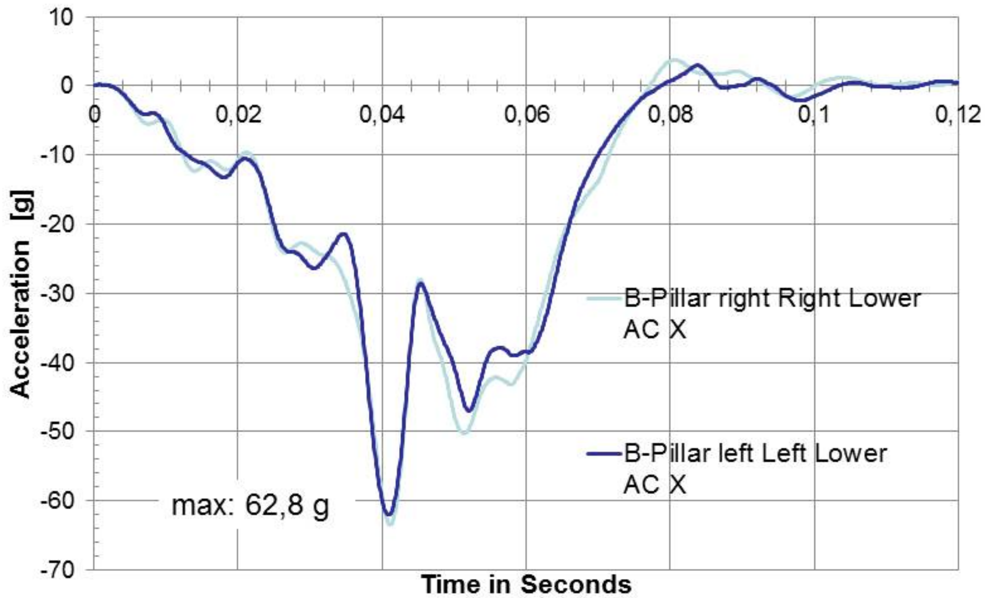
Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Plot: Vehicle acceleration (x, B-pillar)

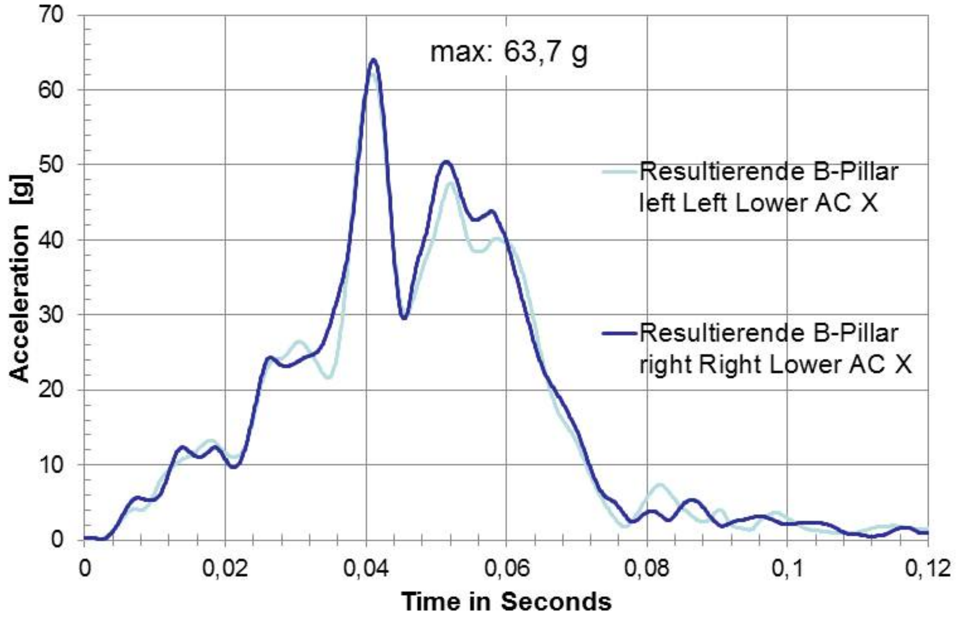


FIMCAR
frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Plot: Vehicle acceleration (Res, B-pillar)

