Euro NCAP MPDB Compatibility Assessment

Barrier Face Measurement calculation

Introduction

This document describes the Barrier Face Measurement calculation performed in the REPORTER templates:

- Euro NCAP MPDB Compatibility Assessment **2020**
- Euro NCAP MPDB Compatibility Assessment **2023**

The calculation follows the method specified in the Euro NCAP Technical Bulletin (TB 027) v1.1.1, which is intended to be used with the Adult Occupant Protection Assessment Protocol v9.1.3. The method is further specified in the MPDB Frontal Impact Testing Protocol v1.1.2.

Introduction (cont.)

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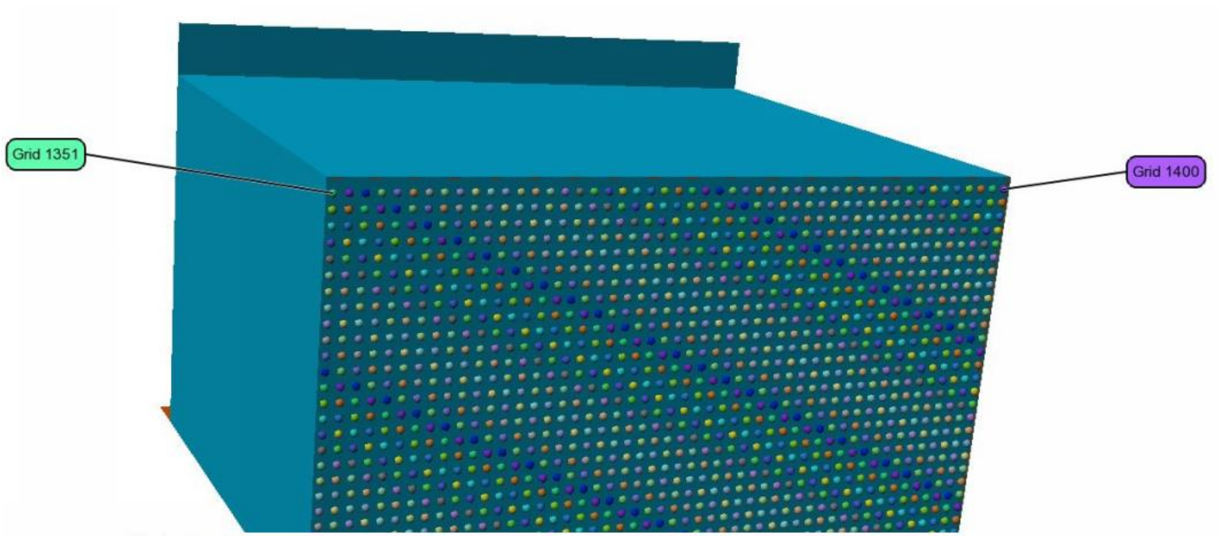
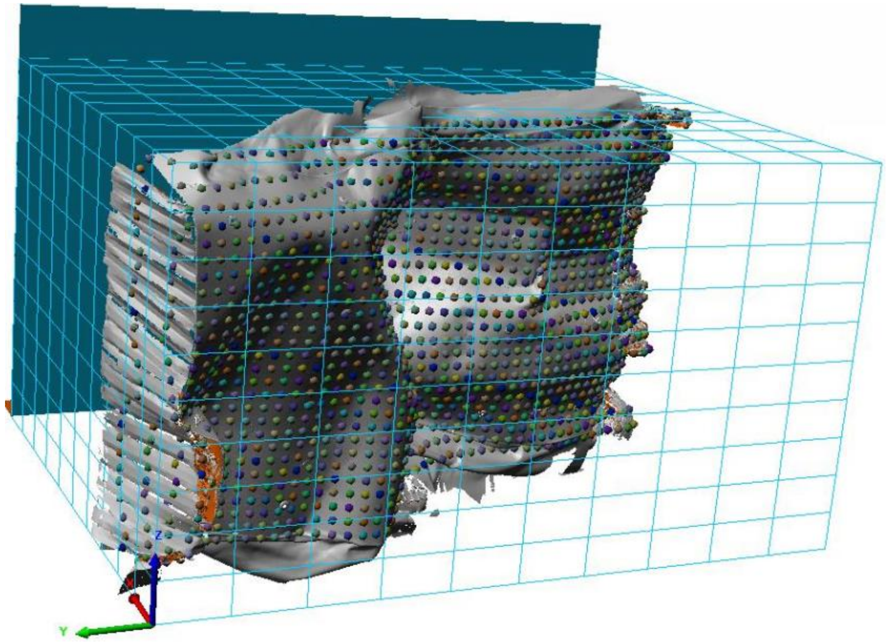
According to the Euro NCAP MPDB Frontal Impact Testing Protocol, the barrier face measurement measures the depth of deformation at the forward projection of 1400 grid points on the barrier backplate. See below images from the Protocol.

