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SEVENTH FRAMEWORK PROGRAMME

FIMCAR
XI – FIMCAR Final Assessment Approach

FIMCAR
frontal impact and compatibility assessment research

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EXECUTIVE SUMMARY

The objectives of the FIMCAR (Frontal Impact and Compatibility Assessment Research) project are to answer the remaining open questions identified in earlier projects (such as understanding of the advantages and disadvantages of force based metrics and barrier deformation based metrics, confirmation of specific compatibility issues such as structural interaction, investigation of force matching) and to finalise the frontal impact test procedures required to assess compatibility. Research strategies and priorities were based on earlier research programs and the FIMCAR accident data analysis. The identified real world safety issues were used to develop a list of compatibility characteristics which were then prioritised within the consortium. This list was the basis for evaluating the different test candidates. This analysis resulted in the combination of the Full Width Deformable Barrier test (FWDB) with compatibility metrics and the existing Offset Deformable Barrier (ODB) as described in UN-ECE Regulation 94 with additional cabin integrity requirement as being proposed as the FIMCAR assessment approach.

The proposed frontal impact assessment approach addresses many of the issues identified by the FIMCAR consortium but not all frontal impact and compatibility issues could be addressed.

1 INTRODUCTION

1.1 FIMCAR Project

To improve real life f vehicle safety in frontal collisions, the compatibility (described by the self and partner-protection level) between the opponents is crucial. Although compatibility has been analysed worldwide for years, no final assessment approach was defined. Taking into account the EEVC WG15 and the FP5 VC-COMPAT project activities, two test approaches are the most promising candidates for the assessment of compatibility. Both are composed of an off-set and a full overlap test procedure. However, no final decision was taken. In addition, another procedure (tests with a moving deformable barrier) is under discussion in today's research programmes.

Within the FIMCAR project, different off-set, full overlap and MDB test procedures will be analysed to be able to propose a compatibility assessment approach, which will 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 consortium and to disseminate the project results 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 describe the testing and assessment procedures for a frontal impact and compatibility test procedure. The deliverable describes the procedures and criteria used to evaluate the different candidate procedure. A summary of the technical results is provided but references to critical technical documents are also identified for further review.

1.3 Structure of this Deliverable

The deliverable is divided into the first chapters describing the decision process and the selection criteria for the different assessment procedure that should be combined into the FIMCAR assessment approach. The advantages and disadvantages of the different candidates and the justification for the FIMCAR decisions are also presented Following this, the FIMCAR assessment approach is presented in an ECE like document, which can be used as a first draft for rule making.

2 BACKGROUND

Passive safety in frontal impacts has been addressed through different regulation and consumer testing in the world. Regulation 94 and Euro NCAP in Europe; FMVSS 208, USNCAP and IIHS in the US; TRIAS-47 and JNCAP in Japan are some of the best known examples internationally. All tests evaluate the passive safety of a vehicle in a fixed barrier configuration but do not consider collisions with another vehicle that has different structural and mass properties. This issue has been investigated by many research groups but, to date, no combined partner and self protection assessment procedure has been developed and validated in Europe, Asia, or North America.

Crash compatibility sometimes is a compromise between self and partner protection and it is important to not sacrifice one for the sake of the other. Compatibility will be used in the following document as a concept that is a combination of both self and partner protection. Individual compatibility characteristics are identified that address only one aspect of frontal impacts i.e. self or partner protection. The test procedures presented in this deliverable may address one or more of these characteristics.

2.1 Previous Research

Compatibility research is globally distributed with the research activities taking place predominantly in US, Japan and Europe. In all these areas, the activities are distributed between industry and government funded research activities. Different test methods have been investigated in the different regions but the global consensus in the IHRA compatibility working group [O'Reilly 2003] was that both an off-set and a full width test are needed to fully assess compatibility and frontal protection performance. Each region has unique compatibility issues related to their respective traffic fleets, but similar strategies and approaches can be observed. Consistent with the need to address both full width and off-set test configurations for compatibility testing, a number of alternatives are available for further development. An overview of the activities previous to FIMCAR is provided below.

2.1.1 Europe

European compatibility research has been undertaken at various research centres but the most significant activities have been coordinated by or reported to the EEVC WG15 (European Enhanced Vehicle Safety Committee Working Group on Car Crash Compatibility and Frontal Impact). This working group finished a mandate to investigate the test procedures needed to assess crash compatibility [Faerber 2007]. The working group results confirm that improving compatibility will have positive cost benefit results for Europe. Test methods to detect and assess compatibility were investigated with a focus on developing structural interaction assessments. The difficulty in defining an objective test approach for structural interaction was encountered by the working group. A list of open questions was developed by the working group identifying the next steps needed to finalise compatibility test approaches.

One recent activity to note is the development of a moving deformable barrier test using a deformable element. This test method has been put forward by many researchers in Europe, USA, and Japan as a long term solution to compatibility and has been reported previously [Summers 2002, Seyer 2003, Versmissen 2006].

2.1.2 USA

Compatibility issues in the US are dominated by LTV/SUV impacts with smaller passenger cars. The most noteworthy development has been the industry voluntary commitment (coordinated through the Alliance of Automobile Manufacturers) [Auto Alliance 2003] to provide overlapping structures in frontal impacts, particularly in LTV to passenger car impacts. The commitment was initiated in 2003 and required 100% compliance for vehicle geometric designs by 2009. Parallel to the geometric requirement for structures, research into the parameters controlling compatibility has been investigated, including physical test requirements. One of the test methods under investigation is the high resolution load cell barrier that measures the force distribution over the vehicle front during a full width barrier test. This test approach is also under investigation by NHTSA and metrics such as the Average Height of Force (AHOF), Initial Stiffness (Ks), and Work Stiffness (Kw) have been derived from this type of test data and correlated to real world crashes [Summers 2005]. The US stakeholders have focussed their research efforts on the full width rigid barrier because it is the foundation of its frontal impact regulation. Most full width tests and analyses in the US have been for rigid barrier face.

Further work in frontal compatibility testing has been proposed in the Auto Alliance expert working group. The implementation of a moving deformable barrier for frontal crash testing had been investigated since the 1990's and has now been reviewed as method to control the frontal force levels in vehicles as well as addressing structural interaction. Further developments of this MDB have not been reported since 2008 although an application of a MDB for small overlap conditions has been under development [Saunders 2012].

2.1.3 Japan

The Japanese vehicle fleet, similar to Europe, is not characterised by a large LTV/SUV population that is found in the US. However, a particular difference in the Japanese and European vehicle fleet is the presence of so called mini cars in Japan that are designed to offer maximum internal space for a limited vehicle length. These cars normally have their bumper directly in front of the engine and do not incorporate any kind of crush can in the design because repair tests i.e. the RCAR bumper test, are not applicable. Legislative and consumer tests in Japan are based on the Full Width Rigid Barrier test and the recent adoption of the R94 offset test. The Japan Automobile Research Institute (JARI) as well as Honda has presented recent investigations of the use of load cell wall data as a method to assess compatibility. Alternative test approaches (with or without deformable honeycomb barriers) have been assessed and compared to car-to-car tests.

The Japanese automobile industry has investigated different testing or evaluation approaches. Toyota has researched the moving deformable barrier test for frontal impacts, partly in conjunction with the US industry research activities, and has developed a specific deformable element more complex than the EEVC (current ECE R94 barrier face) or PDB barrier element. Analysis of load cell wall data from a full width test has also been proposed [Yonezawa 2011].

2.1.4 Objectives for FIMCAR

The FIMCAR project was designed to investigate the possibility of combining different configurations to assess compatibility. These tests are the Full Width Rigid Barrier (FWRB), Full Width Deformable Barrier (FWDB), Offset Deformable Barrier (ODB), Progressive Deformable

Barrier (PDB) and a Mobile Deformable Barrier (MDB). A general description of the available test procedures are provided below. The reader is referred to [Adolph 2012] for detailed descriptions of each of the candidate test procedures.

- Full width load cell barrier tests: The test is effectively a modification of the US FMVSS-208 full width test used for the assessment of self protection. The test is modified by the addition of a high resolution Load Cell Wall. The test should control both partner and self protection. For partner protection, the car's structural interaction potential will be assessed using the measurements from the LCW. Configurations of the test, with and without a deformable honeycomb element are being examined by different research communities. The test configuration is focused on the measurement of structural interaction as well as introducing a high overlap, high deceleration to assess occupant restraint systems.
- Off-set barrier tests: The current off-set test approaches, most common in vehicle testing, are used in the European frontal directive (96/79/EC) and in consumer tests like Euro NCAP. These consist of an impact into a honeycomb barrier (EEVC barrier) with a 40% overlap. There are no current activities investigating the use of this test configuration for measuring structural interaction, but frontal force levels have been measured using a load cell wall mounted behind the deformable element and was investigated previously [Edwards 2007]. Another off-set test procedure – the Progressive Deformable Barrier (PDB) – has been investigated for structural interaction and frontal force level assessment. This 50% off-set test condition measures the deformation of the honeycomb barrier after the test. The PDB honeycomb is stiffer than the EEVC barrier and becomes progressively stiffer with increased deformation. The barrier deformation is used to analyse the structural interaction and force levels of the tested vehicle.
- Moving Deformable Barrier Tests: A frontal impact test using a deformable barrier element mounted on a moving trolley has been investigated, primarily to assess and control frontal force levels. In fixed barrier tests like the full width and off-set tests, the initial kinetic energy of the test vehicle must be absorbed in the deformation of the vehicle and the barrier. In a moving barrier test, the kinetic energy and momentum are distributed between the vehicles depending on the vehicle mass. This allows the test to evaluate vehicles for different conditions depending on their mass.

Based on previous research work towards compatibility (e.g., EUCAR Compatibility project [Zobel 2001], EEVC WG15 [Faerber 2007], VC-COMPAT [Edwards 2007] and other international and national research projects and working groups), the main issues for improving compatibility are:

- Structural interaction
- Global force level matching
- Compartment strength and stability

The two most challenging compatibility issues were those of *structural interaction* and *global force matching.* Structural interaction describes how the contact forces are distributed across collision partners and the stability of the crash response. Good structural interaction is not commonly found in modern vehicles due the differences in vehicle sizes and crashworthiness designs. Poor structural interaction leads to phenomena such as over/underride or fork effect which in turn lead to undesirable deformation and intrusion of the occupant compartment. Frontal force level matching is desirable to ensure that crash energy is appropriately shared between collision partners. Current international consumer and regulation test methods cause frontal crush forces to be mass dependent and require heavier vehicles to be stiffer than lighter vehicles. Earlier studies found this disparity in vehicle force levels caused heavier vehicles to over-crush lighter vehicles and again produce undesired occupant compartment deformations. The two compatibility characteristics described above require a *strong and stable occupant compartment* to support energy absorption in frontal structures.

One explanation for the lack of progress in compatibility can be the terminology and individual definitions used when discussing compatibility. An improved and more detailed description of compatibility characteristics is a key point to base any research project that addresses compatibility. For example, structural interaction can likely be divided into different sub areas dealing with geometrical placements of structures or the way structures are internally distributing loads in the car. Until a terminology is commonly agreed on, there will be difficulty to design and evaluate a test approach with a general description like structural interaction.

The FIMCAR project worked with two main research activities. One was to develop an evaluation strategy for selecting some combination of suitable test configurations and the second was the technical development activities of specific test candidates. The first activity required terminology, priorities and selection criteria. The second involved crash testing, computer simulation, and data processing to develop the test procedures as well as assessment criteria and performance limits. The remainder of the deliverable will address the evaluation strategy. Adolph et al. [Adolph 2012] summarised all the technical research activities for the test methods. Full documentation of the technical developments for each test configuration are reported in FIMCAR Deliverables D2.2 [Lazaro 2013] (offset test), D3.2 [Adolph 2013/2] (full width test) and D4.2 [Versmissen 2013] (moving deformable barrier test).

2.2 Terminology

From a review of previous research, such as the EEVC WG15 [Faerber 2007], VC-COMPAT project [Edwards 2007], and IHRA [O'Reilly 2003] and additional accident analysis [Seyer 2003], FIMCAR members have established and defined a list of issues that describe the challenges in vehicle crashworthiness. The consortium agreed that:

- compatibility consists of self and partner protection.
- improved compatibility will decrease the injury risks for occupants in single and multiple vehicle accidents.
- compatible vehicles will deform in a stable manner allowing the deformation zones to be exploited even when different vehicle sizes and masses are involved

It is important to separate the physical test process from the assessment of the test results for a test configuration. The assessment of compatibility comes when a combination of test configurations and assessment procedures are used to evaluate vehicle performance. The following definitions were developed within FIMCAR to address technical test developments:

- The *test procedure* specifies the test protocol which includes the barrier face, test speed, overlap etc. That means that the test procedure is also a description of how the test is executed.
- The *assessment procedure* includes the test procedure and the definition of the compatibility metrics. The signal processing requirements and performance criteria are identified.

- The *assessment approach* is then the final combination of the assessment procedures that should evaluate the total safety performance of a vehicle for partner and self protection issues.

In order to address compatibility, a detailed list of compatibility characteristics were identified and prioritised by the consortium. The priorities and test selection approach are presented in the next chapter.

3 FIMCAR ASSESSMENT PROCEDURE SELECTION APPROACH

A frontal impact and compatibility description and prioritisation approach was started early in the FIMCAR project. The issues were divided into 4 main groups: Structural Interaction, Compartment Strength, Frontend Force / Deformation, Deceleration Pulse and Restraint System Assessment. These groupings were further broken down into sub groups to focus the test candidate development. The items listed in Figure 3.1 could be identified in previous research activities. Some of the subtopics could be identified as self protection or partner protection issues and the main idea was to provide a comprehensive description of all frontal impact issues. In brief:

- Structural Interaction describes how the structures of a vehicle deform at the local level when interacting with a collision partner. To achieve good structural interaction there must be some type of *structural alignment* which requires that there are corresponding structures in each collision partner that are geometrically and structurally capable of interacting with the opponents main crash structures. It is preferable that this alignment occurs as early as possible in the crash to maximise the energy absorption and ridedown characteristics for the occupant. As it is not possible to achieve good structural alignment for all possible collision types and collision partners, it is desirable to have good *horizontal and vertical load spreading* so that a robust and stable deformation of all structures can be facilitated.
- Compartment Strength is important to ensure the passenger compartment is free of intrusions and that the frontal energy absorbing structures have a stable reaction base. All vehicles must exhibit good compartment *integrity in single vehicle collisions* such as crashes into objects and HGV. Smaller vehicles have extra risks when colliding with heavier vehicles and one can identify the need for some vehicles to have higher requirements for compartment *integrity for self protection in vehicle-to-vehicle collisions.*
- Front End Force/Deformation Characteristics have two complementary functions depending on the vehicle mass. There is a clear relationship between vehicle deformation forces and vehicle size and there is an interest to control the *deformation forces in frontal structures* when different vehicles collide. Although difficult to guarantee, it is important to not create situations where one vehicle is too stiff and over-crushes a partner vehicle and exploits the energy absorption of the partner vehicle before its own energy absorption processes begins. Similarly it is not desirable to create a vehicle that does not deform in, for example, a single vehicle impact. Insufficient *energy absorption management* will produce vehicles that do not suitably protect an occupant. One can view deformation forces in frontal structures as a means to ensure partner protection and energy absorption management as a self protection issue.
- Deceleration Pulse and Restraint System issues are important parts of a vehicle safety assessment. It is desirable to evaluate the *sensing system for deployable systems* to different crash pulses and deformation patterns to avoid single point optimisation of safety performance. There should also be sufficient *capacity of restraint system* so that an occupant is protected for a high severity impact that could be foreseen. An additional point that is interesting to investigate (but may be difficult to implement as a regulation) is the *evaluation of occupant safety in a partner vehicle.*

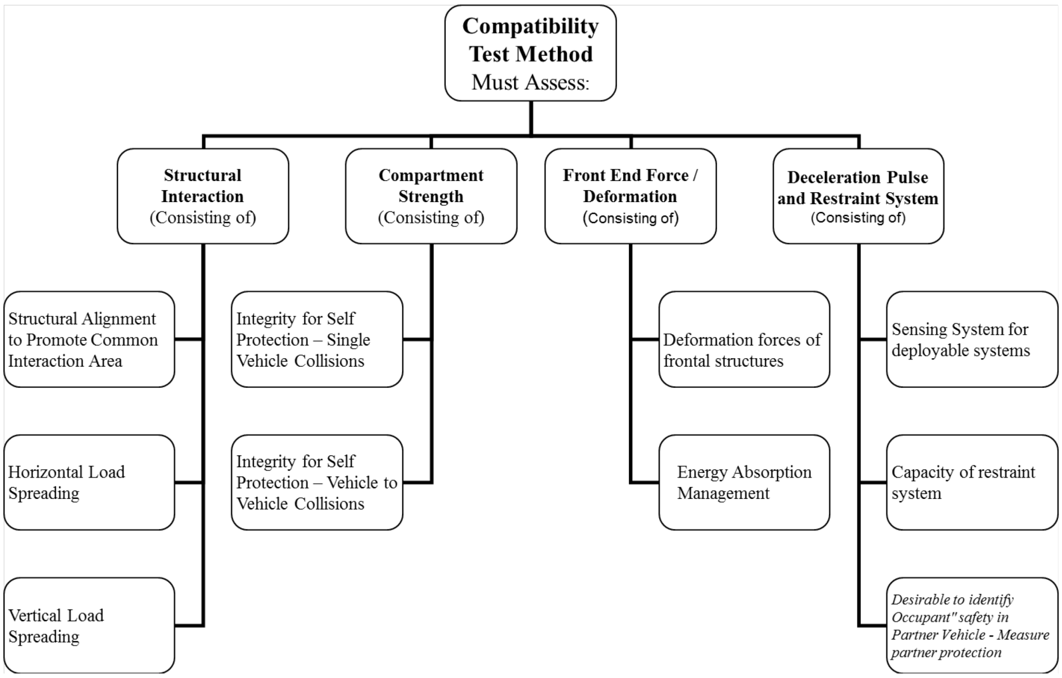

Figure 3.1: Original compatibility characteristics.

