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TEST METHODS FOR EVALUATING AND COMPARING THE PERFORMANCE OF SIDE IMPACT BARRIER FACES

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Paper No 98-S8-O-02

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ABSTRACT

Side-impact safety of passenger cars is assessed in Europe in a full-scale test using a moving barrier. The front of this barrier is deformable and represents the stiffness of an 'average' car. The EU Directive 96/27/EC on side impact protection has adopted the EEVC Side Impact Test Procedure, including the original performance specification for the barrier face when impacting a flat dynamometric rigid wall.

The requirements of the deformable barrier face, as laid down in the Directive, are related to geometrical characteristics, deformation characteristics and energy dissipation figures. Due to these limited requirements, many variations are possible in designing a deformable barrier face. As a result, several barrier face designs are in the market. However, research institutes and car manufacturers report significant differences in test results when using these different devices.

It appears that the present approval test is not able to distinguish between the different designs that may perform differently when they impact real vehicles. Therefore, EEVC Working Group 13 has developed a number of tests to evaluate the different designs. In these tests the barrier faces are loaded and deformed in a specific and/or more representative way. Barrier faces of different design have been evaluated. In the paper the set-up and the reasoning behind the tests is presented. Results showing specific differences in performance are demonstrated.

INTRODUCTION

In full-scale side impact testing, a mobile deformable barrier face (MDB) is used to represent the front of the bullet vehicle. Currently[1,2] the EEVC MDB is specified only in terms of general dimensions and dynamic performance, when impacting a flat unyielding load cell wall. As a result of this ‘performance only’ requirement, several different barrier face designs have been developed. Research institutes and vehicle manufacturers report that different barrier designs, conforming to this specification, can induce different types and amounts of vehicle damage[3], as assessed by the Eurosid-1 dummy.

EEVC Working Group 13 (WG13) have defined a number of alternative test methods for assessing the performance of side impact barrier faces[4]. It also explains the objectives of each test condition and 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 paper is based on a document prepared by EEVC WG13 and describes tests considered and defined by members of the Working Group and by JASIC. Not all of the tests have been fully evaluated and are subject to possible amendment after preliminary trials.

CURRENT STATUS OF THE MOBILE DEFORMABLE BARRIER FACE

The European Side Impact MDB face is defined by geometrical characteristics, material characteristics and deformation characteristics. A MDB face should meet these requirements by design.

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MDB Design

The directive indicates that the barrier should be manufactured from aluminium honeycomb but 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. In order to reduce test variability it is proposed that the trolley surface, onto which the barrier face is fitted, must be ventilated. [For a barrier design with a continuous solid rear surface it will be redundant feature.]

MDB Manufacturing

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.

MDB Certification

The certification test for the MDB is a perpendicular full frontal impact into a flat rigid load cell wall at 35kph. 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 35kph compared with the vehicle test impact velocity of 50kph, since the deforming element would not be capable of absorbing all of the kinetic energy of the mobile barrier moving at 50kph.

DEVELOPMENT OF ALTERNATIVE TEST METHODS

As a result of the present definition of the certification procedure, many different barrier designs showing identical behaviour in a certification test are possible. In order to study the differences between different barrier designs and construction methods, a number of dynamic tests have been developed. These tests, with other suitable tests, could be used to investigate in a controlled manner the dynamic crush performance of side-impact MDB faces.

Pole Impact Tests

Local intrusion of rigid parts into the barrier was found to be a serious point of concern, especially when this part is located one time in the middle of a barrier block, the next time at an intersection between two blocks. To evaluate this phenomenon, two pole impact tests were originally defined by the working group according to figure 1. The set-up was evaluated by JASIC. For this purpose two fundamentally different barrier designs were tested: a profiled (pyramid-shaped) design and a solid (multi-layered) design. The pyramid design barriers had been manufactured with either a full width or segmented front surface.

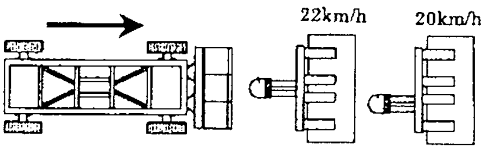

Figure 1: Evaluated test configurations for pole impact

The tests were very severe with very high levels of pole penetration. It was noted that several of the outer blocks became detached from the rear-mounting surface. Total barrier penetration occurred when the pole was offset. In addition, significant differences were observed between barriers manufactured with a continuous front surface and those manufactured with a segmented front.

The evaluation by JASIC showed the need for the pole test but in a slightly different set-up. For that purpose the pole penetration was reduced by adding a rigid wall behind the pole.

Additionally, the impact velocity for the centre pole test should be 22kph and 16kph for the offset pole test. The definitive test set-up is shown in the next chapter.

