A New Generation of Crash Barrier Models for LS-DYNA

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German LS-DYNA Forum October 2006

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Introduction & motivation

- Arup have been creating LS-DYNA models of honeycomb barriers since 1991
- Cellbond is a British company who have been manufacturing and testing honeycomb barriers during the same period
- Now we are collaborating to produce a new generation of barrier models
- Motivation:
  - Improved technology in LS-DYNA: more accurate, more convenient, more robust
  - New legislation, new barrier types

ARUP

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Barriers - Side

Barrier	Test	Notes
IIHS	IIHS – Side Impact	
NHTSA	FMVSS 214 Side FMVSS 301 Rear US-NCAP	Crush behaviour defined by FMVSS 214. Two version of this barrier exist using different honeycomb properties.
AEMDB	Not used for any official test at present. Designed to replace Advanced 2000 (ECE R95)	Current version V3.9.
Advanced 2000 (WG 13)	ECE R95 Euro NCAP AUS NCAP	6 Main elements in two rows.
Multi 2000	ECE R95	Older barrier and is now largely superseded.

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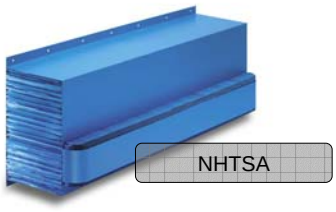
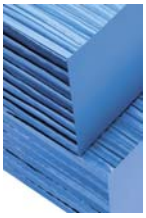
Barriers - Side





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Barriers - Frontal

Barrier	Test	Notes
EEVC – ODB	ECE R94 Euro NCAP IIHS (FMVSS 208) AUS-NCAP	
Full Width Compatibility	Proposed for full width frontal compatibility in VC-Compat	Main element of the barrier consists of two layers of honeycomb. Front layer – 0.34 MPa Crush strength Rear layer - 1.71 MPa Crush Strength
PDB	Alternative proposal to Full width Compatibility.	

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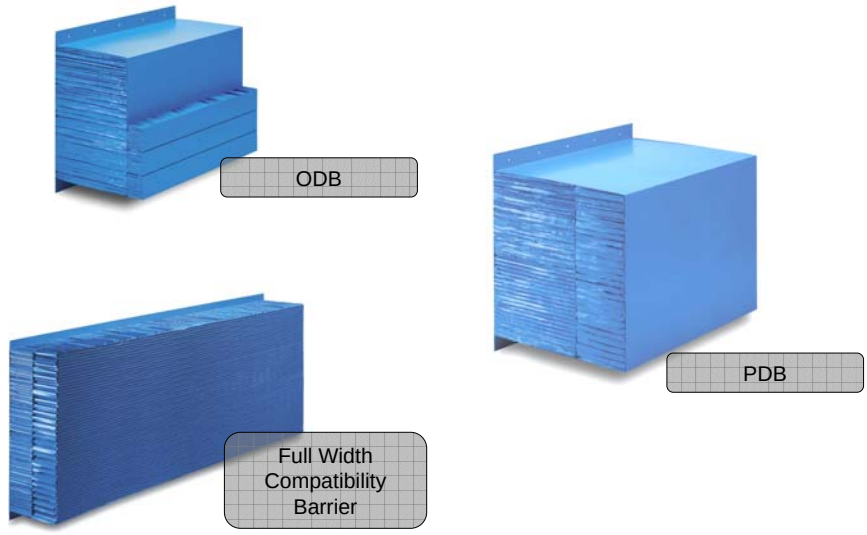
Barriers - Frontal



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Project Background

The aim of this project is to develop a new series of barriers as a rolling process

Phase 1

- Physical testing – Component and full barrier.
- Use the latest developments in LS-DYNA but sticking to the more traditional material models and Lagrangian features.
- Have a time step of 1.2 micro seconds.
- Show good performance in the MPP versions of LS-DYNA.

Phase 2

- Physical testing
- Investigate newer modelling techniques – e.g. EFG.

Planned material testing to support this project

Honeycomb Testing	Adhesive Testing	Full Barrier Testing
Crush Test	Core – Plate Pull Test	Pole
Angle Shear Test	Plate – Plate Pull Test	Rigid Wall
Piercing Test	Plate – Plate Shear Test	50% Offset Wall
		Rear Armature

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Honeycomb Types

Honeycomb materials are defined as follows:

density (pcf) – cell size (inch) – Al alloy

Three main honeycomb materials are used in the barriers:

1.8 Core – 3/4 – 3003

Main Block – NHTSA (b), EEVC-ODB, FWC

1.6 Core - 3/8 – 5053

Main Block – IIHS, NHTSA (a)

5.2 Core - 1/4 – 3003

Main Block – FWC

Bumper – IIHS, NHTSA (a) (b), EEVV-ODB, AEMDB

The situation is more complex for the side impact barriers where the main block is differentially etched.