3.1 Priorities and Selection Criteria

The main sources for establishing the priorities and selection criteria were the FIMCAR accident analysis analysing frontal impact accidents of UN-ECE Regulation 94 compliant cars (FIMCAR deliverable D1.1 [Thompson 2013]) and the experts present in the FIMCAR meetings. Some of the relevant observations from D1.1 were:

- Poor structural interaction was observed to be a problem in the current vehicle fleet. The dominant structural interaction problems in car-to-car impacts are over/underriding of car fronts and low overlap. However, fork effect is seen more in car-to-object impacts because of impacts with narrow objects.
- In a matched pair analysis of car-to-car impacts, a relationship was found between mass ratio and driver injury severity, namely the higher the mass ratio the higher the driver injury severity (note: mass ratio above 1 means that the partner vehicle is heavier). However, no such relationship was found between mass ratio and compartment strength issues in the limited data available.
- Compartment strength is a particular problem in collisions with HGVs and objects, with these collisions having a high proportion of fatal and MAIS 2+ injuries
- AIS 2+ injuries resulting from deceleration loading of the occupant by the restraint system are present in a significant proportion of frontal crashes, regardless of whether intrusion was present or not.
- High proportion of fatal and MAIS 2+ injuries occur in cases with high overlap (>75%)

The last point reinforced the need for a test condition that requires a vehicle safety system (comprising the frontal structural and occupant restraint system) to withstand a high deceleration, large overlap condition that is not addressed by the current UN-ECE Regulation 94 requirements. Based on the information in Figure 3.1 and D1.1, an updated list of critical compatibility requirements could be developed. In addition, the top level issues described in Figure 3.1 could be reviewed and prioritised in the format shown in Table 1.

Table 1: Main compatibility topics and associated priorities.

	Assessment requirements							
	Structural Interaction		Front End Force / Deformation (Consisting of)		Compartment integrity		Restraint system	
	Alignment	Load Spreading (Load paths / connections)	Deformation forces of frontal structures	Energy Absorption Management	Sufficient for single vehicle accident	Enhanced for light vehicles in vehicle to vehicle accident	(Assess over range of pulses)	Test Restraint Capacity
Priorities For FIMCAR	1	1	2	1	1	2	1	1

Priority 1 items are those that the consortium identified as important for FIMCAR to resolve within the project while Priority 2 items were important but deemed not critical to resolve during the project duration. The most interesting points to note were that the *Deformation forces of frontal structures issues* and issues related to *enhanced compartment strength for light vehicles in vehicle-to-vehicle accident situations* were not a high priority for FIMCAR. This is due to the second bullet point from summary of the FIMCAR accident analysis mentioned above where smaller cars were not found to have a higher risk of intrusion than heavier vehicles. Although this was a conclusion in earlier studies [Faerber 2007], evolution of vehicle safety is resulting in stronger vehicle compartments. As lighter vehicles were not found to have a higher risk of compartment intrusions, even for heavier crash partners, frontal force differences between vehicles were not as critical as perceived earlier. This is a conclusion from a limited dataset and it should be noted that there is still a higher injury risk for small vehicle occupants in car-to-car crashes. Further work is needed to make definitive conclusions but the injury risk for small vehicles seems to now be more related to the higher delta-v a small car experiences rather than its structural capacity.

Project discussions of the accident analysis and compatibility requirements and priorities led to a ranking of priority 1 and priority 2 issues that were evaluated in the project, presented in Table 1.

Table 2: Evaluation criteria and associated priorities.

Priority 1

1 A common interaction zone defined as 406-508 mm (based on US Part 581 zone)
2 Initial Loading of barrier is evaluated above and below 457 mm
3 Vertical Load spreading evaluated in Part 581 zone
4 Vertical Load spreading evaluated between 180 and 406 mm above ground
6 Horizontal load spreading between longitudinal members
8 Current compartment strength requirements maintained
9 Appropriate severity levels for occupant protection
11 Field Relevant pulses in the tests
14 Monitor crash pulses from all test configurations
15 Acceptable Repeatability/Reproducibility performance
16 Appropriate pass/fail thresholds
17 No step effects in metrics
18a) Good cars as rated good
18b) Poor cars as rated poor
19 Detection of vehicle architecture

Priority 2

5 Vertical load spreading above 508 mm
7 Horizontal load spreading beyond longitudinal members
10 Address mass dependent injury risk
12 Two different pulses for restraint system triggering
13 Two different pulses for restraint system capacity

The issues in Table 2 became the basis for evaluating the different full-width and offset test procedures and to see which combination of test and assessment procedures can provide a complete assessment approach for frontal impact and compatibility. The different load cases created in the full-width and offset test configurations facilitates the evaluation of different compatibility characteristics. The potential for each test method is illustrated in Figure 3.2. The benefits and limitations of the different test procedures are apparent and, more importantly, the inability of a single test procedure to fulfil all 15 priority 1 requirements. The main weakness of the offset tests is the ability to assess structural alignment in the beginning of a crash (Item 2) while the full width tests do not suitably assess compartment strength (Item 8).

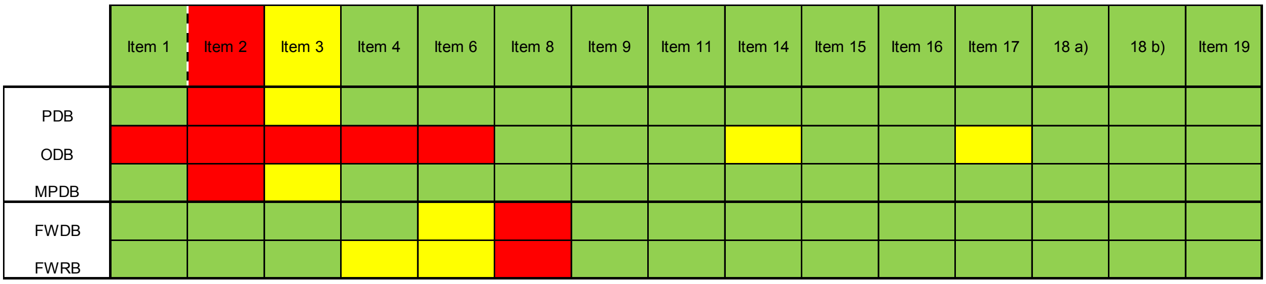

Figure 3.2: Potential of test procedures.

3.2 Evaluation Process

The list of criteria in Table 2 provided a basis for an objective comparison of the test procedures. The technical development of each test and assessment procedure was documented for each of the items. The methods for assessing each criterion varied and were essentially confirmation (yes/no), engineering documentation (data presentation) or assessment with reference vehicles with known properties. The latter case was critical as no single vehicle can be identified as fulfilling all compatibility requirements, but vehicles could be identified with established properties for one or more compatibility characteristic. Lists of physical or numerical vehicle models were developed to document performance in terms of bumper cross beam stiffness, presence of lower load paths, and global performance. Experience in the VC-Compat project [Edwards 2007] suggested that vehicles exhibit a combination of different compatibility characteristics, but specific issues could be isolated in car-to-car tests.

Data from each of the test development work packages in FIMCAR were summarised in a table format based on the items listed in Table 2 but only the Priority 1 issues were addressed in the evaluation conducted in Month 26 of the project. As expected, there was no single test method that could satisfy all the issues and a combination of test procedures was necessary. As a result, the selection of an assessment approach could be separated into two independent evaluations – one for the full width and one for the offset test configurations.

4 RESULTS: FULL WIDTH TEST PROCEDURE

The selection of a full width test procedure was difficult as the 2 candidates each had unique advantages and disadvantages but neither was clearly superior to the other. A list of each test method's advantages were listed in FIMCAR D3.1 [Adolph 2013/1] and are presented in Table 3:

Table 3: Advantages of different full width tests.

FWDB	FWRB
• More representative of real world accident especially in initial stage of impact. • More representative for initial deceleration of vehicle and loading of main rails which is important for sensing of crash for restraint system triggering. • Engine dump loading attenuated, making assessment of vehicle structures that are relevant to crash that are loaded later in the impact, i.e. an assessment can be made of the vehicle's main rails as opposed to its crush cans. • Results in more realistic deformation pattern of the front structure following to shear forces which are not applicable in FWRB • Can detect SEAS structures, so no need for supplementary test, e.g. ORB. • Possibly can assess horizontal structures (bumper beams).	• Effectively already de-facto worldwide standard test so hence would be easier to introduce from harmonisation point of view. • LCW measures vehicle forces directly, i.e. not filtered by deformable element. • No problems with stability of deformable face or possibility of load spreading by deformable face. • More test data available for development of metric

The full width rigid and full width deformable barrier both provide a hard pulse for the occupant and use similar test instrumentation. The main difference is the time window available for assessing vehicle structures. A rigid barrier may only allow a short assessment duration before the engine contacts the load cell wall and begins to mask the structural forces with high contact loads. The deformable barrier face attenuates the engine contact and allows for a longer evaluation period before the engine contact loads mask the structural forces. The technical advantage for assessing structural alignment was for the FWDB while the FWRB offers easier global harmonisation and potentially less test variability due to additional honeycomb materials.

The results of the initial evaluation of the full width procedures are shown in Table 4. The colour coding is used to identify good (green), possible but not confirmed (yellow), not possible (red) and not applicable (blue). Although quite similar, the FWDB had fewer yellow scores than the FWRB and a stronger metric for evaluating the initial structural alignment of main structures. The main weakness of the FWRB was the short time window for analysis.For some vehicles, there was less than 6 ms of data available for assessing the main crash structures. This short time interval would only allow analysis of the bumper and crash boxes but not necessarily the main longitudinals. There appeared to be a risk that vehicles with a bumper that is cantilevered below the longitudinals would be assessed positively even though some evidence suggests this is not a preferred design [Edwards 2007].

Table 4: Evaluation of full width test procedures.

Evaluation Topics *	Description	Full Width Rigid Barrier	Full Width Deformable Barrier
Item 1	Common interaction zone defined as 406-508 mm	Common Interaction zone included in Assessment area 330 mm to 580 mm	Common Interaction zone included in Assessment area 330 mm to 580 mm
Item 2	Initial loading of barrier is evaluated above and below 457 mm	Assessment area evaluates forces above and below 455 mm	Assessment area evaluates forces above and below 455 mm
Item 3	Vertical load spreading evaluated in Part 581	Assessment area evaluates forces above and below 455 mm, criteria for minimum loads above and below centerline	Assessment area evaluates forces above and below 455 mm, criteria for minimum loads above and below centreline
Item 4	Vertical load spreading evaluated between 180 and 406 mm	Additional loads in Row 1&2 can be used in assessment, load path not well detected	Additional loads in Row 1&2 can be used in assessment, load path better detected
Item 6	Horizontal load spreading between longitudinal members	No repeatable metric developed	No repeatable metric developed
Item 8	Current Compartment strength requirements maintained	FW test is an additional test to offset test, not intended for compartment strength	FW test is an additional test to offset test, not intended for compartment strength
Item 9	Appropriate severity level for occupant protection (Delta V)	AIS curves from GIDAS has identified test severity as Delta V 53km/h, proposed test speed 50 km/h	AIS curves from GIDAS has identified test severity as Delta V 53 km/h, proposed initial test speed 50 km/h
Item 11	Field relevant pulse	Overlap greater than 75% second most common impact for fatal and serious injury	Overlap greater than 75% second most common impact for fatal and serious injury
Item 14	Monitor pulses in WP2,3,4	Test data available, ongoing	Test data available, ongoing
Item 15	Repeatability/Reproducibility	Test vehicle selected, testing ongoing, previous data with 2 vehicles, Japanese data available for repeatability	Test vehicle selected, testing ongoing, previous data with 2 vehicles
Item 16	Appropriate pass/fail thresholds	Test thresholds proposed, validation work needed	Test thresholds proposed, validation work needed
Item 17	Check for step effects in metrics	Impact accuracy can control some issues, work ongoing	Impact accuracy can control some issues with load cell size, honeycomb effects should be further evaluated, ongoing
Item 19	Detection of vehicle architecture/loadpaths	Load paths detected in Common Interaction Zone, can assess loads in Row 1&2	Load paths detected in Common Interaction Zone, can potentially assess loads of more rear structures in Row 1&2

The last point in Table 4 was important in the decision to choose a FWRB or a FWDB. The FWRB is able to directly measure the structural loads from the vehicle as there is no honeycomb filtering the forces. However the FWRB could not assess loads in Rows 1&2 as the relevant structures do not load the barrier until later in the impact [Adolph 2013/2].

There has been suggestions to modify the FWRB with an override barrier (ORB) when assessing higher vehicle structures such as SUVs [Patel 2009], but initial FIMCAR data suggests that it may be possible to assess the SEAS that are beneficial for car-to-car collisions by using the FWDB. The GRSP Informal Group on Frontal Impact also advised that additional test requirements were not desirable, even if the test only required for some vehicles.

After the initial evaluation of the test procedures, the consortium selected the full width deformable barrier as the most promising test candidate. There were different metrics available that had exhibited promising results. The outstanding issues that needed to be resolved were the selection and validation of the final assessment metric, criteria for occupant injury, and the test speed. Once this was established, the integration with the offset test was required.

5 RESULTS: OFFSET TEST PROCEDURE

Initial discussions in the FIMCAR project suggested that the existing ODB in UN-ECE Regulation 94 was not capable of evaluating the partner protection characteristics in a vehicle. The PDB and MPDB became the preferred offset test procedures for further development as it was anticipated that a metric for assessing the load spreading capabilities of a vehicle would be developed during the project. There have also been significant discussions on the ability of the PDB to provide a sufficiently severe test condition for all vehicle masses [UNECE 2007].

At the time of the evaluation of the different test candidates, details of the PDB and MPDB testing and simulation activities to assess compatibility characteristics were presented in FIMCAR deliverable D2.1 [Lazaro 2013] and D4.2 [Versmissen 2013]. The results of the offset test candidates are shown in Table 5. There were clear issues with the metrics being developed for the PDB and, at the time of evaluation, no robust metrics were available for the group. The test criteria proposed for assessing load spreading were based on complicated mathematical concepts and involved quantifying iso-curves for barrier deformations. There were discontinuities when the iso-curves crossed the assessment boundaries and this introduced step effects that were not consistent when applied to different vehicles. An additional issue regarding the test severity for heavier vehicles arose for the PDB and, at the time of evaluation, the comparison of test severity for identical vehicles for PDB and ODB tests could not be presented.

