EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

RECOMMENDATIONS FOR A REVISED SPECIFICATION FOR THE EEVC MOBILE DEFORMABLE BARRIER FACE

(As used in ECE Regulation 95 and EU Directive 95/27/EC)

EEVC Working Group 13

November 2001

RECOMMENDATIONS FOR A REVISED SPECIFICATION FOR THE EEVC MOBILE DEFORMABLE BARRIER FACE

EXECUTIVE SUMMARY

The ECE Regulation 95 (and the equivalent EU Directive) defines the deformable element of the mobile deformable barrier in terms of the force-deflection characteristics when impacting a six element load cell wall together with some dimensional requirements. Problems have been experienced by some automobile manufacturers due to the differing behaviour of different side impact MDB faces that claim to meet the dynamic performance required by the Directive and Regulation.

Following an evaluation of all MDB faces available to this specification, EEVC recommended moving to a single specified design of MDB face to improve consistency, repeatability and reproducibility. A Validation Programme was undertaken to assess the draft Design Specification. This test programme has now been completed and analysed and the results have shown that this design specification results in MDB faces that are far more repeatable and reproducible than the original performance specification but that some modifications were needed following some observations in this programme

The tests included the flat rigid load cell wall test, the rigid sill loading test, the offset pole impact test and some full scale impact tests. These were selected to assess the behaviour of the MDB faces both under the flat load cell wall certification test procedure and under more realistic test conditions. Sample prototype MDB faces were obtained from two European manufacturers, one US manufacturer and one Japanese manufacturer. Due to lack of experience with this new specification, not all of the requirements were met for these prototype samples. Nevertheless, valuable results were obtained and conclusions drawn. It is anticipated that production versions of the MDB faces will be even better than these prototype versions once more experience had been gained and full production equipment is in place.

The repeatability and consistency of the new barrier faces in the loadcell wall tests was considerably better than it was with the old barrier faces. This is encouraging, especially bearing in mind that not all of the faces built, in prototype form, completely followed the full design specification requirements.

The new Design Specification includes quasi-static force deformation corridors to batch-control the performance of the individual blocks after treatment to produce the progressive force needed for the MDB face. While most of the draft static corridors appear to be appropriate, for blocks 1 and 3 the dynamic response tended to be towards the lower half of the corridor while the quasi-static response was in the upper half of the corridor. For this reason, the quasi-static corridor for blocks 1 and 3 has been raised slightly to ensure compliance with the dynamic corridor. The static corridors supplement, rather than replace the dynamic corridor requirements.

The repeatability of the overall performance of the barrier faces in both the rigid sill test and the offset pole test was good. However, the variability of the individual blocks was greater. The row of blocks impacting the sill representation for one barrier face partially debonded from the backing plate resulting in a much lower force for blocks 1 to 3 and a much higher force for blocks 4 to 6 than the barrier faces from the other three manufacturers. In the pole test, some blocks from two of the faces debonded from the backplate. The failures and debonding were observed on the MDB faces with the lowest adhesive strength. As a consequence, the minimum adhesive strength requirement has been raised to eliminate this problem.

Four full-scale MDB-to-car tests were performed in order to evaluate the behaviour of the barrier faces in full-scale test conditions. The tests included two using one model of vehicle to evaluate reproducibility between MDB face manufacturers and two others using different vehicle models to widen the model range for which test experience was gained with barrier faces designed to the new specification.

For the tests with two identical vehicle models, the post test vehicle deformation profiles were very similar for the two different barrier faces except for the lowest two measuring lines corresponding

approximately to the dummy pelvis level. For these locations, the intrusion was greater for the Cellbond MDB face forward of the B-pillar. Similarly the reproducibility of the dummy responses for the upper body areas (Head, Chest and Abdomen) was very good. The pubic symphysis response was higher for the Cellbond MDB face than for the AFL face. These dummy responses correspond well with the observed difference in the deformation profiles.

It was observed that there was a tear in the front face of the lower row of blocks in the Cellbond face but not in the AFL face. The AFL face blocks debonded from the backplate in this test but this is unlikely to have affected the tearing of the front plate. The difference in behaviour of the cars at the lowest level is considered to be directly due to this tearing. This is *not* a new phenomena, having been observed in several full scale tests including the EuroNCAP test on this same model. A review of the materials used in the front plates has shown that it is likely that this phenomenon is related to the elongation and strength properties of the material. The draft specification has been modified to specify the Elongation and Ultimate Tensile Strength of the front plate material. The values have been selected to duplicate the AFL barrier face response

The response of the rear struck-side child dummy in a child restraint in these two tests showed good reproducibility.

The behaviour of the AFL and Cellbond MDB faces in the full scale tests with the other two vehicle models appeared to be normal with no undesirable observations except for the debonding of some of the AFL blocks from the rear plate after the test.

Conclusions

1. This programme demonstrated the significant improvement in reproducibility and repeatability of MDB faces designed to meet the proposed new Specification, despite the prototypes not fully meeting all of the requirements. It has also demonstrated the need for some small changes in the Specification.

2. The adhesive bond strength between the aluminium blocks and the back plate for some of the barrier faces was insufficient to ensure maintenance of the bond in the severe pole and rigid sill tests and also in some full scale tests. An increase in minimum strength is proposed.

3. The variation of the individual block forces for these prototype MDB faces is considered to be a result of limited and differing manufacturing experience with the material types used for each block and is expected to improve with experience.

4. While most of the static corridors appear to be appropriate, the proposed corridor for blocks 1 and 3 has been modified

5. MDB faces produced to the new Specification appeared to behave satisfactorily in full scale tests and show good repeatability except where the front plate performance varied. The tearing behaviour of the front plates of two of the MDB faces differed in similar full scale impact tests. The specification for the front face plate material has been revised to specify elongation and UTS in order prevent this.

6. Some additional minor modifications to the Specification are proposed, including strengthening of the ventilation frame and improved backplate attachment details.

7. Suggestions for conformity of production of the faces from batch sampling are made, based on experience in this test programme.

RECOMMENDATIONS FOR A REVISED SPECIFICATION FOR THE EEVC MOBILE DEFORMABLE BARRIER FACE

Introduction.

The EEVC developed a side impact test procedure, during the 1970s, which involved the use of a mobile deformable barrier. The deformable element of this barrier was defined in terms of the force-deflection characteristics when impacting a six element load cell wall together with some dimensional requirements. The detailed design for the barrier face was not specified in the interests of allowing design freedom and hence novel designs to emerge. When this EEVC test procedure was used as the basis for ECE Regulation 95 (and the equivalent EU Directive), this 'performance' specification was also adopted.

Experience with testing to this Regulation has exposed problems experienced by some automobile manufacturers due to the differing behaviour of different side impact MDB faces. Different designs that claim to meet the dynamic performance required by the Directive and Regulation can result in different behaviour of cars when tested in the full scale test.

To try to resolve these difficulties, EEVC evaluated the whole range of MDB faces available to this specification to try to find methods for reducing this variability in performance when testing vehicles. Following this Evaluation Programme, EEVC recommended moving to a single specified design of MDB face to improve consistency, repeatability and reproducibility. EEVC WG13 recommended a design based on the principles of the AFL progress barrier face and produced a draft Specification in collaboration with the main MDB face manufacturers. This was presented to GRSP in December 2000. EEVC believed that it would be advisable to validate the proposed design standard before it could be recommended for adoption in ECE Regulation 95.

A small validation programme was undertaken to assess whether MDB faces produced by several MDB face manufacturers to the same design specification would behave in a more repeatable and reproducible manner. The results have shown that this design specification results in MDB faces that are far more repeatable and reproducible than the original performance specification. However, the Validation Programme has shown some phenomena that demonstrated that the specification could be improved. As a result of this analysis, some modifications to the original draft design specification have been made and the revised specification is offered as a possible replacement for the existing specification. This Design Specification is considered by EEVC to provide significantly improved repeatability, reproducibility and reliability.

Validation Test Programme

Sample MDB faces were obtained from two European manufacturers, one US manufacturer and one Japanese manufacturer. It should be emphasised that none of these manufacturers had made MDB faces to this new specification before this test programme commenced and had not had the opportunity to develop their production methods before the samples were required for the test programme. Some of the manufacturers had no experience of manufacturing with the etching process needed to produce the progressive type of MDB blocks now specified. Consequently not all of the requirements of the specification were met for these prototype samples. Nevertheless, it was considered to be valuable to proceed with the test programme and to evaluate the results in the anticipation that production versions of the MDB faces would be better than these prototype versions once more experience had been gained and full production equipment was in place.

The tests included in the Validation Programme were designed to assess the behaviour of the MDB faces both under the flat load cell wall certification test procedure and under more realistic test conditions. They included two of the special test conditions developed by EEVC under the MDB evaluation test programme and some full scale car impacts.

Flat Rigid Load Cell Wall Test.

The test conditions to followed those specified for the Dynamic Certification test (Figure 1) and these tests provide some information on repeatability and reproducibility under limited test conditions.   Table 1 shows the tests performed.

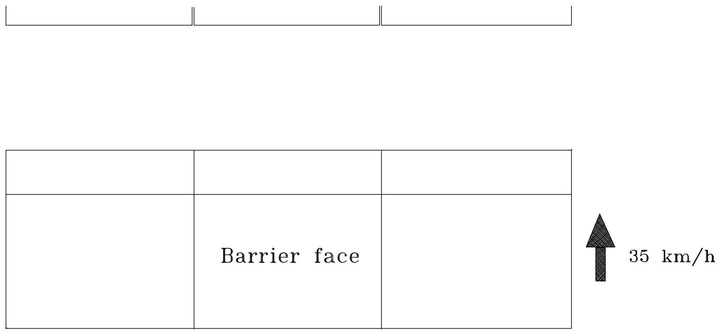

Figure 1 Flat Rigid Load Cell Wall Test Condition (Certification Test Procedure)

Table 1
Test Matrix for Flat Loadcell Wall tests

Test Institute	**MDB**					
UTAC	AFL	CELLBOND	SHOWA	PLASCORE	AFL	AFL
TNO	AFL	CELLBOND	SHOWA	PLASCORE	CELLBOND	CELLBOND
TRL	AFL	CELLBOND	SHOWA	PLASCORE		
BASt	AFL	CELLBOND	SHOWA	PLASCORE		

Rigid Sill Loading Test (RSLT)

The Rigid Sill Loading test, illustrated in Figure 2, 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 was found to be most discriminating in determining the effects of non-axial loading to the honeycomb blocks. The performance of the MDB faces can be determined both by the forces measured on the load cells and by observing the behaviour of the individual blocks from high speed film records of the tests. This provides a good measure of reproducibility under more realistic impact conditions.

The MDB faces tested are given in Table 2.

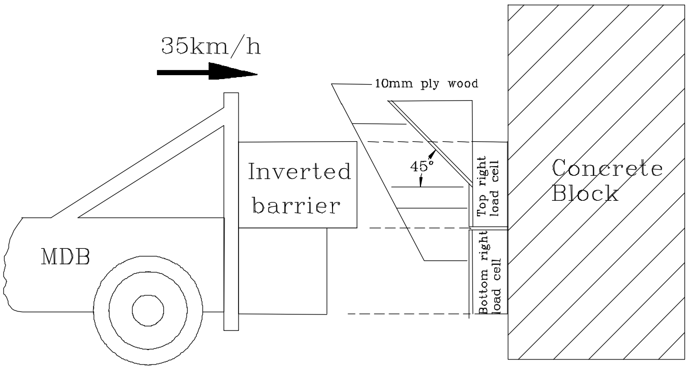

Figure 2. Rigid Sill Loading Test Conditions

Offset Pole Impact test

For this test, the load cell wall is modified by the addition of a 350mm diameter pole centred on the vertical junction between two MDB face blocks (Figure 3).. This test condition was shown to be particularly effective at determining the effect of shear forces applied to the front surface of the MDB face and simulated the effect of tests against a very strong B-pillar. The performance of the MDB faces is determined both by the forces measured on the load cells and by observing the behaviour of the individual blocks from high speed film records of the tests. This provides a good measure of reproducibility under concentrated loading impact conditions, with particular reference to shear behaviour at the front plate interface and the attachment of the blocks to the back plate. The MDB faces tested are given in Table 2

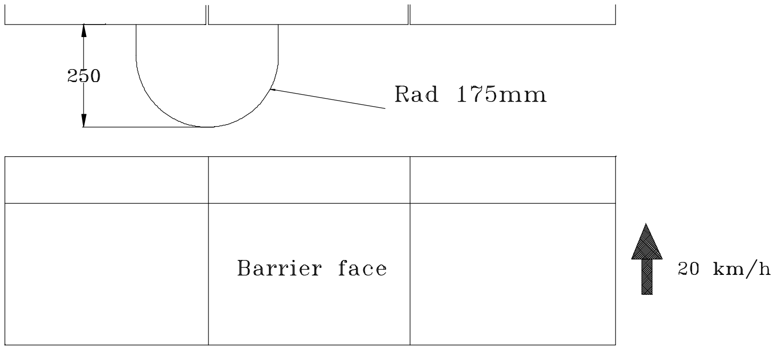

Figure 3 Offset Pole Impact Test Conditions

Table 2
Rigid Sill Loading Test and Pole Test Matrix

Test	Test Institute	MDB Face			
*RSLT	TRL	AFL	CELLBOND	SHOWA	PLASCORE
*Offset Pole	BASt	AFL	CELLBOND	SHOWA	PLASCORE

<u>Full Scale Car Impact Test</u>

Test conditions followed those of the R95 Full Scale Test, with supplementary data collected (e.g. door intrusion velocities, final static deformation profiles). The test programme is shown in Table 3.