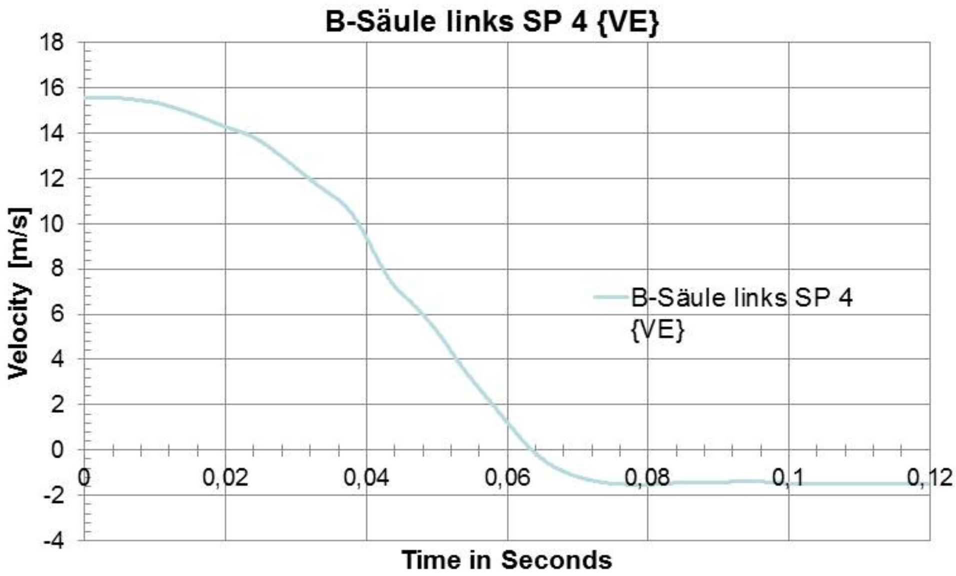


FIMCAR frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Plot: Vehicle velocity (b pillar)

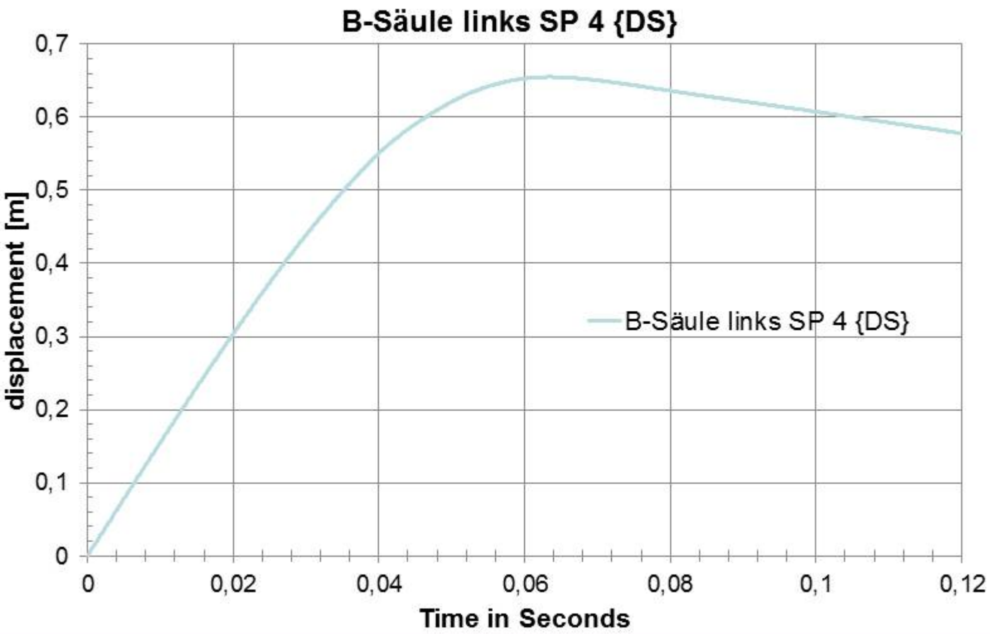


FIMCAR frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Plot: Vehicle displacement (b pillar)



FIMCAR frontal impact and compatibility assessment research

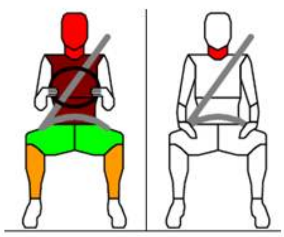
Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Dummy values FWDB Test

The restraint system was not fired!