Even though the ODB provides no potential for partner protection or load spreading compatibility issues, it was able to maintain the current level of self protection for vehicles. The ODB complemented a FW test in terms of fulfilling the compatibility characteristics that were identified in the project. Unfortunately the lack of a horizontal load spreading criteria in the ODB and FW test resulted in one Priority 1 issue not being fulfilled. Given the time available and the uncertainty to produce a PDB metric, the ODB barrier was chosen as the test method to evaluate self protection and maintain compartment strength in single vehicle collisions. There was no perceived benefit for introducing a new offset test procedure without the guarantee of additional developing an assessment criterion for compatibility within the FIMCAR project. The PDB and MPDB were thus not proposed as the offset test configuration.

Subsequent to the FIMCAR evaluation meeting in Month 28, a supplementary assessment of potential PDB metrics was held. This meeting identified new metrics that were promising for horizontal load spreading but were recognised as not being possible to finalise within the FIMCAR project. Given that the existing ODB criteria would require little if any modification during the FIMCAR project, modest resources were directed to further developing the PDB metric for use by future compatibility researchers after the FIMCAR project.

Table 5: Evaluation of offset tests

Evaluation Topics *	Description	PDB Barrier	ODB	Moving Barrier
Item 1	Common interaction zone defined as 406-508 mm	Common Interaction zone included in a larger assessment area 350-600 mm	No measurement in part 581, bumper element can distort loading	As PDB
Item 2	Initial loading of barrier is evaluated above and below 457 mm	Load path is detected in area above and below 457 mm, specific distribution within zone is not conducted at present, PDB cannot assess initial loading	No measurement in part 581, bumper element can distort loading	As PDB
Item 3	Vertical load spreading evaluated in Part 581	Vertical load spreading is not currently evaluated within part 581 but over larger area (350-600 mm)	No measurement in part 581, bumper element can distort loading	As PDB
Item 4	Vertical load spreading evaluated between 180 and 406 mm	Load path detected in area 180-350 mm using corridors, distribution of load path assessed	Load cell behind honeycomb available, no metric proposed	As PDB
Item 6	Horizontal load spreading between longitudinal members	Horizontal load spreading to be assessed with TV values, results of metric partially confirmed	Bumper element will distort horizontal load spreading	As PDB
Item 8	Current compartment strength requirements maintained	Missing data for heavy vehicles	Current standard	Data presented for MPDB shows suitable levels for smaller vehicles. Heavier vehicles will need a different test severity to maintain current levels
Item 9	Appropriate severity level for occupant protection (Delta V)	N/A	N/A	N/A
Item 11	Field relevant pulse	Offset test configuration addresses most relevant real world case (25-75%)	Offset test configuration addresses most relevant real world case (25-75%)	As PDB
Item 14	Monitor pulses in WP2,3,4	Test data available, ongoing	Limited R94 data available, Euro NCAP available	Test data available, ongoing
Item 15	Repeatability/Reproduci-bility	Earlier test data showed no significant issues. Tests planned to address issue, Need to provide detailed barrier handling and scanning procedures	Repeatable self protection evaluation	As PDB, slightly better results
Item 16	Appropriate pass/fail thresholds	Pass fail approach developed, further validation data needed	Current regulation, chest injury evaluation for women and elderly desirable	Pass fail approach developed, further validation data needed
Item 17	Check for step effects in metrics	Assessment criteria are sensitive to boundaries	Body modifier is yes or no	As PDB
Item 19	Detection of vehicle architecture/loadpaths	Detection of load paths possible with percentile evaluation of deformation	Barrier deformations not possible. Load cell data available	As PDB

6 FINAL DEVELOPMENT OF TEST PROCEDURES

6.1 Full Width Test

After selection of the Full Width Deformable Barrier in the FIMCAR assessment approach, further work was needed to finalise the structural alignment metric, confirm a test speed, report the repeatability and reproducibility results and identify the occupant injury criteria. Due to the fact that none of the final FIMCAR test procedures had a positive assessment for horizontal load spreading, some further research of the FWDB for this purpose was conducted.

FIMCAR Deliverable 3.2 [Adolph 2013/2] documents the final verification of the metric for evaluating the structural alignment of vehicles. The main results and recommendations of the FWDB investigations in the later stages were:

- FWDB test speed of 50 km/h. This meets the desired test severity of a 53 km/h delta-v identified from accident analysis and producing a high pulse [Adolph 2013/2].
- Structural Alignment: The metric to assess structural alignment currently proposes that a vehicle must fulfil minimum load requirements in Rows 3&4 and can use loads in Row 2 to help meet this requirement under certain conditions. The minimum load requirement promotes structural alignment and the credit of loads from Row 2 encourages vertical load spreading. The metric can be defined as:
  - Up to time of 40 ms:
    - $F4 + F3 \geq [MIN(200, 0.4F_{T40})$ kN
    - $F4 \geq [MIN(100, 0.2F_{T40})$ kN
    - $F3 \geq [MIN((100\text{-}LR), (0.2F_{T40}\text{-}LR))]$
    - where:
      - F_{T40} = Maximum of total LCW force up to time of 40 ms
      - Limit Reduction (LR) = [F2-70] kN and 0 kN ≤ LR ≤ 50* kN
      - *Note values to be confirmed taking into account the new test velocity

Horizontal Load Spreading: The FWDB test approach is unable to assess the horizontal load spreading do to the test conditions. The FWDB causes preferential loading through the longitudinals and cannot fully exercise the horizontal links [Adolph 2013/2].

6.2 Off-set Test

The ODB test is proposed as is currently specified in UN-ECE Regulation 94. The current test speed is 56 km/h and no load cell or barrier assessments are proposed. Currently an additional requirement on vehicle intrusions is proposed to ensure all vehicles have a stable occupant compartment. A maximum deformation of 50 mm to the A-pillar is the proposed threshold for this requirement. It is important to note that this requirement will not likely change any of the cars produced for the European market today as Euro NCAP requirements are much more demanding. However, the FIMCAR consortium was reluctant to rely on Euro NCAP assessment for future car homologation and proposes the additional requirement for cars that are probably not designed to give good scores in Euro NCAP as a minimum requirement.

6.3 Occupant Protection Assessment

Due to the scope of the FIMCAR project, requirements for the injury assessment from dummy measurements need to be reviewed by a technical working group after the FIMCAR project is completed and results are consolidated in draft regulations. The accident data reviewed in

FIMCAR suggests that the test dummy type, size, instrumentation, seating location and seat positioning requirements should be reviewed. Female and elderly passengers were identified for better protection. Exploratory tests with a 5th percentile female dummy, instrumented with the RibEye system, seated the front seat passenger position have been conducted to build up a dataset for future modifications to the frontal impact legislation. An initial review of the FIMCAR FWDB dummy injury values for full width deformable barrier (FWDB) tests are compared to current regulatory performance limits in UN-ECE R94 and US FMVSS208 as shown in Table 6.

Table 6: Summary of UN-ECE R94 and US FMVSS208 performance limits.

Criteria	**R94 Limit**	**FMVSS208 Limit**	
	50th %tile	**50th %tile**	**5th %tile**
HIC_{36}	1000	1000	
HIC_{15}		700*	700
Head Resultant Acceleration (3 ms excedence)	80g		
Neck Extension Moment	57 Nm		
Neck tension +Z	Excedence corridor 3.3 kN @ 0 ms 2.9 kN @ 35 ms 1.1 kN @ ≥ 60 ms	4.17 kN	2.620 kN
Neck shear X	Excedence corridor 3.1 kN @ 0 ms 1.5 kN @ 25-35 ms 1.1 kN @ ≥ 45 ms		
Neck compression –Z		4.00 kN	2.520 kN
N_{ij}		1.0	1.0
Chest Deflection	50 mm	63mm	52 mm
Viscous Criterion	1.00		
Chest acceleration (3 ms excedence)		60g	60g
Femur Compression	9.7 kN	10.0 kN	6.805 kN
Knee Displacement	15 mm		
Tibia Compression	8 kN		
Tibia Index	1.3		

*HIC_{15} used for advanced airbags generally fitted to vehicles 2004+

Further work will be needed to determine the dummy performance limits needed in the Full Width test. The new limits should enforce the incorporation of appropriate restraint systems. The benefit analysis in Deliverable D1.2 [Edwards 2013] assumes that the new FIMCAR assessment approach will deliver the injury reduction assumed by the injury reduction model used in the analysis.

Dummy injury criteria values normalised to the UN-ECE Regulation 94 performance limits for the FWDB tests in the FIMCAR test database are shown for 4 of the most recent model year vehicles in Figure 6.1. All test results shown had a test speed of 56 km/h. Noting that the UN-ECE R94 limits are in general more stringent than the US FMVSS208 ones, the majority of the requirements are met except for 2 exceptions. In order for a prospective full width test to enforce the fitment of improved restraint systems that will deliver the benefit estimated in Deliverable D1.2, it is likely that more stringent performance limits than the current R94 will be needed or indeed perhaps additional tests with different dummy sizes and/or tests at lower speeds with even more stringent performance limits.

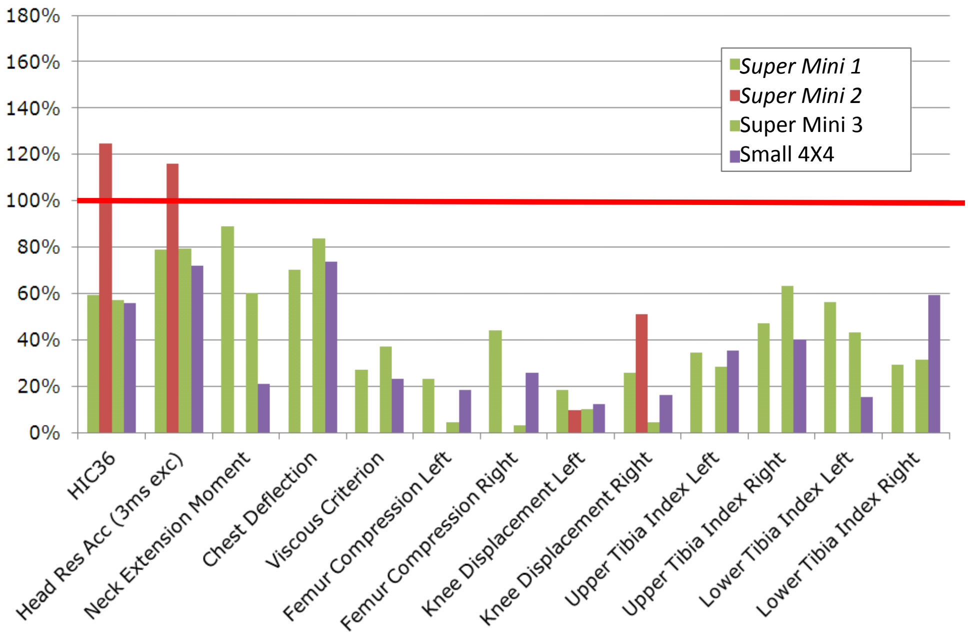

Figure 6.1: Dummy injury criteria values for FWDB tests in FIMCAR test database (late model year cars).

6.4 Conditions for Compliance

Two tests for frontal impact requirements are proposed by FIMCAR and each test configuration must be totally fulfilled, independent of the results of the separate tests.

6.5 Reproducibility and Repeatability

The existing ODB test criteria were not reviewed as the existing regulation test was not subject to this activity. The FWDB was investigated through a combination of component and full scale tests. Component tests were conducted at TRL, BASt, and UTAC and reported in FIMCAR Deliverable D3.2 [Adolph 2013/2]. The component tests showed that the variation of load cell readings was consistent between the tests and below 10%. The component tests also showed no crosstalk or load spreading issues that were critical for the metric.

Full scale tests with a FWDB were reviewed from previous projects (VC-COMPAT [Edwards 2007], APROSYS [Puppini 2007]) and FIMCAR. The earlier projects had limited test data to review - 2 tests with the same vehicle at different test labs. FIMCAR required 3 tests at 2 labs with the same vehicle. The results from the earlier projects showed good correlation for the two test vehicles. The FIMCAR test results were not as consistent. The total loads measured in the three tests were within expected test variation, but the 2 tests at the same research institute had slightly different results which resulted in different evaluation outcomes. The chosen test vehicle had demonstrated instability in car-to-car impacts (FIMCAR D6.1 [Sandqvist 2013]). The Load Cell Wall where the tests were repeated does not meet the instrumentation requirements identified by FIMCAR [Adolph 2013/2] and both of these facts requires further testing to confirm the LCW with deformable barrier is repeatable for the regulation. FIMCAR has concluded that the FWDB 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 vehicle exhibiting a stable front structure and total LCW forces above 500 kN is recommended. Furthermore the LCW requirements as developed by FIMCAR shall be met. The test procedure is repeatable within current test

6.6 Worst Case Vehicle Model Selection

During the type approval process, the manufacturer and technical service will determine the appropriate model configuration to be tested. The manufacturer may wish to test a "worst case" example that can be applied to the approval process of related model variants. The selection of the model configuration is subject to negotiation between the manufacturer and the technical service and the FIMCAR cannot recommend any specific conditions that must be tested. The following information is provided for information based on the experience from the research to date.

The proposed assessment approach involves 2 different impact tests presenting different load cases to the vehicle. The worst case configuration in the offset test is not necessarily the worst case for the full width test. FIMCAR recommends that each test condition should be assessed independent of the other.

The ODB test is focused on structural integrity and intrusion driven dummy criteria. The worst case vehicle setup is usually the case with the largest powertrain version and option level that creates the highest intrusions in the occupant compartment.

The FWDB test focusses on acceleration driven dummy criteria and compatibility metrics related to structural alignment. The worst case option for the dummy criteria is the vehicle model with the largest powertrain resulting in a shorter ridedown distance and high compartment accelerations. The compatibility criteria are more difficult to achieve with the smallest powertrain. In this case the vehicle mass is lower and produces less load on the load cell wall.

The use of computer simulation as a method to demonstrate worst case vehicle selection is encouraged. This procedure can be incorporated into the general homologation process as presented in FIMCAR Deliverable D5.5 [Stein 2013].

6.7 Summary Final Development of the Assessment Procedures

FIMCAR has identified a set of test and assessment procedures that can evaluate a vehicle's frontal impact protection capability. These recommendations will be submitted to rulemaking officials in UN-ECE committees for final evaluation and potential adoption. The current test procedures in the FIMCAR project will potentially introduce new requirements for European vehicles. The introduction of UN-ECE Regulation 94 has eliminated the legislated requirement for a full width test in Europe. Originally, UN-ECE Regulation 12 specified steering wheel intrusion requirements for European vehicles in a FWRB test configuration. However vehicles complying with UN-ECE Regulation 94 will comply with UN-ECE Regulation 12, precluding the need for full width testing of vehicles in Europe.

The FWDB is not a globally harmonised test procedure. As many jurisdictions have the FWRB as a legal requirement, there can be opposition to a test method that is not currently used in any part of the world. Technical advantages for the FWDB have been identified and are documented in Deliverable D3.2 [Adolph 2013/2]. A great deal of attention is being turned to the detection of lower load paths and SEAS as defined in the US voluntary agreement. While no valid test procedure is available for dynamically assessing the lower structures in a vehicle, different studies in the US [Baker 2008, Teoh 2011] have indicated the benefit of the voluntary agreement although the amount of improvement due to the LTV geometry is not conclusive [Greenwall 2012]. Initial evaluations within FIMCAR using simulation, car-to-car testing, and barrier tests indicate that the FWDB may be able to detect the structures relevant for structural alignment and structure interaction without relying on additional tests like the ORB.

The selected offset test procedure, ODB, does not satisfy the load spreading issues identified by the consortium. Subsequent to the initial test candidate selections, work with a horizontal load spreading metric using the FWDB has not succeeded. The FWDB overestimates the loads on longitudinals and does not fully exercise the crossbeam strength of the bumper. This resulted in false evaluations of vehicles that have demonstrated horizontal load spreading properties in car-to-car tests.

