EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC Working Group 13 Report

SIDE IMPACT BARRIER PERFORMANCE TESTING PROCEDURES FOR THE ASSESSMENT OF THE RELATIVE PERFORMANCE OF EEVC SIDE IMPACT BARRIER DEFORMABLE ELEMENTS UNDER REALISTIC LOADING CONDITIONS

January 1999

1 Introduction

In full-scale side impact testing, a Mobile Deformable Barrier (MDB) face is used to represent the front of the bullet vehicle. Currently the EEVC MDB is specified only in terms of general dimensions and dynamic performance, when impacting a flat unyielding load cell wall. The requirements of the barrier are that it must fulfil geometrical requirements (Inc. 1996) and that it conforms to prescribed force-deflection corridors when impacted into a load cell wall at a velocity of 35 km/h, with associated energy absorption limits. As a result of this performance only requirement, several different barrier face designs have been developed. Impact test institutes and vehicle manufacturers report that different barrier designs, conforming to this specification, can induce different types and amounts of vehicle damage. (Benedetto 1994)

The purpose of this document is to present some alternative test methods for assessing the performance of side impact barrier faces. It also explains the objectives of each test condition and to suggest additional desirable features based on current experience. These methods could provide comparative data on various barrier face designs to assist the appropriate authorities to select one or more suitable MDB designs, should a design and performance specification be adopted. The performance of a deformable barrier face can only be fully assessed in a full-scale vehicle impact test. In order to validate fully results of the proposed component based tests it is proposed that full-scale tests are also carried out.

This document is based on discussions within EEVC Working Group 13 and describes test procedures considered and developed by members of the Working Group and by JAMA/JARI. Not all of the test procedures have been fully evaluated and are subject to possible amendment after preliminary trials.

A specification for MDB design with complete build and assembly instructions and certification documentation would increase the repeatability and reproducibility of vehicle testing but would preclude the use of alternative designs of barrier face.

2 Barrier Production & Certification

Certification, Quality Assurance and Conformity of Production of an MDB are considered to be vitally important areas and suitable procedures should be defined, e.g. Barrier manufacturers should be approved to ISO9000 or equivalent. Each barrier should be supplied with traceable certification documentation.

3 MDB Design and Evaluation

The European Side Impact MDB face is defined by general shape, dynamic performance corridors and limits (energy and crush). A MDB face should meet these requirements by design with controlled energy management.

The directive indicates that the barrier should be manufactured from aluminium honeycomb but other alternative materials are permitted if equivalence can be demonstrated. In a honeycomb barrier a large volume of air can be trapped during crush, assuming that the ends of the cells are sealed during crush. The performance of the barrier then being crushed will come from a combination of honeycomb crush and the compression/release of entrapped air. There has been a low level debate, within EEVC WG13, as to whether the face of the trolley, onto which the deformable element is attached, should be ventilated, allowing any trapped air to escape through the rear surface of the barrier. The original UTAC barrier face, no longer manufactured, was designed for use with a ventilated support structure but the use of such a back structure was not included within the certification test specifications or the dynamic test in the Directive. In order to reduce test variability. **It is proposed that the trolley surface, onto which the barrier face is fitted, must be ventilated**. *It is noted that for a barrier design with a continuous solid rear surface it will be redundant feature.*

4 Current requirements

The certification test for the MDB (1994; Inc. 1996) is a perpendicular full frontal impact into a flat rigid load cell wall at 35km/h, Figure 1.