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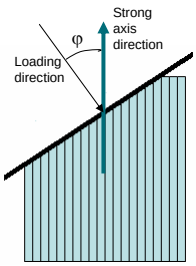
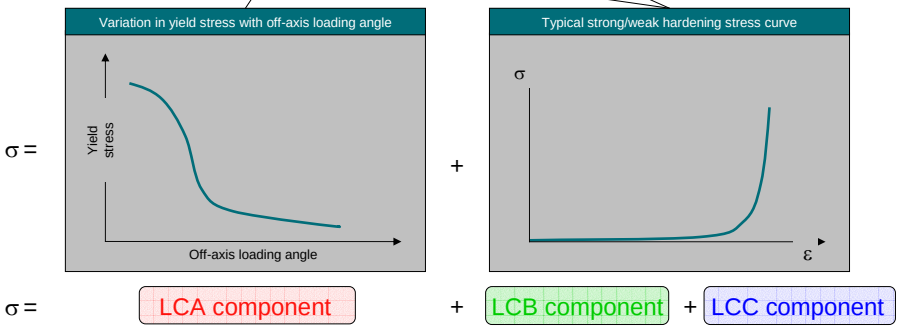
New Mat 126 Developments

2nd yield surface is utilised (**LCA** < 0)

- Yield stress of honeycomb is dependant on off-axis loading angle defined by (**LCA**) **and…**
- A strong direction (**LCB**) hardening stress and a weak direction (**LCC**) hardening stress.



$$\sigma\left(\varphi,\varepsilon^{vol}\right) = \sigma^{b}(\varphi) + (\cos\varphi)^2\,\sigma^{s}\left(\varepsilon^{vol}\right) + (\sin\varphi)^2\,\sigma^{w}\left(\varepsilon^{vol}\right)$$



σ = LCA component + LCB component + LCC component

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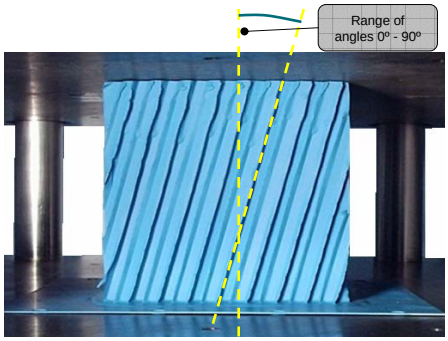
Aluminium Honeycomb Material Testing

- Data for yield stress vs off-axis angle (LCA) generated from quasi-static angled compression tests.
- Data for strong axis hardening stress (LCB) and weak axis hardening stress (LCC) was generated using normal compression tests.
- Data for the LCSR (the strain-rate factor loadcurve) generated from dynamic normal compression test results compared against normal static compression test results.



Angle Compression Test

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Aluminium Honeycomb Material Testing

Determination of shear behaviour of honeycomb for angles: 15, 30, 45, 60, 75 and 90 degrees.

Static Shear tests

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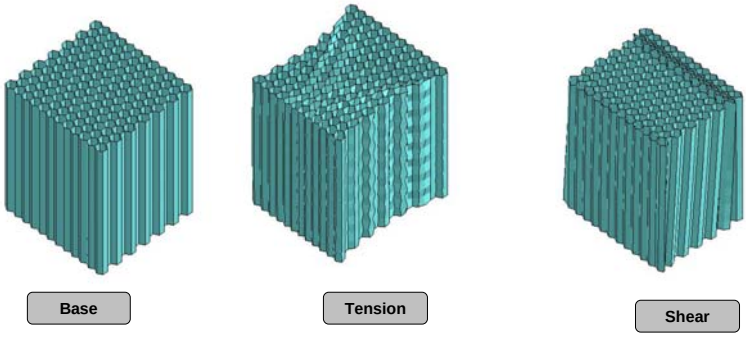
Aluminium Honeycomb Material Testing



Simple Finite element shell models of honeycomb to help characterise properties.

