Development of the Advanced Finite Element Model for ODB Impact Barrier

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Abstract:

The Offset Deformable Barrier (ODB) has been used by Euro NCAP and most of leading car manufacturers worldwide. This deformable barrier is used for frontal offset impact while the specifications developed by EEVC WG11. This paper represents the methodology to create the advanced Finite Element model of Cellbond's ODB barrier and certification through experimental test data. LS-DYNA® was used to analyze the FE model and a number of static compressive tests performed at different angles to construct aluminum honeycomb Material Cards. The strain-rate scale factor curves are also defined to simulate the dynamic stiffening in the aluminium honeycomb during the analysis. Adhesive properties are obtained using Climbing Drum, T-Peel, Tensile and Plate Shear test results. The initial component tests generated a good correlation with FE outputs and to validate the barrier model, similar impact tests were performed in LS-DYNA environment respecting to four. In all assessments, the barriers were mounted on a rigid wall and were tested at certain impactor speeds. The Final comparison on overall results represents a good correlation between test data and CAE results for all tests.

Keywords: ODB, Cellbond, FE Analysis, Cellbond Barriers

INTRODUCTION

The Offset Deformable Barrier (ODB) has been used by Euro NCAP and most of leading car manufacturers worldwide. This deformable barrier is used for frontal offset impact while the specifications developed by EEVC WG11. The specifications for ODB barrier are also recognized by ECE R94 [1] and FMVSS 208 Occupant Crash Protection. The main block of the ODB (Figure 1) is constructed from aluminium honeycomb with crush strength of 0.34 MPa (50 psi) +0-10%. The foil thickness is approximately 0.076 mm and honeycomb cell size should be based on 19.1 mm ± 20% to achieve 28.6 kg/m3 density. The main block is 650 mm long, 1000 mm wide (crash face) and 450 mm deep (crash depth). The bumper is made of three individual but identical honeycomb blocks with 0.81 mm aluminium skin in front face. The crush strength of honeycomb blocks is maintained at 1.71 MPa (250 psi) +0-10% in bumper parts.

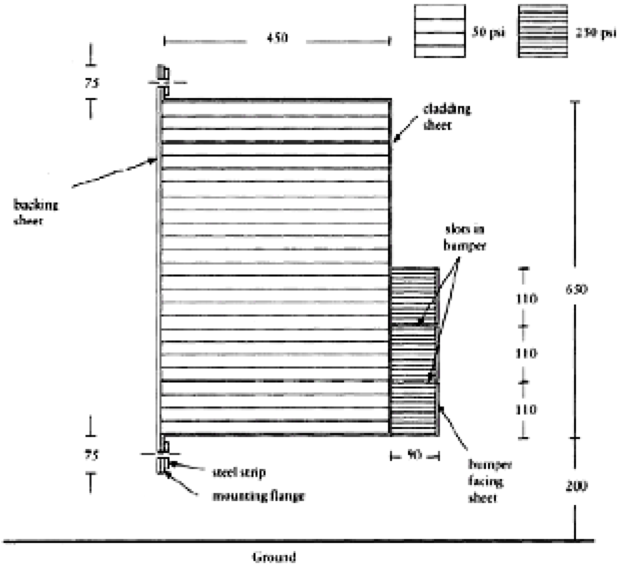


Figure 1. ODB Barrier General Dimensions

The connectivity between individual parts is created using a specific PU adhesive and the overall mass of the barrier is approximately 20 kg. The barrier is then mounted to the support wall through specified holes on top and bottom edges of barrier.