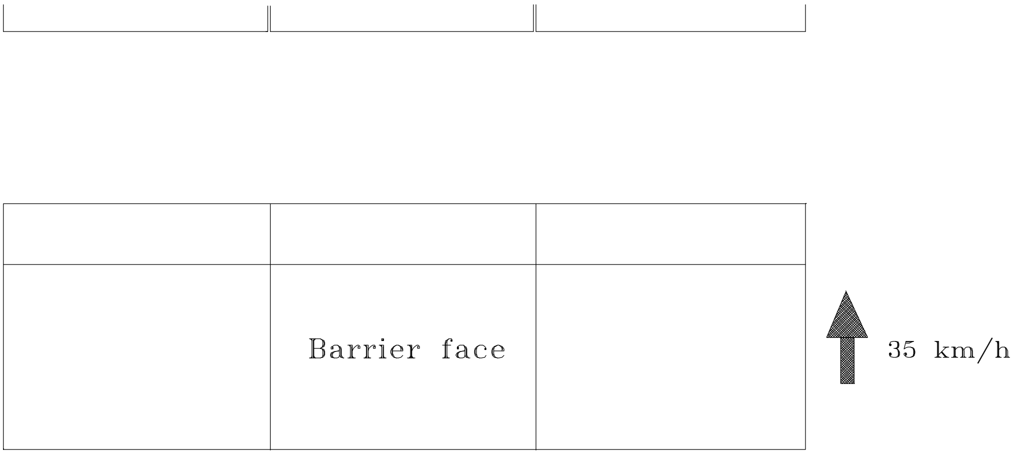

Figure 1. – MDB certification test.

There is a large difference between the certification test conditions and the actual side impact test conditions, in that the load cell wall does not simulate the complex deformation characteristics of the structure of the struck vehicle, which can have a large effect on barrier performance. In a vehicle impact, differential crush occurs across the face of the barrier as well as shear and bending forces within it. Thus the current certification test is of very limited use for examining barrier performance under the conditions that it will experience in a vehicle impact. Another limitation of the certification test is that it is carried out at 35km/h compared with the vehicle test impact velocity of 50km/h, since the deforming element would not be capable of absorbing all of the kinetic energy of the mobile barrier moving at 50km/h.

There is a degree of uncertainty regarding the dynamic performance of different load cell walls. In the assessment of certified performance’ it is proposed that at least one design of MDB face be assessed against more than one load cell wall. In addition some assessment of barrier repeatability is necessary, preferably with barriers taken from different manufacturing batches. The overall test should be examined in terms of calculated energy and momentum losses.

As a result of these problems, the following test procedures are proposed. They can are designed to provide comparative data on the various barrier designs in controlled car equivalent' loading conditions. The tests described in this report should not necessarily be considered to be additional tests or replacements for the certification test in the Side Impact Directive, but some of them could be used for this purpose if it were considered advisable.

5 Additional test procedures

5.1 High speed flat wall impact at 50km/h

This test is a perpendicular impact into a load cell wall. It is fundamentally the same as the current certification procedure, but at the increased velocity of 50km/h. To compensate for the increase in energy an additional energy absorption section, covering the full cross sectional area of the barrier, is necessary. The additional element is to be located between the rear face of the test barrier and the impact trolley, shown in Figure 2. The stiffness of the additional section must be uniform across the whole of the rear of the barrier and have a stiffness equivalent to at least twice the stiffest element from which the barrier is constructed. The depth of this additional element must be at least 300mm and should not influence the crush behaviour of the MDB face during the initial impact. *It is acknowledged that in this test the barrier face may be totally crushed.*