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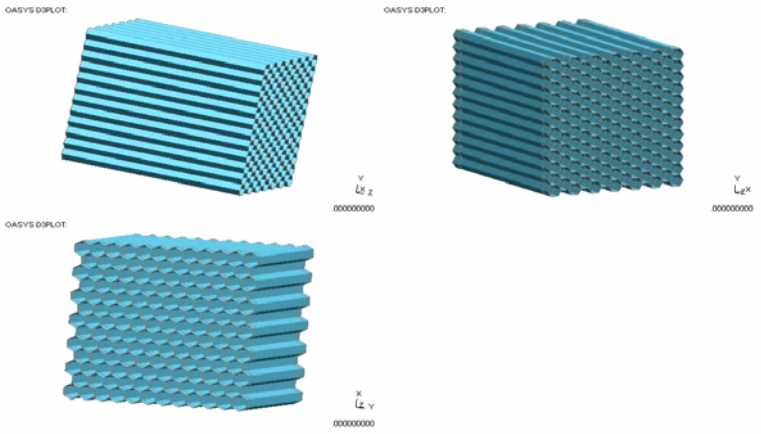
Aluminium Honeycomb Material Testing



Pull tests in X, Y and Z directions

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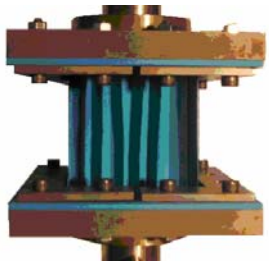
Adhesive Testing

The adhesive has been modeled using *MAT_ARUP_ADHESIVE.

This Material card requires 4 inputs:

- Tensile strength and fracture toughness
- Shear strength and fracture toughness



Two sets of testing were performed to generate data for this material card:

- Tension tests using adherents of:
  - aluminium cladding to honeycomb core of varying densities.
  - aluminium to aluminium
- Lap tests were performed between adherents of aluminium to aluminium.

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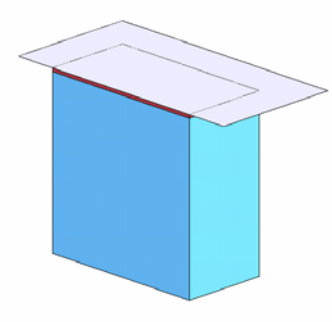
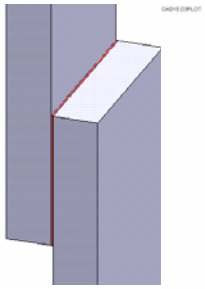
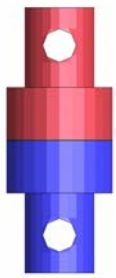
Adhesive Testing







Aluminium Cladding – Core Pull Test

Aluminium – Aluminium Lap Test

Aluminium – Aluminium Tensile Test

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IIHS Barrier Model

Model Description

- The units of the model are Newtons, Tonnes, seconds and millimeters. Versions of the model in other unit systems are available on request.
- The barrier is oriented in standard vehicle coordinates, with the z-axis pointing upwards and the y-axis pointing forward, towards the side of the vehicle.
- The front bumper is in the plane y=0
- The barrier will need to be translated so that it is correctly positioned relative to the vehicle.

Contact Surfaces

- There is one type of contact surface in the barrier model - an automatic single-surface contact which applies to all the contact parts of the barrier (null shells, cladding etc.)

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IIHS Barrier Model

Specification

- The specification used for the barrier in this documentation has been taken from: IIHS, Side Impact
- Crash Test Protocol (version II), October 2003; & IIHS Side impact Crash Test Protocol (version IV) August 2005

Barrier Characteristics

- The mass of the barrier including instrumentation should be 1500kg.
- The barrier consists of two different sized aluminium honeycomb blocks partially covered in aluminium sheets; see Figure 1.1 for more details.
- The main aluminium block should be 1676 mm wide, 759 mm high and 381 mm deep.
- The second 'bumper' block should have a profile of 203 mm high and 102.3mm deep.

Material Characteristics

- The main honeycomb block should have a crush strength of 0.31 MPa ±0.017 MPa.
- The front and top faces of the main block should be covered with 0.7 mm aluminium sheet.
- The top aluminium sheet should be bonded to the main block (Figures 1.3 & 1.3.1).
- The bumper honeycomb block should have a crush strength of 1.69 MPa ±0.103 MPa .
- The front face of the bumper block should be covered with 3 mm aluminium sheet.