FINITE ELEMENT MODEL

A numbers of reliable techniques have been implemented to simulate the aluminium honeycomb crush behaviour [2, 3], however, it becomes time-consuming and almost impossible to create and solve complex geometries with various boundary conditions. In larger structures, however, it will result into huge number of nodes and elements in the model so that the analysis time will be increased. Using the Modified-Honeycomb-Material (Mat 126) card and modeling the honeycomb parts with solid elements creates an efficient methodology to reduce model components and solve the model/s easily. The new manner to simulate the aluminium honeycomb requires accurate material data in different formats. The yielding function technique has given well-mannered results in investigations of IIHS [4], AE-MDB [5], NHTSA [7] crash barriers. This method also represents an appropriate performance on honeycomb composite panels subjected to dynamic headform impact [6]. In this method the yield stress of honeycomb is a function of different parameters [8] as described in equation 1.

$$\sigma^{y}(\varphi,\varepsilon^{vol}) = \sigma^{b}(\varphi) + (\cos\varphi)^{2}\sigma^{s}(\varepsilon^{vol}) + (sin\varphi)^{2}\sigma^{w}(\varepsilon^{vol}) \tag{Eq.1}$$

in which

φ = Section angle with the strong axis (Fig. 3)

$\sigma^{b}(\varphi)$ = Yield stress as a tabulated function of section angle

$\sigma^{s/w}(\varepsilon^{vol})$ = Stiffness as a tabulated function of volumetric strain

Figure 2, illustrates the compressive test procedure for different angled sections of the honeycomb blocks. The composite materials used in the static tests were the Cellbond's 1.8 3/4 5052 and 5.2 1/4 3003 aluminum honeycomb and the block dimensions were 200 mm x 180 mm x 50 mm which was tested at speed of 10 mm/min. All samples were taken randomly from the bulk blocks which are used to manufacture the ODB barrier. Plot (1a), shows the typical value of yield stress versus cut section angle in ODB barrier's main honeycomb blocks. In all tests the highest compressive stress was measured in zero degree (strong axis) and as the angle increases, the compressive stress decreases. The static crush strength of honeycomb drops down significantly after 60 degrees and the 35 degrees cut section represents almost half of normal core strength.

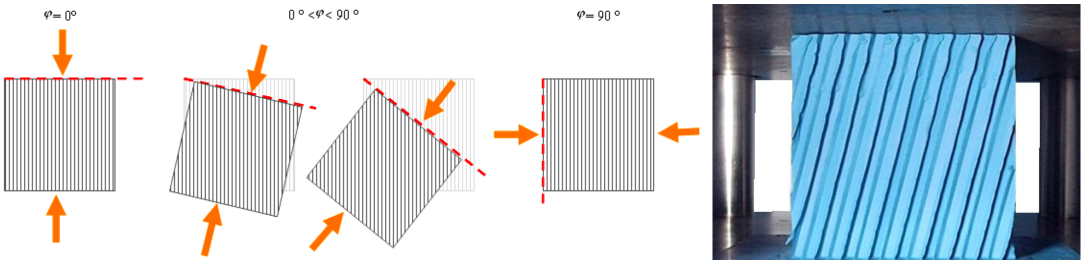
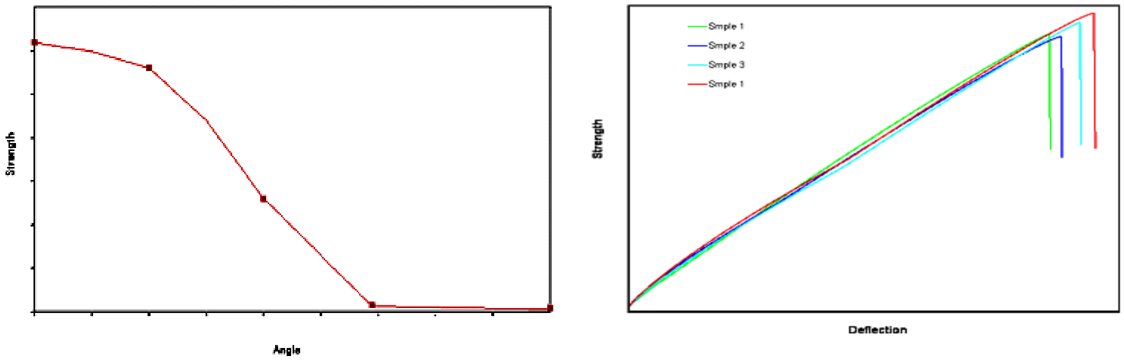