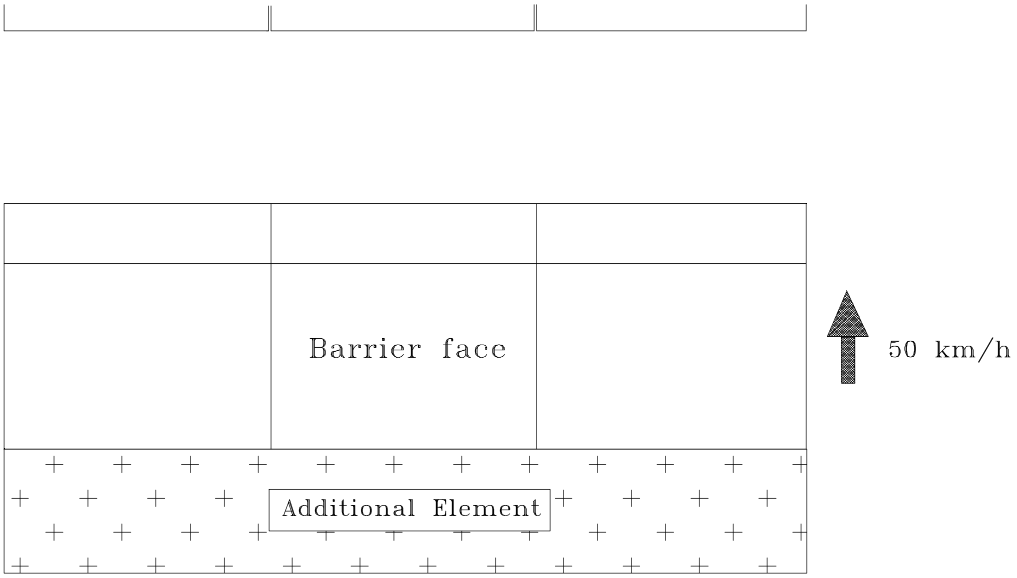

Figure 2. High Speed Flat Rigid Wall Test.

The test condition, Figure 2, will test the barrier at an equivalent speed to the full-scale test procedure. In comparison with the results of the standard configuration test, it can be used to assess the velocity sensitivity of the barrier's face. This test is likely to be able to reproduce better the initial inertial impact stiffness that is experienced in a vehicle test. *A proposal for acceptable initial stiffness is shown in the Appendix.*

5.2 Pole impacts.

Two pole impact tests are proposed in order to assess the extent to which the barrier face represents that of the front of a real vehicle when impacting a narrow obstacle generating a concentrated force. They are designed to test the ability of the barrier face to transfer impact forces from one part of the barrier to an adjacent part in a similar manner to real vehicles and to test its sensitivity to location of the stiff structure.

The pole tests will also be useful for determining the build quality of the barrier, since the outer edges of the barrier will not be directly loaded during the initial phase of the impact.

5.2.1 Central pole test.

The first of the pole tests is one with a pole located in the centre of the barrier, shown in plan view in Figure 3. The test is performed at an impact velocity of 25 km/h into a non-deforming pole of 175mm radius, whose apex is 250mm off the surface of the rigid wall. The total barrier mass is 950 kg.

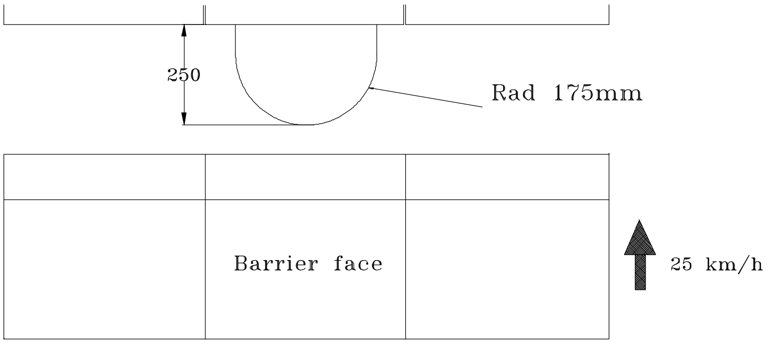

Figure 3. Central pole test.

5.2.2 Offset Pole Test.

The second pole test is similar to the central pole test but the pole is offset to one side and is aligned with the division between the centre and edge blocks, Figure 4. The offset pole test is performed at the reduced velocity of 20km/h. The results of this test will indicate the sensitivity of the MBD face to changes in the location of rigid structures.

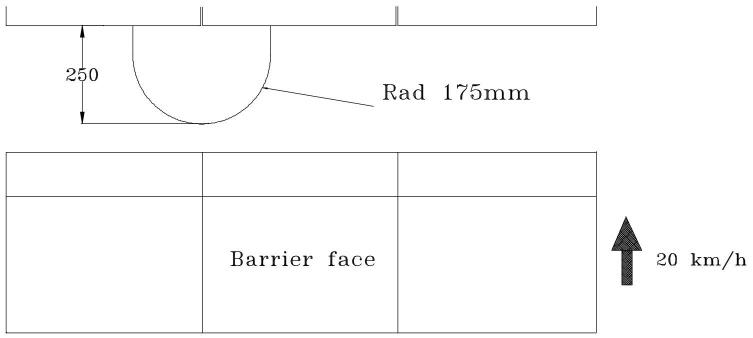

Figure 4. Offset Pole Test.