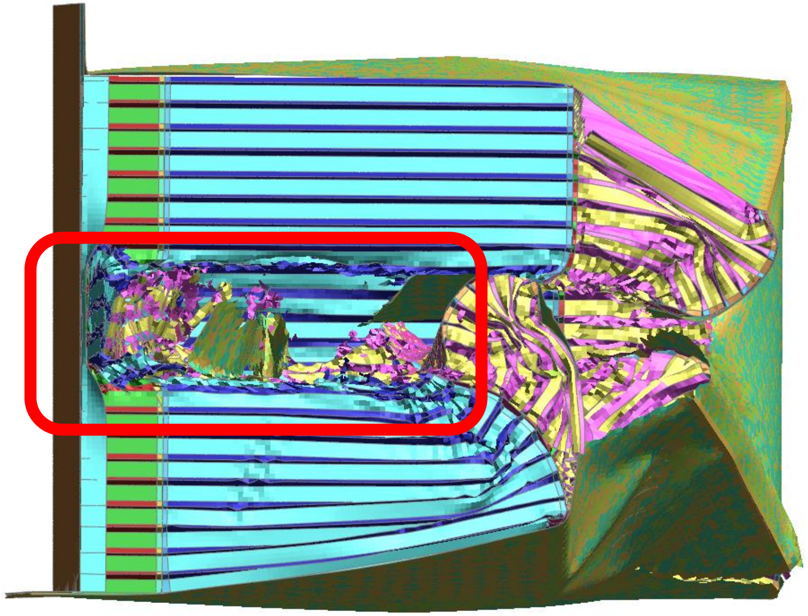


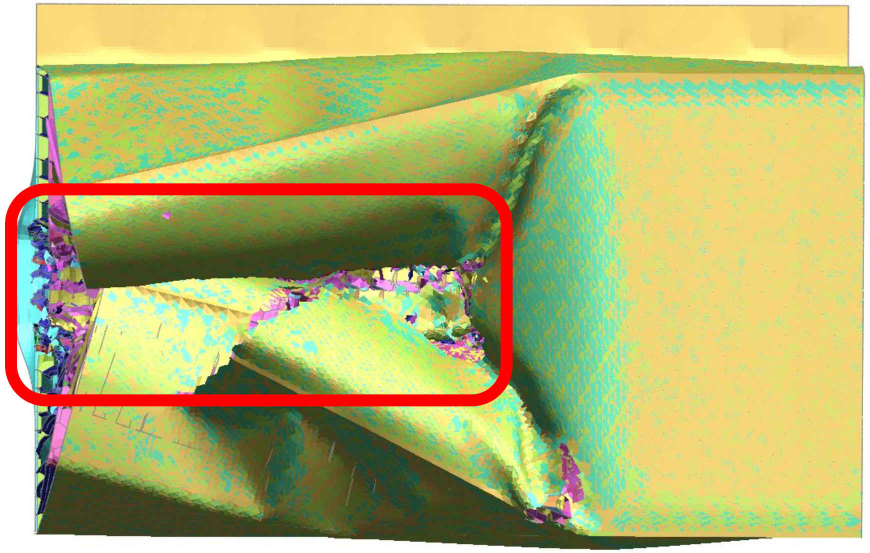


(L) 1400 grid points at 20mm spacing on front surface of undeformed barrier
(R) Projection of those points onto deformed barrier surface to calculate deformation depth

Introduction (cont.)

The region or projection in front of each grid point may include cavities (i.e. 'hooks', as shown below), flying elements, or other deformities. Owing to these features, deformation depth cannot simply be measured as the frontmost position in each projection.