Calibration Procedure

- No calibration test is specified for the deformable barrier as its crush performance is characterised by its material properties.

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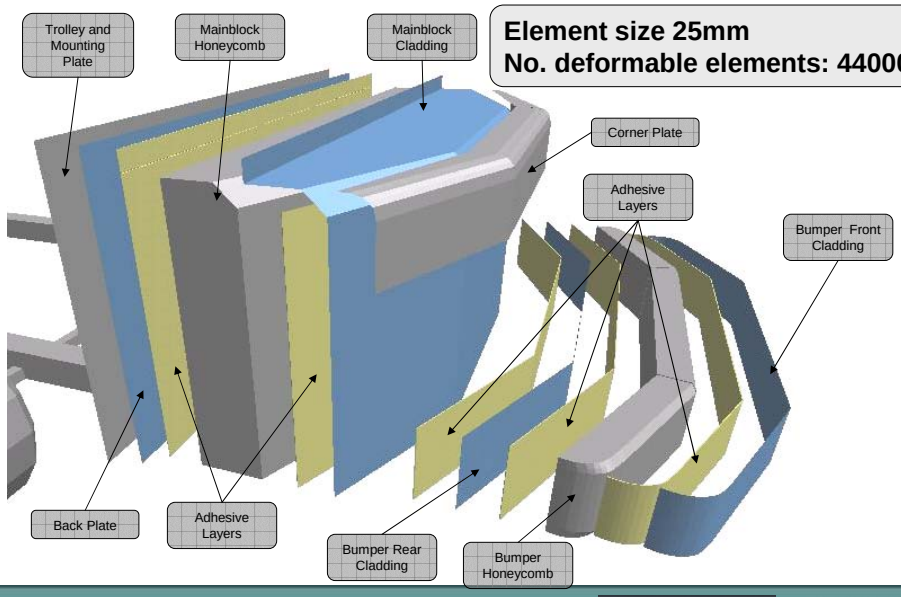
Model Construction



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Model creation progress

Barrier	Create	Correlate
IIHS		
NHTSA		
AEMDB		
ODB		
Compatibility		

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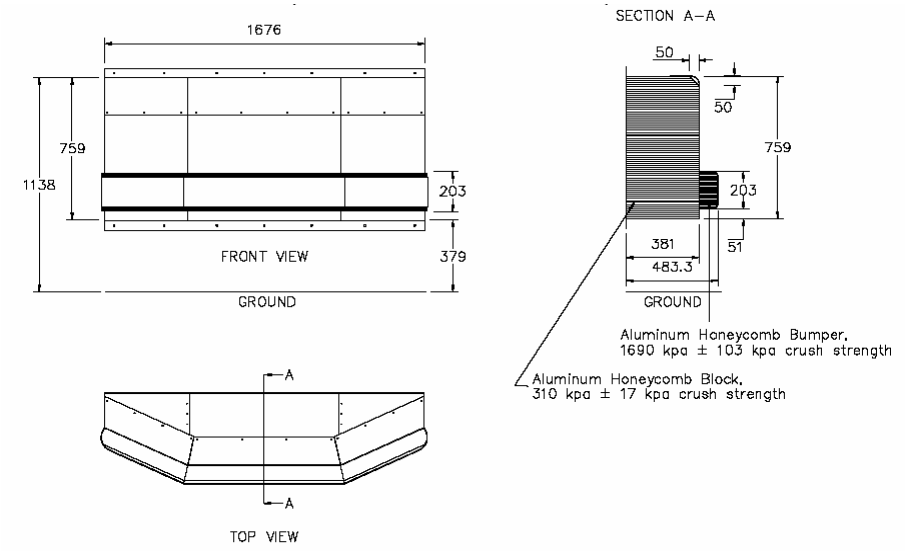
IIHS Barrier



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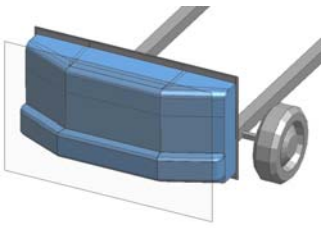
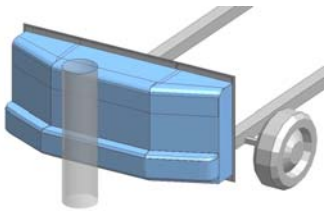
IIHS Full Barrier Validation Tests

Two tests were selected for the validation of the full barrier model.
These tests were performed by Jaguar Land Rover.