5.3 Rigid Angled Wall Tests.

Two test configurations are described at an impact velocity of 35km/h. The impact wall is similar to the MDB certification wall, with six load measuring areas but with the addition of rigid elements attached in appropriate places. The purpose of these tests is to examine the dynamic performance of the barrier face with induced shear and bending with longitudinal crush under controlled conditions. The first configuration examines the influence of stiff structures loading the ends of the barrier and the second the influence of a rigid door sill and the over ride condition. Neither test creates the initial vehicle type’ loading conditions of full face loading followed by shear and bending, never the less the tests will be helpful in studying shear and bending problems, since they would initiate any problems of instability or sensitivity to barrier crush failure. Forces should be measured and can be used for comparative purposes but the prime dynamic evaluation would be from the examination of the dynamic behaviour recorded by high-speed photography. The two test conditions are - Rigid Edge Loading (REL) and Rigid Sill Loading (RSL).

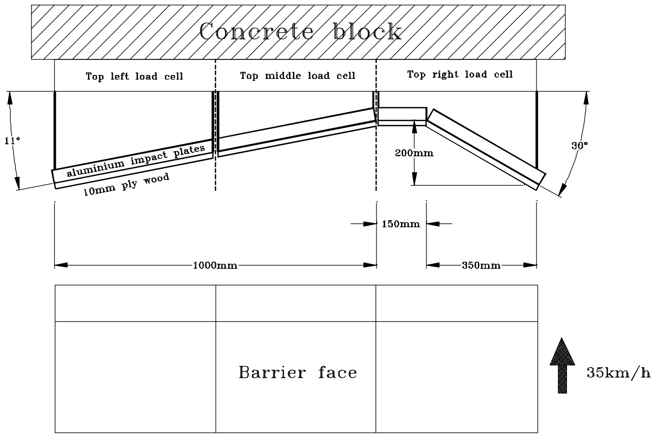

Figure 5. Rigid Edge Loading Test.

5.3.1 Rigid Edge Loading Wall.

The REL test uses the load cell wall with the load cells modified by the addition of rigid wedge shaped blocks, Figure 5. The surface of the wall is wood faced to minimise slip. The test induces

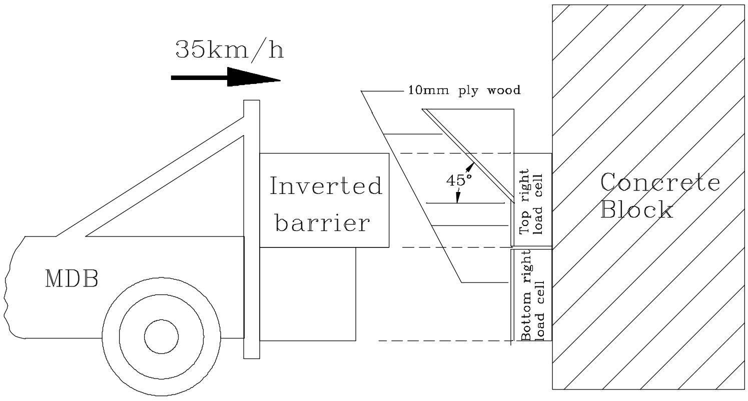

Figure 6. Rigid Sill Loading Test.

different deformations on each of the outer blocks of the barrier face as will be experienced in vehicle tests. The final deformation profile of the deformable face in plan view is representative of that of the final deformation observed in a typical vehicle impact. However, in a vehicle test the whole face of the barrier is initially loaded at the point of impact, whereas in this test the edges of the barrier are loaded first.

5.3.2 Rigid Sill Loading Wall.

The RSL test, illustrated in Figure 6, simulates an impact into a rigid vehicle sill. It uses the load cell wall with the load cells modified by the addition of rigid wedge shaped blocks mounted on the top three load cells. The surface of the wall is wood faced to minimise slip. The barrier is inverted on the mobile trolley so that the bumper section of the barrier face impacts the simulated sill and is prevented from riding over the sill during the impact. The test induces the type of loading that could be experienced in a vehicle impact, although the loading sequence is not car equivalent.