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (HF)		
Head & Neck			0.000			0.000
Head						
HIC 36	2670.91		0.000	3069.15		
Acceleration Resultant	155.55	g		231.46	g	
3ms cumulative	142.93	g	0.000	159.32	g	
Neck						
Shear Force Fx+	0.24	kN	4.000	1.21	kN	0.000
Shear Force Fx-	-3.30	kN	0.000	-0.79	kN	0.000
Tensile Force Fz+	9.43	kN	0.000	2.66	kN	0.000
Extension My-	-86.66	Nm	0.000	-38.40	Nm	
Chest			0.915			
Deflection	-43.60	mm	0.915	-24.94	mm	
VC max	0.40	m/s	4.000	0.25	m/s	
belt at upper diagonal belt Force	4.28	kN		4.46	kN	



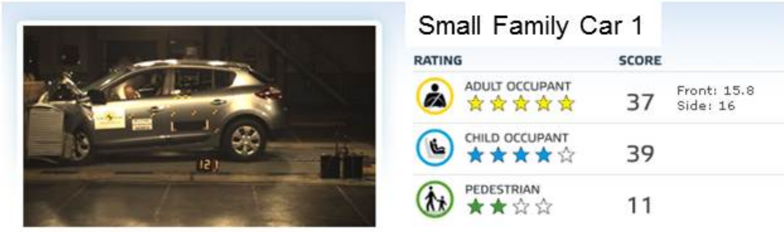
Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (HF)	
Femur & Knee			4.000		
Left					
Femur Force Fz-	-0.57	kN	4.000		
Knee Slider Displacement	-1.61	mm	4.000		
Right					
Femur Force Fz-	-2.17	kN	4.000		
Knee Slider Displacement	-5.35	mm	4.000		
Tibia			2.300		
Left					
Compression Upper Fz-	-2.81	kN	3.459	-2.37	kN
Compression Lower Fz-	-2.77	kN	3.484	-2.74	kN
Tibia Index Upper	0.72		2.598	0.94	
Tibia Index Lower	0.67		2.808	0.32	
Right					
Compression Upper Fz-	-4.12	kN	2.586	-1.80	kN
Compression Lower Fz-	-4.55	kN	2.300	-2.05	kN
Tibia Index Upper	0.76		2.398	1.50	
Tibia Index Lower	0.44		3.837	0.59	

FIMCAR frontal impact and compatibility assessment research

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SEVENTH FRAMEWORK PROGRAMME

Dummy values Euro NCAP Test



Conclusions

- Small Family Car 1 tested with 56 km/h against FWDB
- The vehicle has two load paths
  - Longitudinals which are located in row 3 and 4
  - Subframe with a crossbeam in height of row 2
- The Small Family Car 1 has its main rails slightly higher than would be ideal to meet the original metric requirements easily but because it has a lower load path the modified metric allows it to have its rails at this height and still meet the metric requirements easily
- Max vehicle acceleration: 52 g
- The restraint system was not activated during the test

Small Family Car 1, FWDB 56 km/h, FM07RMFW

SUPERMINI 2 FWDB 40 KM/H @ BAST

Supermini 2
FWDB 40 km/h
Test No. FM08F5FW

Thorsten Adolph

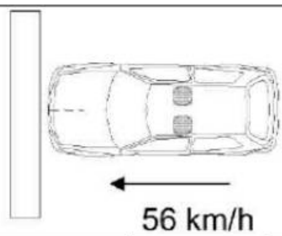
FIMCAR WP 3, 20th September 2012

FIMCAR
fron tal impact and co mpatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

FWDB Supermini 2

Test Date	07/09/2012
Location	BASt
Topic	FWDB Test
Test Number	**FM08F5FW**
Test Protocol	Draft FWDB protocol v1.doc



Vehicle 1: Brand/type	Supermini 2 (black)	Barrier:	FWDB barrier (750mm)
Impact side:	Front		
Speed:	39,96 km/h		
Overlap:	100 %	Impact accuracy	35 mm left 18 mm
Test mass:	1106 kg		
Dummy:	LHS – Hybrid III 50th RHS – Hybrid III 5th	Barrier ground clearance	80 mm
		LCW / barrier dimensions	2000 mm wide 750 mm high 300 mm deep

Test objectives:
To investigate the changes of the FWDB metric with a lower test speed
To investigate the dummy performance with a lower test speed

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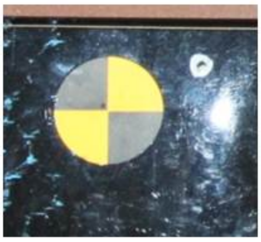
Supermini 2, FWDB 40 km/h, FM08F5FW

