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**EEVC proposal for a revised specification for
the Mobile Deformable Barrier Face for use
in the Side Impact Test Procedure**

draft

DRAFT 2 for GRSP (Information only)

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EEVC proposal for a revised specification for the Mobile Deformable Barrier Face for use in the Side Impact Test Procedure.

Prepared by R Lowne
On behalf of EEVC WG13

1. INTRODUCTION.

ECE Regulation 95 and EU Directive 96/27/EC. include a dynamic full scale impact of a mobile deformable barrier (MDB) into the side of the target vehicle. The MDB comprises a deformable face attached to a trolley. The deformable face is currently defined by overall and element dimensions together with force-deflection and energy dissipation requirements in a certification test against a flat rigid load cell wall at an impact speed lower than the impact test speed. It has been reported that different designs of MDB face, that perform similarly under the certification test, produce significantly different results when used to test cars

EEVC Working Group 13 has evaluated the performance of different designs of deformable faces for the mobile barrier used in the EEVC Side Impact Test Procedure, as currently specified in the Directive and Regulation.

A representative sample of most of the currently available MDB faces were subject to both the normal certification test and to the special EEVC tests. The results and conclusions from this research. was presented in EEVC Report: "EEVC WG13 Recommendations for the Revision of the Side Impact MDB Face Specification", January 2000.^φ

EEVC concluded that the best option for ensuring reliable and consistent performance from an MDB face was to "*Specify a single design and construction together with supplementary tests to ensure performance conformity of the elements of the MDB Face*".

In that report, EEVC recommended that a revised specification for the MDB face be developed which would include (a) the design specification, (b) production definition and control and (c) supplementary quality assurance component testing for the single design of progressive MDB face to be used for the side impact test specified in the Directive and Regulation. The design should be based on the principles of the progressive design generic type.

EEVC noted that this recommendation was subject to:

1. verification of the preferred design generic type in MDB to car impact tests, (there was very little experience with this type if face in car tests)
2. evaluation of the repeatability and reproducibility of the selected MDB face design(s)
3. the ability to specify and control the manufacturing process to ensure consistency in performance

^φ Available on the EEVC Web Site: www.EEVC.org

2. MDB FACE SPECIFICATION DEVELOPMENT

The first draft of the revised specification was created by an ad-hoc group of EEVC Working Group 13, which included technical experts from the main manufacturers of aluminium honeycomb MDB faces in Europe, Japan and the USA.

The specification, which has been drawn up in a form that could easily be adopted as a revised Annex to the existing Regulation, comprises four elements: the definition of the barrier face in terms of the dimensions and the exact material specification, quasi static crush characteristics of each of the six blocks, the dynamic performance characteristics of each block and the whole face in a load cell wall test and some consideration of the conformity of production requirements. Although the principles of the dynamic test are the same as that in the current Regulation, the requirements for the load cell wall and some of the test condition tolerances are more closely specified as a result of experiences in the MDB face evaluation testing.

The revised MDB face specification defines a deformable face based on six blocks, together with a front plate, a back plate and a defined ventilation system. The whole is intended to be mounted onto a trolley with a flat unventilated front mounting plate of specified size so that the interface between MDB face and trolley and the ventilation are controlled.

The material from which the various components of the MDB face are made are carefully specified, using material that should be widely available where possible. Most of the details of the design, such as material thickness, number of honeycomb cells, block dimensions and adhesive type, can be specified. The principle of the design, that is used to achieve the increase in force as the blocks are deformed, is to make the wall thickness of the aluminium honeycomb material thinner the nearer it is to the front of the block, usually by chemical etching. It is not practical to specify this aspect of the dimensions of the face. To circumvent this, the quasi-static stiffness of each block is defined. It is the intention that a sample from each 'batch' of each block type is tested for this static stiffness. In this way, the performance of each MDB face should be certified.

Different manufacturers use different concepts of the term 'batch' in this context. If it means parallel production, where many similar blocks are made simultaneously using, for instance, the same etching bath, then one of these blocks could be used for certification purposes. If it means series production, where a series of similar blocks are made one after the other in the same etching bath, 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. 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.

The dynamic test requirement is seen as a final check on the performance of a production design and would be required far less frequently than the batch sampling for the quasi static test. A suggestion for the frequency of testing to the dynamic requirement is made in this proposal. Now that the complete design is specified, it is considered that the corridors for the dynamic test could be narrower than they are in the current Regulation, which will help to improve repeatability. It will not be possible to define these reduced corridors until a significant batch of new MDB faces have been tested. It is also possible that the quasi-static stiffness corridors may need to be refined after more have been tested. Therefore both the quasi-static and the dynamic performance corridors in this proposal and their related requirements should be considered to be provisional.

3. VALIDATION.

The revised specification is intended to result in a standardised MDB face which performs in a reliable manner when impacting vehicles and which can be manufactured by any competent aluminium honeycomb fabricator with access to the appropriate test equipment. It is intended to ensure that all MDB faces produced by the same manufacturer will perform in the same way (Repeatability) and MDB faces produced by different manufacturers will perform in the same way (Reproducibility).

It is recommended that the revised specification be validated. The Validation programme should enable the Reliability, Repeatability and Reproducibility of MDB faces produced to the new specification to be assessed. An additional advantage would be to enable the improved dynamic performance corridors for this design to be generated.

4. SPECIFICATION.

The proposed 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)

5. ACKNOWLEDGEMENTS

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

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Frédéric Robinet	AFL Honeycomb Structures	Toshio Asada	Showa Aircraft Industry
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Jean-Paul Janssen	Hexcel Composites	Katutaka Yamazaki	Niasco
Jonathan Lowe	Hexcel Composites	Toshikazu Takatsudo	Yokohama
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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.

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.

2.1 Honeycomb blocks

2.1.1 Geometrical characteristics

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)

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.

The number of closed cells within a block should be between 310 and 400. 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

The properties of each block must conform to the quasi-static corridors defined in Appendix 1. The pre-crush shall be performed on the surface of the honeycomb to which the front sheets are attached.

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)

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

The cells dimensions shall be $19 \pm 10\%$ for each block.(see Figure 4.)

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

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

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.