Figure 2. Static angled compressive test procedure

A strain-rate scale factor curve was also defined to simulate the dynamic strengthening status in honeycomb material model. The Arup-Adhesive (Mat 169) material card was developed to simulate the connection between parts in which the results from Climbing Drum, T-Peel, Tensile and Plate-Shear tests were used to get proper card data. Plot 1b, shows the results from Solid-Solid tensile test schematic results.



a) Compressive stress vs. cut section angle   b) Solid-Solid tensile test results

Plot 1

Null material shell elements with reasonable thickness were supplied through solid layers in main body and bumper part to enhance contact control criteria during crash. FE shaded views of ODB barrier model are shown in figure 3.

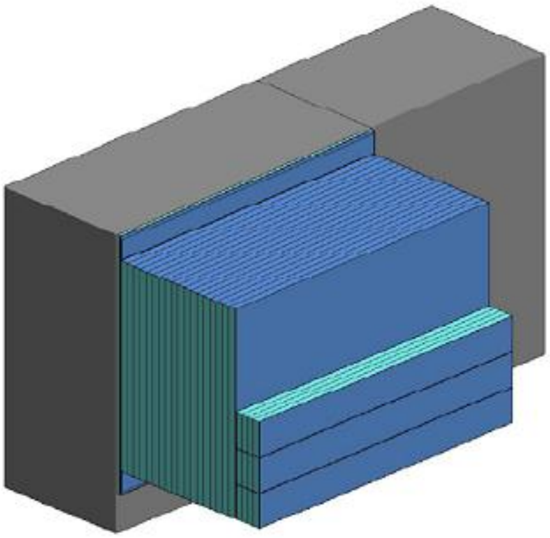
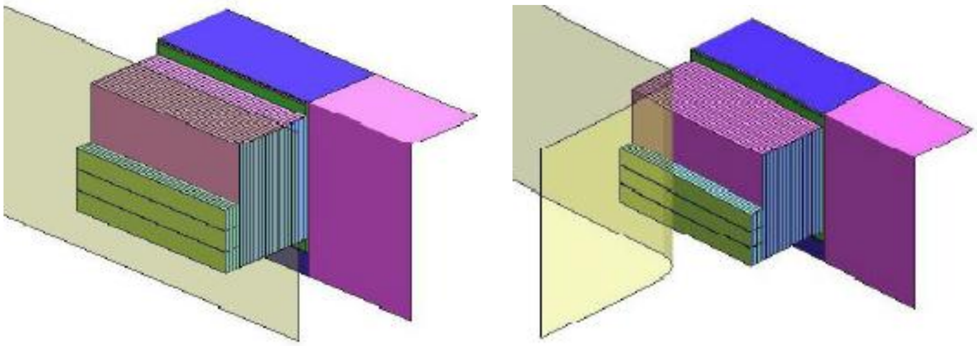


Figure 3. ODB FE Model

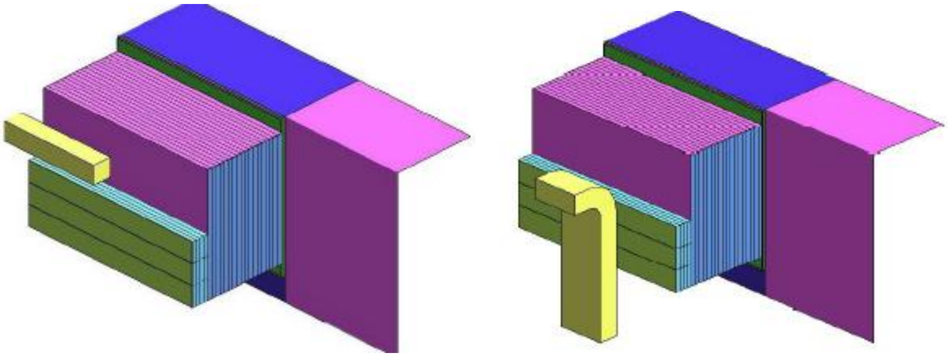
The LS-DYNA default Hourglass control has been used to monitor the element energy on honeycomb parts due to the use of one point corotational solid on honeycomb parts and a control card managed the relevant time-history data to investigate the energy flow in individual components and contacts.