Table 3
Full Scale Car Impact Test programme

Test Institute	Vehicle Model	MDB Face			
FIAT	A	AFL	CELLBOND		
TNO	B			CELLBOND	
UTAC	C				AFL

Results

Flat Loadcell Wall Tests

The results of the loadcell wall tests in the *previous* MDB Face Evaluation programme, for all of the MDB faces available at that time, are shown in figure 4. This shows the total force vrs barrier face deformation for all of the different designs of barrier face tested at all test institutes.

The equivalent results from the current validation test programme, with the MDB Faces to the new design specification are shown in figure 5.

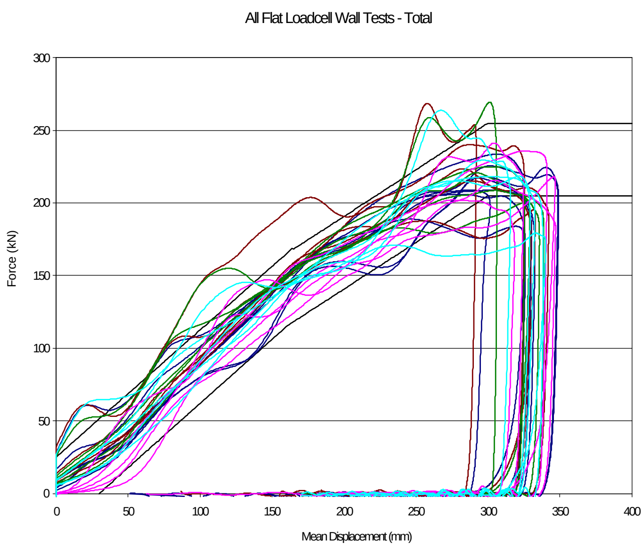

Figure 4. Total Force vrs barrier displacement – Evaluation Test Programme, 7 MDB faces, 4 test institutes (28 test results)

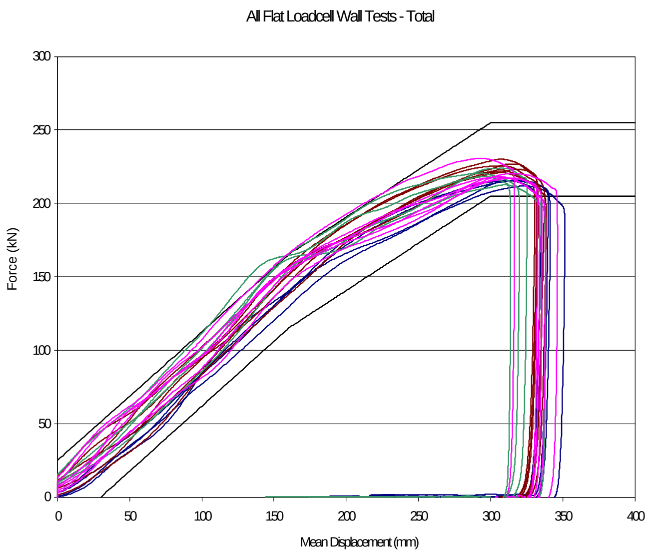

Figure 5. Total Force vrs barrier displacement – Validation Test Programme, 4 MDB faces, 4 test institutes (20 test results, including repeat tests)

As can clearly be seen, the variability of the new barrier faces is considerably better than it was with the old barrier faces. In addition, the shape of the force-deflection curves is a much better match to the shape of the corridor with the new barrier faces. This is encouraging, especially bearing in mind that not all of the faces built, in prototype form, completely followed the full design specification requirements.

This improvement can also be illustrated by comparing reproducibility of MDB faces from all manufacturers and reproducibility at different test institutes.

Figure 6 shows the total force results for all four MDB manufacturers at one test institute (BASt), showing very good reproducibility between manufacturers.

Figure 7 shows the results for one MDB face manufacturer at all of the test institutes, including three repeat tests at one institute. This shows that very similar results are obtained at all of these test institutes. There was a marked test institute variation with some MDB face designs in the previous study.

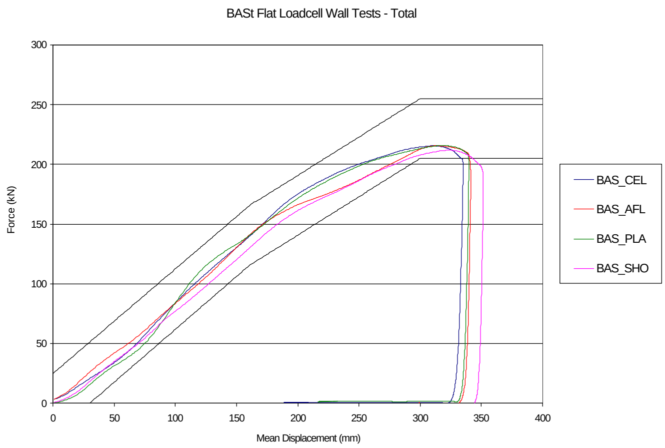

Figure 6. Total force vrs deformation for 4 different manufacturers at one test institute (BASt)

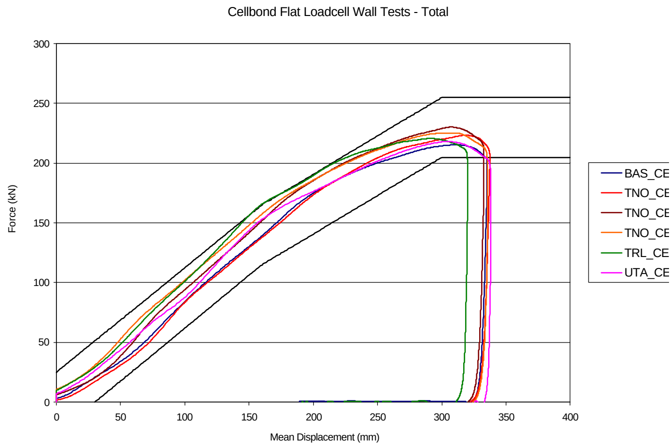

Figure 7. Total force vrs deformation for 1 manufacturer (Cellbond); at all test institutes

The reproducibility for individual blocks was less good. Results for Block 1 and Block 4 are shown in Figures 8 and 9 as examples. The repeatability varied by block and by manufacturer. This was attributed to differing experiences with the aluminium type and manufacturing process. It is anticipated that this will improve significantly with further experience

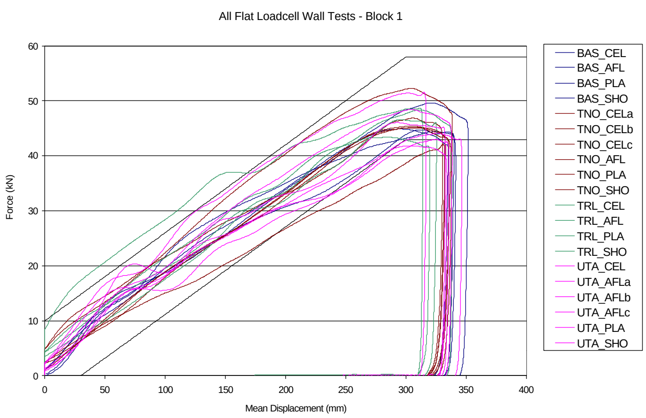

Figure 8. Force-deflection curves for Block 1 – Validation Programme

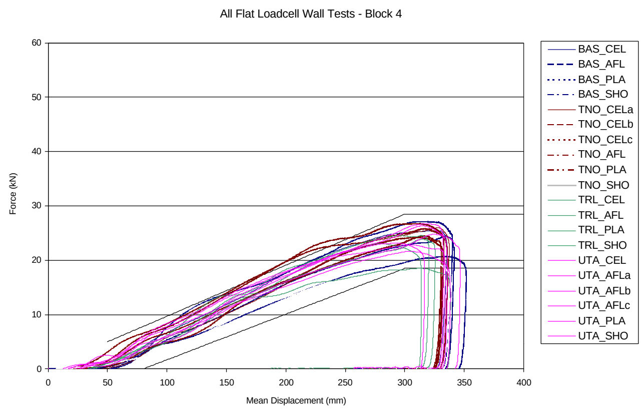

Figure 9. Force-deflection curves for Block 4 – Validation Programme

Energy Absorption Requirements.

The results from the flat load cell wall tests can be compared with the existing requirements for energy absorption and the theoretical values from the dynamic force deflection corridors. Table 4 below shows the test results for all of the barrier faces tested and also only for those barrier face blocks that fully met the static force corridors. Based on these results, recommendations are made for a revised set of energy absorption requirements. These are the same as the current requirements except for Block 2 for which it is proposed the energy absorption should be increased from 14 to 15 kJ and Blocks 1 and 3 which are reduced from 10 to 9.5 kJ to bring them closer to both the theoretical values and the results for these tests.

Table 4
Energy absorption requirements (kJ)

BLOCK No.	1 & 3	2	5 & 6	4	Total force	Sum of blocks
R95/Directive	10 ±2	14 ± 2	3.5 ± 1	4 ± 1	45 ± 5	45
Theoretical	9.09	15.3	3.075	3.52	44.0	43.15
MDB Kinetic Energy					44.9	
Test Programme (all result)	9.5	15.5	3.9	4.1	46.4	
Std Dev	*0.92*	*0.98*	*0.46*	*0.43*	*1.02*	
Test Programme ("passes" only)	9.3	15.5	3.6	4.1	45.4	
Std Dev	*0.80*	*0.93*	*0.42*	*0.27*	-	

Recommended values (kJ)	**9.5 ± 2**	**15 ± 2**	**3.5 ± 1**	**4 ± 1**	**45 ± 3**

Impactor Deformation

The theoretical maximum deformation of the MDB face, when all of the kinetic energy has been absorbed, is 330mm and this is the typical value seen on the force-displacement curves. However, this is a dynamic value and there is a certain amount of elastic recovery observed with aluminium honeycomb barrier faces. It was considered that the final residual static impactor deformation was a valuable characteristic that would control the amount of elastic recovery and that is simple to measure. Therefore it is recommended that the current requirement for the deformation measured after the test be replaced by two requirements: the maximum dynamic deformation measured during the test (330 ± 20mm) and the permanent residual deformation measured after the test (310 ± 20mm)

Static Force Requirements

The design of the barrier faces, built according to the proposed specification, can be defined in detail except for the wall thickness of the aluminium honeycomb *after* treatment to produce the desired progressive force deformation response. An important aspect of the new Specification has been the introduction of the quasi-static force deformation corridors to control this and to ensure consistent production, since each batch can be tested in this manner.

The relationship between the quasi-static force-deflection response from the manufacturers' batch certification tests was compared with the dynamic response for each block from the flat load cell wall tests. In this prototype batch of MDB faces, not all of those produced fell inside the proposed quasi-static test corridors. Where a certification response was high in the static corridor relative to the certification response of other blocks from the same manufacturer, the dynamic response tended to be high relative to the dynamic response for the other blocks. However, the trend was weak and not consistent across all the blocks, although this may be due to the variability in dynamic block response. For blocks 1 and 3, the dynamic response tended to be towards the lower half of the corridor while the quasi-static response was in the upper half of the corridor. For this reason, the quasi-static corridor for blocks 1 and 3 has been raised slightly to ensure compliance with the dynamic corridor.

Not all of the blocks that met the quasi-static response corridor gave dynamic responses which met the dynamic corridor. Thus compliance with the static test corridors is not sufficient to guarantee compliance with the dynamic corridors. For this reason it is recommended that periodic dynamic testing of the barrier faces is still necessary to ensure their dynamic performance.

Rigid Sill Loading Test

Figure 10 shows the total force – deflection responses for the rigid sill loading test.