As the ODB barrier requires no significant development work, a modest effort was directed to the PDB metrics subsequent even after it was eliminated from the FIMCAR final assessment approach. The PDB and MPDB tests are currently the only configurations that can potentially assess horizontal load spreading. Candidates for assessing load spreading were identified but there is still validation and repeatability issues that must be resolved before the candidates can be forwarded to rule makers. This eliminates them from the final FIMCAR test protocol but not for evaluation after the completion of the project.

7 CONCLUSIONS

The FIMCAR project has made a significant step forward in the assessment of vehicle compatibility. Until this project there were competitive approaches for compatibility assessment available but no clear protocol could be provided by any international research group. FIMCAR has established a prioritised list of evaluation criteria for future frontal impact assessments. This evaluation procedure is developed to the level where specific issues can be addressed without introducing confounding factors in the evaluation process. There is still a lack of appropriate reference vehicles for assessing each performance criteria, but sufficient examples exist to provide objective, technical evaluations of any test or assessment procedure.

Benefit analysis indicates that the introduction of the current FIMCAR assessment approach will increase vehicle safety beyond that which is anticipated through continued vehicle safety developments [Edwards 2013 and van Montfort 2013]. Unfortunately the full potential for improved safety cannot be achieved until an offset test procedure can be developed to assess horizontal and vertical load spreading. New assessment candidates have been identified for the PDB and MPDB and promising results have been obtained to date.

The complete assessment of vehicle frontal impact protection for self and partner protection was confirmed to consist of an offset and a full width test procedure. The combined benefits of assessing loads early in the collision with a full width deformable barrier test, as well as concentrating loads on the vehicle structures with an offset test, address a list of 19 safety issues. The FWDB test at 50 km/h is able to address the high overlap cases that subject occupants to high deceleration loads. These types of injuries are a significant part of the European casualties. The current ODB test at 56 km/h and 40% overlap is a severe load case for the occupant compartment and has resulted in a strengthening of the vehicle structures since its introduction. By maintaining the ODB test, future vehicles should not be able to compromise vehicle self protection which could otherwise be reduced if the requirements in UN-ECE Regulation 94 were to only include those of the FWDB. Both tests enforce designs of vehicles for different, complementary, load cases that are supported by accident data [Thompson 2013].

The 50 km/h FWDB test speed recommended by FIMCAR is based primarily on simulation data. Further testing to confirm the deceleration pulse and assessment criteria, with its reference values, are recommended. Initial repeatability and reproducibility results are promising for the FWDB but need to be repeated using equipment satisfying all the Load Cell Wall instrumentation and specification requirements. The test vehicle should exhibit stable frontal structures to avoid the confounding factors observed in the FIMCAR tests [Adolph 2013/2].

Future activities to evaluate the type of injury risk assessment are encouraged. FIMCAR accident analysis has identified an increased risk of injury to females and elderly vehicle occupants. Different instrumentation and dummy sizes were tested in FIMCAR. The combination of a new, high deceleration, test configuration can be combined with different dummies and injury assessment criteria addressing the more vulnerable car occupants. This will push the development of newer occupant restraint systems that can address a wider range of occupants beyond the 50%ile male.

8 PROPOSED REGULATION FOR FRONTAL IMPACT

1 SCOPE

This Regulation applies to vehicles of category M_1 [1]/ of a total permissible mass not exceeding 2.5 tonnes; other vehicles may be approved at the request of the manufacturer.

2. DEFINITIONS

For the purposes of this Regulation:

2.1. "Protective system" means interior fittings and devices intended to restrain the occupants and contribute towards ensuring compliance with the requirements set out in paragraph 5. below;

2.2. "Type of protective system" means a category of protective devices which do not differ in such essential respects as:

Their technology;
Their geometry;
Their constituent materials;

2.3. "Vehicle width" means the distance between two planes parallel to the longitudinal median plane (of the vehicle) and touching the vehicle on either side of the said plane but excluding the rear-view mirrors, side marker lamps, tyre pressure indicators, direction indicator lamps, position lamps, flexible mud-guards and the deflected part of the tyre side-walls immediately above the point of contact with the ground;

2.4. "Overlap" means the percentage of the vehicle width directly in line with the barrier face;

2.5. "Deformable barrier face" means a crushable section mounted on the front of a rigid block;

2.5.1 “Load Cell Wall” or LCW means the array of force measuring sensors placed on a rigid block

2.6. "Vehicle type" means a category of power-driven vehicles which do not differ in such essential respects as:

2.6.1. The length and width of the vehicle, in so far as they have a negative effect on the results of the impact test prescribed in this Regulation,

2.6.2. The structure, dimensions, lines and materials of the part of the vehicle forward of the transverse plane through the "R" point of the driver's seat, in so far as they have a negative effect on the results of the impact test prescribed in this Regulation,

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[1]/ As defined in Annex 7 to the Consolidated Resolution on the Construction of Vehicles (R.E.3), (TRANS/WP.29/78/Rev.1/Amend.2 as last amended by its Amendment 4).

2.6.3. The lines and inside dimensions of the passenger compartment and the type of protective system, in so far as they have a negative effect on the results of the impact test prescribed in this Regulation,

2.6.4. The siting (front, rear or centre) and the orientation (transversal or longitudinal) of the engine,

2.6.5. The unladen mass, in so far as there is a negative effect on the result of the impact test prescribed in this Regulation,

2.6.6. The optional arrangements or fittings provided by the manufacturer, in so far as they have a negative effect on the result of the impact test prescribed in this Regulation,

2.7. "Passenger compartment" means the space for occupant accommodation, bounded by the roof, floor, side walls, doors, outside glazing and front bulkhead and the plane of the rear compartment bulkhead or the plane of the rear-seat back support;

2.8. "R" point" means a reference point defined for each seat by the manufacturer in relation to the vehicle's structure, as indicated in Annex 6;

2.9. "H" point" means a reference point determined for each seat by the testing service responsible for approval, in accordance with the procedure described in Annex 6;

2.10. "Unladen kerb mass" means the mass of the vehicle in running order, unoccupied and unladen but complete with fuel, coolant, lubricant, tools and a spare wheel (if these are provided as standard equipment by the vehicle manufacturer).

2.11. "Airbag" means a device installed to supplement safety belts and restraint systems in power-driven vehicles, i.e. systems which, in the event of a severe impact affecting the vehicle, automatically deploy a flexible structure intended to limit, by compression of the gas contained within it, the gravity of the contacts of one or more parts of the body of an occupant of the vehicle with the interior of the passenger compartment.

2.12. "Passenger airbag" means an airbag assembly intended to protect occupant(s) in seats other than the driver's in the event of a frontal collision.

2.13. "Child restraint" means an arrangement of components which may comprise a combination of straps or flexible components with a securing buckle, adjusting devices, attachments, and in some cases a supplementary chair and/or an impact shield, capable of being anchored to a power driven vehicle. It is so designed as to diminish the risk of injury to the wearer, in the event of a collision or of abrupt deceleration of the vehicle by limiting the mobility of the wearer's body.

2.14. "Rearward-facing" means facing in the direction opposite to the normal direction of travel of the vehicle.

3. APPLICATION FOR APPROVAL

As documented in current R94

4. APPROVAL

As documented in current R94

5. SPECIFICATIONS

5.1. <u>General specifications applicable to all tests</u>

The following specifications apply to all tests described in Annexes 3a and 3b.

5.1.1. The "H" point for each seat shall be determined in accordance with the procedure described in Annex 6.

5.1.2. When the protective system for the front seating positions includes belts, the belt components shall meet the requirements of Regulation No. 16.

5.1.3. Seating positions where a dummy is installed and the protective system includes belts, shall be provided with anchorage points conforming to Regulation No. 14.

5.2. <u>Specifications</u>

Full Width Deformable Tests of the vehicle carried out in accordance with the method described in Annex 3a shall be considered satisfactory if all the conditions set out in paragraphs 5.2.1a.and 5.2.2 to 5.2.6. below are all satisfied at the same time.

Offset Deformable Tests of the vehicle carried out in accordance with the method described in Annex 3b shall be considered satisfactory if all the conditions set out in paragraphs 5.2.1b.and 5.2.2 to 5.2.6. below are all satisfied at the same time.

All specifications prescribed under 5.2 must be fulfilled at the same time.

5.2.1.a Full Width Test

5.2.1.a.1 The performance criteria recorded, in accordance with Annex 8.a, on the dummies in the front outboard seats shall meet the following conditions:

Note: Annex 8.a to be updated by GRSP Dummy Expert working group for the Full Width Deformable Barrier. Relevant Performance Criteria will then be defined in this section

5.2.1.a.2 The vehicles structural performance criteria recorded, in accordance to the method described in Annex 11, shall comply to one of the following conditions

5.2.1.a.2.1 Condition 1

- $F4 + F3 \geq [MIN(200, 0.4F_{T40})$ kN
- $F4 \geq [MIN(100, 0.2F_{T40})$ kN
- $F3 \geq [MIN((100), (0.2F_{T40}))]$

5.2.1.a.2.2 Condition 2

- $F4 + F3 \geq [MIN(200, 0.4F_{T40})$ kN
- $F4 \geq [MIN(100, 0.2F_{T40})$ kN
- $F3 \geq [MIN((100-LR), (0.2F_{T40}-LR))]$ but not less than 70] kN

– where:

- Limit Reduction (LR) = [MIN([F2-70], 30)] kN

5.2.1.b Offset Test

5.2.1.b.1 The performance criteria recorded, in accordance with Annex 8.b, on the dummies in the front outboard seats shall meet the following conditions:

Note: Annex 8.b is currently proposed to be the existing Annex 8 in R94 unless updated by GRSP Dummy Expert working. Relevant Performance Criteria will then be defined in this section

5.2.1.b.2 The vehicles structural performance criteria recorded, in accordance to the method described in Annex 12, shall comply to one of the following conditions

5.2.1.b.2.1 The A-Pillar intrusions described in Annex 12 shall not exceed 50 mm.

5.2.2. Residual steering wheel displacement, measured at the centre of the steering wheel hub, shall not exceed 80 mm in the upwards vertical direction and 100 mm in the rearward horizontal direction.

5.2.3. During the test no door shall open.

5.2.4. During the test no locking of the locking systems of the front doors shall occur.

5.2.5. After the impact, it shall be possible, without the use of tools, except for those necessary to support the weight of the dummy:

5.2.5.1. To open at least one door, if there is one, per row of seats and, where there is no such door, to move the seats or tilt their backrests as necessary to allow the evacuation of all the occupants; this is, however, only applicable to vehicles having a roof of rigid construction;

5.2.5.2 To release the dummies from their restraint system which, if locked, shall be capable of being released by a maximum force of 60 N on the centre of the release control;

5.2.5.3. To remove the dummies from the vehicle without adjustment of the seats.

5.2.6. In the case of a vehicle propelled by liquid fuel, no more than slight leakage of liquid from the fuel feed installation shall occur on collision.

5.2.7. If there is continuous leakage of liquid from the fuel-feed installation after the collision, the rate of leakage shall not exceed 30 g/min; if the liquid from the fuel-feed system mixes with liquids from the other systems and the various liquids cannot easily be separated and identified, all the liquids collected shall be taken into account in evaluating the continuous leakage.

6. Instructions for users of vehicles equipped with airbags

Unchanged from existing R94

7. MODIFICATION AND EXTENSION OF APPROVAL OF THE VEHICLE TYPE

Unchanged from existing R94

8. CONFORMITY OF PRODUCTION

Unchanged from existing R94

9. PENALTIES FOR NON-CONFORMITY OF PRODUCTION

Unchanged from existing R94

10. PRODUCTION DEFINITELY DISCONTINUED

Unchanged from existing R94

11. TRANSITIONAL PROVISIONS

To be defined by GRSP

12. NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR CONDUCTING APPROVAL TESTS, AND OF ADMINISTRATIVE DEPARTMENTS

Unchanged from existing R94

Annex 1 – COMMUNICATION

As specified in current regulation

Annex 2 -ARRANGEMENTS OF THE APPROVAL MARK

As specified in current regulation – only significant issue is if “94” is appropriate

Annex 3a Full Width TEST PROCEDURE

1. INSTALLATION AND PREPARATION OF THE VEHICLE

1.1. Testing ground

The test area shall be large enough to accommodate the run-up track, barrier and technical installations necessary for the test. The last part of the track, for at least 5 m before the barrier, shall be horizontal, flat and smooth.

1.2. Barrier

1.2.1 Rigid Block

Fixtures related to barrier faces and instrumentation shall be mounted on a fixed rigid barrier. The barrier has a mass of not less than 7 x 10^4 kg, the front face of which is vertical within ± 1°. The mass is anchored in the ground or placed on the ground with, if necessary, additional arresting devices to restrict its movement.

1.2.2 Load cell wall (LCW)

The rigid block will be fitted with a load cell wall. The load cell wall is to be formed by a matrix of individual load cells with a spacing of 125mm in the horizontal and vertical directions. 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 250mm. The height is to be equal to or greater than the height of the deformable element. [Width 2000mm, height 1000mm]. The lower edge of the load cell wall shall be 80 mm above the ground surface. Specifications for the load cell elements and construction accuracy are given in Annex 11.

1.2.3 Deformable Element

The front face of the barrier will be fitted by a deformable structures specified in Annex 9a.

1.3. 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. 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 1000mm, 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 125mm 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 125mm steps beginning at 80mm relative to the ground.]

1.3.1 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. The vertical alignment of the vehicle is to be recorded prior to the test. The measurement is the vertical distance between the wheel to ground contact for each wheel and the wheel arch immediately above the contact patch. Prior to measurement the vehicle will be at test mass and rolled back and forward at least one vehicle length to settle the vehicle.

1.4. State of vehicle

1.4.1. General specification

The test vehicle shall be representative of the series production, shall include all the equipment normally fitted and shall be in normal running order. Some components may be replaced by equivalent masses where this substitution clearly has no noticeable effect on the results measured under paragraph 6.

1.4.2. Mass of vehicle

1.4.2.1. For the test, the mass of the vehicle submitted shall be the unladen kerb mass;

1.4.2.2. The fuel tank shall be filled with water to mass equal to 90 per cent of the mass of a full as specified by the manufacturer with a tolerance of $\pm$ 1 per cent;

1.4.2.3. All the other systems (brake, cooling, ...) may be empty in this case, the mass of the liquids shall be carefully compensated;

1.4.2.4. If the mass of the measuring apparatus on board the vehicle exceeds the 25 kg allowed, it may be compensated by reductions which have no noticeable effect on the results measured under paragraph 6. below.

1.4.2.5. The mass of the measuring apparatus shall not change each axle reference load by more than 5 per cent, each variation not exceeding 20 kg.

1.4.2.6. The mass of the vehicle resulting from the provisions of paragraph 1.4.2.1. above shall be indicated in the report.

1.4.3. Passenger compartment adjustments

1.4.3.1. Position of steering wheel

The steering wheel, if adjustable, shall be placed in the normal position indicated by the manufacturer or, failing that, midway between the limits of its range(s) of adjustment. At the end of propelled travel, the steering wheel shall be left free, with its spokes in the position which according to the manufacturer corresponds to straight-ahead travel of the vehicle.

1.4.3.2. Glazing

The movable glazing of the vehicle shall be in the closed position. For test measurement purposes and in agreement with the manufacturer, it may be lowered, provided that the position of the operating handle corresponds to the closed position.

1.4.3.3. Gear-change lever

The gear-change lever shall be in the neutral position.

1.4.3.4. Pedals

The pedals shall be in their normal position of rest. If adjustable, they shall be set in their mid position unless another position is specified by the manufacturer.

1.4.3.5. Doors

The doors shall be closed but not locked.

1.4.3.6. Opening roof

If an opening or removable roof is fitted, it shall be in place and in the closed position. For test measurement purposes and in agreement with the manufacturer, it may be open.

1.4.3.7. Sun-visor

The sun-visors shall be in the stowed position.

1.4.3.8. Rear-view mirror

The interior rear-view mirror shall be in the normal position of use.