EXPERIMENTAL TESTS AND RESULTS

To evaluate and verify the accuracy of the new ODB barrier model, the dynamic analysis was based on four experimental test results. The overall mass of the barrier was 20 kg and the barrier was mounted on a rigid wall in all evaluation tests. In Rigid Wall test the barrier was subjected to a flat moving impactor in which the test speed was 8.2 m/sec (29 km/h). The Half Wall test represents a condition in which the ODB barrier was subjected to an impactor targeted only half of the barrier (50% overlap). Test speed at Half Wall test was 8.6 m/sec (31 km/h). In High Horizontal Bar impact a horizontal bar impacted the upper section of the barrier to investigate the local penetration in mentioned division. The average test speed was recoded at 6.5 m/sec (23 km/h). The Vertical Bar impact involves a solid bar impacting the central line of the barrier at test speed of 8.9 m/se (33 km/h). Figures 4a-4d illustrate the configuration for verification tests respectively.



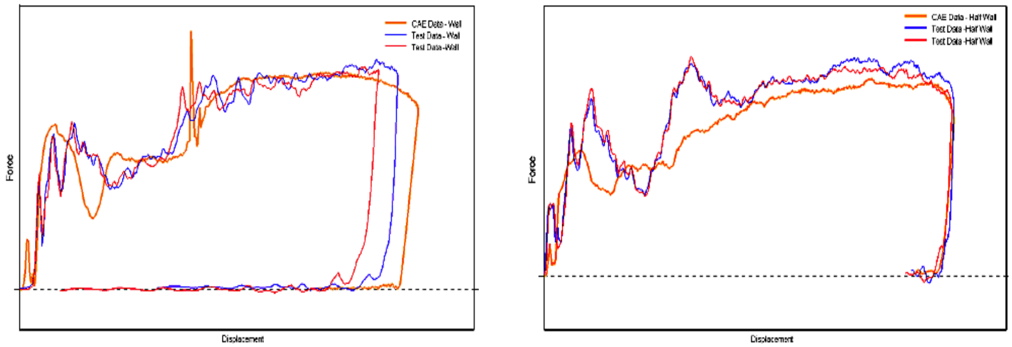
a) Flat Wall test b) Half Wall test



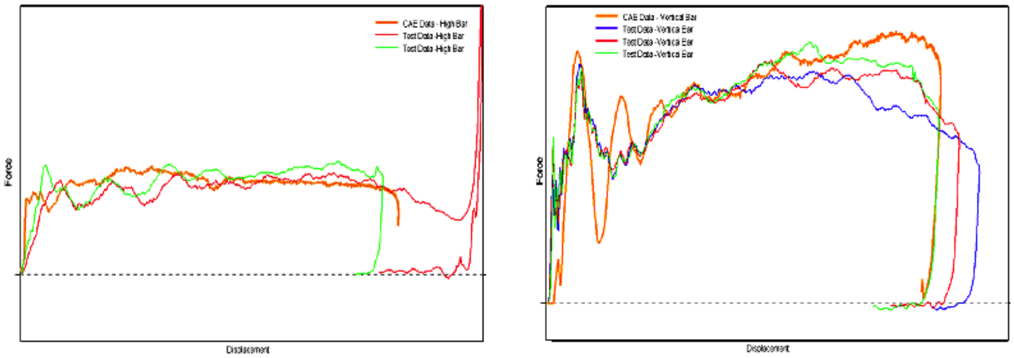
a) High Horizontal Bar test b) Vertical Bar test

Figure 4. ODB verification tests

In this research the assessment was based on load-cell resultant force output and the. In FE model, the data are obtained at pre-defined time steps from the same procedure using the cut section load measurement tool. Plots 2a-2d illustrate a comparison of experimental test data versus FE analysis for ODB verification process. The deformed barriers are also compared with CAE results in figures 5a-5d.