2.1.4 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. (*corridors subject to revision*)

2.1.5 Dynamic Test

The Dynamic deformation characteristics, when impacted according to the protocol described in Section 6 (subject to revision)

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

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

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

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

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

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

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

2.1.5.4 The rigidity of part 2 is such that its force deflection curves between corridors of Figure 2b.

2.1.5.5 The rigidity of part 4 is such that its force deflection between corridors of Figure 2c.

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

2.1.5.7 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.

2.1.5.8 The dissipated energy[°] against parts 1 and 3 during the test shall be equal to $[9.1 \pm 2\text{kJ}]$ for these parts.

[°] The amounts of energy indicated are the amounts of energy dissipated by the system when the extent to which the impactor is crushed is greatest.

- 2.1.5.9 The dissipated energy against parts 5 and 6 during the test shall be equal to $[3.1 \pm 1\text{kJ}]$ for these parts.
- 2.1.5.10 The dissipated energy against part 4 shall be equal to $[3.5 \pm 1\text{kJ}]$.
- 2.1.5.11 The dissipated energy against part 2 shall be equal to $[15 \pm 2\text{kJ}]$.
- 2.1.5.12 The dissipated total energy during the impact shall be equal to $[33.9 \pm 5\text{kJ}]$.
- 2.1.5.13 Impactor deformation measured after the test at level B (Figure 2) shall be equal to $[330 \pm 20\text{mm.}]$

2.2 Front plates

2.2.1 Geometrical characteristics

- 2.2.1.1 The dimensions of the front plates are $1500 \pm 1\text{mm}$ wide and $250 \pm 1\text{mm}$ high. The thickness is $0.5 \pm 0.05\text{mm}$.
- 2.2.1.2 When assembled the overall dimensions of the impactor (defined in Figure 2) shall be $1500 \pm 2.5\text{mm}$ wide and $500 \pm 2.5\text{mm}$ 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

The front plates are manufactured from aluminium of series Al Mg 2 to Al Mg 3 with a hardness between 50 and 65 HBS.

2.3 Back plate

2.3.1 Geometric characteristics

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

2.3.2 Material characteristics

The back plate shall consist of a 3 mm aluminium sheet. The specification for the material used to make the back plate shall be the same as that used for the front plates. (See 2.2.2)

This plate shall be perforated with holes for ventilation: the location, the diameter and pitch are shown in Figures 5 and 7.

2.4 Location of the honeycomb blocks

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 m² 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 $[0.4\text{ Mpa, (58 psi)]}$, tested according to section 2.5.

2.5.3 Bonding strength tests:

Flatwise tensile testing is used to measure bond strength of adhesives according to ASTM C297-61 (*the text of the standard may need to be included at this point in place of the reference*).

The test piece should be 100mm x 100mm, and 15 mm deep, bonded to a sample of the 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 precrushing.

2.6 Impactor attachment.

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.

2.7 Traceability :

Impactors shall carry consecutive serial numbers from which the batch and the date of manufacture can be established

3 CHARACTERISTICS OF THE TROLLEY

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

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

3.3 The interface between the trolley and the ventilation system should be solid, rigid and flat. Moreover, the ventilation device is considered to be 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.

4 CONFORMITY OF PRODUCTION

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

- 4.1 Ensure the existence of effective procedures so that the quality of the products can be inspected,
- 4.2 Have access to the testing equipment needed to inspect the conformity of each product,
- 4.3 Ensure that the test results are recorded and that the documents remain available for a time period of 10 years after the tests,
- 4.4 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,
- 4.5 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.
- 4.6 The manufacturer's level of certification must be at least ISO 9002.
- 4.7 Minimum conditions for the control of productions: the holder of an agreement will do the control of conformity following the methods hereunder described.

5 STATIC TESTS

A sample taken from each batch of processed honeycomb core shall be tested, according to the following test procedure:

- 5.1 The sample size of the aluminium honeycomb for static tests shall be 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.
- 5.2 The samples should be compressed between two parallel loading plates which are at least [20]mm larger than the block cross section.
- 5.3 The compression speed shall be 100 millimetres per minute, with a tolerance of 5 %.
- 5.4 The data acquisition for static compression shall be sampled at a minimum of 5Hz.
- 5.5 The static test shall be continued until the block compression is at least 350mm.

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

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 m 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 meters wide and not less than 1.5 m 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-track 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 : $12 \pm [1]$ mm), 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 displacement. 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

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.

6.3.3.1 The central accelerometer shall lie in a vertical longitudinal plane within $\pm [10]$ mm of the centre of gravity of the MDB and within [500]mm of the location of the centre of gravity of the MDB.

6.3.3.2 The side accelerometers shall be at the same height as each other $\pm [10]$ mm and at the same distance from the front surface of the MDB $\pm [20]$ mm

6.3.3.3 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

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

6.5 General specifications of the impactor.

6.5.1.1 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.

6.6 Data processing procedure

6.6.1 Raw data: At time = t_0 , all offsets should be removed from the data. The method by which offsets are removed shall be defined 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 deflection

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

6.6.3.2 The initial conditions for deflection are :

- velocity = impact velocity (from speed measuring device).
- displacement = 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 10 mm.

6.6.3.5 If the displacements 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 displacement of the barrier face.

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

6.6.3.7 If the displacement calculated from all three accelerometers (left hand side, right hand side and mid-line) are NOT within the 10 mm 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 displacement 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.

6.6.4 The mean acceleration, velocity and displacement will be plotted against time for each test.

6.7 Calculation of energy

The absorbed energy should be calculated for each block up to the point of peak deflection.

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

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 displacement of the trolley calculated according to 6.6.3.

6.8 Verification of dynamic force data

6.8.1 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 ($M^* V$).