1.4.3.9. Arm-rests

Arm-rests at the front and rear, if movable, shall be in the lowered position, unless this is prevented by the position of the dummies in the vehicles.

1.4.3.10. Head restraints

Head restraints adjustable for height shall be in their uppermost position.

1.4.3.11. Seats

1.4.3.11.1. Position of front seats

Seats adjustable longitudinally shall be placed so that their "H" point, determined in accordance with the procedure set out in Annex 6 is in the middle position of travel or in the nearest locking position thereto, and at the height position defined by the manufacturer (if independently adjustable for height). In the case of a bench seat, the reference shall be to the "H" point of the driver's place.

1.4.3.11.2. Position of the front seat-backs

If adjustable, the seat-backs shall be adjusted so that the resulting inclination of the torso of the dummy is as close as possible to that recommended by the manufacturer for normal use or, in the absence of any particular recommendation by the manufacturer, to 25° towards the rear from the vertical.

1.4.3.11.3. Rear seats

If adjustable, the rear seats or rear bench seats shall be placed in the rearmost position.

2. DUMMIES

2.1. Front seats

The dummy size, seating, and positioning requirements should be reviewed by the GRSP dummy expert group

2.1.1. A dummy corresponding to the specifications for Hybrid III [2]/ fitted with a 45° ankle and meeting the specifications for its adjustment shall be installed in each of the front outboard seats in accordance with the conditions set out in Annex 5. The dummy shall be equipped for recording the data necessary to determine the performance criteria with measuring systems corresponding to the specifications in Annex 8. The ankle of the dummy shall be certified in accordance with the procedures in Annex 10.

2.1.2. The car will be tested with restraint systems, as provided by the manufacturer.

3. Propulsion and course of vehicle

1 3.1. The vehicle shall be propelled either by its own engine or by any other propelling device.

3.2. At the moment of impact the vehicle shall no longer be subject to the action of any additional steering or propelling device.

3.3. The course of the vehicle shall be such that it satisfies the requirements of paragraphs 1.2. and 1.3.1.

4. TEST SPEED

4.1 Vehicle speed at the moment of impact shall be 50 -0/+1 km/h. However, if the test was performed at a higher impact speed and the vehicle met the requirements, the test shall be considered satisfactory.

5. MEASUREMENTS TO BE MADE ON DUMMY IN FRONT SEATS

5.1. All the measurements necessary for the verification of the performance criteria shall be made with measurement systems corresponding to the specifications of Annex 8.

5.2. The different parameters shall be recorded through independent data channels of the following CFC (Channel Frequency Class):

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[2]/ The technical specifications and detailed drawings of Hybrid III, corresponding to the principal dimensions of a fiftieth percentile male of the United States of America, and the specifications for its adjustment for this test are deposited with the Secretary-General of the United Nations and may be consulted on request at the secretariat of the Economic Commission for Europe, Palais des Nations, Geneva, Switzerland.

5.2.1. Measurements in the head of the dummy

The acceleration (a) referring to the centre of gravity is calculated from the triaxial components of the acceleration measured with a CFC of 1000.

5.2.2. Measurements in the neck of the dummy

5.2.2.1. The axial tensile force and the fore/aft shear force at the neck/head interface are measured with a CFC of 1000.

5.2.2.2. The bending moment about a lateral axis at the neck/head interface are measured with a CFC of 600.

5.2.3. Measurements in the thorax of the dummy

The chest deflection between the sternum and the spine is measured with a CFC of 180.

5.2.4. Measurements in the femur and tibia of the dummy

5.2.4.1. The axial compressive force and the bending moments are measured with a CFC of 600.

5.2.4.2. The displacement of the tibia with respect to the femur is measured at the knee sliding joint with a CFC of 180.

6. MEASUREMENTS TO BE MADE ON THE VEHICLE

6.1. To enable the simplified test described in Annex 7 to be carried out, the deceleration time history of the structure shall be determined on the basis of the value of the longitudinal accelerometers at the base of the "B" pillar on both sides of the vehicle with a CFC of 180 by means of data channels corresponding to the requirements set out in Annex 8;

6.2. The speed time history which will be used in the test procedure described in Annex 7 shall be obtained from average of the longitudinal accelerometers at the "B" pillars on both sides of the vehicle.

Annex 3b OFFSET TEST PROCEDURE

1. INSTALLATION AND PREPARATION OF THE VEHICLE

1.1. Testing ground

The test area shall be large enough to accommodate the run-up track, barrier and technical installations necessary for the test. The last part of the track, for at least 5 m before the barrier, shall be horizontal, flat and smooth.

1.2. Barrier

1.2.1 Rigid Block

Fixtures related to barrier faces and instrumentation shall be mounted on a fixed rigid barrier. The barrier has a mass of not less than 7 x 10^4 kg, the front face of which is vertical within ± 1°. The mass is anchored in the ground or placed on the ground with, if necessary, additional arresting devices to restrict its movement.

1.2.2 Offset Deformable Test

Based on 1.2.1, the following conditions apply to the Offset test:

1.3 Orientation of the barrier

The orientation of the barrier is such that the first contact of the vehicle with the barrier is on the steering-column side. Where there is a choice between carrying out the test with a right-hand or left-hand drive vehicle, the test shall be carried out with the less favourable hand of drive as determined by the Technical Service responsible for the tests.

1.3.1. Alignment of the vehicle to the barrier

The vehicle shall overlap the barrier face by 40 per cent ± 20 mm.

1.4. State of vehicle

1.4.1. General specification

The test vehicle shall be representative of the series production, shall include all the equipment normally fitted and shall be in normal running order. Some components may be replaced by equivalent masses where this substitution clearly has no noticeable effect on the results measured under paragraph 6.

1.4.2. Mass of vehicle

1.4.2.1. For the test, the mass of the vehicle submitted shall be the unladen kerb mass;

1.4.2.2. The fuel tank shall be filled with water to mass equal to 90 per cent of the mass of a full as specified by the manufacturer with a tolerance of ± 1 per cent;

1.4.2.3. All the other systems (brake, cooling, ...) may be empty in this case, the mass of the liquids shall be carefully compensated;

1.4.2.4. If the mass of the measuring apparatus on board the vehicle exceeds the 25 kg allowed, it may be compensated by reductions which have no noticeable effect on the results measured under paragraph 6. below.

1.4.2.5. The mass of the measuring apparatus shall not change each axle reference load by more than 5 per cent, each variation not exceeding 20 kg.

1.4.2.6. The mass of the vehicle resulting from the provisions of paragraph 1.4.2.1. above shall be indicated in the report.

1.4.3. Passenger compartment adjustments

1.4.3.1. Position of steering wheel

The steering wheel, if adjustable, shall be placed in the normal position indicated by the manufacturer or, failing that, midway between the limits of its range(s) of adjustment. At the end of propelled travel, the steering wheel shall be left free, with its spokes in the position which according to the manufacturer corresponds to straight-ahead travel of the vehicle.

1.4.3.2. Glazing

The movable glazing of the vehicle shall be in the closed position. For test measurement purposes and in agreement with the manufacturer, it may be lowered, provided that the position of the operating handle corresponds to the closed position.

1.4.3.3. Gear-change lever

The gear-change lever shall be in the neutral position.

1.4.3.4. Pedals

The pedals shall be in their normal position of rest. If adjustable, they shall be set in their mid position unless another position is specified by the manufacturer.

1.4.3.5. Doors

The doors shall be closed but not locked.

1.4.3.6. Opening roof

If an opening or removable roof is fitted, it shall be in place and in the closed position. For test measurement purposes and in agreement with the manufacturer, it may be open.

1.4.3.7. Sun-visor

The sun-visors shall be in the stowed position.

1.4.3.8. Rear-view mirror

The interior rear-view mirror shall be in the normal position of use.

1.4.3.9. Arm-rests

Arm-rests at the front and rear, if movable, shall be in the lowered position, unless this is prevented by the position of the dummies in the vehicles.

1.4.3.10. Head restraints

Head restraints adjustable for height shall be in their uppermost position.

1.4.3.11. Seats

1.4.3.11.1. Position of front seats

Seats adjustable longitudinally shall be placed so that their "H" point, determined in accordance with the procedure set out in Annex 6 is in the middle position of travel or in the nearest locking position thereto, and at the height position defined by the manufacturer (if independently adjustable for height). In the case of a bench seat, the reference shall be to the "H" point of the driver's place.

1.4.3.11.2. Position of the front seat-backs

If adjustable, the seat-backs shall be adjusted so that the resulting inclination of the torso of the dummy is as close as possible to that recommended by the manufacturer for normal use or, in the absence of any particular recommendation by the manufacturer, to 25° towards the rear from the vertical.

1.4.3.11.3. Rear seats

If adjustable, the rear seats or rear bench seats shall be placed in the rearmost position.

2. DUMMIES

2.1. Front seats

The dummy size, seating, and positioning requirements should be reviewed by the GRSP dummy expert group

2.1.1. A dummy corresponding to the specifications for Hybrid III [3]/ fitted with a 45° ankle and meeting the specifications for its adjustment shall be installed in each of the front outboard seats in accordance with the conditions set out in Annex 5. The dummy shall be equipped for recording the data necessary to determine the performance criteria with measuring systems corresponding to the specifications in Annex 8. The ankle of the dummy shall be certified in accordance with the procedures in Annex 10.

2.1.2. The car will be tested with restraint systems, as provided by the manufacturer.

3. Propulsion and course of vehicle

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[3]/ The technical specifications and detailed drawings of Hybrid III, corresponding to the principal dimensions of a fiftieth percentile male of the United States of America, and the specifications for its adjustment for this test are deposited with the Secretary-General of the United Nations and may be consulted on request at the secretariat of the Economic Commission for Europe, Palais des Nations, Geneva, Switzerland.

3.1. The vehicle shall be propelled either by its own engine or by any other propelling device.

3.2. At the moment of impact the vehicle shall no longer be subject to the action of any additional steering or propelling device.

3.3. The course of the vehicle shall be such that it satisfies the requirements of paragraphs 1.2. and 1.3.1.

4. TEST SPEED

4.1 Offset Test

Vehicle speed at the moment of impact shall be 56 -0/+1 km/h. However, if the test was performed at a higher impact speed and the vehicle met the requirements, the test shall be considered satisfactory.

5. MEASUREMENTS TO BE MADE ON DUMMY IN FRONT SEATS

5.1. All the measurements necessary for the verification of the performance criteria shall be made with measurement systems corresponding to the specifications of Annex 8.

5.2. The different parameters shall be recorded through independent data channels of the following CFC (Channel Frequency Class):

5.2.1. <u>Measurements in the head of the dummy</u>

The acceleration (a) referring to the centre of gravity is calculated from the triaxial components of the acceleration measured with a CFC of 1000.

5.2.2. <u>Measurements in the neck of the dummy</u>

5.2.2.1. The axial tensile force and the fore/aft shear force at the neck/head interface are measured with a CFC of 1000.

5.2.2.2. The bending moment about a lateral axis at the neck/head interface are measured with a CFC of 600.

5.2.3. <u>Measurements in the thorax of the dummy</u>

The chest deflection between the sternum and the spine is measured with a CFC of 180.

5.2.4. <u>Measurements in the femur and tibia of the dummy</u>

5.2.4.1. The axial compressive force and the bending moments are measured with a CFC of 600.

5.2.4.2. The displacement of the tibia with respect to the femur is measured at the knee sliding joint with a CFC of 180.

6. MEASUREMENTS TO BE MADE ON THE VEHICLE

6.1. To enable the simplified test described in Annex 7 to be carried out, the deceleration time history of the structure shall be determined on the basis of the value of the longitudinal accelerometers at the base of the "B" pillar on the struck side of the vehicle with a CFC of 180 by means of data channels corresponding to the requirements set out in Annex 8;

6.2. The speed time history which will be used in the test procedure described in Annex 7 shall be obtained from the longitudinal accelerometer at the "B" pillar on the struck side.

6.3 Intrusion measurements of the A-pillar shall be conducted in accordance to Appendix 12

ANNEXES 4-8 SHOULD BE REVIEWED BY GRSP

Annex 9a DEFINITION OF FULL WIDTH DEFORMABLE BARRIERS

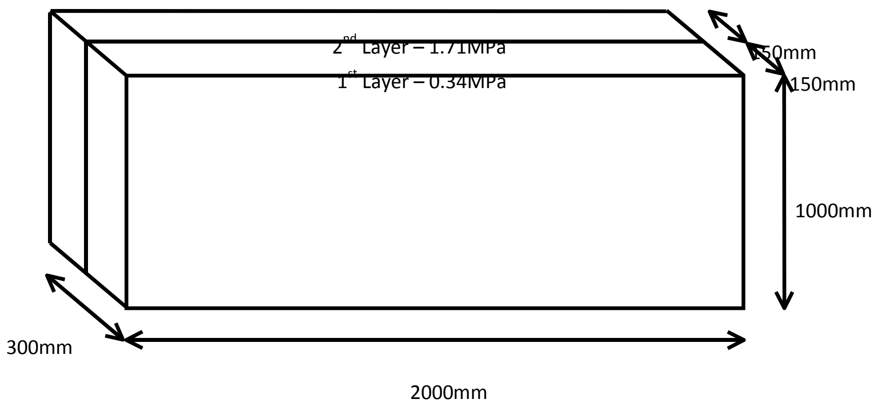
1. COMPONENT AND MATERIAL SPECIFICATIONS

Main honeycomb block

The external dimensions of the barrier are illustrated in Figure 1. The deformable element is formed from two layers of aluminium honeycomb, with an overall depth of 300mm, a height of 1000mm and a width of 2000mm. [For larger vehicles the height and the width of the deformable element should be increased in 125mm increments vertically and 250mm increments horizontally to ensure that no part of the vehicle directly impacts the LCW.]

Figure 1

Full Width Deformable Barrier external dimensions (not to scale).



1.1 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%

1.2 Rear honeycomb layer

Height: 1000mm [□ 2.5mm] (in direction

Width: 2000mm [□ 2.5mm]

Depth: 150mm [□ 1mm] (in direction of hon

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%

1.3 Backing sheet

Height: 1080 mm □ 2.5 mm

Width: 2000 mm □ 2.5 mm

Thickness: 0.5 mm □ 0.1 mm

Material: Aluminium 5251

1.4 The adhesive to be used throughout should be a two-part polyurethane (such as Ciba-Geigy XB5090/1 resin with XB5304 hardener, or equivalent).

2. ALUMINIUM HONEYCOMB CERTIFICATION

A complete testing procedure for certification of aluminium honeycomb is given in NHTSA TP-214D. The following is a summary of the procedure that should be applied to materials for the frontal impact barrier, these materials having a crush strength of 0.342 MPa and 1.711 MPa respectively.

2.1. <u>Sample locations</u>

To ensure uniformity of crush strength across the whole of the barrier face, eight samples shall be taken from four locations evenly spaced across the honeycomb block. For a block to pass certification, seven of these eight samples shall meet the crush strength requirements of the following sections.

The location of the samples depends on the size of the honeycomb block. First, four samples, each measuring 300 mm x 300 mm x 50 mm thick shall be cut from the block of barrier face material. Please refer to Figure 2 for an illustration of how to locate these sections within the honeycomb block. Each of these larger samples shall be cut into samples for certification testing (150 mm x 150 mm x 50 mm). Certification shall be based on the testing of two samples from each of these four locations. The other two should be made available to the applicant, upon request.

2.2. <u>Sample size</u>

Samples of the following size shall be used for testing:

Length: 150 mm ± 6 mm

Width: 150 mm ± 6 mm

Thickness: 50 mm ± 2 mm

The walls of incomplete cells around the edge of the sample shall be trimmed as follows:

In the "W" direction, the fringes shall be no greater than 1.8 mm (see Figure 3).

In the "L" direction, half the length of one bonded cell wall (in the ribbon direction) shall be left at either end of the specimen (see Figure 3).

2.3. Area measurement

The length of the sample shall be measured in three locations, 12.7 mm from each end and in the middle, and recorded as L1, L2 and L3 (Figure 3). In the same manner, the width shall be measured and recorded as W1, W2 and W3 (Figure 3). These measurements shall be taken on the centreline of the thickness. The crush area shall then be calculated as:

$$A = \frac{(L1 + L2 + L3)}{3} \text{ x } \frac{(W1 + W2 + W3)}{3}$$

2.4. Crush rate and distance

The sample shall be crushed at a rate of not less than 5.1 mm/min and not more than 7.6 mm/min. The minimum crush distance shall be 16.5 mm.