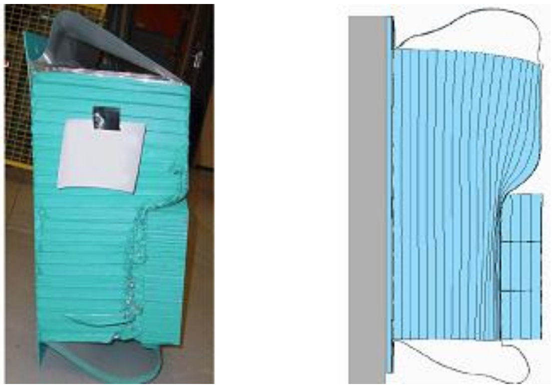


a) Flat Wall test b) Half Wall test



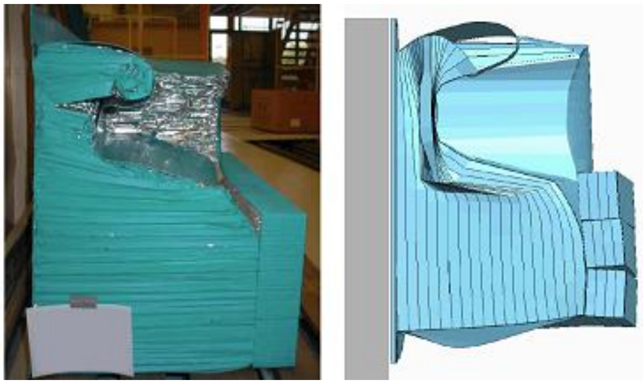
c) High Horizontal Bar test d) Vertical Bar test

Graph 4. ODB model evaluation test results vs. CAE

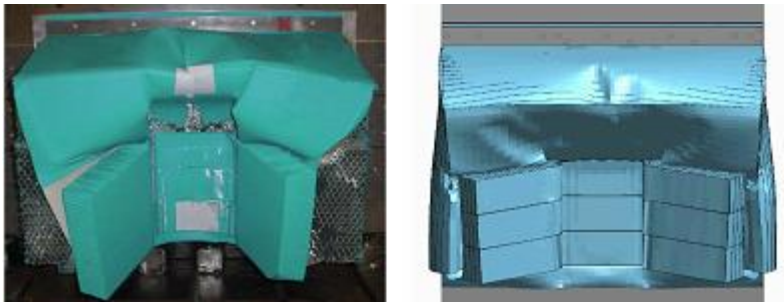


a) Flat Wall test (side view)

b) Half Wall test (top view)



c) High Horizontal Bar test (side view)



d) Vertical Bar test (front view)

Figure 5. ODB model evaluation tests

DISCUSSION

Plots 4(a-d) show that the model generates accurate performance in terms of numerical output comparing to the experimental test results. The model gives consistency with the physical barrier output in the Flat Wall test configuration. The model represents all peak points and follows the general shape of test graphs. In Half Wall test, the model seems marginally softer than the barrier at the beginning. This is, however, negligible while the overall performance is considered and output is investigated throughout the graph. A good correlation could also be seen in results for High Horizontal Bar and Vertical Bar tests despite a number of local differences at plot magnitudes. In the other hand, the model generates accurate deformation modes comparing to experimental test results and developed model represents the local strokes under each boundary condition and loading case. An important observation in this investigation is that, the collision time and thus the crash distance is similar at test and CAE despite the structural complicacy. Using Null elements between solid layers helped to control internal contact and improved the structural behaviour under local shear applications.

CONCLUTION

Analysis of the data for ODB model shows consistent numerical and visual correlation between FE model and experimental investigation in all test configurations. The yielding function technique to define the MAT 126 properties, in conjunction with implementing Null shell elements with a reasonable thickness within solid layers, gives acceptable results. This also enables the model to monitor the element contact criteria and control internal and external interfaces. The stiffening curve contributed a precise performance and gave reasonable output compared to the experimental test data. The developed technique is a superior method to regular non-linear analysis since the convergence time is reduced a great deal.

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