5.4 Yielding Wall.

This test configuration will assess the performance of the of the barrier face in a similar manner to the way a barrier deforms when it impacts a vehicle. In terms of barrier loading sequence, it is the best of the proposed test procedures. This test replicates the sequence of initial flat loading followed by differential progressive crush, bending and shear. The test produces a convex deformation profile in the barrier.

In the test, illustrated in Figure 7, the struck vehicle is replaced by a three-element energy absorbing system. The central element is a rigid plate constrained to move along the longitudinal axis of the mobile barrier with controlled energy absorption. The two outer elements are free-swinging rigid hinged doors whose outer hinges are fixed and whose inner edges bear on the centre plate. The wall at the commencement of the impact is flat. As the barrier loads the wall the centre plate is pushed backwards and the two outer elements swing developing a three surface concave profile. Barrier loading and deformation in this test simulates that occurring in a vehicle test but produces three flat surfaces compared to the parabolic profile of a vehicle test. The test would be performed at a velocity commensurate with car induced deformation - 50km/h. The major assessment of barrier failure would be based on an evaluation of the deformation characteristics obtained by high speed photography, although some comparisons could be made if forces were measured behind the MDB face.

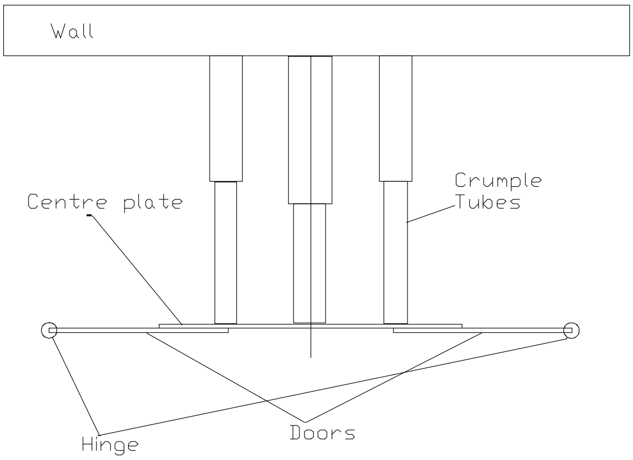

Figure 7. Yielding Wall Test.

5.5 Full-scale vehicle test.

The final MDB evaluation should be based on full-scale vehicle tests where the assessment of barrier performance or variations in performance are based on a) Visual deformation of the barrier. b) EuroSID-1 based parameters at the thorax, abdomen and pelvis levels and c) Vehicle based parameters (acceleration and deformation). The test procedure should be the same as that prescribed in the Side Impact Directive/Regulation (1994; Inc. 1996). Tests should be performed with the same model of vehicle, using the full range of barrier faces under consideration. In order to eliminate any element of vehicle based bias, the tests should be performed with at least two different types/sizes of vehicle.

6 DESIRABLE FEATURES

The following section lists the desirable features of the deformable face of a mobile barrier, for use in side impact testing. It is based on several years experience with different designs of barrier face.

6.1 Design Features

1. There should be traceable Certification and Conformity of Production data for each individual barrier. The data should preferably be directly associated with the individual barrier rather than by batch or design relationship.

2. The barrier should be well built and sufficiently robust to survive transportation from manufacturer to test facility, to survive pre-impact preparation and the pre-impact acceleration of the trolley.

3. A barrier should deform differentially when subjected to highly localised stresses, at any position. Elements and or inter layers should not spread the load excessively within the barrier.

4. The build and manufacturing quality, dimensional control, bonding systems and squareness of construction should be controlled.

5. The front surface of the deformable barrier face should be continuous across the width of the barrier face, thus preventing any object from penetrating the barrier between adjacent blocks or into the blocks without resistance.
6.
7. The barrier material, adhesives and construction should be environmentally stable, covering aspects such as humidity, temperature, UV sensitivity and ageing.