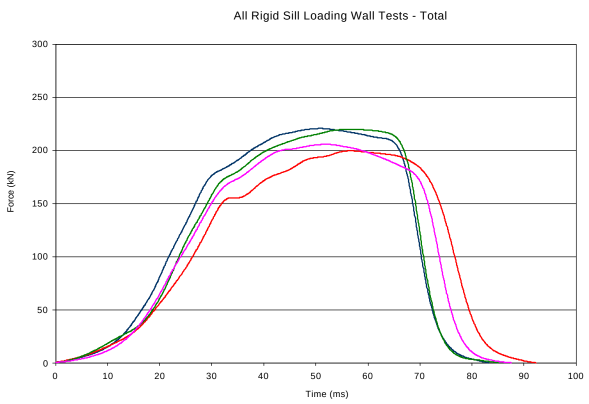

Figure 10: Total force vrs barrier displacement – Validation Test Programme, rigid sill loading wall tests

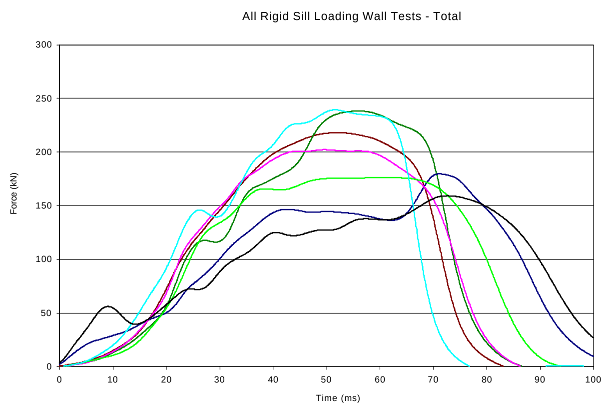

Figure 11: Total force vrs barrier displacement – Evaluation Test Programme, rigid sill loading wall tests

The repeatability of the overall performance of the barrier faces is good. However, the variability of the individual blocks was much greater, with the AFL barrier faces showing much lower forces for blocks 1 to 3 and much higher forces for blocks 4 to 6 than the barrier faces from the other three manufacturers. This was because the top row of blocks (numbers 1 to 3 in the rigid sill loading test) partially debonded from the backplate. Nevertheless, this is a significant improvement over the results with the original MDB faces in the previous Evaluation programme (Figure 11)

Offset Pole Test

Figure 12 shows the total force – deformation results for the offset pole test seen in the earlier programme with the original MDB faces. The variation between MDB face designs is clear. Figure 13 shows the results in this test with the new design of MDB face for 4 manufacturers. The improved reproducibility is obvious from these results.

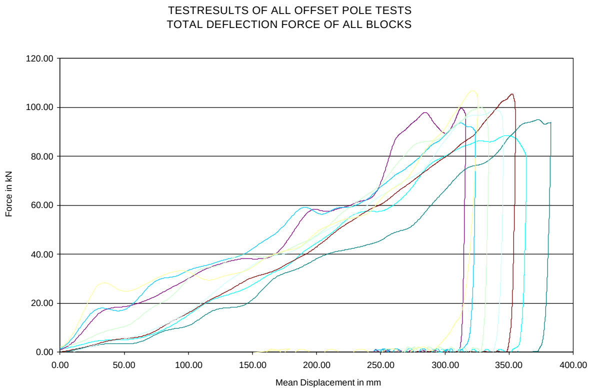

Figure 12 Offset Pole Test results in the Evaluation test programme with the original MDB faces

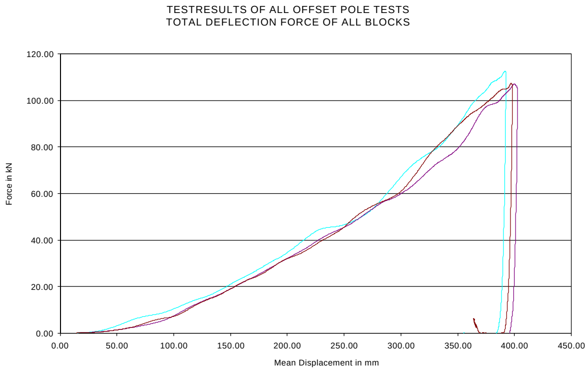

Figure 13. Offset Pole Test results in the Validation test programme with MDB faces built to the revised Design Specification

Full Scale Tests

Four full-scale MDB-to-car tests were performed in order to evaluate the behaviour of the barrier faces in full-scale test conditions. The test conditions followed those of the R95 Full Scale Test, although supplementary data were collected (e.g. final static deformation profiles).

Test Procedure

The test matrix can be seen in Table 3. The two tests at Fiat used one model of vehicle to evaluate reproducibility between MDB face manufacturers. The tests at UTAC and TNO used different vehicle models to widen the model range for which test experience was gained with barrier faces designed to the new specification. The vehicles had a EuroSID-1 dummy in the front struck-side seating position and child dummies in child restraints in the rear seat, following the EuroNCAP protocol.

Results

<u>Vehicle Profiles</u>

Vehicle crush profiles for Vehicle A are shown in Figure 14. The post test vehicle profiles are very similar between the two cars tested with the different barrier faces except for the lowest two measuring lines, set at 300mm and 425mm above the ground, corresponding approximately to the dummy pelvis level.

For these locations, the intrusion was greater for the Cellbond MDB face forward of the B-pillar. This is also apparent from the door intrusion velocities at this location derived from the acceleration data.

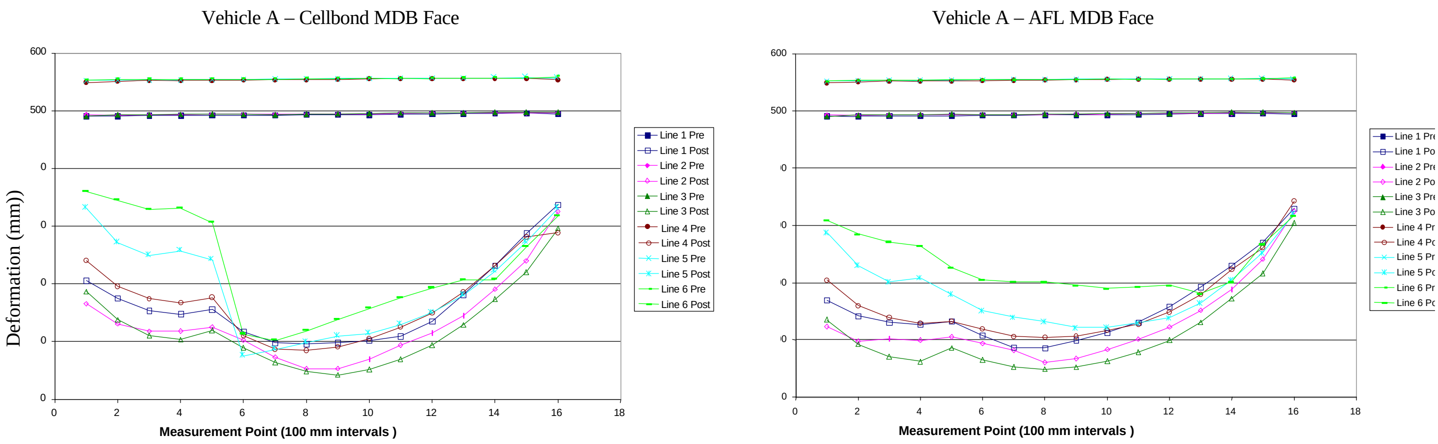

Figure 14. Pre and Post Test car profiles, Model A Cellbond and AFL MDB Faces

The behaviour of the AFL and Cellbond MDB faces in the other full scale tests with Vehicle Models B and C appeared to be normal with no undesirable observations except for the debonding of some of the AFL blocks from the rear plate after the test

Dummy Measurements

Driver dummy (EuroSID-1) responses for all full scale tests are shown in **Table 4** and the reproducibility results for Vehicle Model A are illustrated in Figure 15

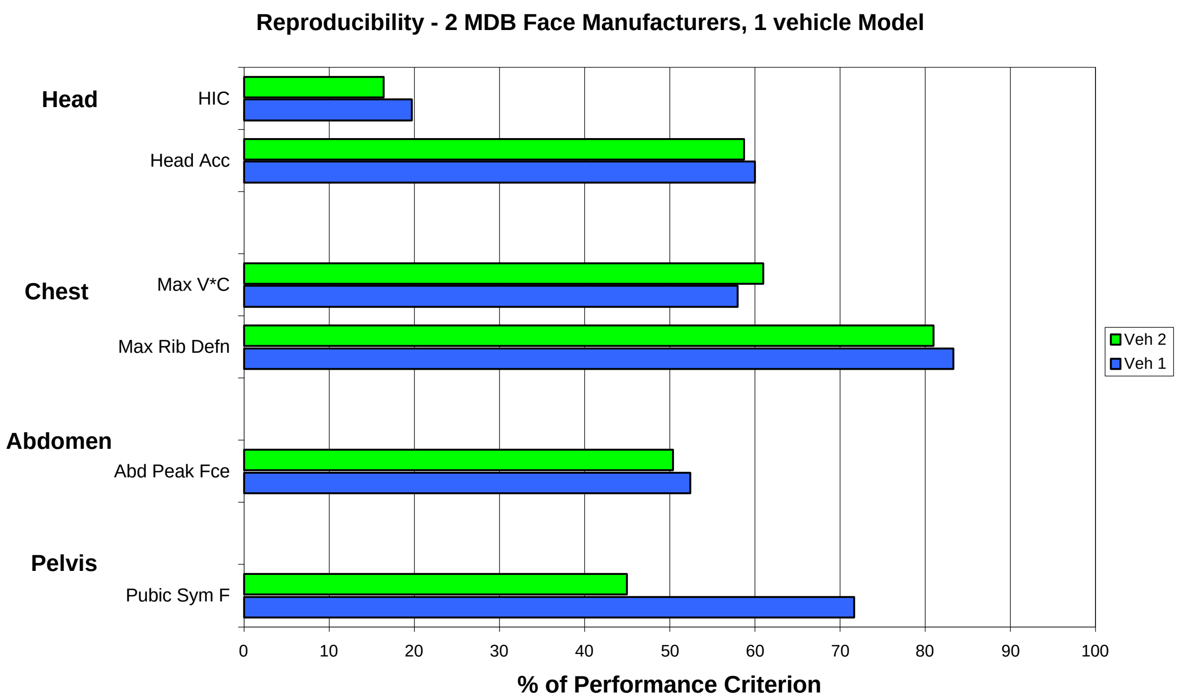

Figure 15 Driver Dummy responses for Vehicle Model A, Cellbond and AFL Barrier Faces.

Table 4
Dummy Responses in the Full Scale Tests

Test Institute		Fiat			TNO		UTAC
MDB Face		**Cellbond**	**AFL**		**Cellbond**		**AFL**
Vehicle Model		**Model A**	**Model A**		**Model B**		**Model C**
HEAD							
HIC_{36}		197	164		88.40		101
3 ms exceedance (g)		48	47		37		38
CHEST							
Top Rib							
Compression (mm)		26	29		33		1
V*C (ms^{-1})		0.26	0.32		0.34		0.002
Middle Rib							
Compression (mm)		35	34		26		no data
V*C (ms^{-1}))		0.54	0.61		0.26		no data
Bottom Rib							
Compression (mm)		31	31		16.71		13.2
V*C (ms^{-1})		0.58	0.56		0.17		0.07
ABDOMEN							
Peak lateral force	Total	1.31	1.26		1.35		-
(kN)	{Front						no data}
	{Mid						0.72
	{Rear						1.18
PELVIS							
Pubic symphysis force (kN)		4.3	2.7		2.8		3.3

It can be seen that the reproducibility of the dummy responses for the upper body areas (Head, Chest and Abdomen) is very good. The pubic symphysis response was higher for the Cellbond MDB face than for the AFL face. This corresponds well with the observed difference in the deformation profiles at the lower measurement points.

Figures 16 and 17 show the AFL and Cellbond barrier faces after tests with vehicle model A.

It can be seen that there is a tear in the front face of the lower row of blocks in the Cellbond face but not in the AFL face. The AFL face blocks debonded from the backplate in this test but this is unlikely to have influenced the tearing of the front plate.

It should be noted that this is not a new phenomenon. Figure 18 shows the MDB face used in the EuroNCAP test on this same model. Although the MDB face used in EuroNCAP does not fully comply with the requirements of ECE R95, it is close and the tear in the front face is an observation that has been seen in other tests also. However, it is undesirable that two barrier faces built to the same specification should perform differently.

Careful review of the materials used in the front plates has shown that it is likely that this phenomenon is related to the elongation and strength properties of the material. In the draft specification, only the material and hardness has been specified. The draft specification has been modified to specify the Elongation and Ultimate Tensile Strength of the front plate material. The values have been selected to result in a performance which duplicates the AFL barrier face response.

Figure 16 AFL MDB Face Post Vehicle A Test

Figure 17 Cellbond MDB Face Post Vehicle A Test

Figure 18 EuroNCAP MDB Face after Test with Vehicle Model A.

The rear struck-side dummy (P1½ child dummy) results are shown in Table 5. Again, the repeatability of the tests performed by Fiat with vehicle model A is very good.