Rigid Wall Test



Pole Test

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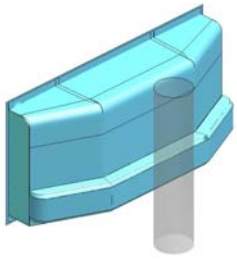
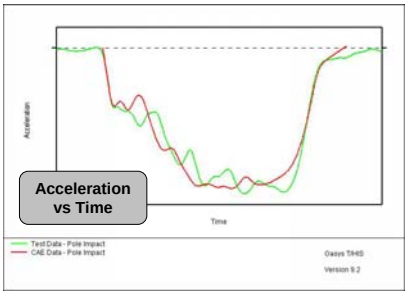
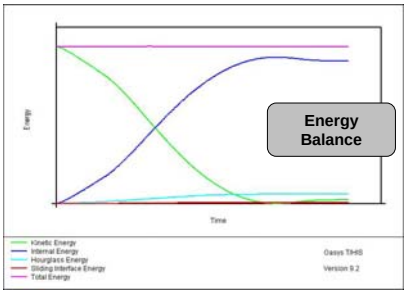
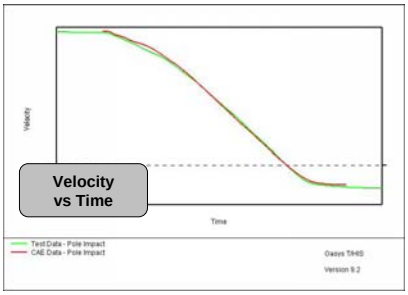
IIHS Full Barrier Validation Tests – Pole Test









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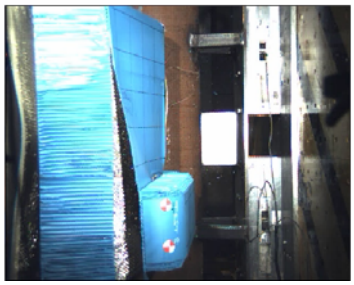
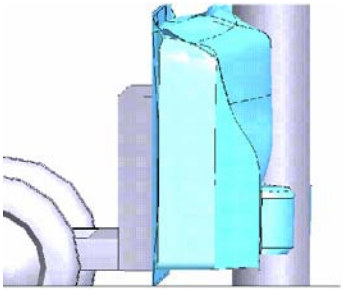
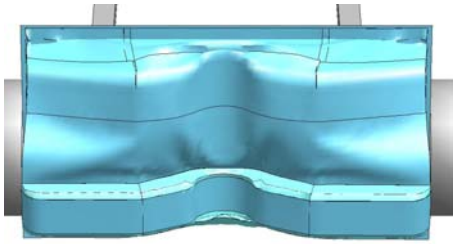
IIHS Full Barrier Validation Tests – Pole Test







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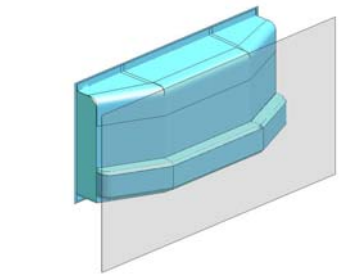
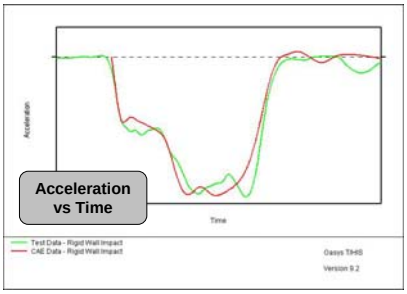
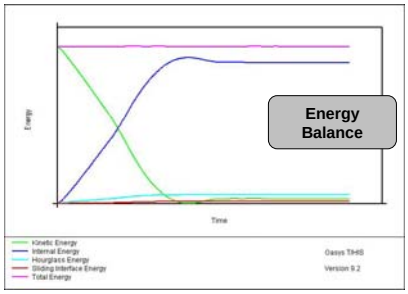
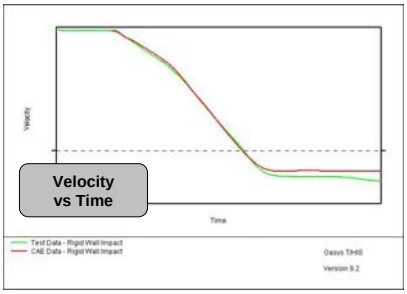
IIHS Full Barrier Validation Tests – Wall Test