(L) Elevation showing a cavity (marked in red) – an accurate result recognizes deformation reaches the back of the barrier.
(R) View from front. The cavity is obscured by 'hooks', so the frontmost position does not correspond to deformation depth.

Introduction (cont.)

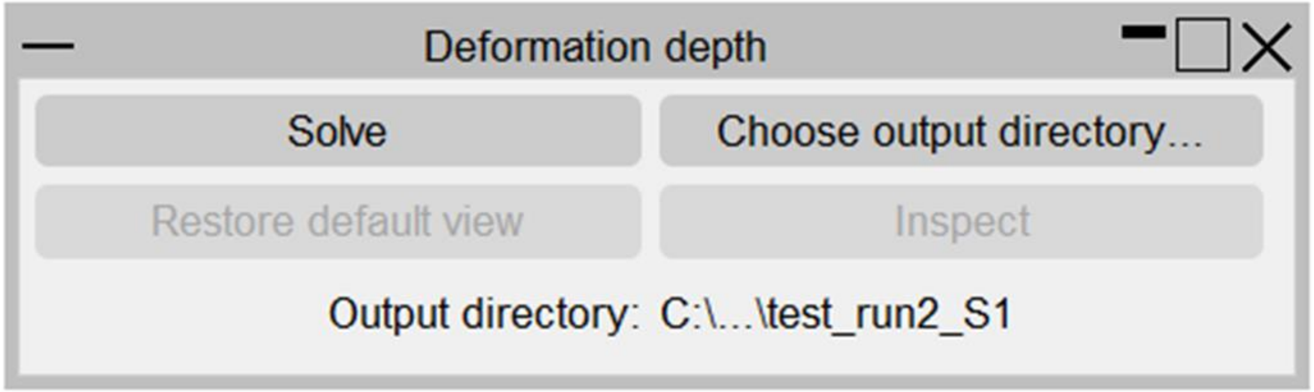
REPORTER

A more accurate calculation would disregard the presence of flying elements and consider that when hooking occurs, the deformation depth is properly measured to be at the back of the cavity rather than at the front.

Script operation

The script is executed directly from the REPORTER templates without additional user interaction.

It can also be run on its own in D3PLOT for a model with initial and final solved states. It can be run with a user interface for more straightforward QA.



Initial pane of user interface when run through D3PLOT.

Script operation (cont.)

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The ‘Solve’ button executes the solver.

The user can also specify a directory where script outputs will be saved. By default, this is the model directory.

After a solution is found, the ‘Restore default view’ and ‘Inspect’ buttons can be used.

‘Restore default view’ shows the elements of the barrier in the final state of the model and plots the deformation depth at each grid point.

‘Inspect’ allows the user to click on a grid point to see which Shell elements were used to calculate the deformation depth at that point.