6.8.2 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 ($M^* V$) is not equal to the total impulse (I) $\{\pm 5\%$

or if the total energy absorbed (E_{En}) is not equal to the kinetic energy, E_K $\{\pm 5\%$

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

draft

DESIGN OF IMPACTOR¹

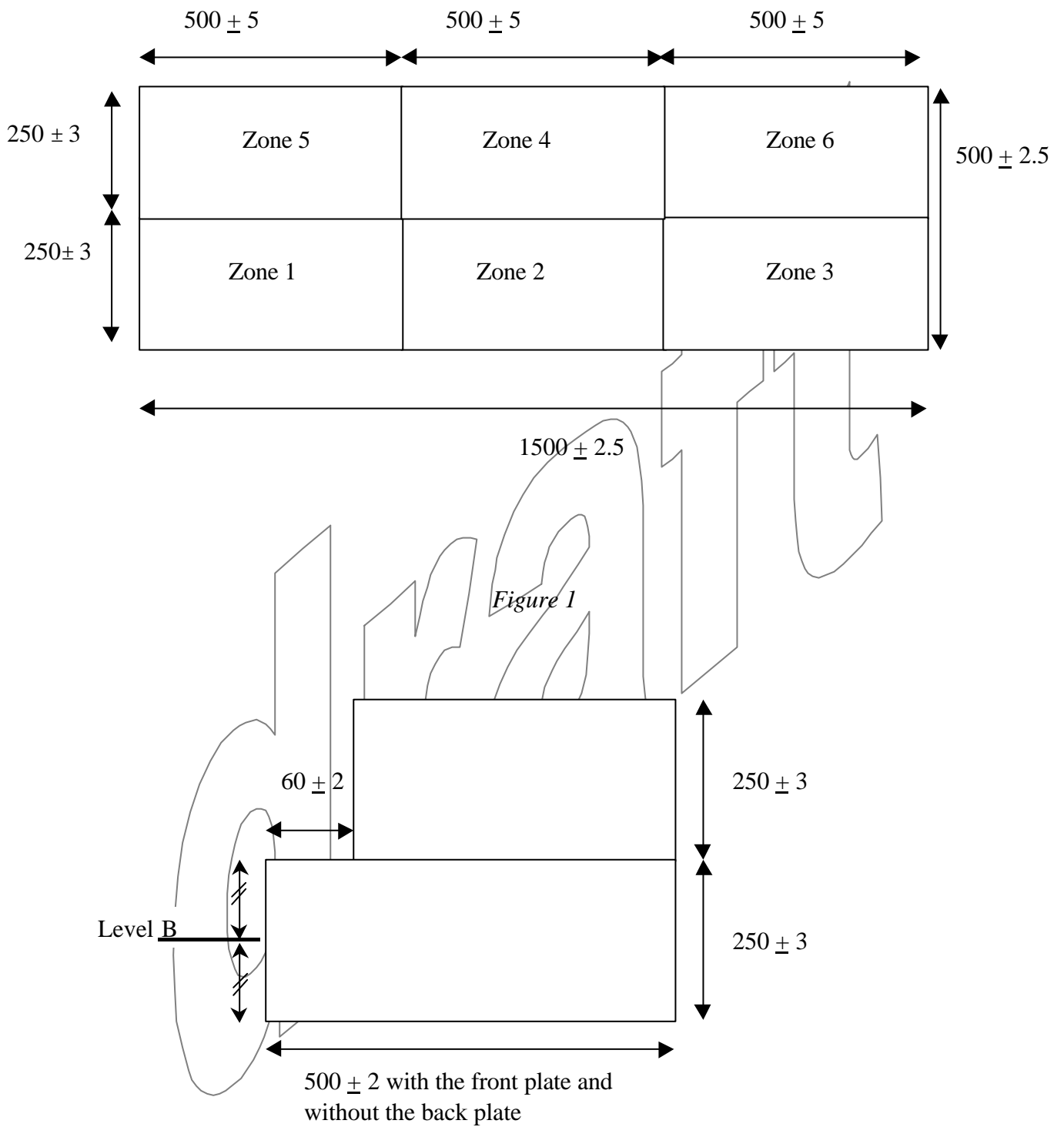


Figure 2

¹ Note: the tolerance on the dimensions of the blocks allow for the difficulties of measuring cut aluminium honeycomb. The tolerance on the overall dimension of the impactor can be 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.