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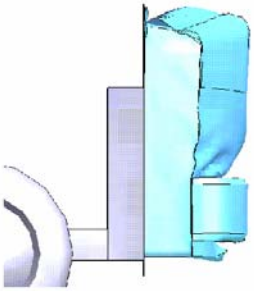

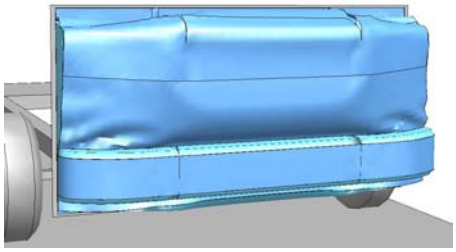

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NHTSA Full Barrier Validation Tests

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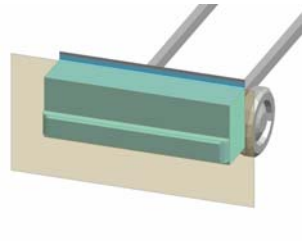
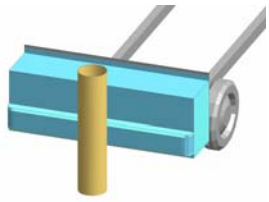
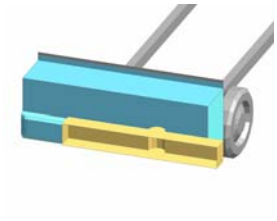


Rigid Wall Test



Pole Test



Rear Armature Test

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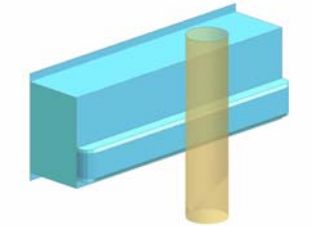
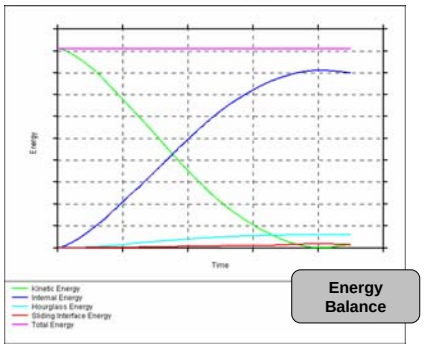
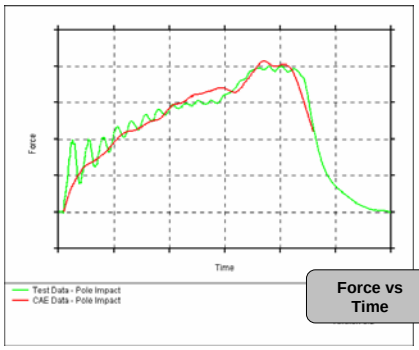
NHTSA Full Barrier Validation Tests – Pole Test





Energy Balance



Force vs Time

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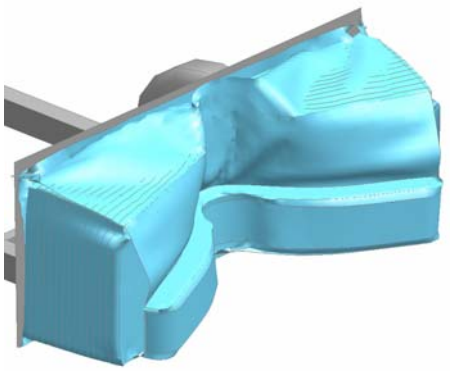
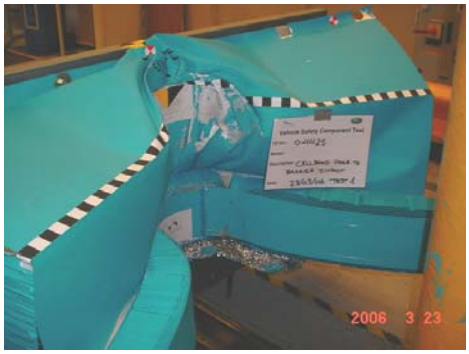
NHTSA Full Barrier Validation Tests – Pole Test