2.5. Data collection

Force versus deflection data are to be collected in either analog or digital form for each sample tested. If analog data are collected then a means of converting this to digital shall be available. All digital data shall be collected at a rate of not less than 5 Hz (5 points per second).

2.6. Crush strength determination

Ignore all data prior to 6.4 mm of crush and after 16.5 mm of crush. Divide the remaining data into three sections or displacement intervals (n = 1, 2, 3) (see Figure 4) as follows:

(1) 06.4 mm - 09.7 mm inclusive,

(2) 09.7 mm - 13.2 mm exclusive,

(3) 13.2 mm - 16.5 mm inclusive.

Find the average for each section as follows:

$$F(n) = \frac{(F(n)1 + F(n)2 + ... + F(n)m)}{m}; \quad m = 1, 2, 3$$

where m represents the number of data points measured in each of the three intervals. Calculate the crush strength of each section as follows:

$$S(n) = \frac{F(n)}{A}; \quad n = 1, 2, 3$$

2.7. Sample crush strength specification

For a honeycomb sample to pass this certification, the following conditions shall be met:

0.308 MPa ≤ S(n) ≤ 0.342 MPa for 0.342 MPa material

1.540 MPa ≤ S(n) ≤ 1.711 MPa for 1.711 MPa material

n = 1, 2, 3.

2.8. Block crush strength specification

Eight samples are to be tested from four locations, evenly spaced across the block. For a block to pass certification, seven of the eight samples shall meet the crush strength specification of the previous section.

3. ADHESIVE BONDING PROCEDURE

3.1. Immediately before bonding, aluminium sheet surfaces to be bonded shall be thoroughly cleaned using a suitable solvent, such as 1-1-1 Trichloroethane. This is to be carried out at least twice or as required to eliminate grease or dirt deposits. The cleaned surfaces shall then be abraded using 120 grit abrasive paper. Metallic/Silicon Carbide abrasive paper is not to be used. The surfaces shall be thoroughly abraded and the abrasive paper changed regularly during the process to avoid clogging, which may lead to a polishing effect. Following abrading, the surfaces shall be thoroughly cleaned again, as above. In total, the surfaces shall be solvent cleaned at least four times. All dust and deposits left as a result of the abrading process shall be removed, as these will adversely affect bonding.

3.2. The adhesive should be applied to one surface only, using a ribbed rubber roller. In cases where honeycomb is to be bonded to aluminium sheet, the adhesive should be applied to the aluminium sheet only.

A maximum of 0.5 kg/m^2 shall be applied evenly over the surface, giving a maximum film thickness of 0.5 mm.

4. CONSTRUCTION

4.1. The rear honeycomb layer is segmented every 125mm in the horizontal and vertical directions starting at 125mm 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 5mm wide.]

4.2. The rear honeycomb layer shall be bonded to the backing sheet with adhesive such that the cell axes are perpendicular to the sheet.

4.3. 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 300mm, a minimum height and width of 1000mm and 2000mm respectively. [For larger vehicles the height and the width of the deformable element should be increased in 125mm increments vertically and 250mm increments horizontally to ensure that no part of the vehicle directly impacts the LCW.]

5. MOUNTING

5.1. The deformable barrier shall be rigidly fixed to the edge of a mass of not less than 7 x 10^4 kg or to some structure attached thereto. The attachment of the barrier face shall be such that the vehicle shall not contact any part of the structure more than 75 mm from the top surface of the barrier (excluding the upper flange) during any stage of the impact[1]. The front face of the surface to which the deformable barrier is attached shall be flat and continuous over the height and width of the face and shall be vertical ± 1° and perpendicular ± 1° to the axis of the run-up track. The attachment surface shall not be displaced by more than 10 mm during the test. If necessary, additional anchorage or arresting devices shall be used to prevent displacement of the concrete block. The edge of the deformable barrier shall be aligned with the edge of the concrete block appropriate for the side of the vehicle to be tested.

5.2. 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 as shown in Figure 2. The bolts used to attach the clamping plate must not pass through the mounting flange.

[1] A mass, the end of which is between 125 mm and 925 mm high and 1,000 mm deep, is considered to satisfy this requirement.

<u>Figure 2</u>

Mounting details for full width deformable barrier

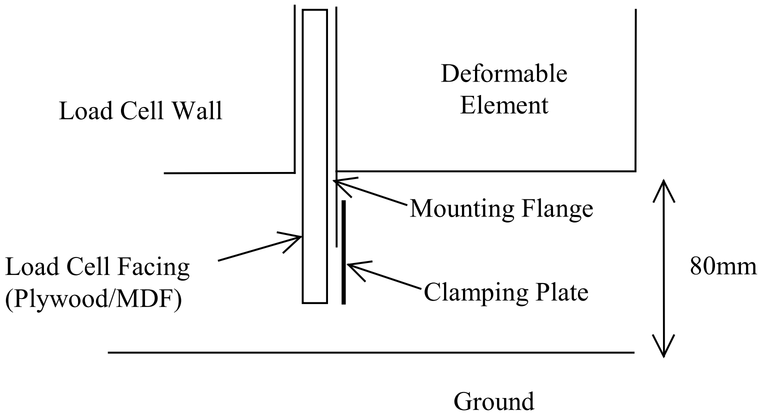
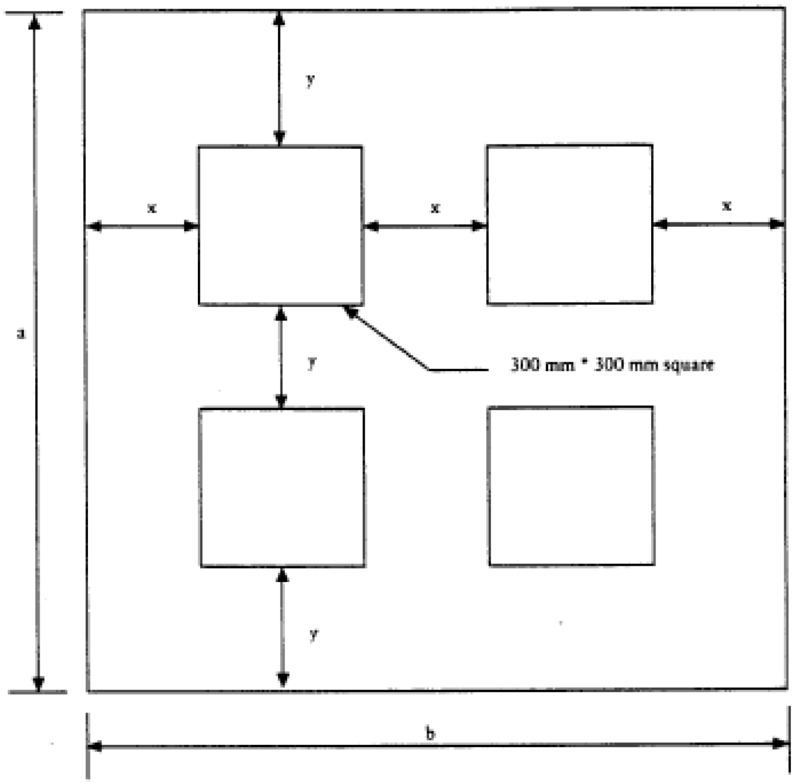
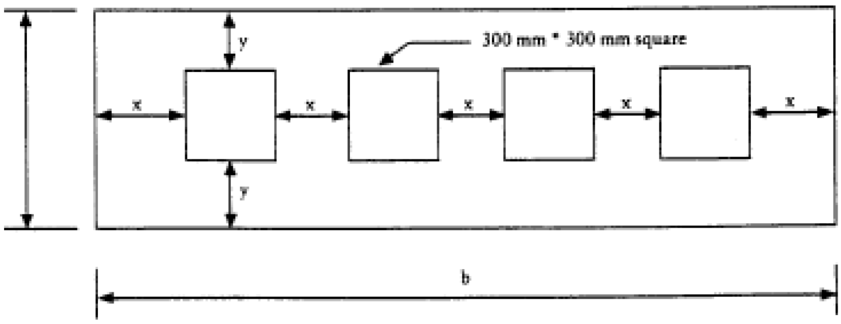


Figure 3

Location of the sample for certification



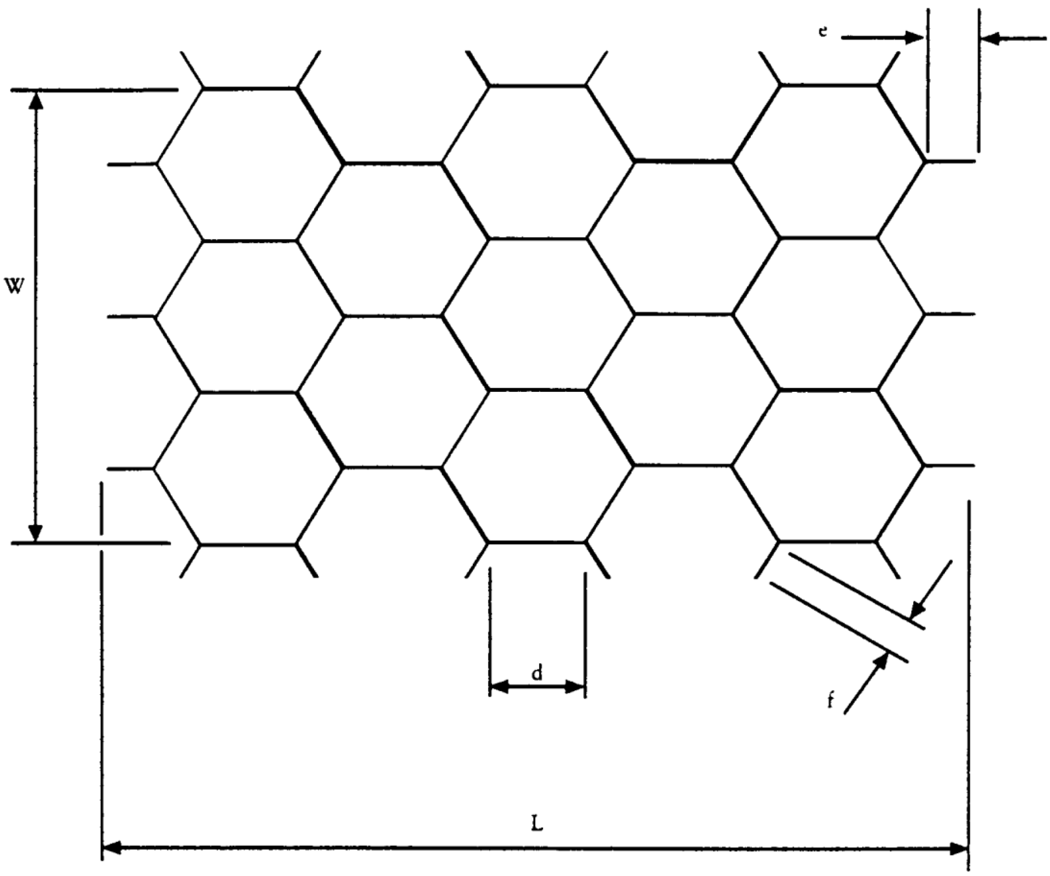
If a ≥ 900 mm: x = 1/3 (b-600mm) and y = 1/3 (a-600mm) (for a ≤ b)



If a < 900 mm: x = 1/5 (b - 1200 mm) and y = ½ (a - 300 mm) (for a ≤ b)

Figure 4

Honeycomb axes and measured dimensions



e = d/2
f = 0,8 mm

Figure 5

Crush force and displacement

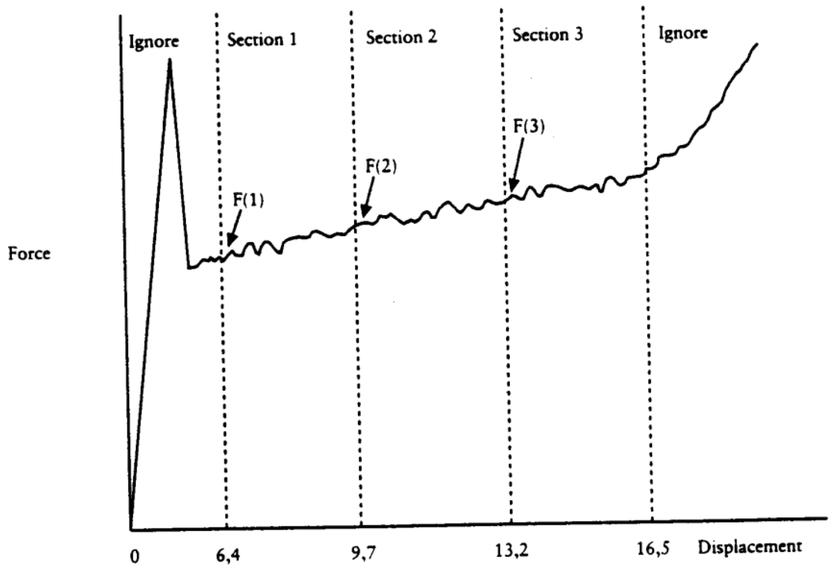
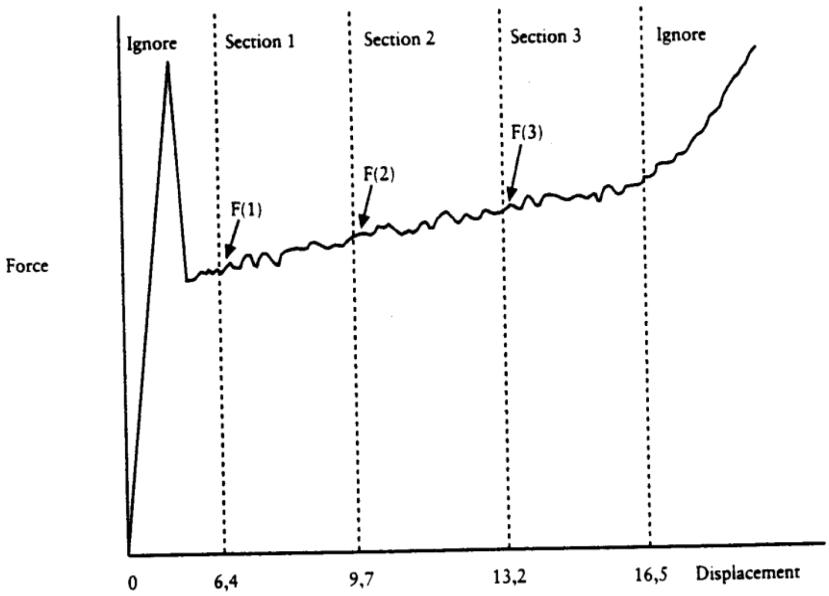


Figure 6

Position of holes for barrier mounting



Hole diameters 9.5 mm.

All dimensions in mm.

Annex 9b DEFINITION OF OFFSET DEFORMABLE BARRIERS

1. COMPONENT AND MATERIAL SPECIFICATIONS

The dimensions of the barriers are illustrated in Figure 1 of this annex. The dimensions of the individual components of the barrier are listed separately below.

1.1. Main honeycomb block

Dimensions:

Height: 650 mm (in direction of honeycomb ribbon axis)

Width: 1,000 mm

Depth: 450 mm (in direction of honeycomb cell axes)

All above dimensions should allow a tolerance of ± 2.5 mm

Material: Aluminium 3003 (ISO 209, Part 1)

Foil Thickness: 0.076 mm ± 15 per cent

Cell Size: 19.1 mm ± 20 per cent

Density: 28.6 kg/m^3 ± 20 per cent

Crush Strength: 0.342 MPa +0 per cent -10 per cent 1/

1.2. Bumper element

Dimensions:

Height: 330 mm (in direction of honeycomb ribbon axis)

Width: 1,000 mm

Depth: 90 mm (in direction of honeycomb cell axes)

All above dimensions should allow a tolerance of ± 2.5 mm

Material: Aluminium 3003 (ISO 209, Part 1)

Foil Thickness: 0.076 mm ± 15 per cent

Cell Size: 6.4 mm ± 20 per cent

Density: 82.6 kg/m^3 ± 20 per cent

Crush Strength: 1.711 MPa +0 per cent -10 per cent [1]

1.3. Backing sheet

Dimensions

Height: 800 mm ± 2.5 mm

Width: 1000 mm ± 2.5 mm

[1] In accordance with the certification procedure described in paragraph 2. of this annex.