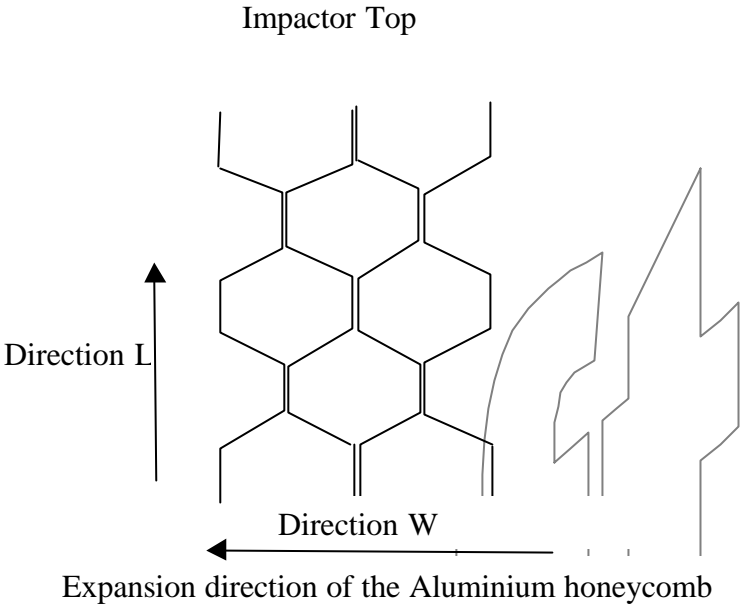


Figure 3 Aluminium Honeycomb Orientation

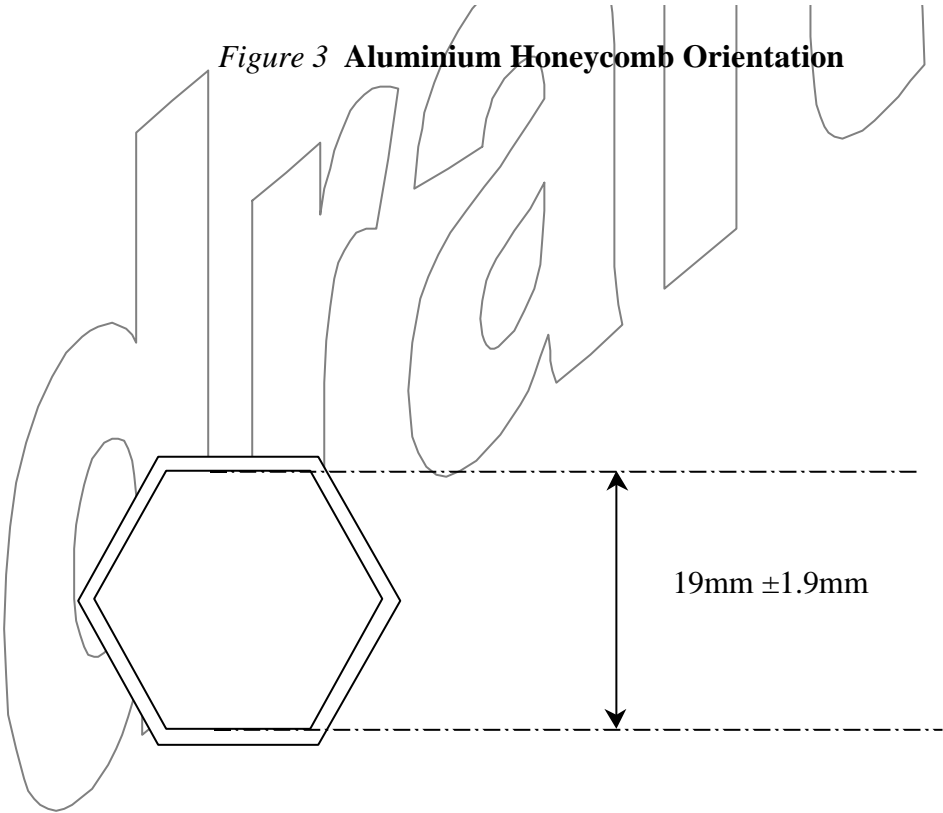


Figure 4. Dimension of Aluminium Honeycomb Cells

DESIGN OF THE BACK PLATE

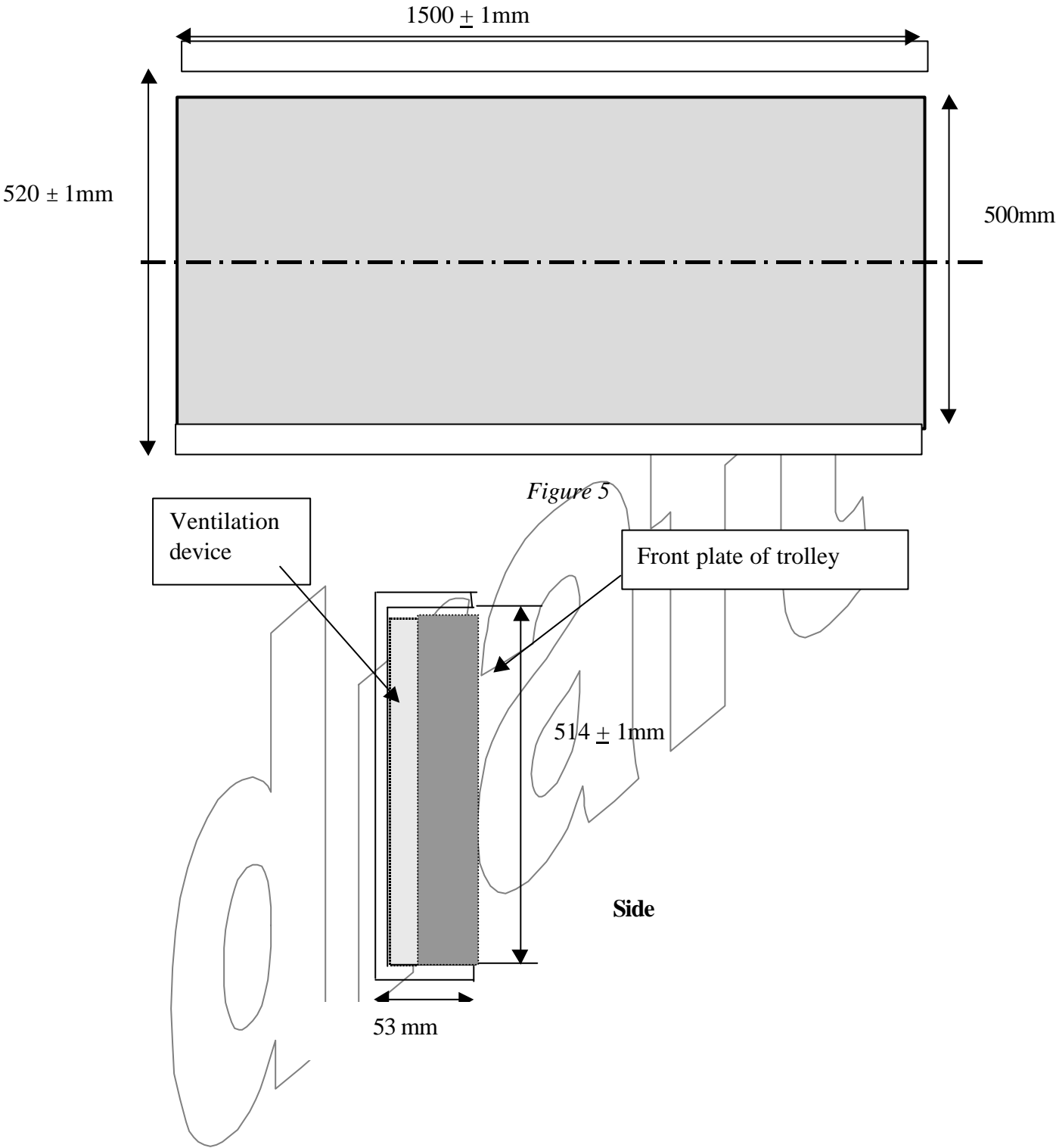