7. Post impact barrier disposal should be environmentally satisfactory.

6.2 Dynamic performance

1. The barrier should not be sensitive to small changes in the location of high stiffness impacts across the surface of a block. Transitional changes will occur between elements and close to the edges of a block but minimal variation should exist across the surface of each block.

7 ASSESSMENT METHODS

The aim of this part of the document is to define assessment techniques. This will provide a robust methodology to assess the potential performance of any energy absorbing barrier (in particular the European side impact deformable barrier) to deliver a realistic, reliable and repeatable impact to the side of a vehicle, in a legislative test. Some of the tests and evaluation criteria are easy to assess and are thus straightforward to use and to rank the performance of any barrier designs. Other criteria are much more difficult to quantify since they are subjective. In order to evaluate these criteria it is proposed that a group of technical experts on vehicle impact testing could examine the barriers pre and post impact, together with film and transducer data of the tests. The group of experts could then assess the quantifiable and subjective data. They would comment on and rank these aspects of barrier performance and report.

In some of the tests it is possible to calculate and compare theoretical and actual test energies. These calculations should be made and reported.

NOTE: It is acknowledged that the details of the test procedures described in this report will need to be specified in more detail before they could be used for barrier evaluation.

7.1 Certification tests

7.1.1 Quantitative performance.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. All barrier face designs must fulfil all of the currently specified design and performance criteria - force deflection corridors, deflection limits and energy absorption limits as defined in the certification test procedure (1994; Inc. 1996).

3. The initial stiffness of the barrier face shall be compared with the mean theoretical initial stiffness. The difference should be no greater that ±10%. *The assessment method is defined in the Appendix.*

7.1.2 Subjective requirements

1. The motion and deformations of the barrier face will be examined photographically. A failure would be defined as one in which a block or interface moved into an adjacent block or interface inducing a failure in the adjacent member, that could result in a reduction in the for/aft stiffness of that element .

2. The barrier should fail by crush and not explosion or other poorly controlled fracture mechanism. Explosive' failure is where a barrier breaks up early in the impact and the crush performance comes from a combination of the burst and crush stiffness of what remains of the barrier, or when the dynamic performance comes just from controlled explosion, in concept similar to the controlled deflation of an air bag. Some disassembly of the tested barrier may be necessary in order to examine the collapse mechanism(s) of the barrier.

7.2 High Speed Flat Wall

7.2.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. The initial stiffness of the barrier face shall be compared with the initial stiffness recorded in the certification test. The initial stiffness should be the same as in the 35km/h test within a tolerance of ± [20%]. *The assessment method is defined in the Appendix.*

3. Determine the distribution of absorbed energy for each area, as a function of the total absorbed barrier energy. The variation, by area, from the 35km/h test distribution should be less than 10%.

7.2.2 Subjective requirements

The subjective requirements are at detailed in section 7.1.2

7.3 Centred Pole

7.3.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. The forces measured at the pole/wall should indicate progressive resistance throughout the period of barrier penetration and not a very rapid rise at the end of the test.

3. The absorbed energy for each block should be determined. These energies could be used for further evaluation if necessary.

7.3.2 Subjective requirements

The subjective requirements are at detailed in section 7.1.2

7.4 Offset Pole

7.4.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. The forces measured at the pole/wall should indicate progressive resistance throughout the period of barrier penetration and not a very rapid rise at the end of the test.

3. The absorbed energy for each block should be determined. These energies could be used for further evaluation if necessary.

7.4.2 Subjective requirements

The subjective requirements are at detailed in section 7.1.2

7.5 Rigid Edge Loading Wall

7.5.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. When different designs of barrier are compared the proportion of absorbed energy for each block area, as a function of the total absorbed barrier energy, should be similar, as assessed by measurements taken from the load cell wall. If crush forces behind the barrier face on the trolley are measured similar comparisons can be made.

7.5.2 Subjective requirements

The subjective requirements are at detailed in section 7.1.2

7.6 Rigid Sill Loading Wall

7.6.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. Force measurements should be the same for the outer edge blocks. Differences in the instantaneous forces should be no greater than [5%] of the lower measured force.

3. The absorbed energy for each block should be determined, if load cells are used behind the barrier face on the trolley. These energies could be used for further evaluation if necessary.