Table 5: P1 ½child dummy results (if applicable)

Test Institute	Fiat			TNO
MDB Face	Cellbond	AFL		Cellbond)
Vehicle Model	Model A	Model A		Model B
HEAD				
Resultant acceleration (g)	44	41		56
3 ms exceedance (g)	36	36		52
CHEST				
Resultant Acceleration (g)	35	36		39
3 ms exceedance (g)	28	32		35

JASIC Test Programme.

JASIC undertook a complementary test programme in Japan, including flat load cell wall tests and full scale tests. Again, the MDB faces were prototypes produced very soon after release of the draft Design Specification and the conclusions need to take this into account.

The results for the JASIC tests have been presented to EEVC. Their findings and results for the energy absorption and dynamic and residual deformation have contributed to the proposed revision to the draft Specification.

JASIC found a similarly improved consistency in performance in the load cell wall tests. They performed four full scale impact tests to the same vehicle model (a compact 4-door saloon). Three of these tests used different progressive MDB faces produced to the new specification; two Japanese and one European, and the forth test used a conventional multilayer MDB face produced to the current specification.

JASIC found no significant difference between all three new-progressive MDB faces nor between these and the older multi-layer design MDB face for chest deflection and V*C. Nor did they find significant differences for the two Japanese progressive design faces and the older multi-layer design for pelvis force. The pelvic force for the Cellbond MDB new progressive design face showed a similar trend to that observed in the Fiat test (higher peak force). This may be related to the front plate material used for the Cellbond MDB face. The abdominal force for each of the new progressive MDB faces was similar and they were all lower than for the older multi-layer design.

JASIC recommends a reduction in the tolerance for the force-deformation corridor for block 2, believing that the variation in the force developed by this block to be the cause of the pelvic force difference seen in the full scale test.

JASIC also recommends changing the limit on the range of cells in each block in the proposed specification to a mass range. They have also recommended changing the specification of the front plate material and adhesive strength requirements, in line with the EEVC recommendation. These three recommendations are in agreement with those proposed by EEVC.

For the static force-deformation test, JASIC has proposed modifications to all of the corridors based on their tests. However, the tests at the European laboratories in comparison with the test results from the MDB face manufacturers, do not support such a wide ranging change. EEVC proposes changing only the corridors for Block 1 and 3, recommending adoption of the JASIC proposals for these blocks.

Batches and Batch Testing

The manufacture of MDB faces to the design specification requires blocks of base aluminium honeycomb to be processed to develop the progressive force needed to comply with the static and dynamic force-deformation requirements. The process involves treatment of “batches” of blocks. This provides the opportunity of performing conformity of production testing and assessment of batches. The Validation programme included the certification of batches of the blocks forming whole MDB face units and some useful experience has been gained in this procedure.

Different manufacturers use different concepts of the term 'batch' in this context. If the processing involves parallel production, where many similar blocks are made simultaneously using, for instance, the same etching bath, then one of these blocks can be used for certification purposes. If the blocks are treated as a series production, where a series of similar blocks are made one after the other in the same etching bath and from the same original batch of aluminium honeycomb, it may be advisable to test one block at the start of production and one at the end to ensure that there have been no changes in the etching qualities during production. If the first sample complies with the requirements but the last does not, it may be necessary to take further samples from earlier in the production until a sample that does comply is found. Only the blocks between these samples can be considered to comply. Once experience is gained with the consistency of production control, it may be possible to combine both sampling approaches, so that more than one group of parallel production can be considered to be a batch provided samples from the first and last production groups comply.

The system for such quality control will have to depend on production method and is considered to be an aspect to be dealt with when considering the Regulation or Directive, rather than a matter for research, although the suggestions made in this report, are based on experience within the EEVC Validation Test Programme.

When complete MDB faces are produced, using four block types (blocks 1 &3, blocks 5 &6, block 2, block 4), the batch from which each of the six individual blocks should be identified. A certification for each MDB face can then be supplied to confirm that each block comes from a batch for which the tested sample complies with the static force-deformation requirements, that the materials and honeycomb cell sizes are all according to the specification and that the minimum adhesive force requirement is met. The original design specification also called for a count of cells for each block to ensure consistency between blocks in the batch. This is a particularly arduous and time-consuming requirement to check. In place of this, it is proposed that the mass of the sample block tested should be determined and the additional requirement added that all blocks in that batch should not differ from that of the tested sample by more than [5] per cent. To assist with this, it is proposed that MDB faces (Impactors) should carry consecutive serial numbers which are stamped, etched or otherwise permanently attached, from which the block batches and the date of manufacture can be established.

The manufacturer of the MDB face should be able to demonstrate that the samples tested are a reliable measure of the performance of the batch.

Conclusions

1. The Validation programme has proved to be valuable in demonstrating the significant improvement in reproducibility and repeatability of MDB faces designed to meet the proposed new Specification, despite the prototypes not fully meeting all of the requirements. It has also demonstrated the need for some small changes in the Specification.

2. The adhesive bond strength between the aluminium blocks and the back plate for some of the barrier faces was insufficient to ensure maintenance of the bond in the severe pole and rigid sill tests and also in some full scale tests. It is recommended that the requirement be increased from 0.4 Mpa to 0.6 Mpa.

3. The individual block forces for these prototype MDB faces showed more variation than the total force results. This was reflected in the quasi-static test results. This is considered to be a result of limited and differing manufacturing experience with the material types used for each block and is expected to improve with experience.

4. Most of the proposed quasi-static corridors appear to be correct but a modified corridor for blocks 1 and 3 is now recommended.

5. MDB faces produced to the new Specification appeared to behave satisfactorily in full scale tests and showing good repeatability except where the front plate performance varied. The tearing behaviour of the front plates of two of the MDB faces differed in similar full scale impact tests. The specification for the front face plate material has been revised to specify elongation and UTS in order prevent this.

6. Some additional minor modifications to the Specification are proposed, including strengthening of the ventilation frame and improved backplate attachment details.

7. Suggestions for conformity of production of the faces from batch sampling are made, based on experience in this test programme.

Specification.

The proposed design specification for the MDB is given in ANNEX 1 and is provided in a style that would simplify consideration as a replacement for the existing MDB Specification. (e.g. ECE Regulation 95, ANNEX 5)

Acknowledgements

The draft specification was assembled and presented to EEVC WG13 for discussion by an ad-hoc group, comprising:

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ANNEX 1
MOBILE DEFORMABLE BARRIER CHARACTERISTICS

1. CHARACTERISTICS OF THE MOBILE DEFORMABLE BARRIER

1.1 The mobile deformable barrier includes both an impactor and a trolley.

1.2 The total mass shall be 950 ± 20 kg.

1.3 The centre of gravity shall be situated in the longitudinal median vertical plane within 10 mm, 1000 ± 30 mm behind the front axle and 500 ± 30 mm above the ground.

1.4 The distance between the front face of the impactor and the centre of gravity of the barrier shall be 2000 ± 30 mm.

1.5 The ground clearance of the impactor shall be 300 ± 5 mm measured in static conditions from the lower edge of the lower front plate, before the impact.

1.6 The front and rear track width of the trolley shall be 1500 ± 10 mm.

1.7 The wheelbase of the trolley shall be 3000 ± 10 mm.

2. CHARACTERISTICS OF THE IMPACTOR

The impactor consists of six single blocks of aluminium honeycomb, which have been processed in order to give a progressively increasing level of force with increasing deflection. (See section 2.1). Front and rear aluminium plates are attached to the aluminium honeycomb blocks.

<u>2.1 Honeycomb blocks</u>

2.1.1 Geometrical characteristics

2.1.1.1 The impactor consists of 6 joined zones whose forms and positioning are shown in Figures 1 and 2. . The zones are defined as 500 ± 5 mm x 250 ± 3 mm in Figures 1 and 2. The 500mm should be in the W direction and the 250mm in the L direction of the aluminium honeycomb construction. (See Figure 3)

2.1.1.2 The impactor is divided into 2 rows. The lower row shall be 250 ± 3 mm high, and 500 ± 2 mm deep after pre-crush (see 2.1.2), and deeper than the upper row by 60 ± 2 mm.

2.1.1.3 The blocks must be centred on the six zones defined in Figure 1 and each block (including incomplete cells) should cover completely the area defined for each zone).

2.1.2 Pre-crush

2.1.2.1 The pre-crush shall be performed on the surface of the honeycomb to which the front sheets are attached.

2.1.2.2 Blocks 1, 2 and 3 should be crushed by 10 ± 2 mm on the top surface prior to testing to give a depth of 500 ±2 mm. (Figure 2)

2.1.2.3 Blocks 4, 5 and 6 should be crushed by 10 ± 2 mm on the top surface prior to testing to give a depth of 440 ± 2 mm.

2.1.3 Material characteristics

2.1.3.1 The cells dimensions shall be 19 ± 10% for each block.(see Figure 4.)

2.1.3.2 The cells must be made of 3003 aluminium for the upper row.

2.1.3.3 The cells must be made of 5052 aluminium for the lower row.

2.1.3.4 The aluminium honeycomb blocks should be processed such that the force deflection-curve when statically crushed (according to the procedure defined in Section 2.1.4.) is within the corridors defined for each of the six blocks in Appendix 1. Moreover the processed honeycomb material used in the honeycomb blocks to be used for constructing the barrier, should be cleaned in order to remove any residue that may have been produced during the processing of the raw honeycomb material.

2.1.3.5 The mass of the blocks in each batch shall not differ by more than [5]% of the mean block mass for that batch.

2.1.4 Static tests

2.1.4.1 A sample taken from each batch of processed honeycomb core shall be tested according to the Static Test procedure described in Section 5

2.1.4.2 The Force-Compression for each block tested shall lie within the force deflection corridors defined in Appendix 1. Static force-deflection corridors are defined for each block of the barrier.

2.1.5 Dynamic Test

2.1.5.2 The Dynamic deformation characteristics, when impacted according to the protocol described in Section 6.

2.1.5.3 Deviation from the limits of the force-deflection corridors characterising the rigidity of the impactor - as defined Appendix 2- may be allowed provided that:

2.1.5.3.1 the deviation occurs after the beginning of the impact and before the deformation of the impactor is equal to 150 mm;

2.1.5.3.2 the deviation does not exceed 50% of the nearest instantaneous prescribed limit of the corridor;

2.1.5.3.3 each deflection corresponding to each deviation does not exceed 35 mm of deflection, and the sum of these deflections does not exceed 70 mm (see Appendix2)

2.1.5.3.4 the sum of energy derived from deviating outside the corridor does not exceed 5 % of the gross energy for that block.]

2.1.5.4 Blocks 1 and 3 are identical. Their rigidity is such that their force deflection curves fall between corridors of Figure 2a.

2.1.5.5 Blocks 5 and 6 are identical. Their rigidity is such that their force deflection curves fall between corridors of Figure 2d.

2.1.5.6 The rigidity of Block 2 is such that its force deflection curves fall between corridors of Figure 2b.

2.1.5.7 The rigidity of Block 4 is such that its force deflection curves fall between corridors of Figure 2c.

2.1.5.8 The force-deflection of the impactor as a whole shall fall between corridors of Figure 2e.

2.1.5.9 The force-deflection curves shall be verified by a test detailed in Annex 5 – Section 6, consisting of an impact of the barrier against a dynamometric wall at 35 ± 0.5 km/h.

2.1.5.10 The dissipated energy[ϕ] against Blocks 1 and 3 during the test shall be equal to 9.5 ± 2kJ for these Blocks.

2.1.5.11 The dissipated energy against Blocks 5 and 6 during the test shall be equal to 3.5 ± 1kJ for these Blocks.

2.1.5.12 The dissipated energy against Block 4 shall be equal to 4 ± 1kJ.

2.1.5.13 The dissipated energy against Block 2 shall be equal to 15 ± 2 kJ.

2.1.5.14 The dissipated total energy during the impact shall be equal to 45 ± 5 kJ].

2.1.5.15 The maximum impactor deformation from the point of first contact, calculated from integration of the accelerometers according to 6.6.3, shall be equal to 330 ± 20 mm.

2.1.5.16 The final residual static impactor deformation measured after the dynamic test at level B (Figure 2) shall be equal to 310 ± 20 mm.

[NOTE: the values of energy absorption for only blocks 1&3 and 2 differ from that in the existing Regulation 95]

2.2 Front Plates

2.2.1 Geometrical characteristics

2.2.1.1 The dimensions of the front plates are 1500 ± 1mm wide and 250 ± 1mm high. The thickness is 0.5 ± 0.06 mm.

2.2.1.2 When assembled the overall dimensions of the impactor (defined in Figure 2) shall be 1500 ± 2.5mm wide and 500 ± 2.5mm high.

2.2.1.3 The upper edge of the lower front plate and the lower edge of the upper front plate should be aligned within 4mm.

2.2.2 Material characteristics

2.2.2.1 The front plates are manufactured from aluminium of series Al Mg 2 to Al Mg 3 with elongation ≥ 12%, and a UTS ≥ 175 N/mm^2.