Thickness: 2.0 mm ± 0.1 mm

1.4. Cladding sheet

Dimensions

Length: 1700 mm ± 2.5 mm

Width: 1000 mm ± 2.5 mm

Thickness: 0.81 ± 0.07 mm

Material: Aluminium 5251/5052 (ISO 209, part 1)

1.5. Bumper facing sheet

Dimensions

Height: 330 mm ± 2.5 mm

Width: 1000 mm ± 2.5 mm

Thickness: 0.81 mm ± 0.07 mm

Material: Aluminium 5251/5052 (ISO 209, part 1)

1.6. Adhesive

The adhesive to be used throughout should be a two-part polyurethane (such as Ciba-Geigy XB5090/1 resin with XB5304 hardener, or equivalent).

2. ALUMINIUM HONEYCOMB CERTIFICATION

A complete testing procedure for certification of aluminium honeycomb is given in NHTSA TP-214D. The following is a summary of the procedure that should be applied to materials for the frontal impact barrier, these materials having a crush strength of 0.342 MPa and 1.711 MPa respectively.

2.1. Sample locations

To ensure uniformity of crush strength across the whole of the barrier face, eight samples shall be taken from four locations evenly spaced across the honeycomb block. For a block to pass certification, seven of these eight samples shall meet the crush strength requirements of the following sections.

The location of the samples depends on the size of the honeycomb block. First, four samples, each measuring 300 mm x 300 mm x 50 mm thick shall be cut from the block of barrier face material. Please refer to Figure 2 for an illustration of how to locate these sections within the honeycomb block. Each of these larger samples shall be cut into samples for certification testing (150 mm x 150 mm x 50 mm). Certification shall be based on the testing of two samples from each of these four locations. The other two should be made available to the applicant, upon request.

2.2. Sample size

Samples of the following size shall be used for testing:

Length: 150 mm ± 6 mm

Width: 150 mm ± 6 mm

Thickness: 50 mm ± 2 mm

The walls of incomplete cells around the edge of the sample shall be trimmed as follows:

In the "W" direction, the fringes shall be no greater than 1.8 mm (see Figure 3).

In the "L" direction, half the length of one bonded cell wall (in the ribbon direction) shall be left at either end of the specimen (see Figure 3).

2.3. Area measurement

The length of the sample shall be measured in three locations, 12.7 mm from each end and in the middle, and recorded as L1, L2 and L3 (Figure 3). In the same manner, the width shall be measured and recorded as W1, W2 and W3 (Figure 3). These measurements shall be taken on the centreline of the thickness. The crush area shall then be calculated as:

$$A = \frac{(L1 + L2 + L3)}{3} \text{ x } \frac{(W1 + W2 + W3)}{3}$$

2.4. Crush rate and distance

The sample shall be crushed at a rate of not less than 5.1 mm/min and not more than 7.6 mm/min. The minimum crush distance shall be 16.5 mm.

2.5. Data collection

Force versus deflection data are to be collected in either analog or digital form for each sample tested. If analog data are collected then a means of converting this to digital shall be available. All digital data shall be collected at a rate of not less than 5 Hz (5 points per second).

2.6. Crush strength determination

Ignore all data prior to 6.4 mm of crush and after 16.5 mm of crush. Divide the remaining data into three sections or displacement intervals (n = 1, 2, 3) (see Figure 4) as follows:

(1) 06.4 mm - 09.7 mm inclusive,
(2) 09.7 mm - 13.2 mm exclusive,
(3) 13.2 mm - 16.5 mm inclusive.

Find the average for each section as follows:

$$F(n) = \frac{(F(n)1 + F(n)2 + ... + F(n)m)}{m}; \quad m = 1, 2, 3$$

where m represents the number of data points measured in each of the three intervals. Calculate the crush strength of each section as follows:

$$S(n) = \frac{F(n)}{A};\ \ n = 1, 2, 3$$

2.7. Sample crush strength specification

For a honeycomb sample to pass this certification, the following conditions shall be met:

0.308 MPa ≤ S(n) ≤ 0.342 MPa for 0.342 MPa material

1.540 MPa ≤ S(n) ≤ 1.711 MPa for 1.711 MPa material

n = 1, 2, 3.

2.8. Block crush strength specification

Eight samples are to be tested from four locations, evenly spaced across the block. For a block to pass certification, seven of the eight samples shall meet the crush strength specification of the previous section.

3. ADHESIVE BONDING PROCEDURE

3.1. Immediately before bonding, aluminium sheet surfaces to be bonded shall be thoroughly cleaned using a suitable solvent, such as 1-1-1 Trichloroethane. This is to be carried out at least twice or as required to eliminate grease or dirt deposits. The cleaned surfaces shall then be abraded using 120 grit abrasive paper. Metallic/Silicon Carbide abrasive paper is not to be used. The surfaces shall be thoroughly abraded and the abrasive paper changed regularly during the process to avoid clogging, which may lead to a polishing effect. Following abrading, the surfaces shall be thoroughly cleaned again, as above. In total, the surfaces shall be solvent cleaned at least four times. All dust and deposits left as a result of the abrading process shall be removed, as these will adversely affect bonding.

3.2. The adhesive should be applied to one surface only, using a ribbed rubber roller. In cases where honeycomb is to be bonded to aluminium sheet, the adhesive should be applied to the aluminium sheet only.

A maximum of 0.5 kg/m^2 shall be applied evenly over the surface, giving a maximum film thickness of 0.5 mm.

4. CONSTRUCTION

4.1. The main honeycomb block shall be bonded to the backing sheet with adhesive such that the cell axes are perpendicular to the sheet. The cladding shall be bonded to the front surface of the honeycomb block. The top and bottom surfaces of the cladding sheet shall not be bonded to the main honeycomb block but should be positioned closely to it. The cladding sheet shall be adhesively bonded to the backing sheet at the mounting flanges.

4.2. The bumper element shall be adhesively bonded to the front of the cladding sheet such that the cell axes are perpendicular to the sheet. The bottom of the bumper element shall be flush with the bottom surface of the cladding sheet. The bumper facing sheet shall be adhesively bonded to the front of the bumper element.

4.3. The bumper element shall then be divided into three equal sections by means of two horizontal slots. These slots shall be cut through the entire depth of the bumper section and extend the whole width of the bumper. The slots shall be cut using a saw; their width shall be the width of the blade used and shall not exceed 4.0 mm.

4.4. Clearance holes for mounting the barrier are to be drilled in the mounting flanges (shown in Figure 5). The holes shall be of 9.5 mm diameter. Five holes shall be drilled in the top flange at a distance of 40 mm from the top edge of the flange and five in the bottom flange, 40 mm from the bottom edge of that flange. The holes shall be at 100 mm, 300 mm, 500 mm, 700 mm, 900 mm from either edge of the barrier. All holes shall be drilled to ± 1 mm of the nominal distances. These hole locations are a recommendation only. Alternative positions may be used which offer at least the mounting strength and security provided by the above mounting specifications.

5. MOUNTING

5.1. The deformable barrier shall be rigidly fixed to the edge of a mass of not less than 7 x 10^4 kg or to some structure attached thereto. The attachment of the barrier face shall be such that the vehicle shall not contact any part of the structure more than 75 mm from the top surface of the barrier (excluding the upper flange) during any stage of the impact[2]. The front face of the surface to which the deformable barrier is attached shall be flat and continuous over the height and width of the face and shall be vertical ± 1° and perpendicular ± 1° to the axis of the run-up track. The attachment surface shall not be displaced by more than 10 mm during the test. If necessary, additional anchorage or arresting devices shall be used to prevent displacement of the concrete block. The edge of the deformable barrier shall be aligned with the edge of the concrete block appropriate for the side of the vehicle to be tested.

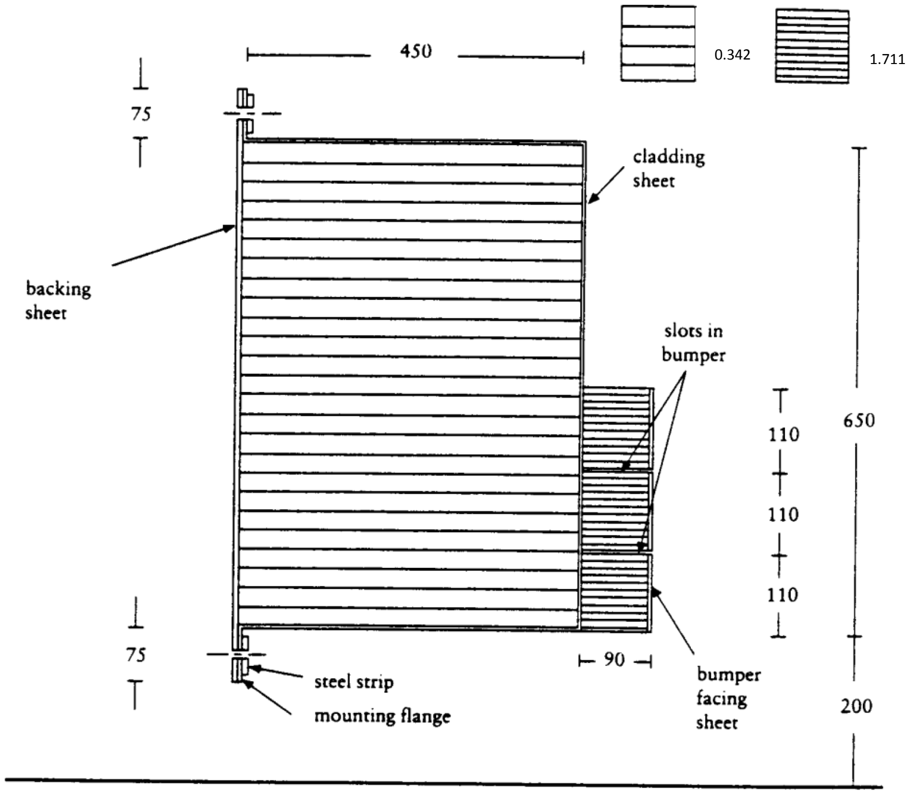
5.2. The deformable barrier shall be fixed to the concrete block by means of ten bolts, five in the top mounting flange and five in the bottom. These bolts shall be of at least 8 mm diameter. Steel clamping strips shall be used for both the top and bottom mounting flanges (see Figures 2 and 6). These strips shall be 60 mm high and 1000 mm wide and have a thickness of at least 3 mm. The edges of the clamping strips should be rounded-off to prevent tearing of the barrier against the strip during impact. The edge of the strip should be located no more than 5 mm above the base of the upper barrier-mounting flange, or 5 mm below the top of the lower barrier-mounting flange. Five clearance holes of 9.5 mm diameter must be drilled in both strips to correspond with those in the mounting flange on the barrier

[2] A mass, the end of which is between 125 mm and 925 mm high and 1,000 mm deep, is considered to satisfy this requirement.

(see paragraph 4.). The mounting strip and barrier flange holes may be widened from 9.5 mm up to a maximum of 25 mm in order to accommodate differences in back-plate arrangements and/or load cell wall hole configurations. None of the fixtures shall fail in the impact test. In the case where the deformable barrier is mounted on a load cell wall (LCW) it should be noted that the above dimensional requirements for mountings are intended as a minimum. Where a LCW is present, the mounting strips may be extended to accommodate higher mounting holes for the bolts. If the strips are required to be extended, then thicker gauge steel should be used accordingly, such that the barrier does not pull away from the wall, bend or tear during the impact. If an alternative method of mounting the barrier is used, it should be at least as secure as that specified in the above paragraphs.

Figure 1

Deformable barrier for offset frontal impact testing



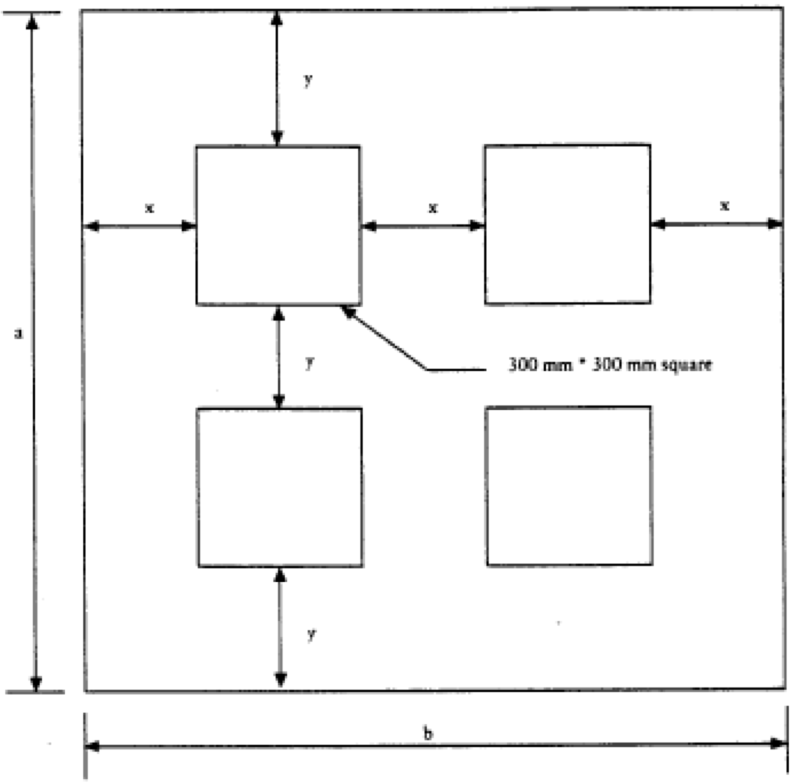
Ground

Barrier width: 1 000 mm

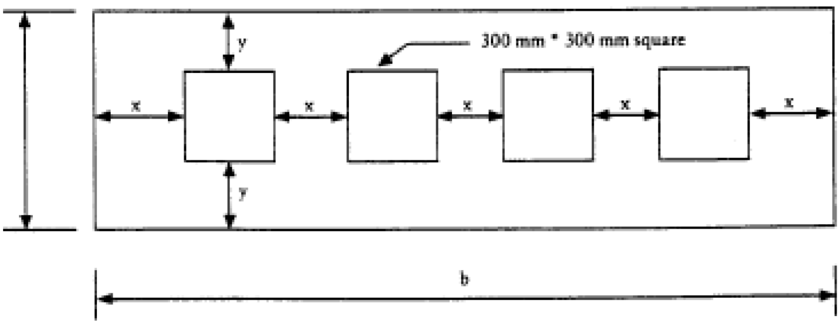
All dimensions in mm.