Figure 6

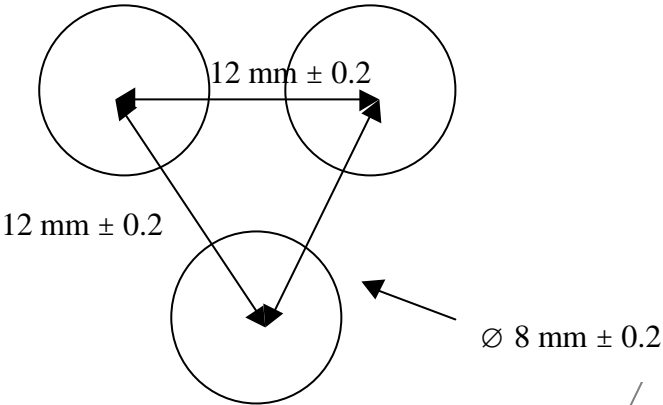


Figure 7 - Staggered pitch

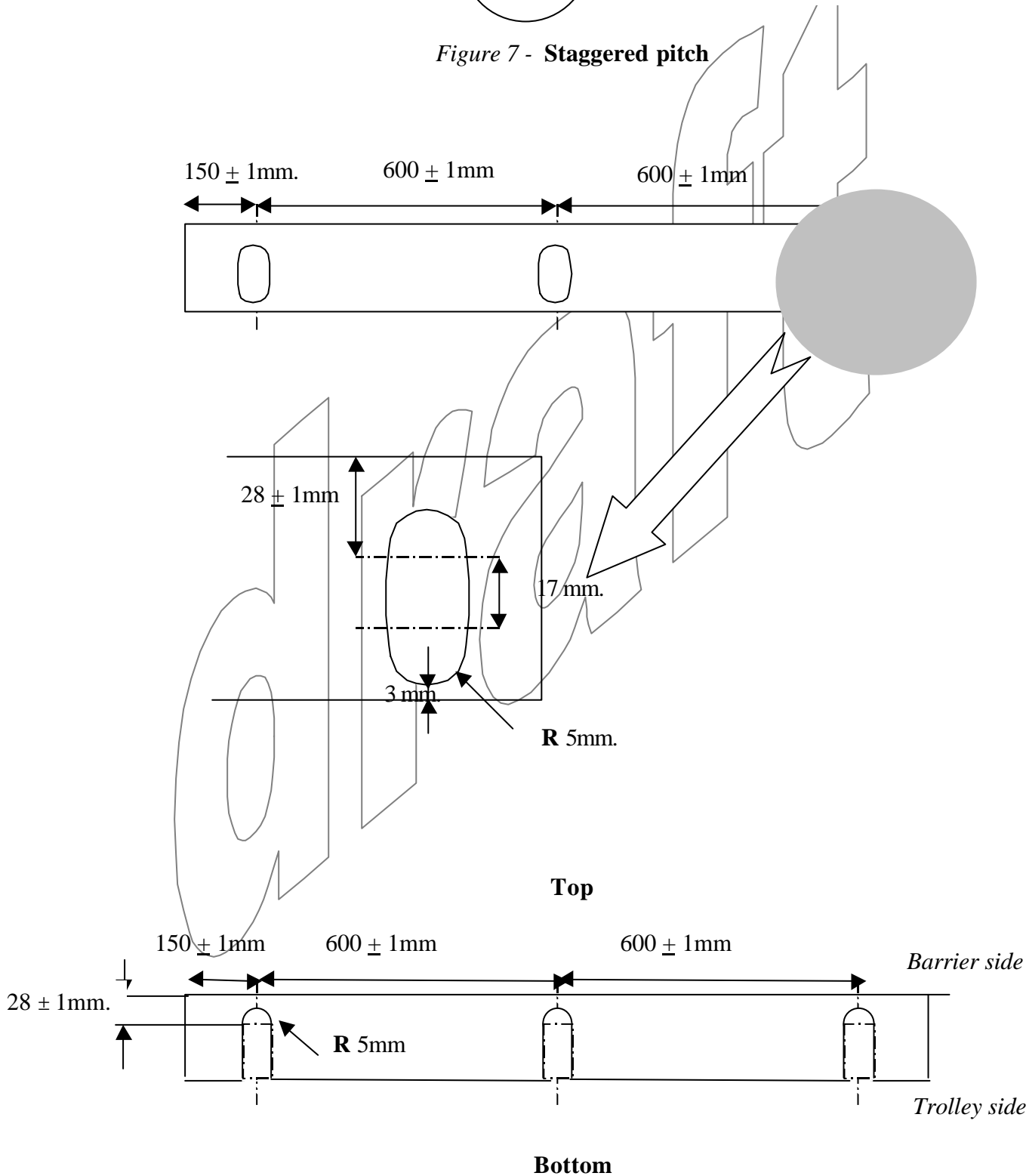


Figure 8

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 M8 holes in order to let air circulate horizontally.