Script outputs

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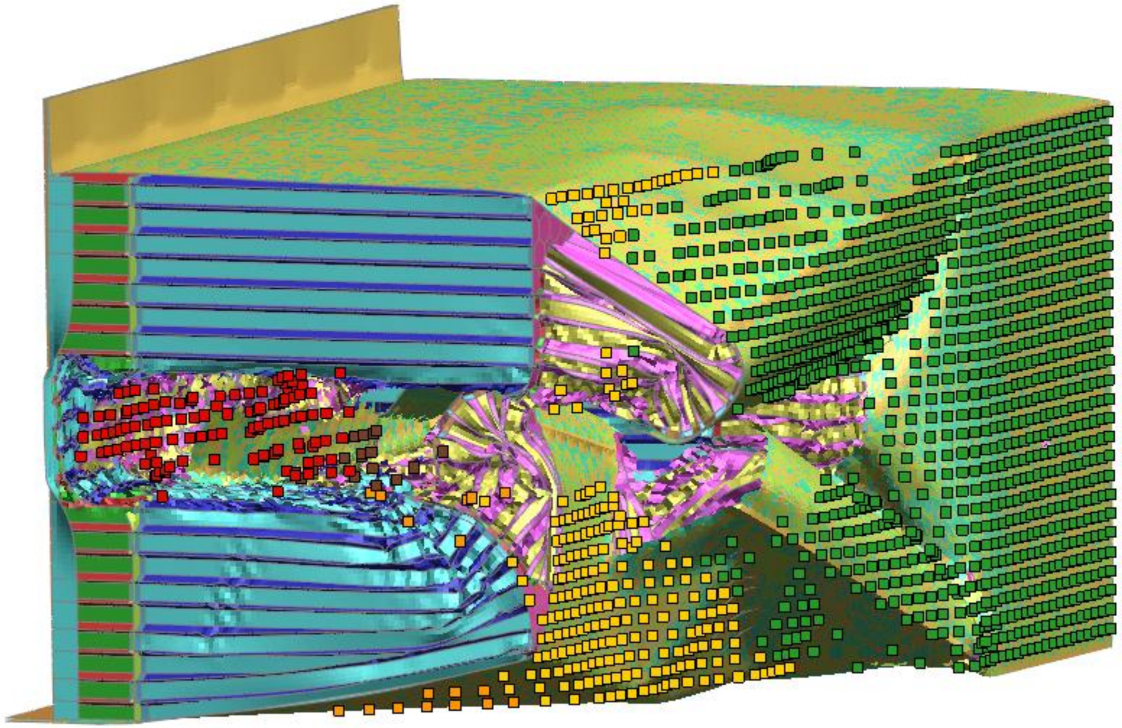
The script can produce several outputs, including Blob plots for visualization of the solution.



The script outputs Blob plots for visualization of the solution.

Calculation methodology – coordinate systems

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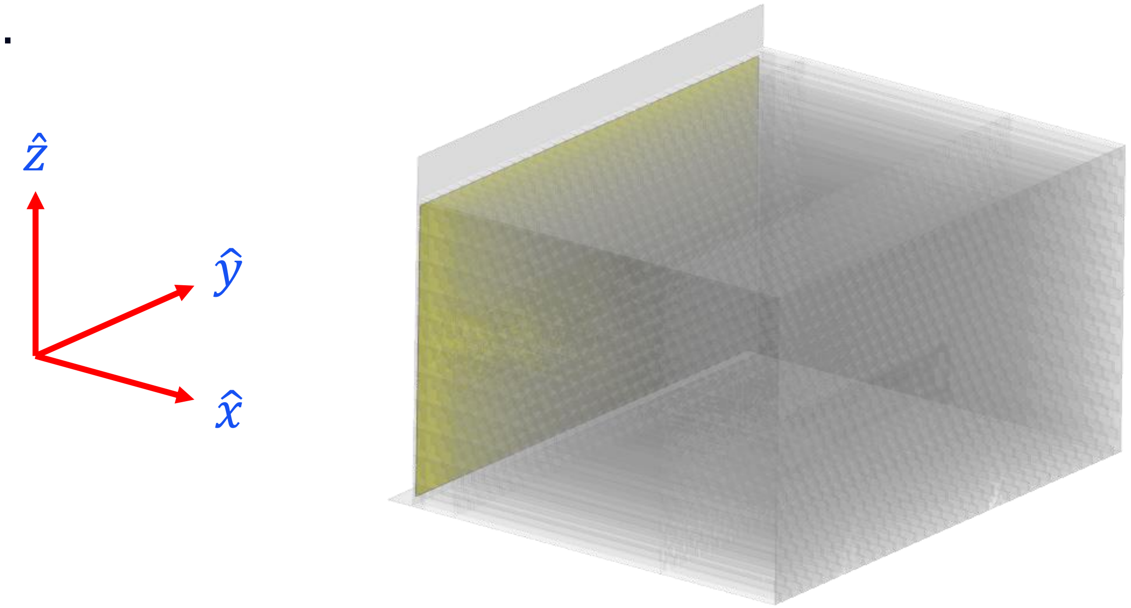
Local coordinate systems in the initial and final model states are defined relative to the rigid backplate. The local $\hat{x}$ vector is taken to be normal to the plate, i.e. in the depth dimension, and the local and $\hat{y}$ and $\hat{z}$ vectors are taken to be in the plane of the plate, with the $\hat{y}$ vector along the long edge and the $\hat{z}$ vector along the short edge.