2.3 Back Plate

2.3.1 Geometric characteristics

2.3.1.1 The geometrical characteristics shall be according to Figures 5 and 6.

2.3.2 Material characteristics

2.3.2.1 The back plate shall consist of a 3 mm aluminium sheet. The back plate shall be manufactured from aluminium of series Al Mg 2 to Al Mg 3 with a hardness between 50 and 65 HBS. This plate shall be perforated with holes for ventilation: the location, the diameter and pitch are shown in Figures 5 and 7.

[ϕ] The amounts of energy indicated are those dissipated by the system when the impactor is at maximum crush.

2.4 Location of the Honeycomb Blocks

2.4.1 The honeycomb blocks shall be centred on the perforated zone of the back plate (Figure 5.).

2.5 Bonding

2.5.1 For both the front and the back plates, a maximum of 0.5kg per m^2 shall be applied evenly directly over the surface of the front plate, giving a maximum film thickness of 0.5 mm. The adhesive to be used throughout should be a two-part polyurethane {such as Ciba-Geigy XB5090/1 resin with XB5304 hardener} or equivalent.

2.5.2 For the back plate the minimum bonding strength shall be 0.6 Mpa, (87 psi)], tested according to section 2.5.3

2.5.3 Bonding strength tests:

2.5.3.1 Flatwise tensile testing is used to measure bond strength of adhesives according to ASTM C297-61. *(Note: GRSP may wish to consider whether the text of the standard needs to be included at this point in place of the reference*).

2.5.3.2 The test piece should be 100mm x 100mm, and 15 mm deep, bonded to a sample of the ventilated back plate material. The honeycomb used should be representative of that in the impactor, i.e. chemically etched to an equivalent degree as that near to the back plate in the barrier but without pre-crushing.

2.6 Traceability :

2.6.1 Impactors shall carry consecutive serial numbers which are stamped, etched or otherwise permanently attached, from which the batches for the individual blocks and the date of manufacture can be established

2.7 Impactor Attachment.

2.7.1 The fitting on the trolley must be according to Figure 8. The fitting will use six M8 bolts, and nothing shall be larger than the dimensions of the barrier in front of the wheels of the trolley. Appropriate spacers must be used between the lower back plate flange and the trolley face to avoid bowing of the back plate when the attachment bolts are tightened.

3. VENTILATION SYSTEM

3.1 The interface between the trolley and the ventilation system should be solid, rigid and flat. The ventilation device is part of the trolley and not of the impactor as supplied by the manufacturer. Geometrical characteristics of the ventilation device shall be according to figure 9.

3.2 Ventilation Device Mounting Procedure.

3.2.1 Mount the ventilation device to the front plate of the trolley;

3.2.2 Ensure that a 0.5 mm thick gauge cannot be inserted between the ventilation device and the trolley face at any point. If there is a gap greater than 0.5mm, the ventilation frame will need to be replaced or adjusted to fit without a gap of >0.5mm.

3.2.3 Dismount the ventilation device from the front of the trolley;

3.2.4 Fix a 1.0 mm thick layer of cork to the front face of the trolley;

3.2.5 Re-mount the ventilation device to the front of the trolley and tighten to exclude air gaps.

4. CONFORMITY OF PRODUCTION

4.1 The manufacturer shall be responsible for the conformity of production procedures and for that purpose must in particular:

4.1.1 Ensure the existence of effective procedures so that the quality of the products can be inspected,

4.1.2 Have access to the testing equipment needed to inspect the conformity of each product,

4.1.3 Ensure that the test results are recorded and that the documents remain available for a time period of 10 years after the tests,

4.1.4 Demonstrate that the samples tested are a reliable measure of the performance of the batch (examples of sampling methods according to batch production are given below).

4.1.5 Analyse results of tests in order to verify and ensure the stability of the barrier characteristics, making allowance for variations of an industrial production, such as temperature, raw materials quality, time of immersion in chemical, chemical concentration, neutralisation etc, and the control of the processed material in order to remove any residue from the processing,

4.1.6 Ensure that any set of samples or test pieces giving evidence of non-conformity gives rise to a further sampling and test. All the necessary steps must be taken to restore conformity of the corresponding production.

4.2 The manufacturer's level of certification must be at least ISO 9002.

4.3 Minimum conditions for the control of production: the holder of an agreement will ensure the control of conformity following the methods hereunder described.

4.4 Examples of sampling according to batch.

4.4.1 If several examples of one block type are constructed from one original block of aluminium honeycomb and are all treated in the same treatment bath (parallel production), one of these examples could be chosen as the sample, provided care is taken to ensure that the treatment is evenly applied to all blocks. If not, it may be necessary to select more than one sample

4.4.2 If a limited number of similar blocks (say three to twenty) are treated in the same bath (serial production), then the first and last block treated in a batch, all of which are constructed from the same original block of aluminium honeycomb, should be taken as representative samples. If the first sample complies with the requirements but the last does not, it may be necessary to take further samples from earlier in the production until a sample that does comply is found. Only the blocks between these samples should be considered to be approved.

4.4.3 Once experience is gained with the consistency of production control, it may be possible to combine both sampling approaches, so that more than one groups of parallel production can be considered to be a batch provided samples from the first and last production groups comply.

5. STATIC TESTS

5.1 One or more samples (according to the batch method) taken from each batch of processed honeycomb core shall be tested , according to the following test procedure:

5.2 The sample size of the aluminium honeycomb for static tests shall be the size of a normal block of the impactor, that is to say 250mm x 500mm x 440mm for top row and 250mm x 500mm x 500mm for the bottom row.

5.3 The samples should be compressed between two parallel loading plates which are at least [20]mm larger that the block cross section.

5.4 The compression speed shall be 100 millimetres per minute, with a tolerance of 5 %.

5.5 The data acquisition for static compression shall be sampled at a minimum of 5Hz.

5.6 The static test shall be continued until the block compression is at least 300mm. for blocks 4 to 6 and 350mm. for blocks 1 to 3.

6. DYNAMIC TESTS

For every [100] barrier faces produced, the manufacturer shall make one dynamic test against a dynamometric wall supported by a fixed rigid barrier, according to the method described below.

6.1 Installation

6.1.1 Testing ground

6.1.1.1 The test area shall be large enough to accommodate the run-up-track of the mobile deformable barrier, the rigid barrier and the technical equipment necessary for the test. The last part of the track, for at least 5 metres before the rigid barrier, shall be horizontal, flat and smooth.

6.1.2 Fixed rigid barrier and dynamometric wall

6.1.2.1 The rigid wall shall consist of a block of reinforced concrete not less than 3 metres wide and not less than 1.5 metres high. The thickness of the rigid wall shall be such that it weighs at least 70 tonnes.

6.1.2.2 The front face shall be vertical, perpendicular to the axis of the run-up-tack and equipped with six load cell plates, each capable of measuring the total load on the appropriate block of the mobile deformable barrier impactor at the moment of impact. The load cell impact plate area centres shall align with those of the six impact zones of the mobile deformable barrier face. Their edges shall clear adjacent areas by 20 mm such that, within the tolerance of impact alignment of the MDB, the impact zones will not contact the adjacent impact plate areas. Cell mounting and plate surfaces shall be in accordance with the requirements set out in the annex to ISO 6487/1987.

6.1.2.3 Surface protection, comprising a plywood face (thickness : 12 ±1mm), is added to each load cell plate such that it shall not degrade the transducer responses.

6.1.2.4 The rigid wall shall be either anchored in the ground or placed on the ground with, if necessary, additional arresting devices to limit its deflection. A rigid wall (to which the load cells are attached) having different characteristics but giving results that are at least equally conclusive may be used.

6.2 Propulsion of the Mobile Deformable Barrier

At the moment of impact the mobile deformable barrier shall no longer be subject to the action of any additional steering or propelling device. It shall reach the obstacle on a course perpendicular to the front surface of the dynamometric wall. Impact alignment shall be accurate to within 10 mm.

6.3 Measuring Instruments

6.3.1 Speed

The impact speed shall be 35 ± 0.5 km/h. the instrument used to record the speed on impact shall be accurate to within 0.1 percent.

6.3.2 Loads

Measuring instruments shall meet the specifications set forth in ISO 6487/1987

CFC for all blocks : 60 Hz

CAC for blocks 1 and 3 : 200 kN

CAC for blocks 4,5 and 6 : 100 kN

CAC for block 2 : 200 kN

6.3.3 Acceleration

6.3.3.1 The acceleration in the longitudinal direction shall be measured at three separate positions on the trolley, one centrally and one at each side, at places not subject to bending.

6.3.3.2 The central accelerometer shall be located within 500mm of the location of the centre of gravity of the MDB and shall lie in a vertical longitudinal plane which is within ±10mm of the centre of gravity of the MDB.

6.3.3.3 The side accelerometers shall be at the same height as each other ±10mm and at the same distance from the front surface of the MDB ±20mm

6.3.3.4 The instrumentation shall comply with ISO 6487/1987 with the following specifications:

CFC 1000 Hz (before integration)

CAC 50 g.

6.4 General Specifications of Barrier

6.4.1 The individual characteristics of each barrier shall comply with paragraph 1 and shall be recorded.

6.5 General Specifications of the Impactor.

6.5.1 The suitability of an impactor as regards the dynamic test requirements shall be confirmed when the outputs from the six load cell plates each produce signals complying with the requirements indicated in this Appendix.

6.5.2 Impactors shall carry consecutive serial numbers which are stamped, etched or otherwise permanently attached, from which the batches for the individual blocks and the date of manufacture can be established.

6.6 Data Processing Procedure

6.6.1 Raw data: At time $T = T_{0,}$ all offsets should be removed from the data. The method by which offsets are removed shall be recorded in the test report.

6.6.2 Filtering

6.6.2.1 The raw data will be filtered prior to processing/calculations.

6.6.2.2 Accelerometer data for integration will be filtered to CFC 180, ISO 6487/1987.

6.6.2.3 Accelerometer data for impulse calculations will be filtered to CFC 60, ISO 6487/1987.

6.6.2.4 Load cell data will be filtered to CFC 60, ISO 6487/1987.

6.6.3 Calculation of MDB face deflection

6.6.3.1 Accelerometer data from all three accelerometers individually (after filtering at CFC 180), will be integrated twice to obtain deflection of the barrier deformable element.

6.6.3.2 The initial conditions for deflection are :

6.6.3.2.1 velocity = impact velocity (from speed measuring device).

6.6.3.2.2 deflection = 0

6.6.3.3 The deflection at the left hand side, mid-line and right hand side of the mobile deformable barrier will be plotted with respect to time.

6.6.3.4 The maximum deflection calculated from each of the three accelerometers should be within 10 mm. If it is not the case, then the outlier should be removed and difference between the deflection calculated from the remaining two accelerometers checked to ensure that it is within 10mm.

6.6.3.5 If the deflections as measured by the left hand side, right hand side and mid-line accelerometers are within 10 mm, then the mean acceleration of the three accelerometers should be used to calculate the deflection of the barrier face.

6.6.3.6 If the deflection from only two accelerometers meets the 10mm. requirement, then the mean acceleration from these two accelerometers should be used to calculate the deflection for the barrier face.

6.6.3.7 If the deflections calculated from all three accelerometers (left hand side, right hand side and mid-line) are NOT within the 10mm requirement, then the raw data should be reviewed to determine the causes of such large variation. In this case the individual test house will determine which accelerometer data should be used to determine mobile deformable barrier deflection or whether none of the accelerometer readings can be used, in which case, the certification test must be repeated. A full explanation should be given in the test report.

6.6.3.8 The mean deflection-time data will be combined with the loadcell wall force-time data to generate the force-deflection result for each block.

6.6.4 Calculation of Energy

The absorbed energy for each block and for the whole MDB face should be calculated up to the point of peak deflection of the barrier.

$$E_n = \int_{t_0}^{t_1} F_n . ds_{mean}$$

Where: t_0 is the time of first contact

t_1 is the time where the trolley comes to rest, i.e. where u = 0.

s is the deflection of the trolley deformable element calculated according to 6.6.3.

6.6.5 Verification of Dynamic Force Data

6.6.5.1 Compare the total impulse, **I**, calculated from the integration of the total force over the period of contact, with the momentum change over that period (M*ΔV).

6.6.5.2 Compare the total energy change to the change in kinetic energy of the MDB, given by

$$E_K = \frac{1}{2} M V_i^2$$

where V_I is the impact velocity and *M* the whole mass of the MDB

If the momentum change (M*ΔV). is not equal to the total impulse (**I**) {±[5]%}

or if the total energy absorbed (Σ En) is not equal to the kinetic energy, E_K{±5%}

then the test data must be examined to determine the cause of this error.