Figure 2

Location of the samples for certification



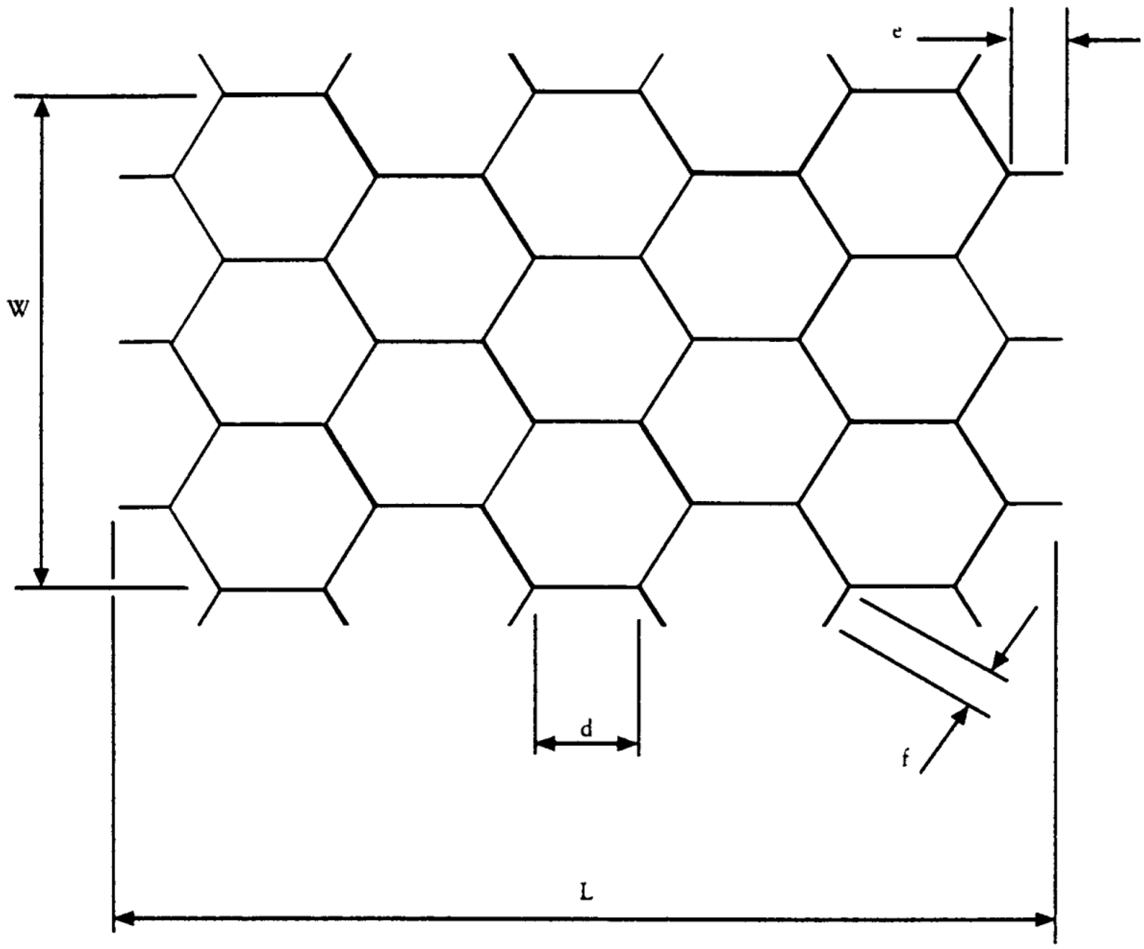
If a ≥ 900 mm: x = 1/3 (b-600mm) and y = 1/3 (a-600mm) (for a ≤ b)



If a < 900 mm: x = 1/5 (b - 1200 mm) and y = ½ (a - 300 mm) (for a ≤ b)

Figure 3

Honeycomb axes and measured dimensions



e = d/2
f = 0,8 mm

Figure 4

Crush force and displacement

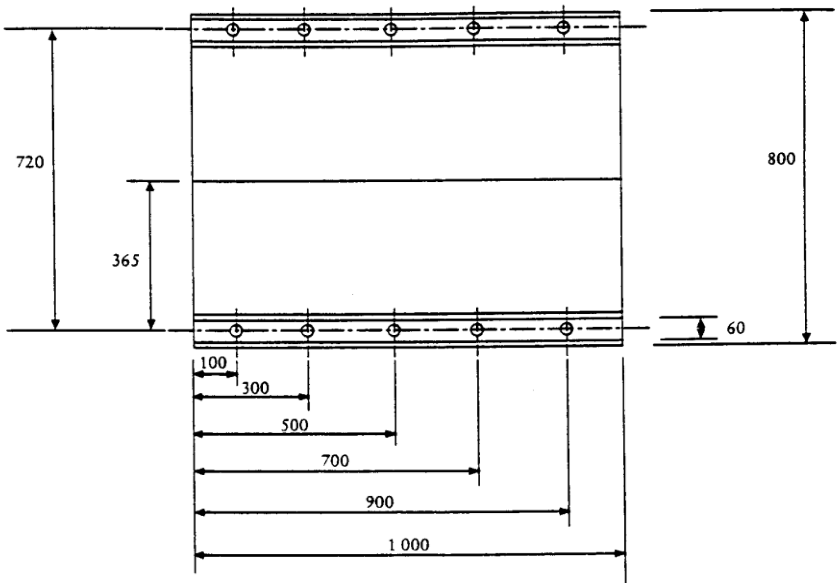
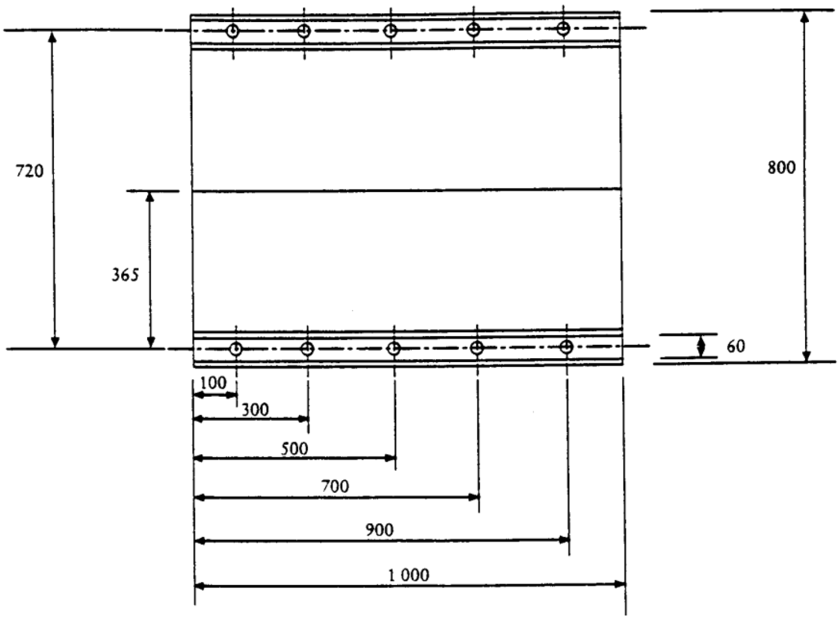


Figure 5

Position of holes for barrier mounting



Hole diameters 9.5 mm.

All dimensions in mm.

Annex 11 LOAD CELL WALL INSTRUMENTATION AND DATA PROCESSING

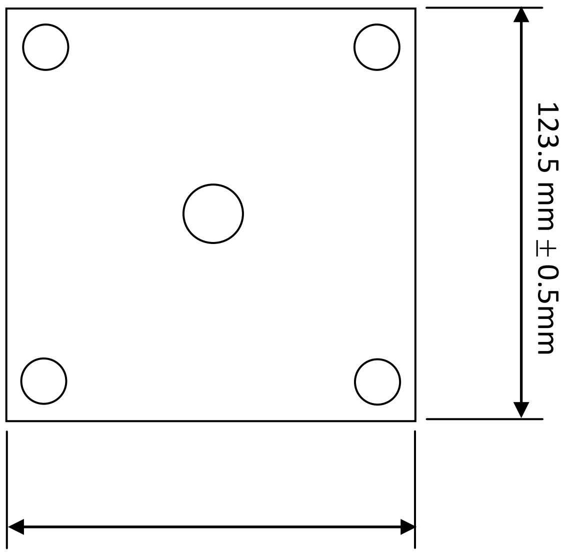
1. The load cell wall is to be formed by a matrix of individual load cells with a spacing of 125mm in the horizontal and vertical directions. The centre spacing of the load cells is 125mm x 125mm. The width of the load cell wall is to be equal to or greater than the width of the deformable barrier and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

1.1 Dimensions and layout

Each load cell tile on the load cell wall (LCW) has a nominal frontal area of 125mm x 125mm. 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.

Figure 1

External dimensions of individual load cells



1.2 Each load cell shall be faced with an 18mm 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.

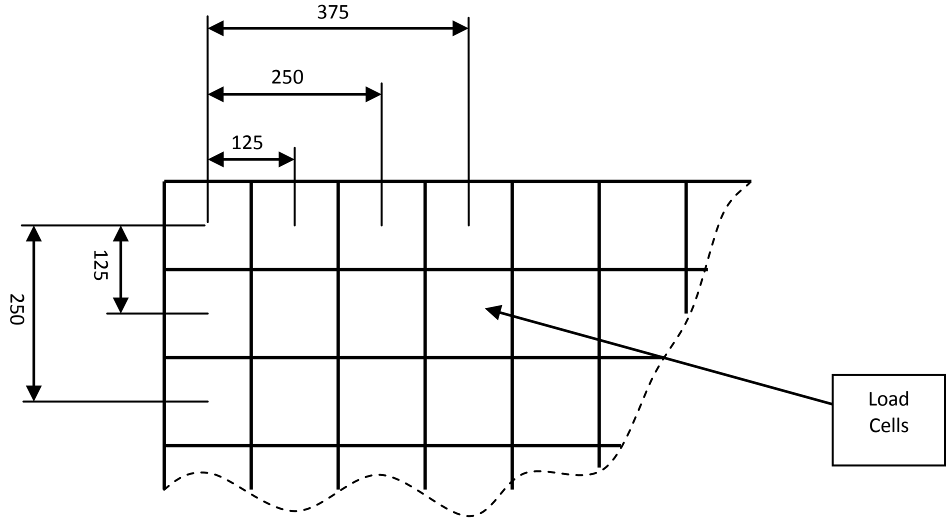
1.3 Each load cell must have threaded holes on the loading face to allow the mounting of deformable barrier faces and the MDF facings. A suggested pattern of holes is shown in the previous figure.

1.4 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 2000mm wide by 1000mm 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 ±2 mm.]

1.5 The load cells shall be spaced such that the centre of each load cell is 125mm 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.

Figure 2

Organisation of individual load cells in an array



1.6 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.

1.7 Technical Specifications of individual Load Cells

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^oC to $+70^oC$

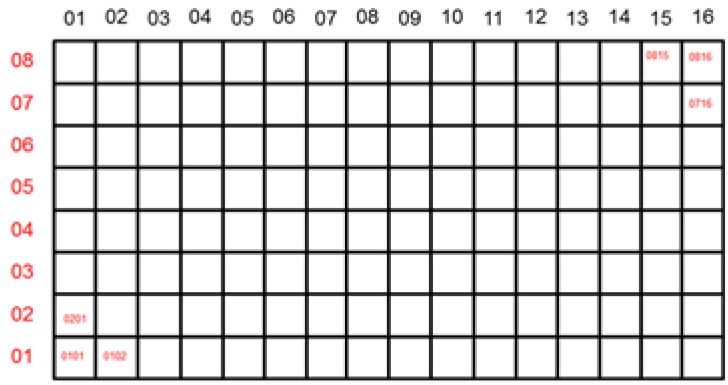
2. Calculation of Compatibility Metric

2.1 All LCW channels are recorded according to SAE J211 and filtered to CFC 60 before further processing

2.2 Each load cell position is labelled by row and column with row 1 and column 1 being in the left lower corner of the LCW when looking in the vehicle's direction of motion. The load in the X direction for each load cell is labelled L_{ij} were i is the row and j is the column label.

Figure 3

Load Cell Wall numbering



2.3 The row loads Fk are calculated by summing the load cell measurements in all columns by the following equation at each sampling point:

$$Fk = \sum_{j=1}^{16} L_{k,j} \text{ where } k=1,8$$

2.4 Calculation of Structural Alignment metric

The maximum value of the row loads F2, F3, and F4 are up to 40 ms after barrier contact. The combined loads in row 3&4 (F4+F3) and the maximum total cell wall loads(F_T) for each sample point are calculated from:

$$F4+F3 = \sum_{i=3}^{4}\sum_{j=}^{16} L_{i,j}$$

$$F_T = \sum_{i=1}^{8}\sum_{j=}^{16} L_{i,j}$$

and are used to calculate F_{T40} which is the maximum value of F_T up to 40 ms

2.5 Requirements for Structural Alignment metric

The vehicle fulfils the structural alignment criteria if one of the following conditions is met

– Condition 1

- F4 + F3 ≥ [MIN(200, 0.4F_{T40}) kN
- F4 ≥ [MIN(100, 0.2F_{T40}) kN
- F3 ≥ [MIN(100, 0.2F_{T40}) kN]

Condition 2

- F4 + F3 ≥ [MIN(200, 0.4F_{T40}) kN
- F4 ≥ [MIN(100, 0.2F_{T40}) kN
- F3 ≥ [MIN((100-LR), (0.2F_{T40}-LR))]

– where:

  - Limit Reduction (LR) = [MIN([F2-70])] kN, 0 ≤ LR ≤ [50 kN]

Annex 12 INTRUSION MEASUREMENTS

Measurement Methods and Acceptance Values

1 For vehicle deformation and intrusion measurements a 3D measuring system which is capable of recording 3 dimensional co-ordinates of a point in space can be used. A tolerance of +/- 1mm is applicable to such a system. The system requires an axis system to be set up relative to the object to be measured, typically the transverse, longitudinal and vertical directions of a vehicle. An origin is first needed, followed by a point on the positive x axis and then a point in the positive x-y plane. Since the front of the vehicle is highly deformed after the impact, it is simplest to use some structure at the rear of the vehicle as a reference for measurement; this obviates the need to level the car after testing, the accuracy of which is limited. Most of the procedure which follows relates to the setting up of these axes.

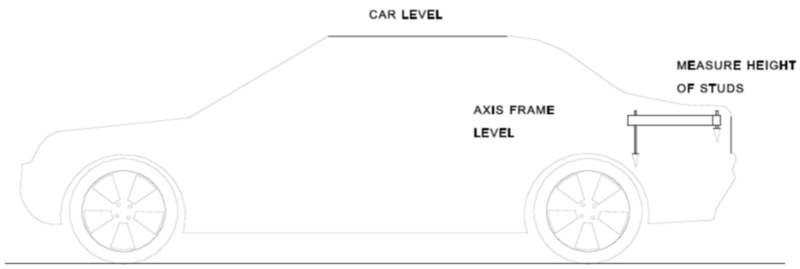
2 Before Test

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.

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

Figure 1

Preparation of vehicles axis reference frame



2.1.1 Level the reference frame.

2.1.2 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.

2.1.3 If it is necessary to lean on the vehicle to reach the following points, the vehicle should be

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

2.1.5 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.

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

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

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

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

2.1.8 Working on the driver's side of the vehicle determine and mark the positions on the A and B posts which are:

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

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

2.1.9 Use the arm to measure the pre-impact positions of the marks identified.

2.2 After Test

2.2.1 Remove the dummies according to Annex 5 and remove the data acquisition and emergency abort equipment (if fitted) from the luggage compartment.

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

2.2.3 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 2.1.2. Set the studs of the frame to the same heights as in Section 2.1.5 (Figure 2). The frame should now be in the same position relative to the car as it was before impact. Set up the measurement axes from the frame.

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

2.2.5 Compare the vertical co-ordinate of the B-post sill point before (Section 1.1.6) and after (Section 1.1.8) the test.

2.2.6 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).

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

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

2.2.8 Where □ is the angle determined in Section1.2.6. X and Z should now be in the same frame of reference as the pre-impact measurements.

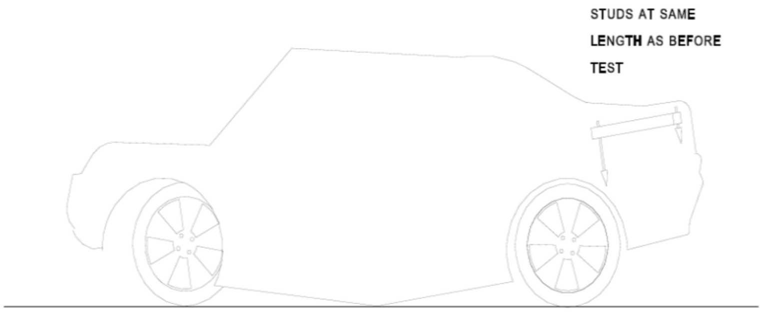
2.2.9 From the pre-impact and adjusted post-impact data collected, determine

i) the rearward movement of the A-post at waist level
ii) the reduction in width of the door aperture at waist and sill levels

2.2.10 Record these intrusion measurements in the test details.

Figure 2

Resetting the vehicle axis reference frame



2.3 The A-Pillar intrusion levels shall not exceed 50 mm.

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