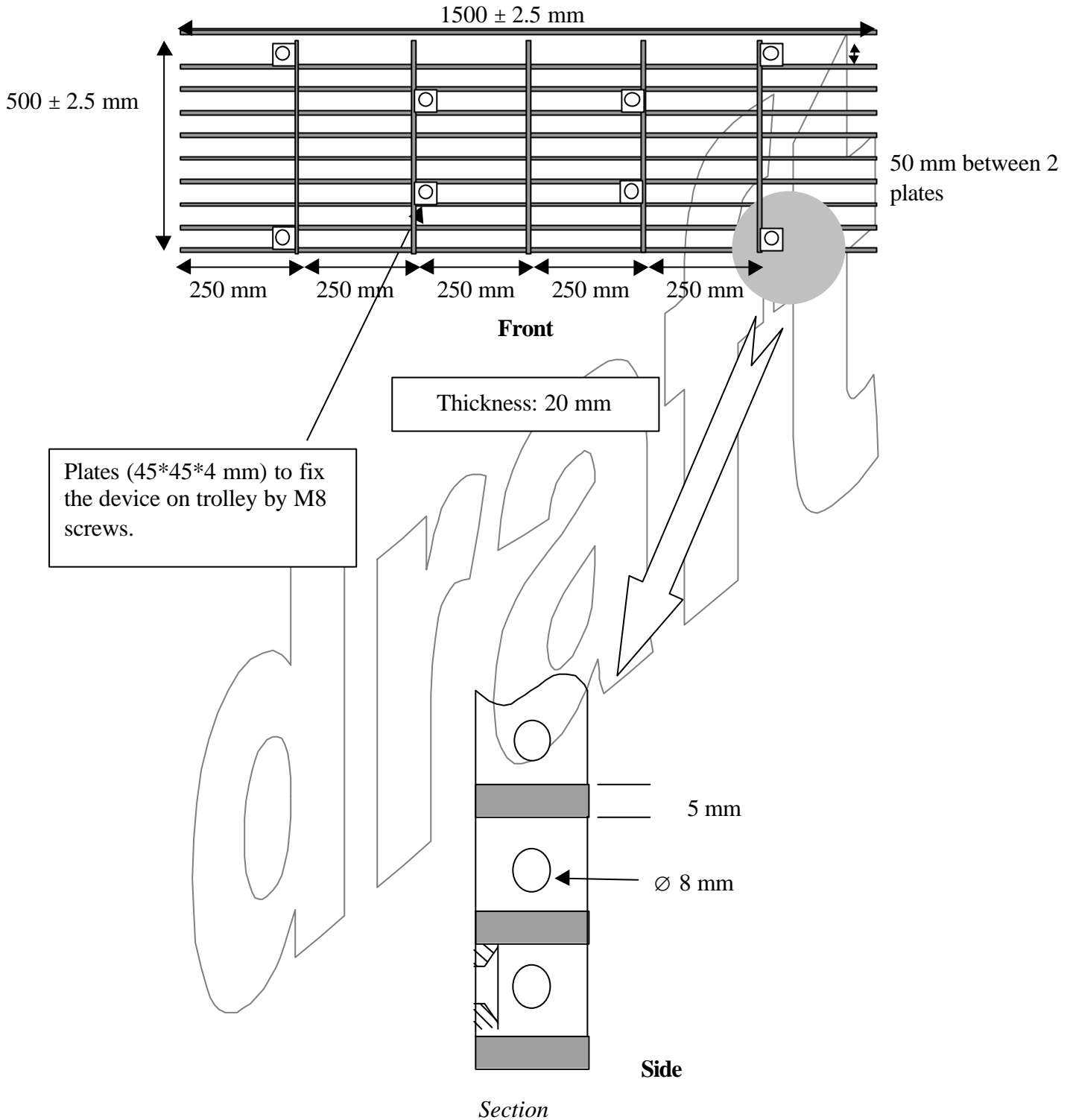
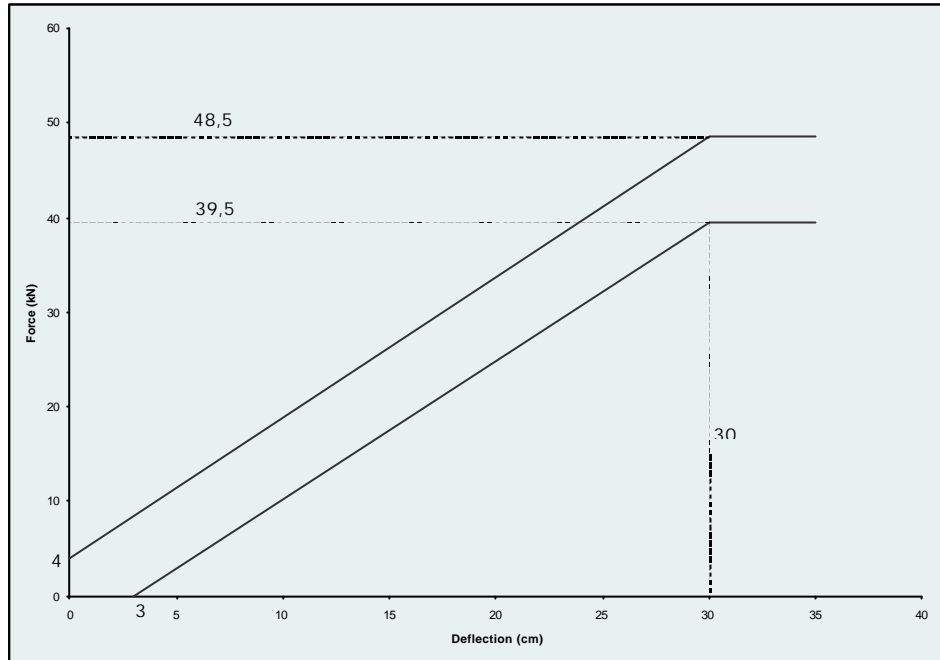