DESIGN OF IMPACTOR[1]

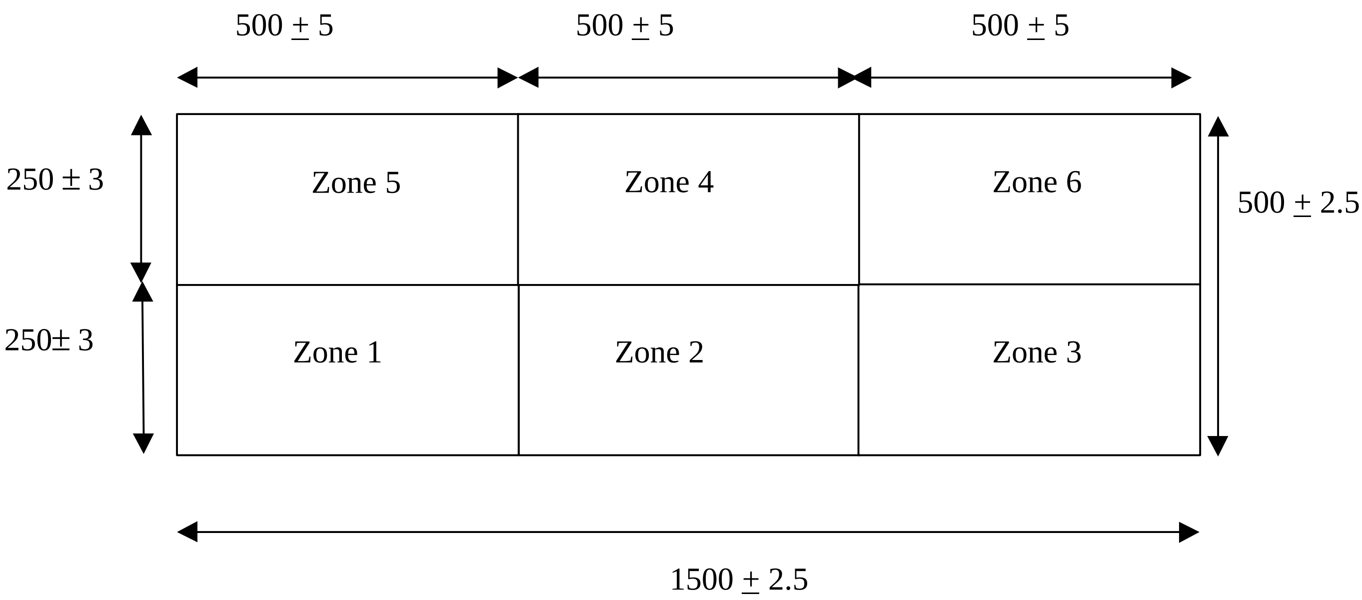


Figure 1

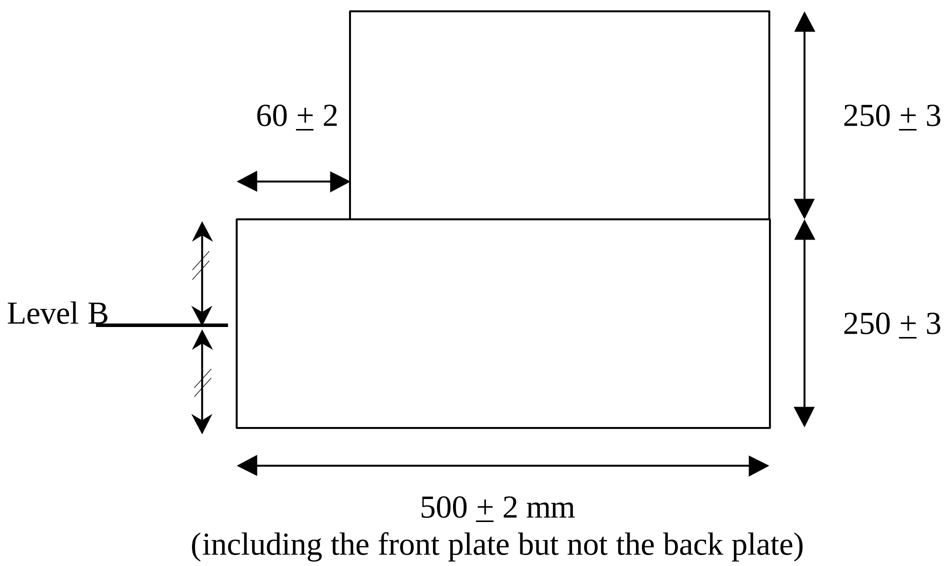


Figure 2

[1] Note: All dimensions are in mm. The tolerances on the dimensions of the blocks allow for the difficulties of measuring cut aluminium honeycomb. The tolerance on the overall dimension of the impactor is less than that for the individual blocks since the honeycomb blocks can be adjusted, with overlap if necessary, to maintain a more closely defined impact face dimension.