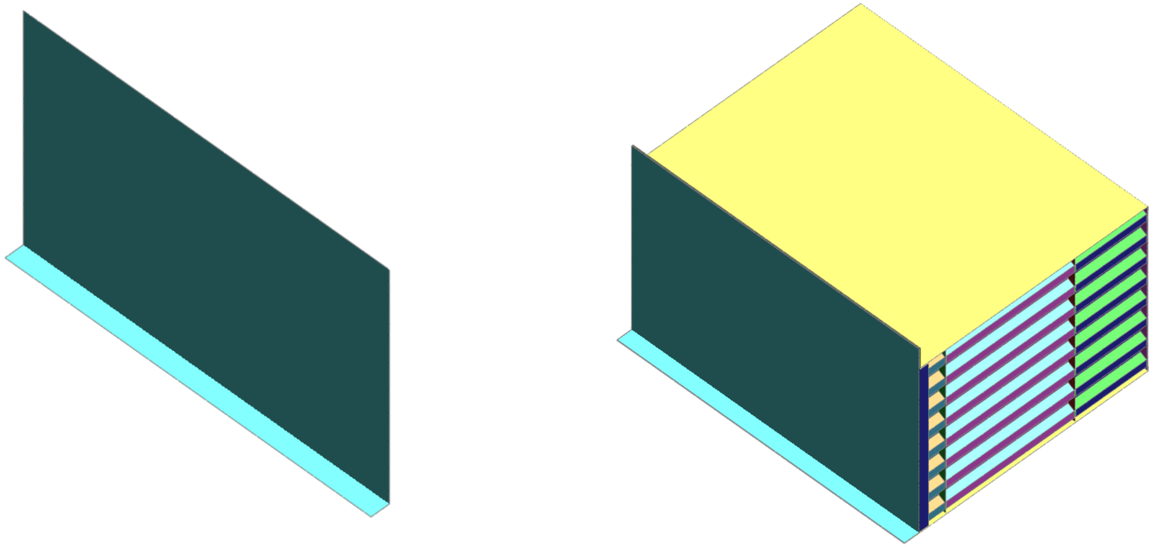


Local coordinate systems are defined such that the $\hat{x}$ direction is normal to the plane of the backplate. $\hat{y}$ and $\hat{z}$ are in the plane of the backplate and point along its long and short edges, respectively.

Calculation methodology – coordinate systems (cont.)

REPORTER

Some barrier models (including the LSTC barrier model) include a rigid backplate that is not simply planar. Local coordinate vectors are taken with respect to a simplified plane that excludes elements not in the main plane of the rigid backplate.