Angled Wall Test

The angled wall test is originally set-up by ACEA/JRC. In this test the wall comprises two symmetrical plates at 30° (left-right symmetrical). This wall profile is not representative of a 'vehicle like' deformed profile (see figure 2). Based on the analysis of twenty side impact tests using fifteen different types/models of vehicles, a new angled rigid wall test was developed by TRL. The analysis examined the post deformation of both vehicles and barrier faces. The aim of the angled walls is to reproduce 'typical' impact deformation on barrier faces, as found in full-scale car tests, so that more realistic performance comparisons can be made between the various barrier designs.

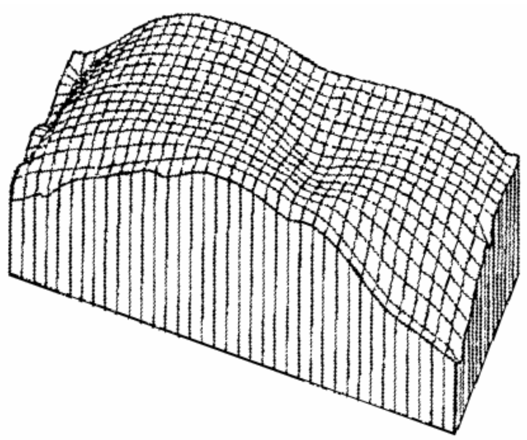

Figure 2: Average profile of 20 crashed barriers.

Seven validation barrier face impact tests, into the new angled wall, have been performed using four designs of aluminium honeycomb barrier face, including both profiled and solid designs. The tests clearly show significant differences in impact performance and barrier failure mechanisms between the different designs of barrier face. Therefore the angled wall test is included in the barrier evaluation programme. The definitive test set-up is shown in the next chapter.

Yielding Wall Test

The interaction between barrier face and car side structure governs the sequence of deformation and deformation pattern. Depending on the stiffness experienced, the barrier or the car will deform. Both structures hit with an originally flat structure. At TNO, a test set-up was developed which also allows the wall to deform. The test produces a convex deformation profile in the barrier.

The impacted wall 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.

A series of four tests was carried out to evaluate the discriminating potential of this method. Four different barriers were used, one foam barrier and three profiled barriers. As one of the most important features during side impact is the velocity of the deforming door, the velocity of the central element was monitored.

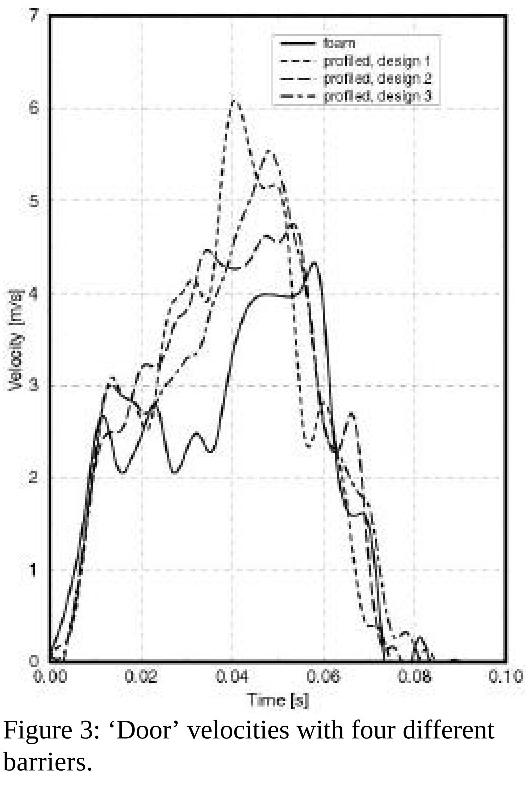

Figure 3: 'Door' velocities with four different barriers.

Figure 3 shows quite different velocities during the time of impact. This justifies the acceptance of this test in the barrier evaluation programme. The definitive test set-up is shown in the next chapter.

BARRIER EVALUATION PROGRAMME

The tests described here should not necessarily be considered to be additional tests or replacements for the certification test in the Directive, but some of them could be used for this purpose if it were considered advisable. It is also acknowledged that the details of the test procedures described below will need to be specified in more detail before they could be used for barrier evaluation.

High Speed Flat Wall Impact Test

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 50kph. 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. 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. The test is used to assess the velocity sensitivity of the barrier's face when compared to the standard 35kph certification test. This test is likely to be able to reproduce better the initial inertial impact stiffness that is experienced in a vehicle test.

Pole Impact Tests

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.

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 4. The test is performed at an impact velocity of 25 kph 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.

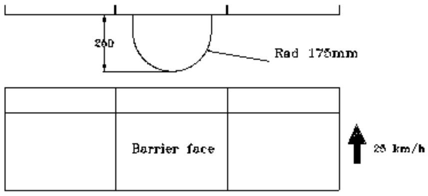

Figure 4. Central pole test.

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 5. The offset pole test is performed at the reduced velocity of 20kph. The results of this test will indicate the sensitivity of the MDB face to changes in the location of rigid structures.