Figure 9

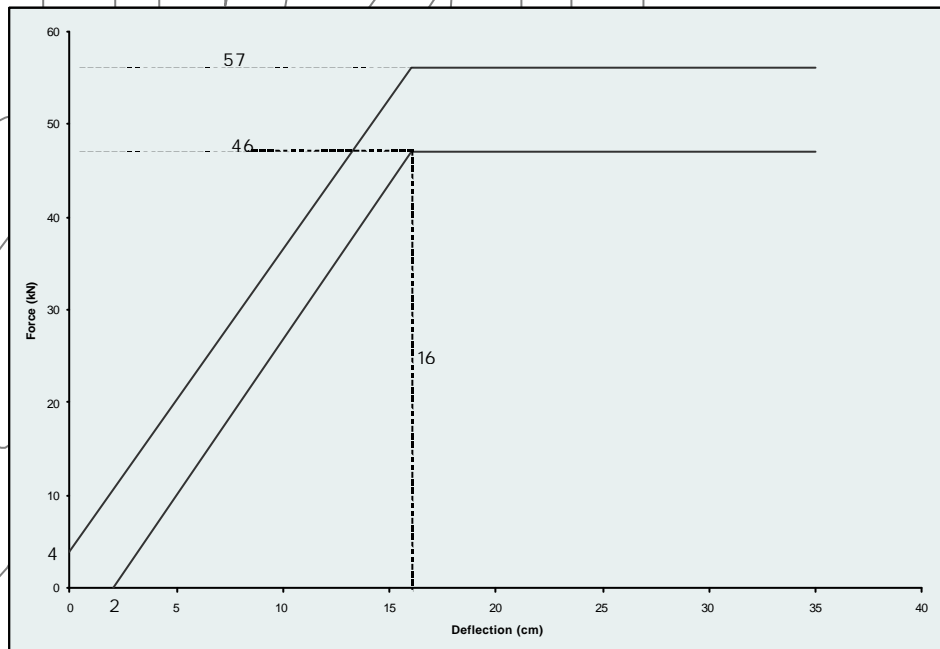
ANNEX 1, APPENDIX 1

FORCE-DEFLECTION CURVES FOR STATIC TESTS

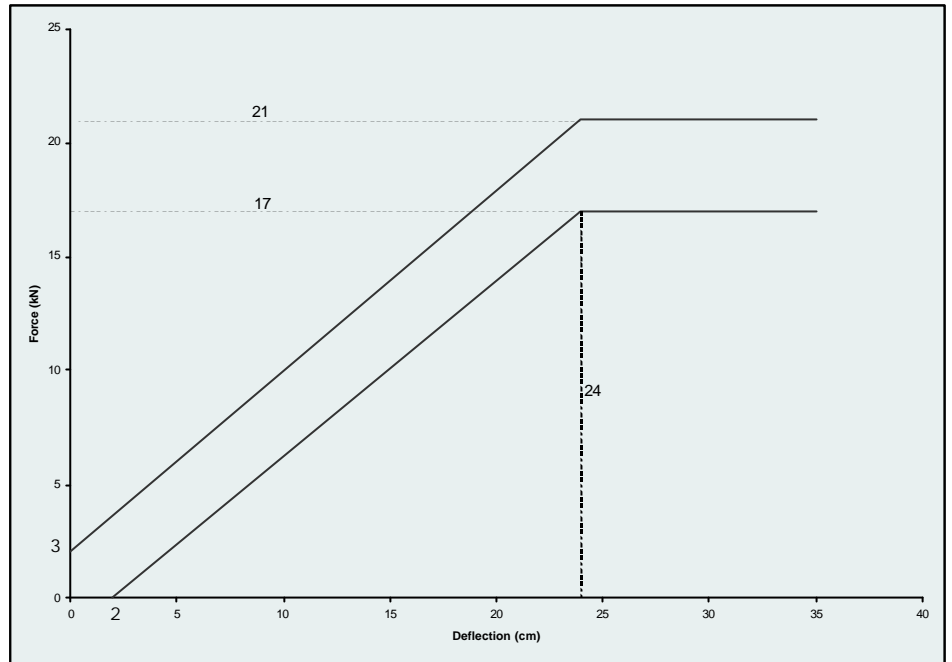
**Blocks 1 & 3
Figure 1a**



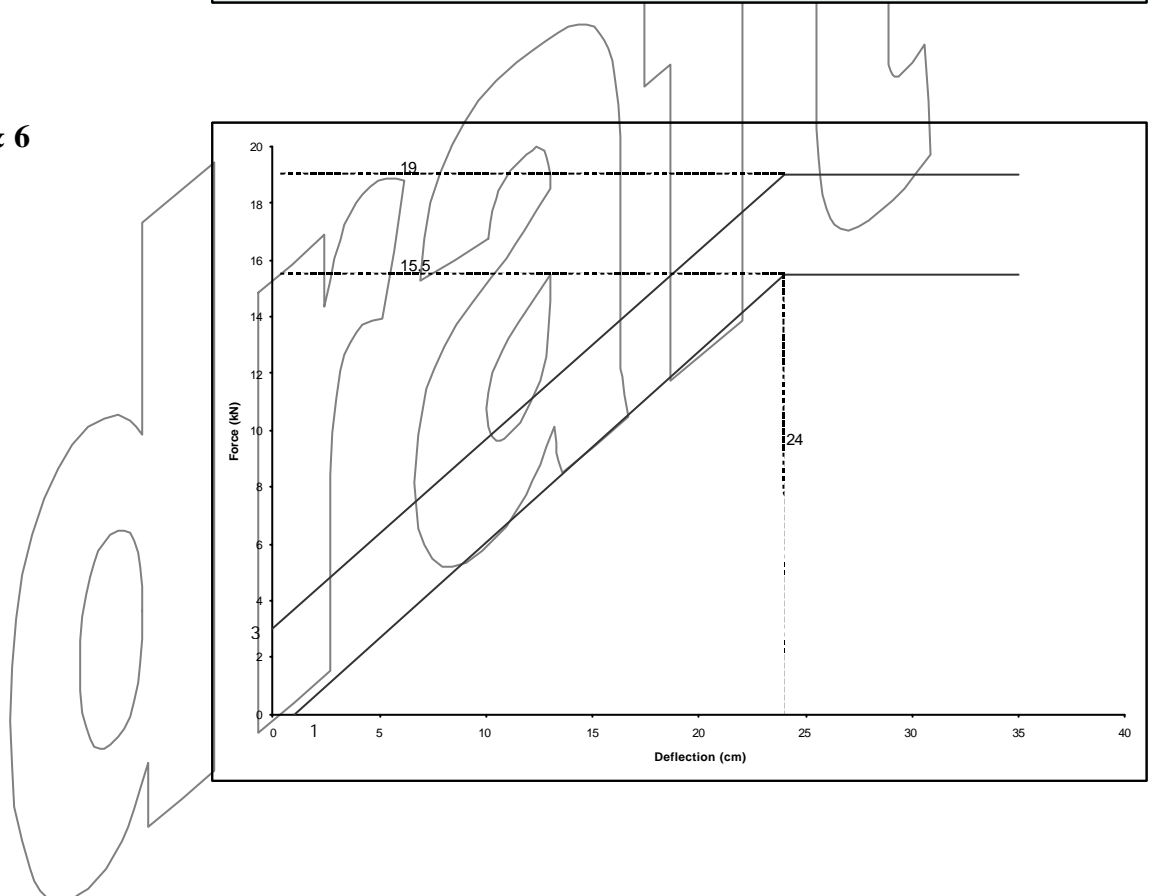
**Block 2
Figure 1b**



**Block 4
Figure 1c**



**Blocks 5 & 6
Figure 1d**

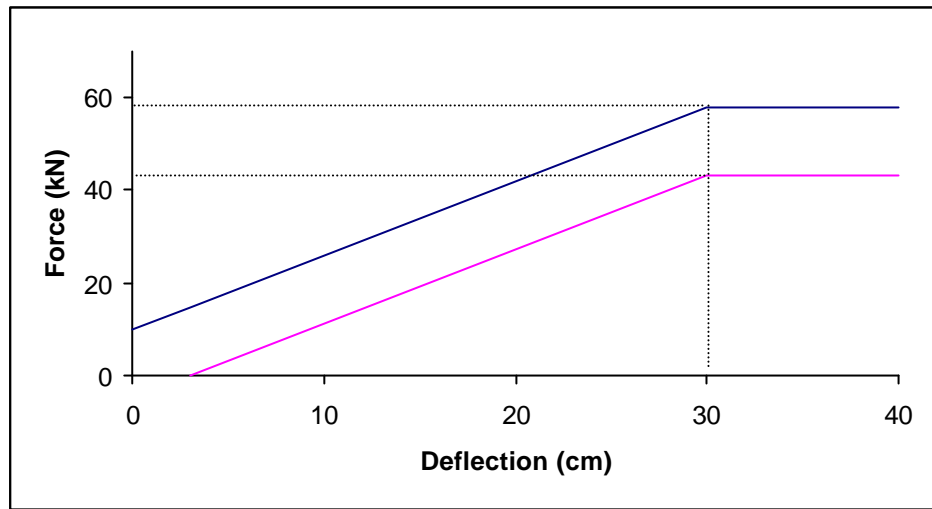


Note : , The static corridors were determined according to an average nominal value based on the