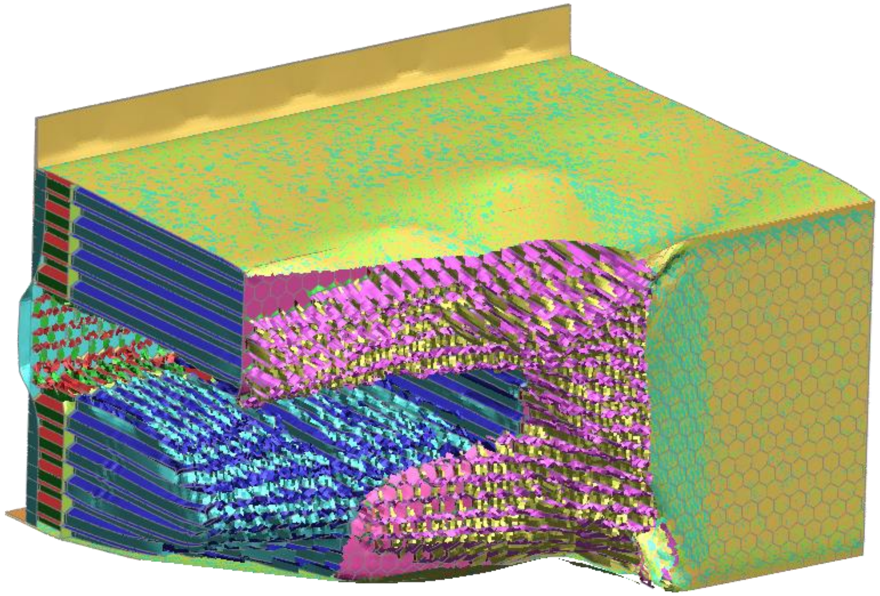


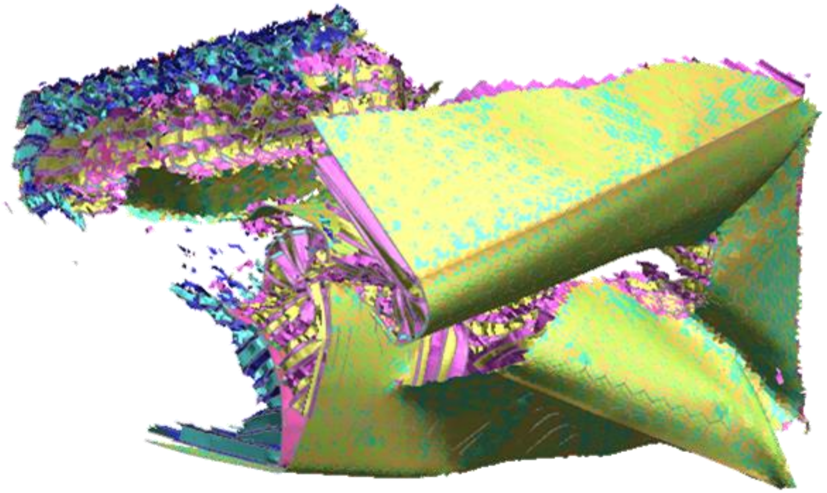
The LSTC barrier model includes a rigid backplate that is not simply planar.
When defining the plane of the backplate, elements in the protruding lip are excluded.

Calculation methodology – Shell element classification

The position of all Shell element centroids is calculated in the initial and final model states. If available, plastic strain (EPL) data is also collected. This information is used to determine whether each Shell has been significantly deformed.

Property files are written demonstrating the results of this classification.





(L) Shell elements of the barrier classified as not significantly deformed. Read in from Property file.
(R) Shell elements of the barrier classified as significantly deformed. Read in from Property file.

Calculation methodology – sort to nearest grid point

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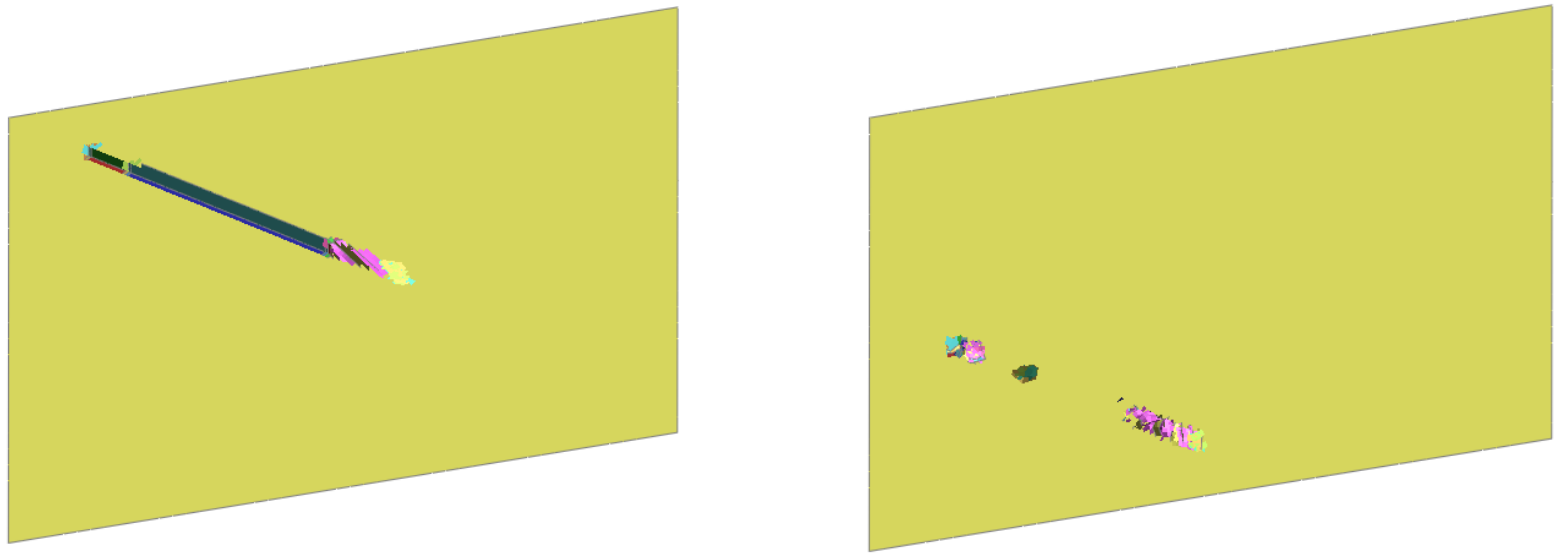
The Protocol specifies that measurements are to be taken at 1400 locations in a grid across the backplate.