7.6.2 Subjective requirements

The subjective requirements are at detailed in section 7.1.2

7.7 Yielding Wall

7.7.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. If force measurements are made on the impact trolley behind the barrier face, then they should be same for the outer edge blocks. Differences in the instantaneous forces should be no greater than 5% of the lower measured force..

3. The absorbed energy for each block should be determined, if load cells are used behind the barrier face on the trolley. These energies could be used for further evaluation if necessary.

7.7.2 Subjective requirements.

The subjective requirements are at detailed in section 7.1.2

7.8 Full scale vehicle impact

7.8.1 Quantitative performance aspects.

1. No detachment of component parts or blocks of the barrier shall occur during the crush phase of the impact, although some small opening up of the barrier might be acceptable, after the peak forces have been recorded, during the unloading phase of impact.

2. When different designs of barrier are compared the proportion of absorbed energy for each block area and force time history should be similar, if crush forces behind the barrier face on the trolley are measured. This assessment is made for each make/model of vehicle evaluated.

3. When tests using different designs of barrier are compared the measured parameters, dummy and vehicle should not vary by more than 10%. This assessment is made for each make/model of vehicle evaluated.

7.8.2 Subjective requirements

The subjective requirements are at detailed in section 7.1.2

8 CONCLUSION

The test procedures described in the report and associated assessment techniques should give a clear indication as to the relative merits of the different barrier designs and design concepts. It is possible that the sub system tests will lead to a recommendation for either a single design specification for a MDB face or to a significant tightening up of the existing specifications possibly excluding some generic designs of MDB face. The vehicle tests will indicate whether any unacceptable variability would still exist following such recommendations. It is therefore proposed that if any measured parameter, in the vehicle tests, varies by more than 10% between tests using the recommended’ barriers, with the same model of vehicle, then a further tightening of the barrier specification should be undertaken, and evaluated as appropriate. If a single design specification were to be recommended then at least two vehicle tests, with each type of vehicle, and barriers from different manufacturing batches, should be undertaken to investigate the reproducibility of the performance of the single barrier design in vehicle tests.

Acknowledements

Report prepared for EEVC WG13 by AK Roberts and C Owen - TRL, United Kingdom, and agreed by EEVC Working Group 13.

APPENDIX

Definition of Initial Stiffness

In the certification test (35 km/h) the barrier face should conform to the prescription:

$K_e = K_t \pm [10\%]$ The values of K_e are derived from the force/deflection characteristics of the individual elements or whole barrier between points F_1 and F_2..

where: K_e = "Effective Initial Stiffness"
K_t = "Theoretical Initial Stiffness"
K_{e50} = "Effective Initial stiffness" at 50 km/h
K_{e35} = "Effective Initial Stiffness" at 35km/h
and with F_1 = 10kN
F_2 = 50kN for the complete barrier
or F_1 = 2kN
F_2 = 10kN for blocks 1,2 and 3
F_2 = 6kN for blocks 4,5 and 6

In the 50km/h test the barrier face should conform to the prescription:

$K_{e50} = K_{t35} \pm [20\%]$ The values of K are derived from the force/deflection characteristics of the individual elements or whole barrier between points F_1 and F_2.

NOTE:- The forces, for these criteria must be taken from the vehicle mass multiplied by the longitudinal acceleration of the mobile deformable barrier chassis rather than from the force measuring wall.

Figure 8 graphically shows how the calculation of initial stiffness is derived.

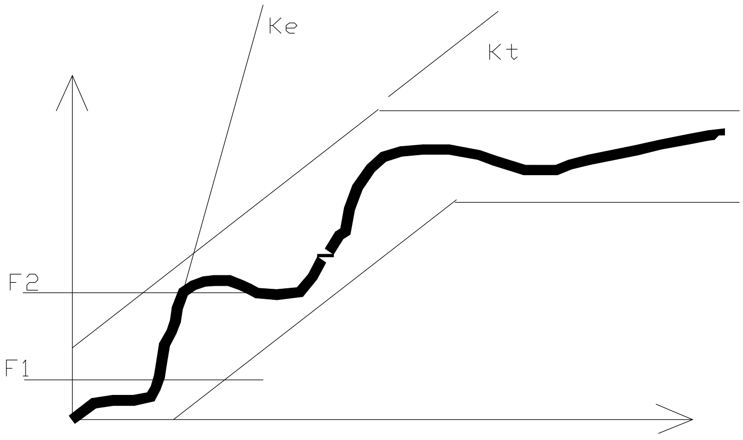

Figure 8. Derivation of initial stiffness

ANNEX 1

Manufacturers of MDB faces, known to EEVC WG13.