data supplied by the manufacturers. The corridor's width was reduced in order to try to obtain better reproducibility in the dynamic results.

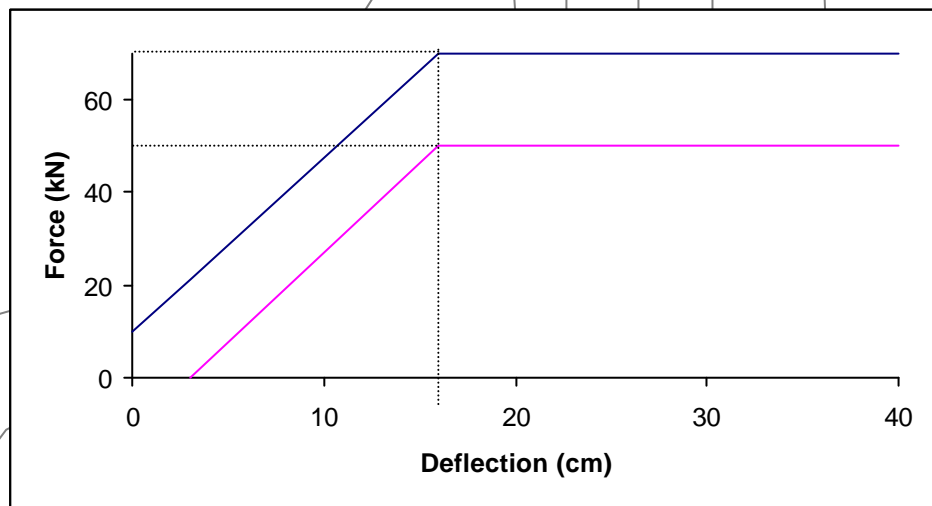
ANNEX 1 APPENDIX 2

FORCE-DEFLECTION CURVES FOR DYNAMIC TESTS

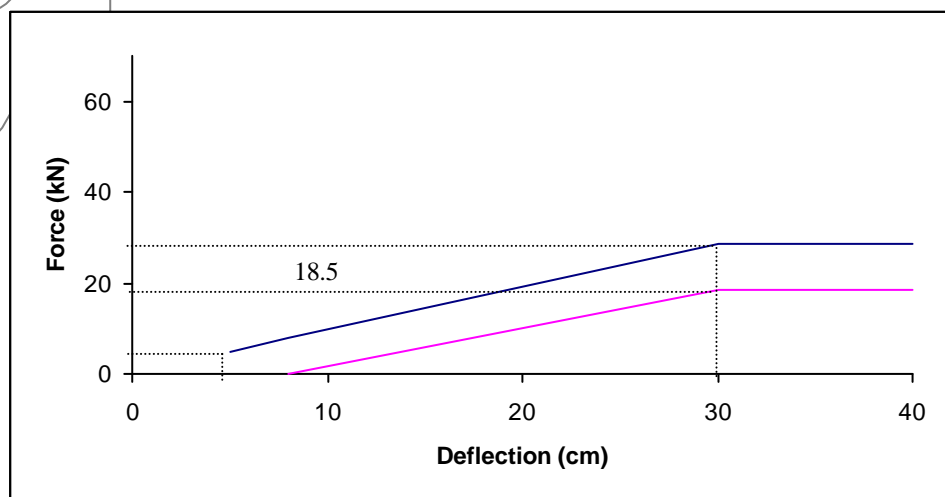
Blocks 1 & 3
Figure 2a



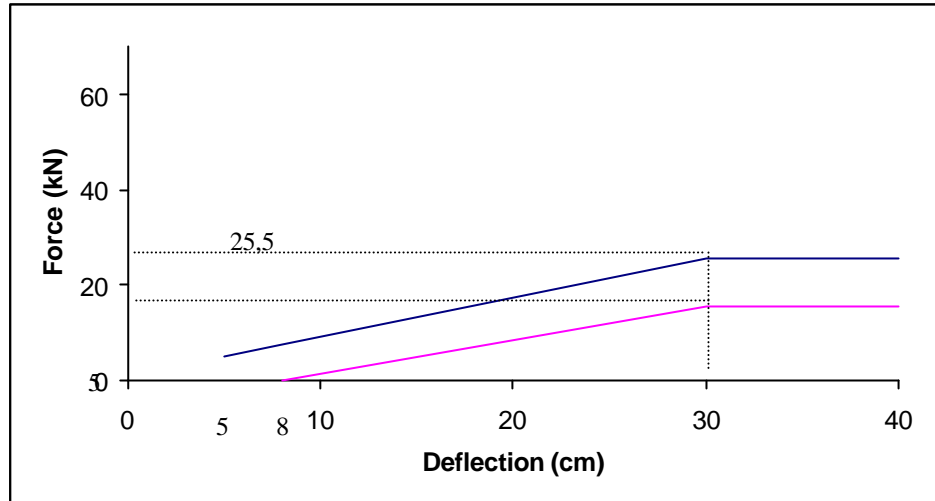
Block 2
Figure 2b



Block 4
Figure 2c



Blocks 5 & 6
Figure 2d



Blocks total
Figure 2e