Each Shell element is assigned to the nearest grid point based on the projection of its centroid in the final model state onto the backplate. Each grid point is therefore associated with a group of Shell elements in front of it, i.e. in the out-of-plane direction.



(L) Shell elements associated with a grid point on the backplate. These elements are contiguous from the backplate.
(R) Shell elements associated with a different grid point. These elements show a discontinuity larger than the gap width tolerance.

Calculation methodology – calculate deformation depth

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Scan those elements from back, i.e. nearest to the backplate, to front.

For each Shell element, consider whether it is significantly deformed.

If so, check against a gap width tolerance to determine whether it is contiguous with the structure behind it or separated from it by a cavity.

If not, infer that the barrier structure behind it is also not significantly deformed.

Calculation methodology – catch outliers

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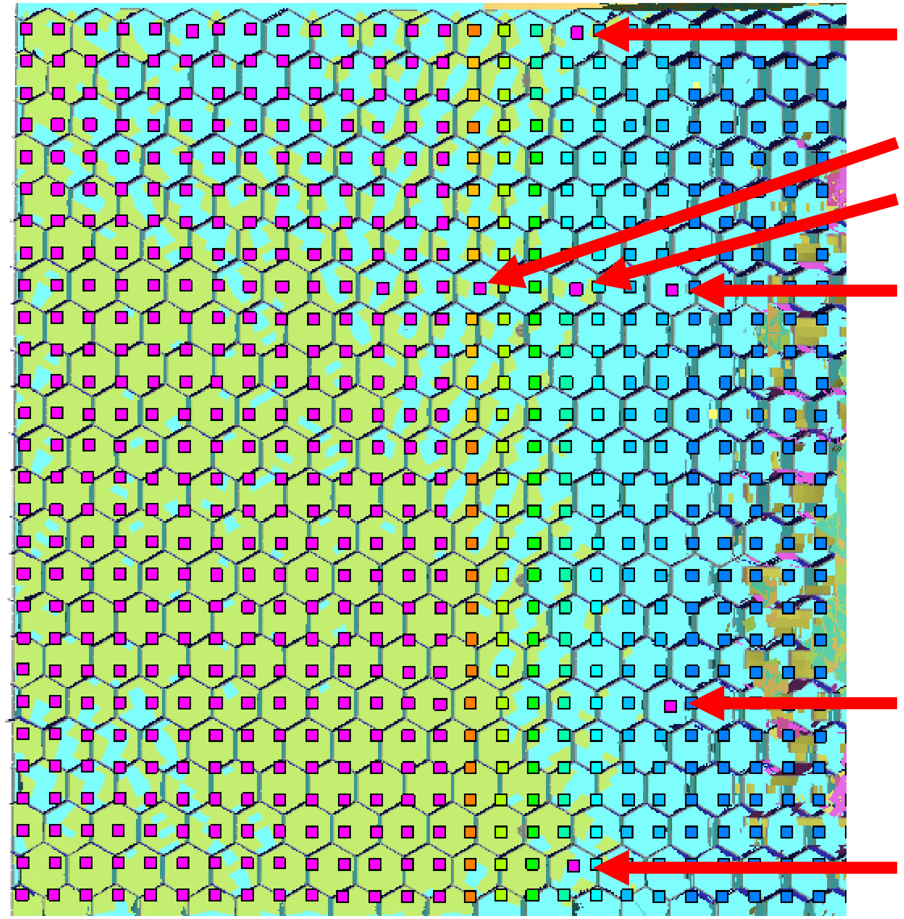
Outliers typically occur at grid points near the central axis of the barrier honeycomb structures.