SEVENTH FRAMEWORK PROGRAMME

Test parameters

- **Vehicle data: Supermini 2 (Left hand drive)**
- **Vehicle identification no (VIN):**
- **Engine / Transmission: 1,2 l, manual transmission**
- **Test speed: 39,96 km/h**
- **Test weight: Front 664 kg / Rear 442 Total 1106 kg**
- **Test impact accuracy: 85 mm left, 18 mm up**

- **Test vehicle status:**
    - **Normal ride height but adjusted to previous Supermini 2 test at FIAT**



Supermini 2, FWDB 40 km/h, FM08F5FW

Ride Height

	Front		Rear	
	Left	**Right**	**Left**	**Right**
Supermini 2 BASt (50 km/h)	625	628	628	631
Supermini 2 Fiat (56 km/h)	627	628	634	636

Supermini 2, FWDB 40 km/h, FM08F5FW

Pre-test Pictures Vehicle




FIMCAR frontal impact and compatibility assessment research

Supermini 2, FWDB 40 km/h, FM08F5FW

SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures Vehicle

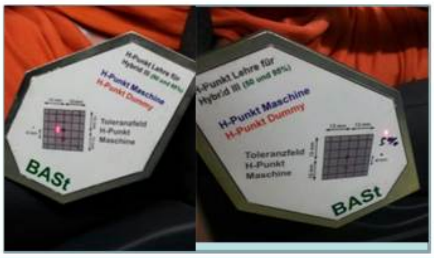


FIMCAR frontal impact and compatibility assessment research

Supermini 2, FWDB 40 km/h, FM08F5FW

SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures Dummy

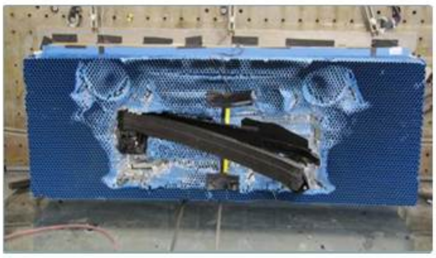


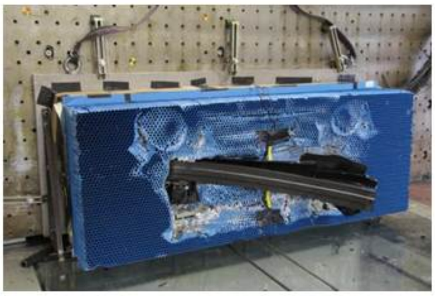
Supermini 2, FWDB 40 km/h, FM08F5FW

Post-test Pictures Vehicle Overview

Supermini 2, FWDB 40 km/h, FM08F5FW

Post-test Pictures
Barrier





Supermini 2, FWDB 40 km/h, FM08F5FW

Post-test Pictures Dummy

Supermini 2, FWDB 40 km/h, FM08F5FW

Front end structure

Dimensions [mm]	Top height	Bottom height	Width	Depth
Engine	737	167	470	263
Gear Box	370	160	372	-
PEAS	514	401	-	-

Three front load paths

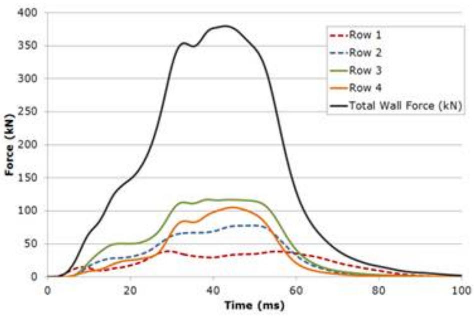
- *Upper load path: Frontend assembly/radiator support at bonnet leading edge*
- *Lower load path: Longitudinals / crush can/ bumper crossbeam → PEAS*
- *3rd load path: Sub frame/crush can/crossbeam → SEAS*
- *Vertical connection between all load paths*


Supermini 2, FWDB 40 km/h, FM08F5FW

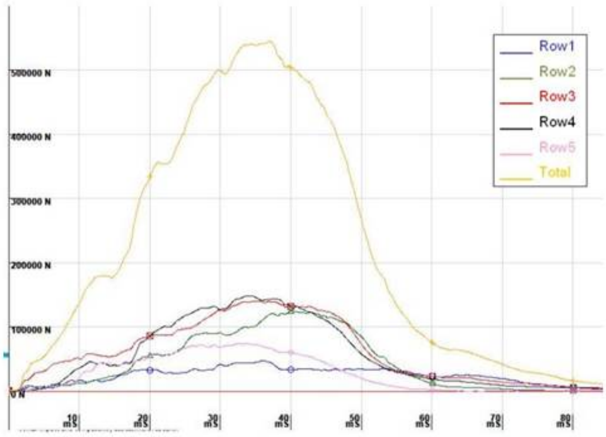
Plot: Row forces over time

40 km/h FWDB

Peak forces up to 40ms:
Total = 376kN
Row 1 = 38.8kN
Row 2 = 68.7kN
Row 3 = 117.0kN
Row 4 = 97.7kN