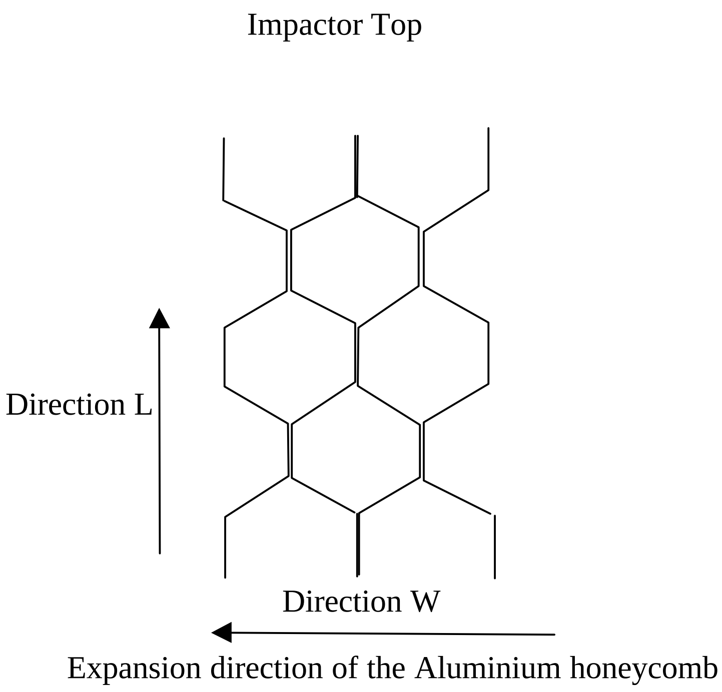


Figure 3. Aluminium Honeycomb Orientation

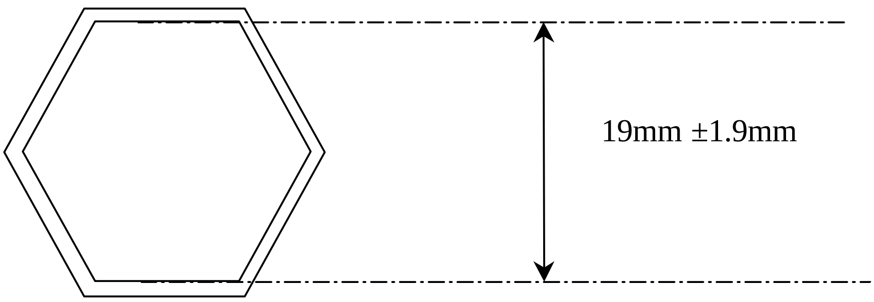


Figure 4. Dimension of Aluminium Honeycomb Cells

DESIGN OF THE BACK PLATE

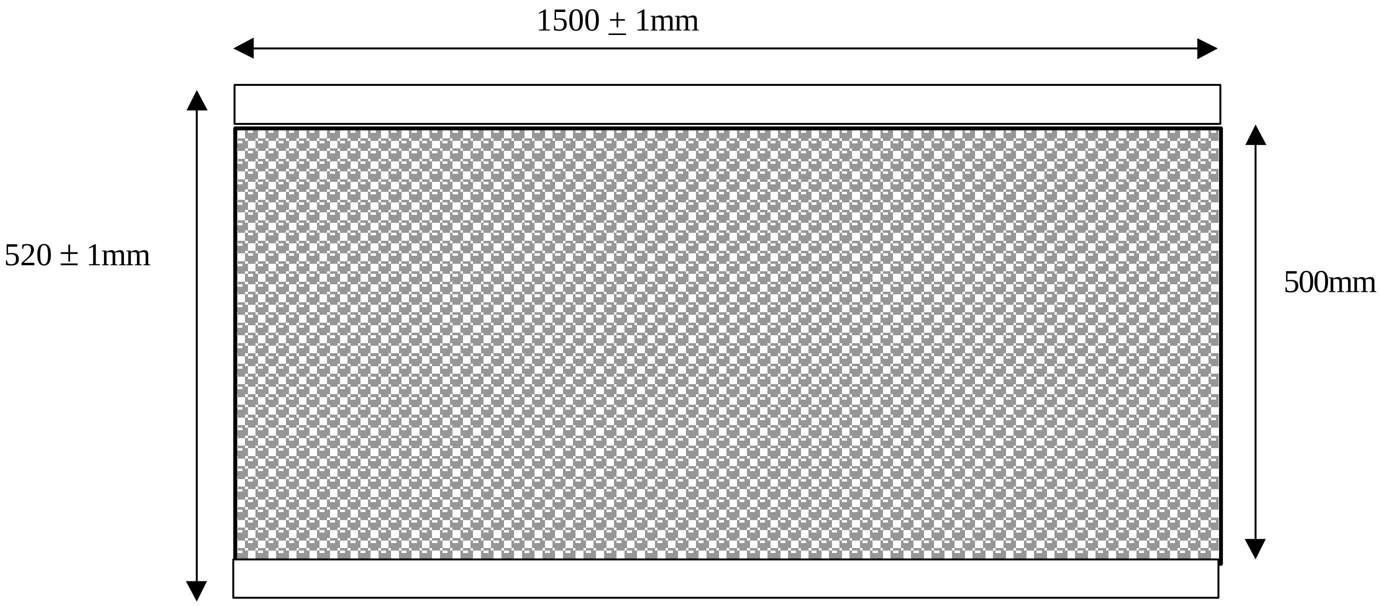


Figure 5

Front View

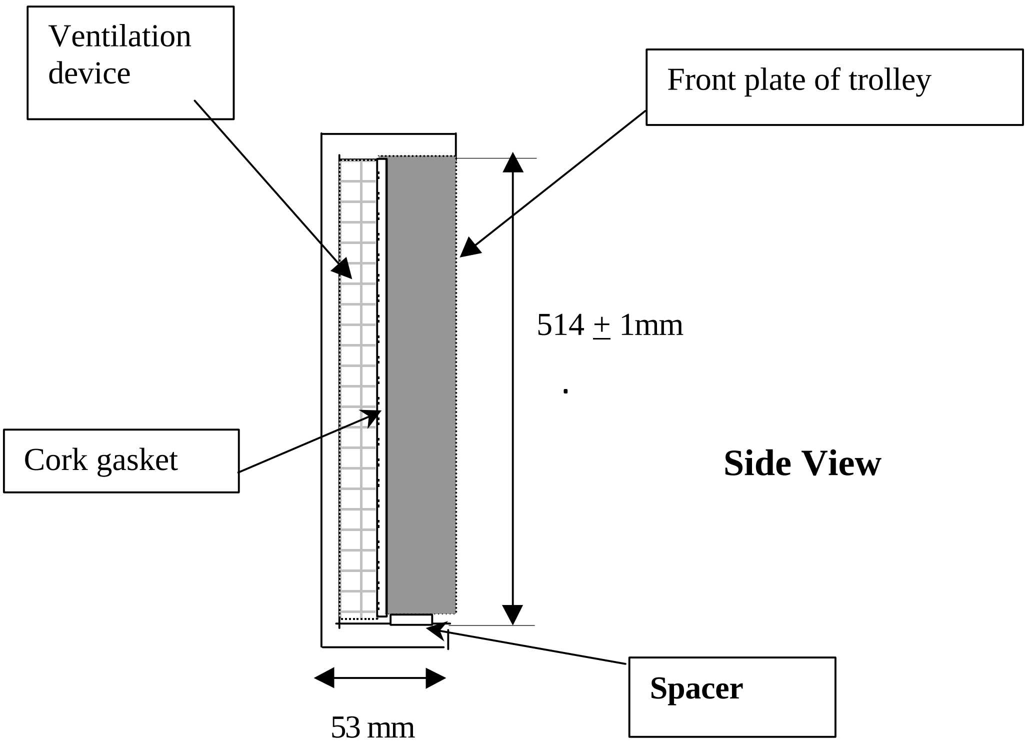


Figure 6
Attachment of backplate to ventillation device and trolley face plate

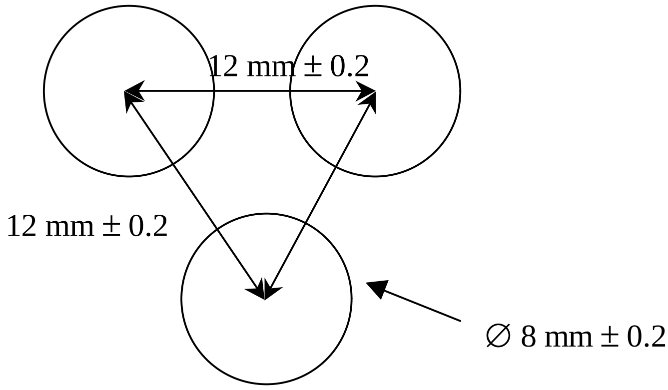
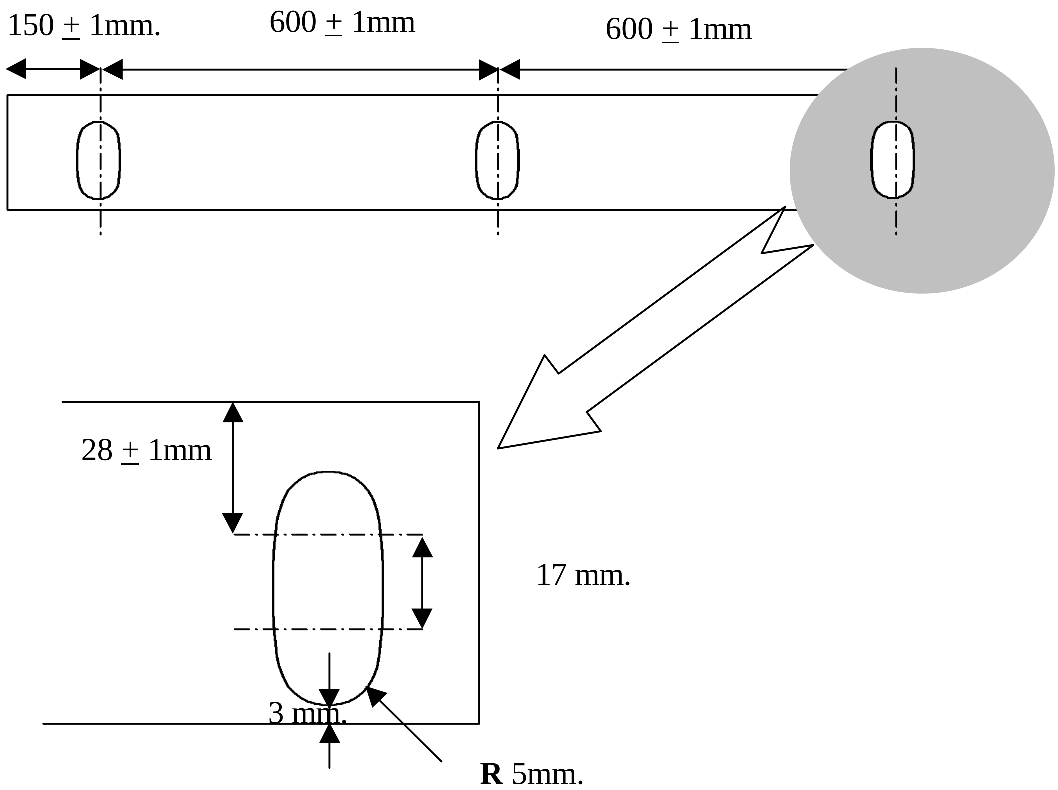


Figure 7 - Staggered pitch for the back plate ventilation holes



Top and Bottom Back Plate Flanges

NOTE: The attachment holes in the bottom flange may be opened to slots, as shown below, for ease of attachment provided sufficient grip can be developed to avoid detachment during the whole impact test.

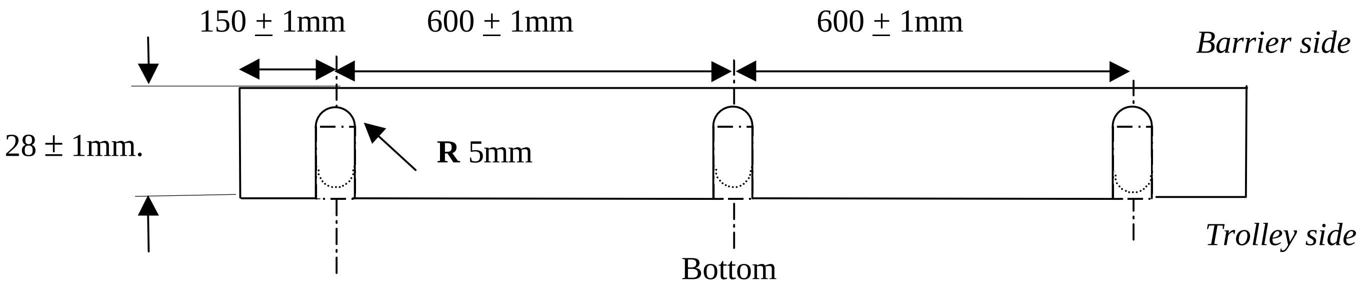


Figure 8

VENTILATION FRAME

The ventilation device is a structure made of a plate that is 5 mm thick and 20 mm wide. Only the vertical plates are perforated with nine 8mm. holes in order to let air circulate horizontally.

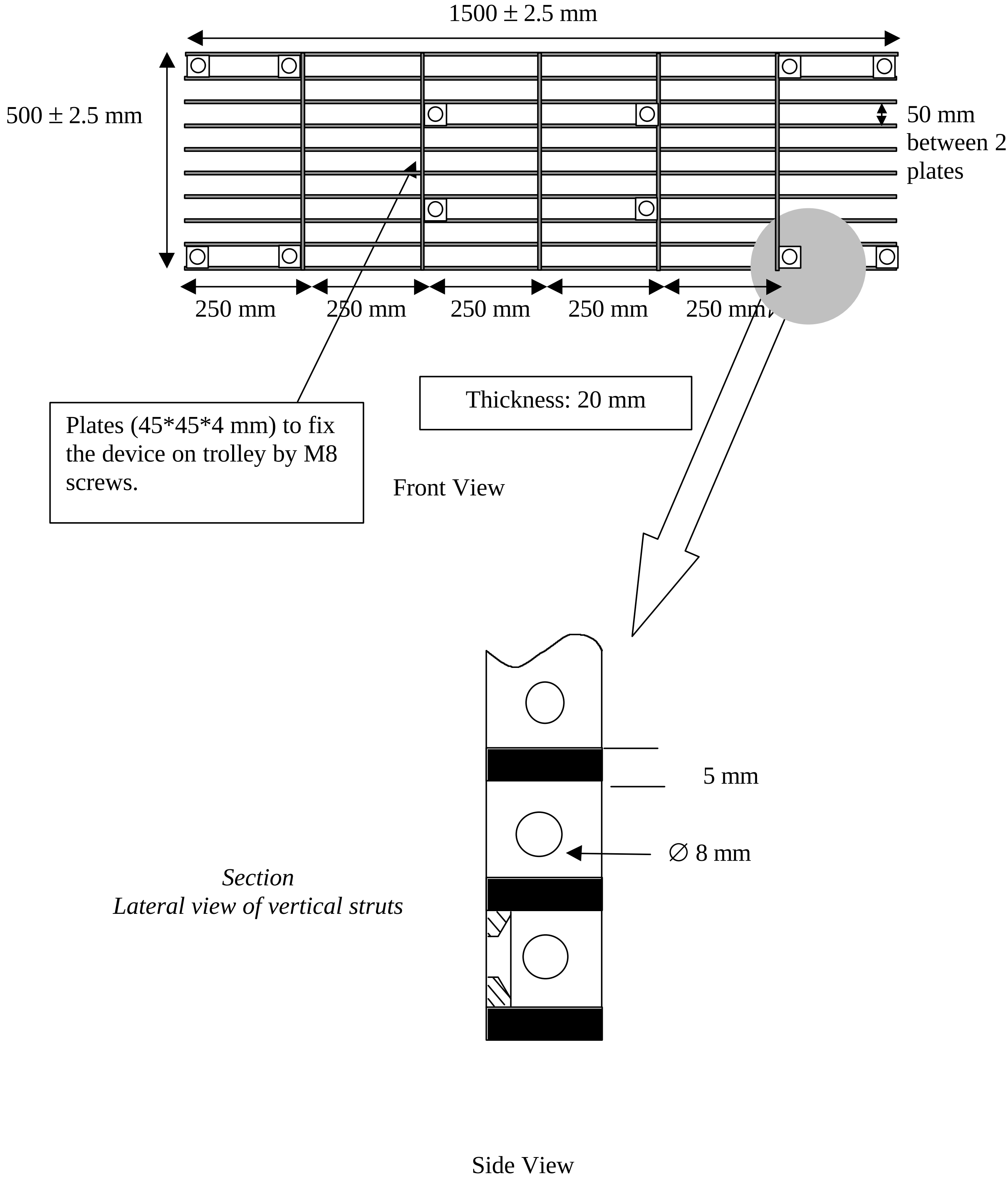
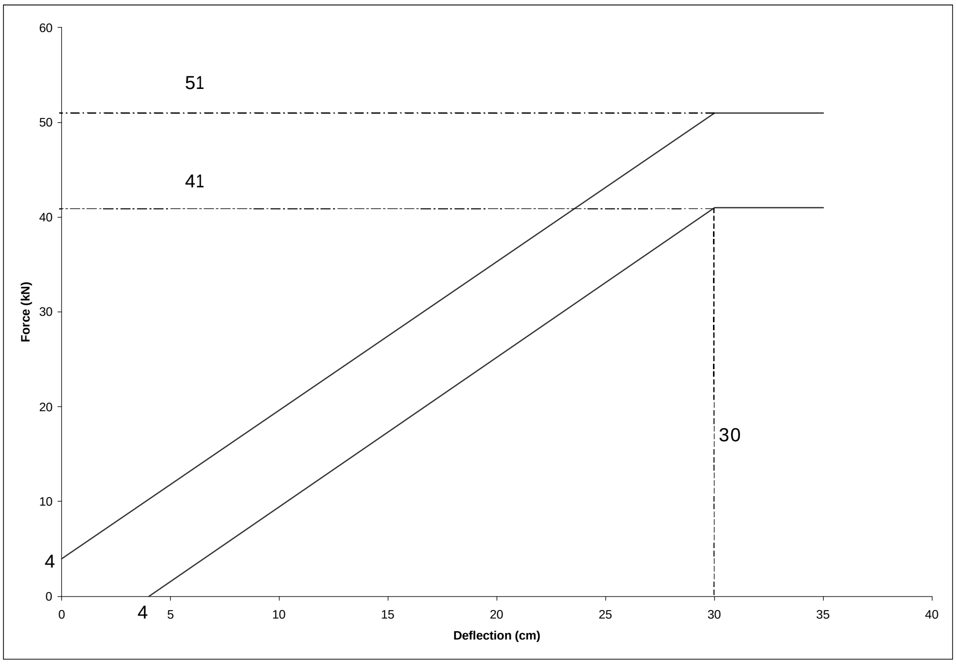