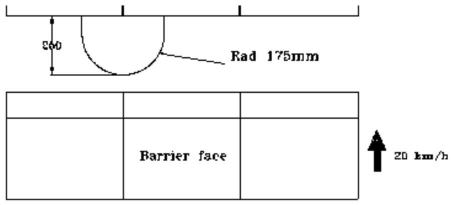

Figure 5. Offset Pole Test.

Rigid Angled Wall Tests

Two test configurations are described at an impact velocity of 35kph. 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 override condition. Neither test creates the initial 'vehicle type' loading conditions of full face loading followed by shear and bending, nevertheless 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 tests, the Rigid Edge Loading Test (REL) and Rigid Sill Loading Test (RSL) are specified below.

Rigid Edge Loading Test - The REL test uses the load cell wall with the load cells modified by the addition of rigid wedge shaped blocks, Figure 6. The surface of the wall is wood faced to minimise slip.

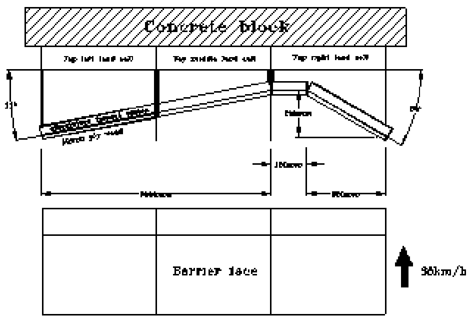

Figure 6. Rigid Edge Loading Test.

The test induces 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.

Rigid Sill Loading Test - The RSL test, illustrated in figure 7, 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'.

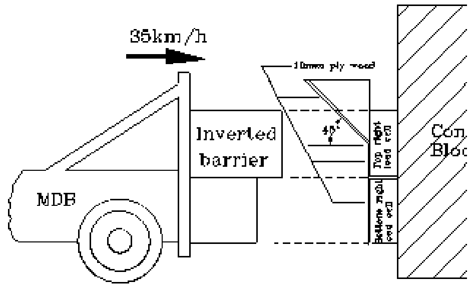

Figure 7. Rigid Sill Loading Test.

Yielding Wall Test

This test configuration will assess the performance 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 considered to be the best of the proposed tests. This test replicates the sequence of initial flat loading followed by differential progressive crush, bending and shear.

In the test, illustrated in Figure 8, the struck vehicle is replaced by a three-element energy absorbing system. The central plate is linearly guided and supported by crumple tubes. The left and right plates are free-swinging rigid hinged doors, at the inner edges supported by the centre plate. The crumple tubes are configured in such a way that 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 - 50kph. 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.

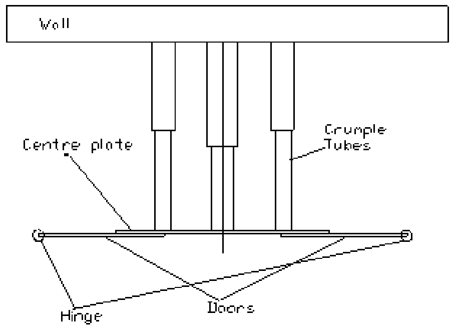

Figure 8. Yielding Wall Test.

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 or Regulation[1,2]. 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.

ASSESSMENT

Assessment techniques 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.

Hereafter criteria related to proper design, dynamic performance and subjective requirements are summarised. 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.

Design Aspects

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 build and manufacturing quality, dimensional control, bonding systems and squareness of construction should be controlled.
3. 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.
4. The barrier material, adhesives and construction should be environmentally stable, covering aspects such as humidity, temperature, UV sensitivity and ageing.
5. The barrier should be sufficiently robust to survive transportation from manufacturer to test facility, to survive pre-impact preparation and the pre-impact acceleration of the trolley.
6. 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.
7. Post impact barrier disposal should be environmentally satisfactory.

Quantitative Performance Aspects

1. All barrier face designs must fulfil the present requirements as defined in the certification test procedure[1,2].
2. 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.
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%. This holds for the certification test. In the high speed flat wall impact test the initial stiffness should be the same as in the 35kph test within a tolerance of [20%]. The variation of absorbed energy distribution for each area, as a

function of the total absorbed barrier energy, from the 35kph test distribution should be less than 10%.
4. The absorbed energy for each block should be determined, if possible. These energies could be used for further evaluation if necessary. If crush forces behind the barrier face on the trolley are measured comparisons can be made.
5. In tests with a symmetrical test configuration the 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.
6. 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.
7. In full-scale vehicle tests using different designs of barrier the measured parameters (dummy and vehicle) should not vary by more than 10%. This assessment is made for each make/model of vehicle evaluated.
8. 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.

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 by explosion or other poorly controlled fracture mechanism. Disassembly of the tested barrier may be necessary in order to examine the collapse mechanism(s) of the barrier.

CONCLUSION

The tests 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.

FUTURE WORK

Funding for carrying out the barrier evaluation programme is being sought. It is expected that the programme will start late 1998 and will be completed by the end of 1999.

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