56 km/h FWDB



Supermini 2, FWDB 40 km/h, FM08F5FW

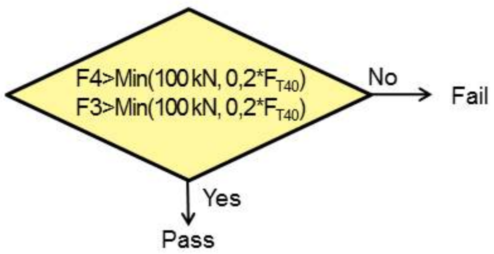
Metrics evaluation

40 km/h FWDB

	Supermini 2 40km/h		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	117	75.3	OK
F4 > MIN[100, 0.2Ft40]	97.7	75.3	OK
Global	OK		

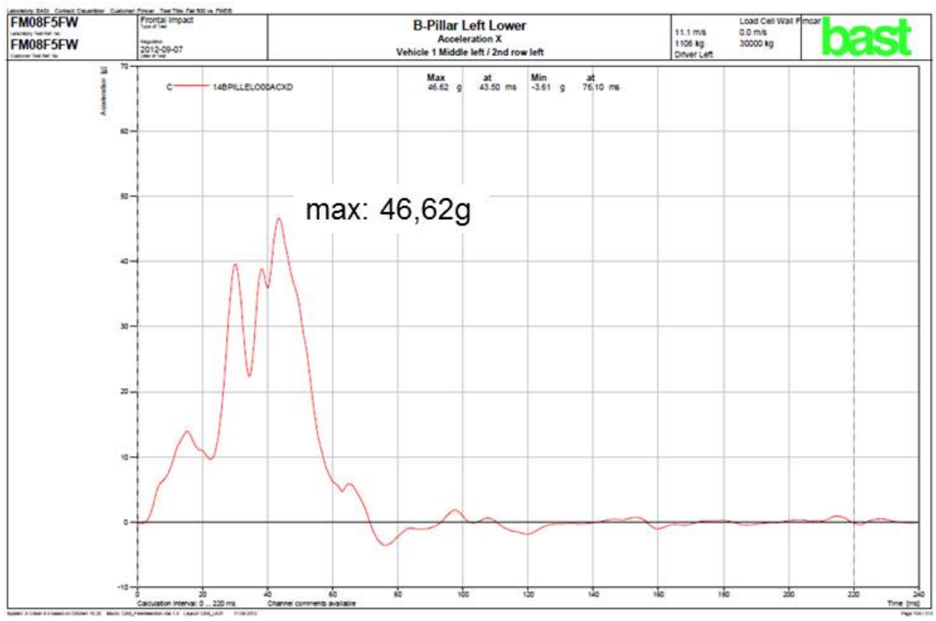
56 km/h FWDB

	Supermini 2 FWDB 56 km/h		
	Value	0.2*Ft40	OK/KO
F3 > MIN[100, 0.2Ft40]	140.1	108.7	OK
F4 > MIN[100, 0.2Ft40]	148.1	108.7	OK
Global	OK		