Figure 9

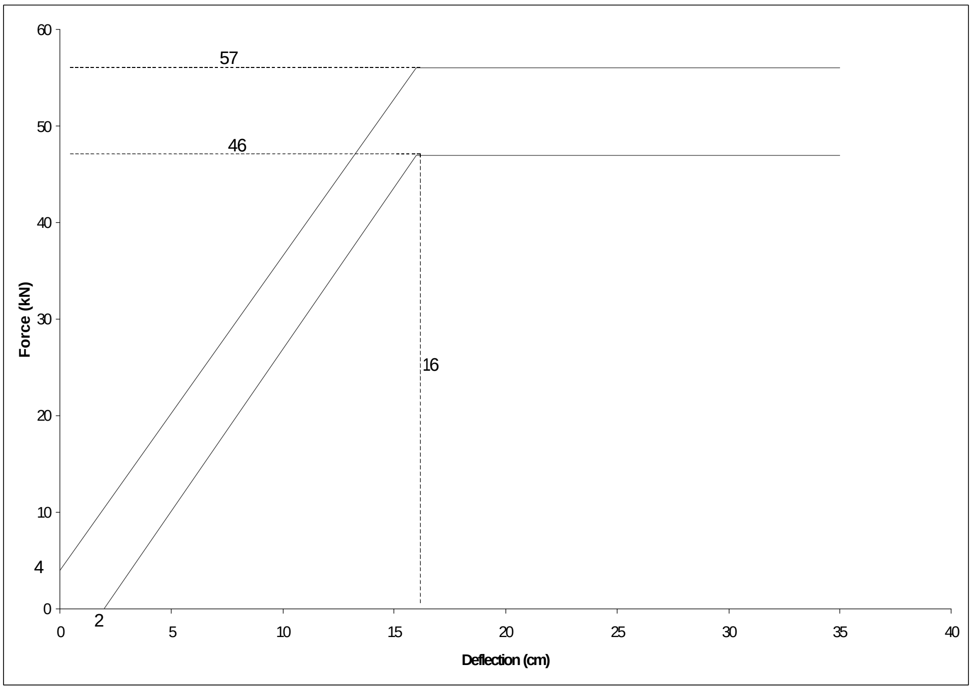
ANNEX 1, APPENDIX 1

FORCE-DEFLECTION CURVES FOR STATIC TESTS

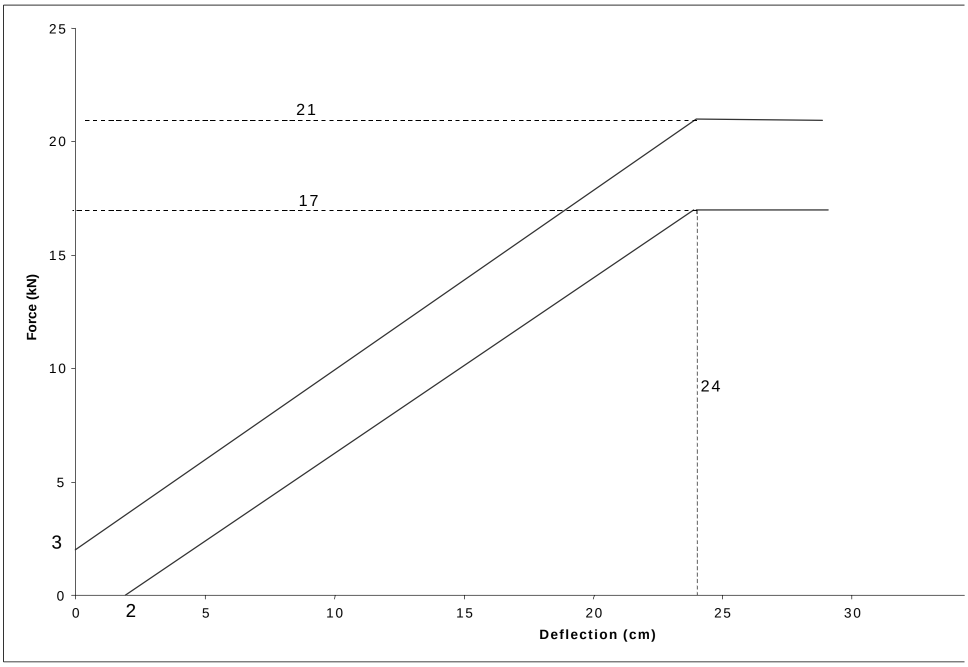
Blocks 1 & 3
Figure 1a



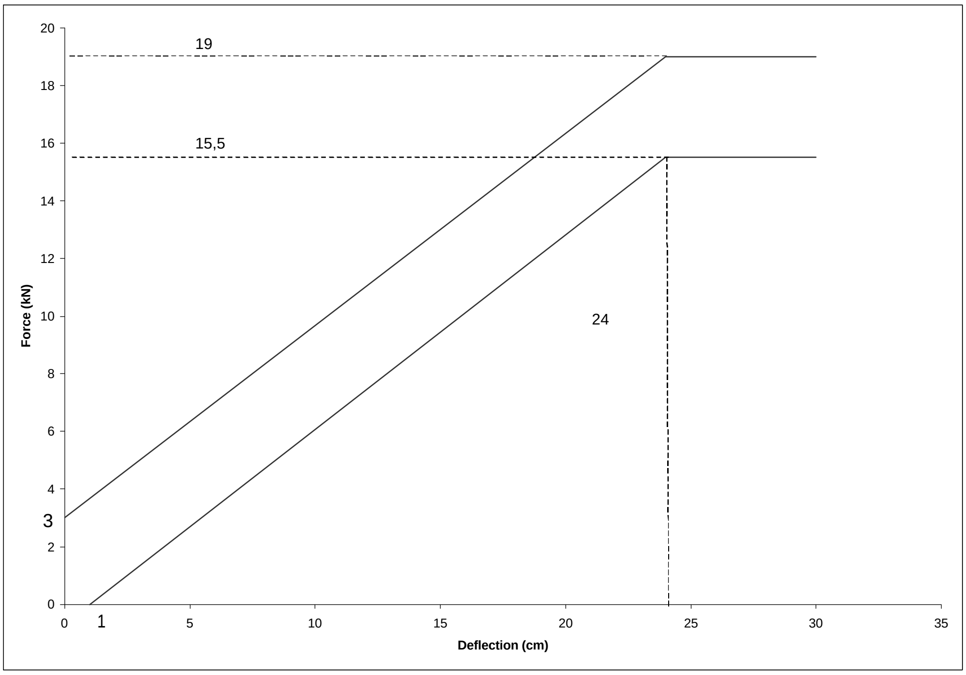
Block 2
Figure 1b



Block 4
Figure 1c



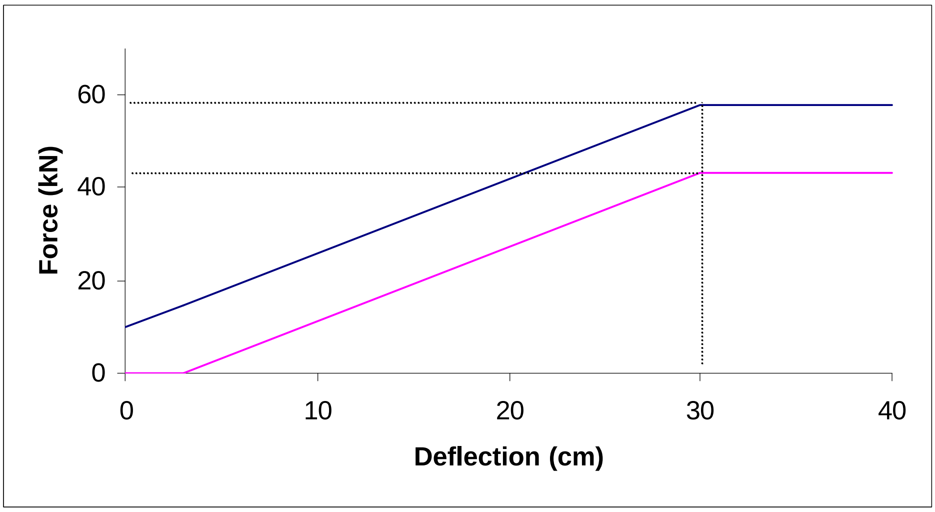
Blocks 5 & 6
Figure 1d



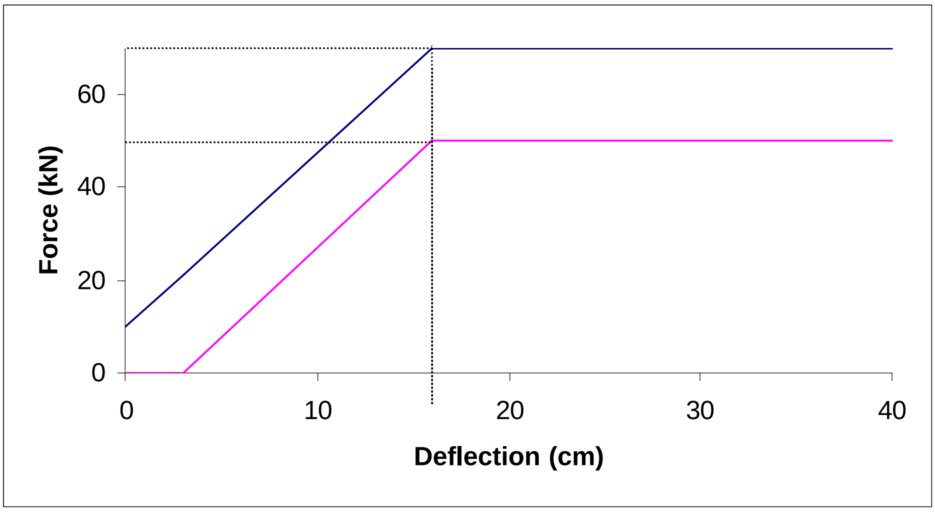
ANNEX 1 APPENDIX 2

FORCE-DEFLECTION CURVES FOR DYNAMIC TESTS

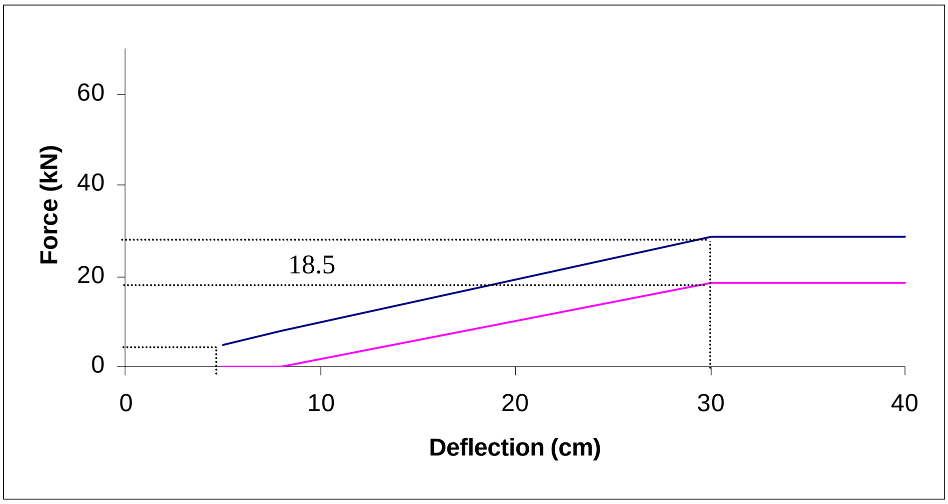
Blocks 1 & 3
Figure 2a



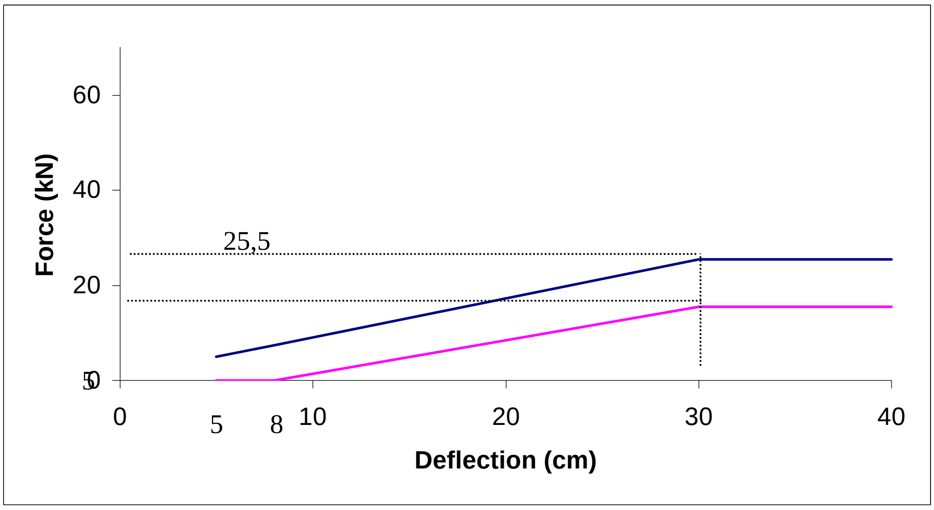
Block 2
Figure 2b



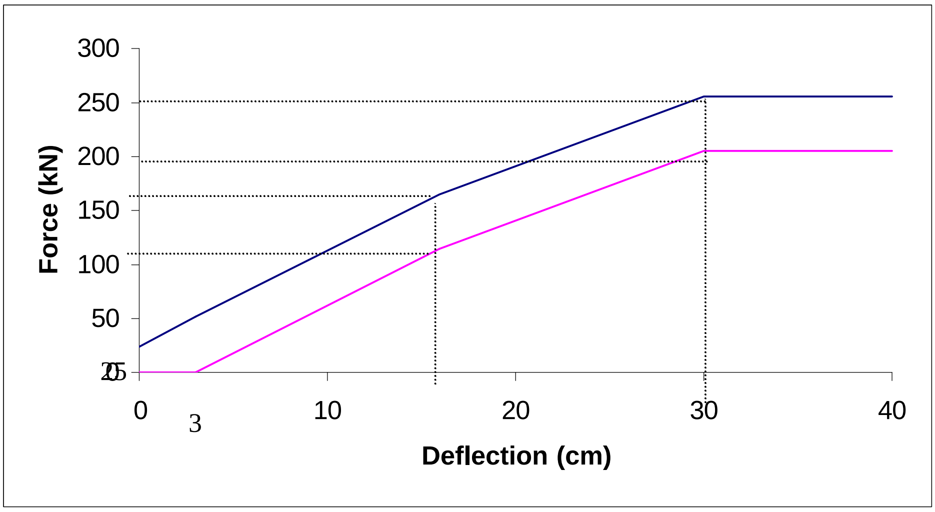
Block 4
Figure 2c



Blocks 5 & 6
Figure 2d



Blocks total
Figure 2e



[NOTE: Dynamic corridors are <u>not</u> changed from the existing ECE Regulation 95]