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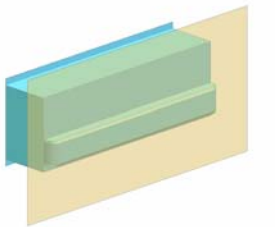
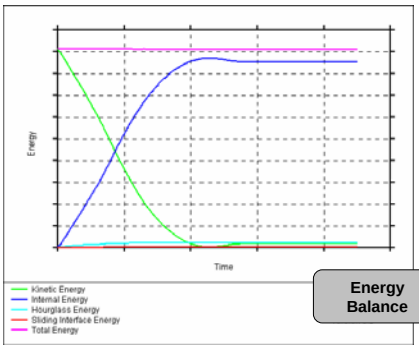
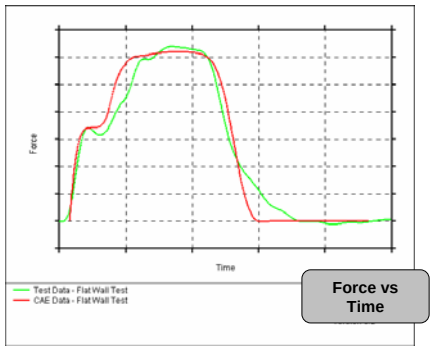
NHTSA Full Barrier Validation Tests – Wall Test





Energy Balance



Force vs Time

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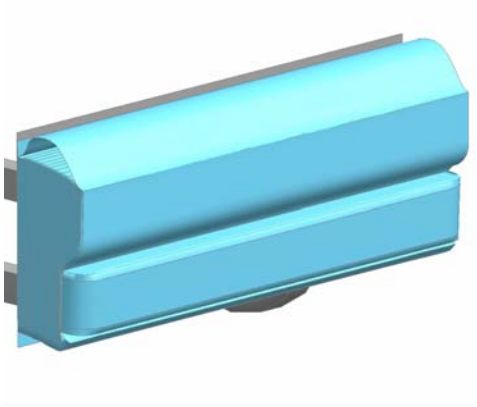
NHTSA Full Barrier Validation Tests – Wall Test



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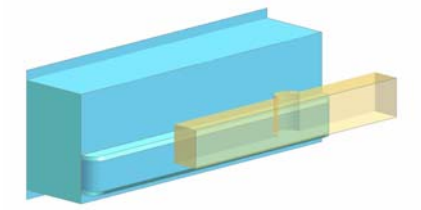
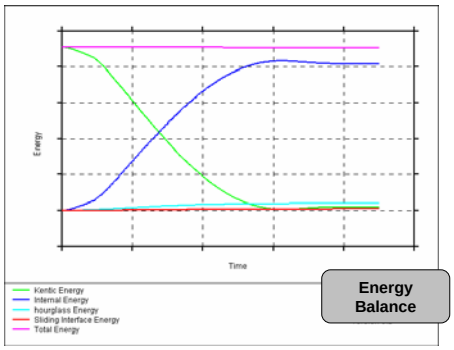
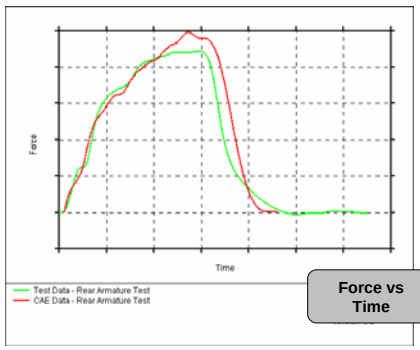
NHTSA Full Barrier Validation Tests – Rear Armature





Energy Balance



Force vs Time

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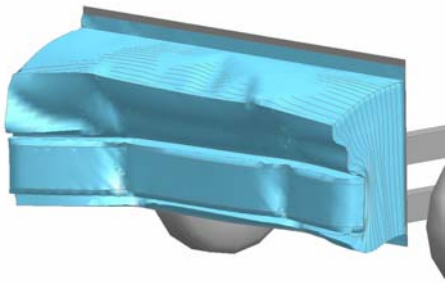

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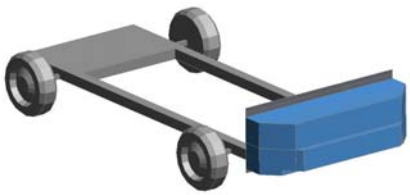
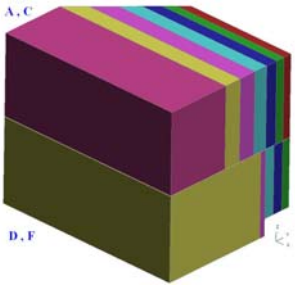
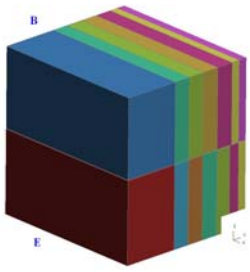
AEMDB







Barrier is divided into 6 main block – Differentially etched.