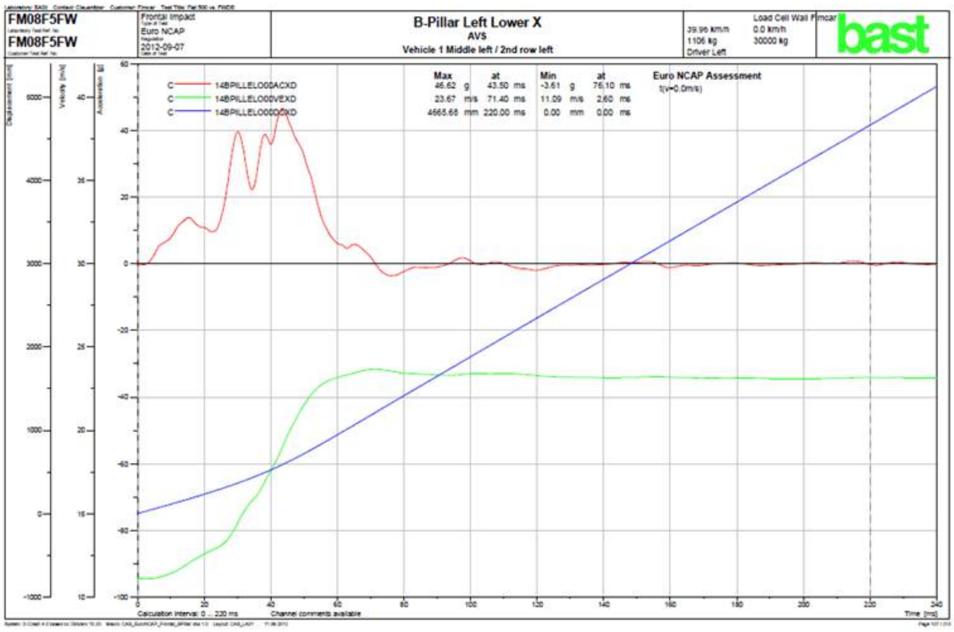
Supermini 2, FWDB 40 km/h, FM08F5FW

Plot: Vehicle acceleration (x, B-pillar)



Supermini 2, FWDB 40 km/h, FM08F5FW

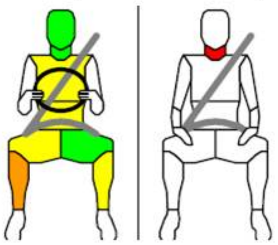
Plot: Vehicle velocity / displacement (b pillar)



Supermini 2, FWDB 40 km/h, FM08F5FW

Dummy values

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (HF)		
Head & Neck			4.000 *			0.000 *
Head						
HIC 36	718.07			1119.39		
Acceleration Resultant	76.13	g	4.000 *	88.03	g	
3ms cumulative	74.39	g		86.79	g	
Neck						
Shear Force Fx+	0.76	kN	4.000 *	0.41	kN	0.000 *
Shear Force Fx-	-0.25	kN	4.000 *	-0.41	kN	0.000 *
Tensile Force Fz+	1.28	kN	4.000 *	0.66	kN	0.000 *
Extension My-	-14.03	Nm	4.000 *	-18.28	Nm	
Chest			3.321 *			
Deflection	-26.75	mm	3.321 *	-20.51	mm	
VC max	0.16	m/s	4.000 *	0.18	m/s	
belt at upper diagonal belt Force	3.44	kN		3.63	kN	



Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (HF)	
Femur & Knee			3.657 *		
Left					
Femur Force Fz-	-0.54	kN	4.000 *		
Knee Slider Displacement	-0.14	mm	4.000 *		
Right					
Femur Force Fz-	-3.69	kN	4.000 *		
Knee Slider Displacement	-6.77	mm	3.657 *		
Tibia			2.128 *		
Left					
Compression Upper Fz-	-1.61	kN	4.000 *	-1.45	kN
Compression Lower Fz-	-1.93	kN	4.000 *	-1.72	kN
Tibia Index Upper	0.52		3.483 *	0.44	
Tibia Index Lower	0.37		4.000 *	0.65	
Right					
Compression Upper Fz-	-4.07	kN	2.618 *	-1.20	kN
Compression Lower Fz-	-4.81	kN	2.128 *	-1.56	kN
Tibia Index Upper	0.52		3.445 *	0.80	
Tibia Index Lower	0.45		3.778 *	0.72	
Sum			13.106		(0.000)

Supermini 2, FWDB 40 km/h, FM08F5FW

Dummy values Euro NCAP Test

SUMMARY   Supermini 2

Adult Occupant Rating

Frontal Driver	
Head and Neck assessment	4.00
Chest assessment	3.82
Knee, Femur and Pelvis assessment	4.00
Lower Leg, Foot and Ankle assessme	3.29
Frontal Passenger	
Head and Neck assessment	4.00
Chest assessment	3.94
Knee, Femur and Pelvis assessment	4.00
Lower Leg assessment	3.84
Door Opening	0
OVERALL FRONT	15.11

Conclusions

- High head acceleration for the 5% HIII Dummy on the passenger seat due to airbag deployment
- Higher loading of the lower extremity for the driver compared to the Euro NCAP test
- Maximum vehicle acceleration of 46 g

- Vehicle has a far forward located lower load path. However it passes the metric in the 56 km/h test.
- In this 40 km/h test the vehicle passes as well the FWDB metric even without the need of a lower limit reduction

Supermini 2, FWDB 40 km/h, FM08F5FW