1. **AFL (France).** ***(*)***

> This is a barrier built from profiled sections of aluminium honeycomb and is a development of the original UTAC barrier face. *The original UTAC barrier face in no longer in production.*

UTAC-AFL
Ateliers de Fontenay sur Loing
45210 Fontenay sur Loing
FRANCE
Tel: +33 (0) 238 89 42 40, Fax: +33 (0) 238 89 42 47

2. **Cellbond Composites Ltd (UK).** ***(*)***

> This is a barrier built from profiled sections of aluminium honeycomb, similar in style to the AFL barrier.

Cellbond Composites Ltd (UK)
5 Stukeley Business Centre
Blackstone Road
Huntingdon
Cambridgeshire, UK
PE18 6EF
Tel: +44 (0)1480 435302, Fax: +44 (0)1480 432019
sales@cellbond.co.uk

3. **Cellbond Composites Ltd (UK) -** Multi 2000 barrier.

> This is a barrier developed with the Transport Research laboratory. It is a solid aluminium barrier made from layers of honeycomb of varying stiffnesses.

Contacts as above.

4. **Plascore (USA)**

> This is a barrier developed within the USA in collaboration with Ford (US). It is a solid aluminium barrier made from a range of honeycombs of varying stiffnesses.

Plascore Inc.
6 North Fairview Street
Zeeland
Michigan 49464
USA
Tel: +1 616 772 1220, Fax: +1 616 772 5508

5. **Fritzmeier (Germany)**

The current Fritzmeier barrier is manufactured from polyurethane foam and is a development of the original Fritzmeier barrier that was manufactured from blocks of cored included cored polyurethane foam. The current barrier is made from profiled blocks of foam and is similar to the AFL design.

Fritzmeier GmbH & Co KG
Heimatweg 1
83052 Bruckmuhl-Hinrichssegen
Germany
Tel: +49 (0) 8062 90257, Fax: +49 (0) 80629670

6. **Showa Aircraft Industry Co Ltd (Japan)**

This is a barrier developed in Japan. It is a solid aluminium barrier made from a range of honeycombs of varying stiffnesses

Showa Aircraft Industry Co Ltd
Honeycomb Sales Department
Honeycomb Division
Nishi-Shinjuku Showa Building
13-12 Nishi-Shinjuku1-Chrome
Shinjuku-ku
Tokuyo 160
JAPAN
Tel: +81 (0)3 3347 0603, Fax: +81 (0)3 3347 0617

7. **Yokohama (Japan)**

The Yokohama barrier is essentially the same as the Showa barrier. Since it is not made with exactly the same materials and manufacturing techniques it should considered to be an alternative barrier design.

Yokohama Rubber Co
Tokyo
Japan
Fax: +0 81 (0) 3 5400 4830

8. **Hexcell Composites (Belgium)** ***(*)***

> This aluminium honeycomb barrier appears to be the same as the original UTAC barrier.

Hexcell Composites S.A.
Rue Trois Burdone 54
B-4840
Welkenraedt
BELGIUM
Tel: +33 (0) 87 30 74 88, Fax: +32 (0) 87 88 28 95

9. **Darchem (UK)** ***(**)***

> This is understood to be an aluminium honeycomb based specially prepared honeycomb to give progressive stiffness.

Darchem Engineering Ltd
Stillington
Stockton on Tees
Cleveland
TS21 1LB
Tel: +44 (0)1740 630461, Fax: +44 (0)1740 631259

10. **UTAC (France)**

> No design details are available for this aluminium ‘etched’ barrier.

Contacts as above.