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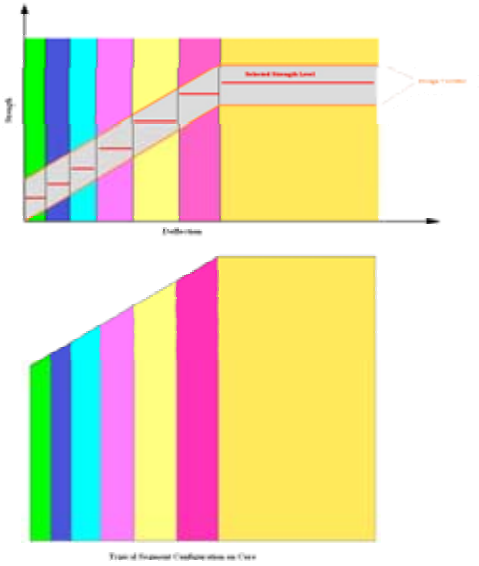
AEMDB – Strength Corridors



A total number of 89 Static test have been carried out to develop Mat. cards

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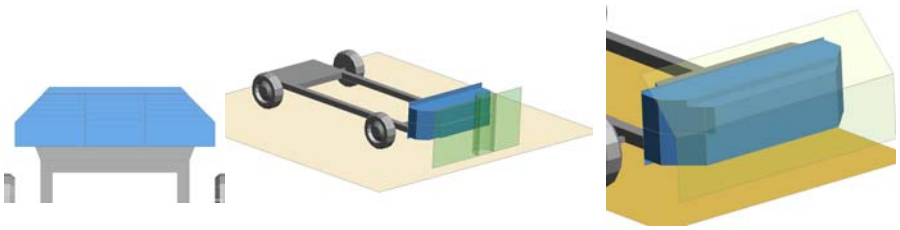
AEMDB Full Barrier Validation Tests

Three tests were selected for the validation of the full barrier model.



Rigid Wall Test | Pole Test | Sill Test

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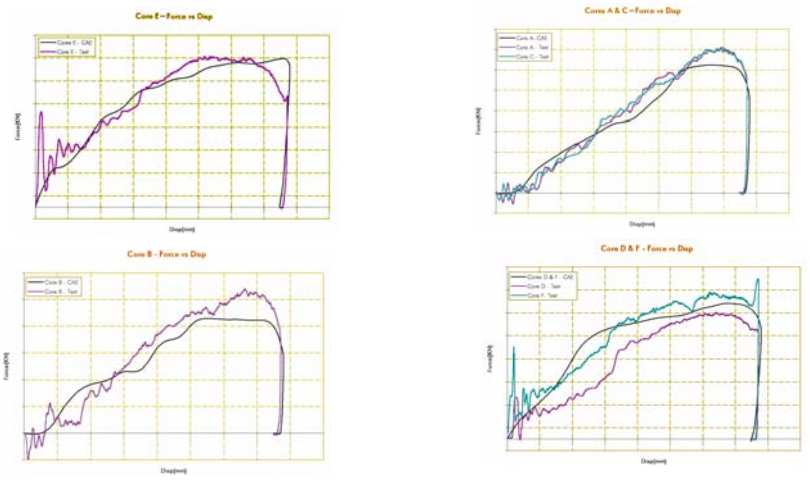
AEMDB – Results RIGID WALL (WIP)



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Barrier-to-vehicle and other tests

- **Barrier-to-vehicle tests: correlation to test**
  - Work in progress
  - Results are good, but we cannot show them yet.
- **Robustness tests: preventing "error terminations"**
  - Impact against different shaped targets
- **Code variation testing**
  - MPP vs SMP
  - Number oc CPUs
  - 970, 971
  - Platforms, Windows, HPUX, AIX etc

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Barrier Release Schedule

Barrier models using this new technology will be released as follows

Barrier Model	Progress	Release Date
IIHS	100% complete	Released
NHTSA	95% complete	Oct 2006
AE-MDB	90% complete	Nov 2006
EEVC ODB	Not started	Q1 2007
PDB	Not started	Q1 2007
Full Width Compatibility	Not started	Q2 2007

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A New Generation of Crash Barrier Models for LS-DYNA

German LS-DYNA Forum October 2006

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