This is because unless very significant deformation takes place, there are relatively few Shell elements projecting onto these grid points, and without much information an inaccurate result is found.

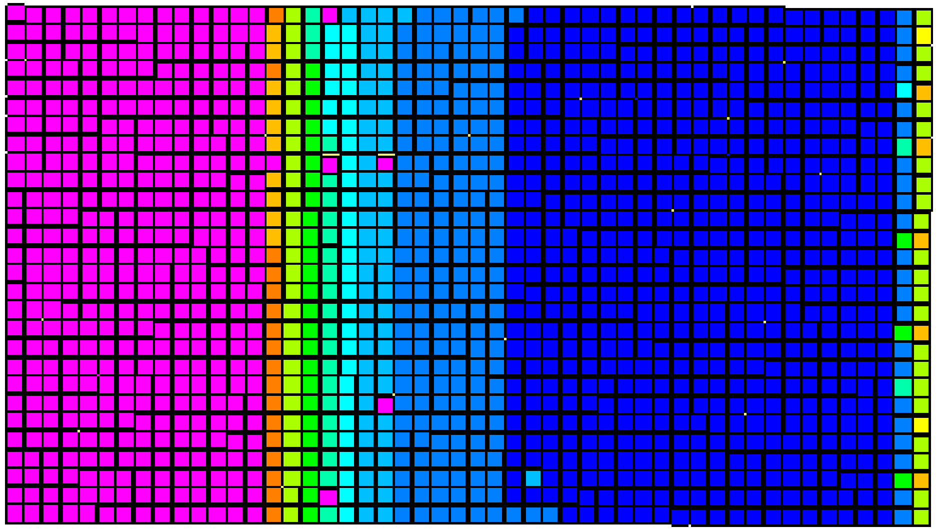
The LSTC barrier model is more likely to produce outliers than the Arup Cellbond model because it includes larger honeycomb structures (43.5 mm vs. 30.0 mm between second-nearest-neighbor points).

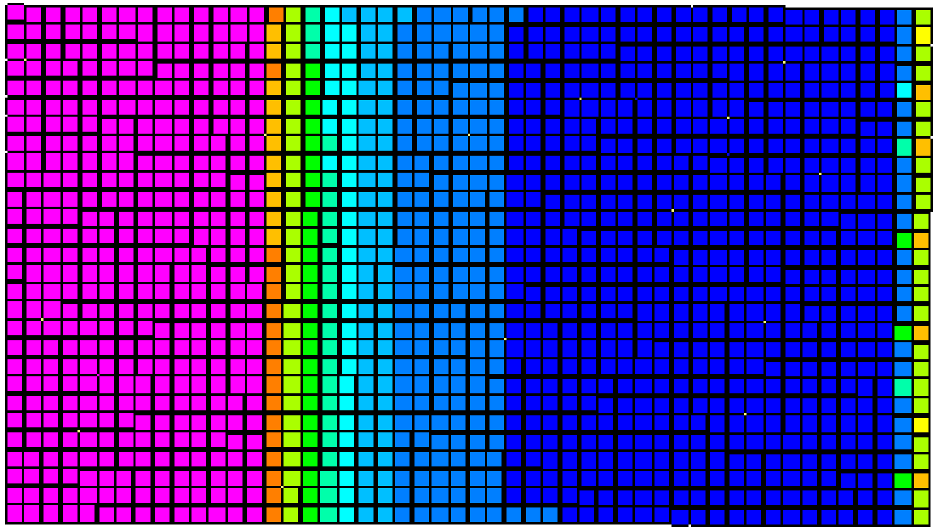


Outliers are typically found at grid points near the central axis of the barrier honeycomb structures.
Contours of Blob plot modified for clarity on this point.

Calculation methodology – catch outliers (cont.)

These outliers are identified and corrected by recalculating deformation depth without applying a gap width tolerance.





(L) Deformation depths before outlier correction – several outliers can be seen.
(R) Deformation depths after outlier correction.
Contours of Blob plot modified for clarity on this point.

Calculation methodology – refine deformation depth

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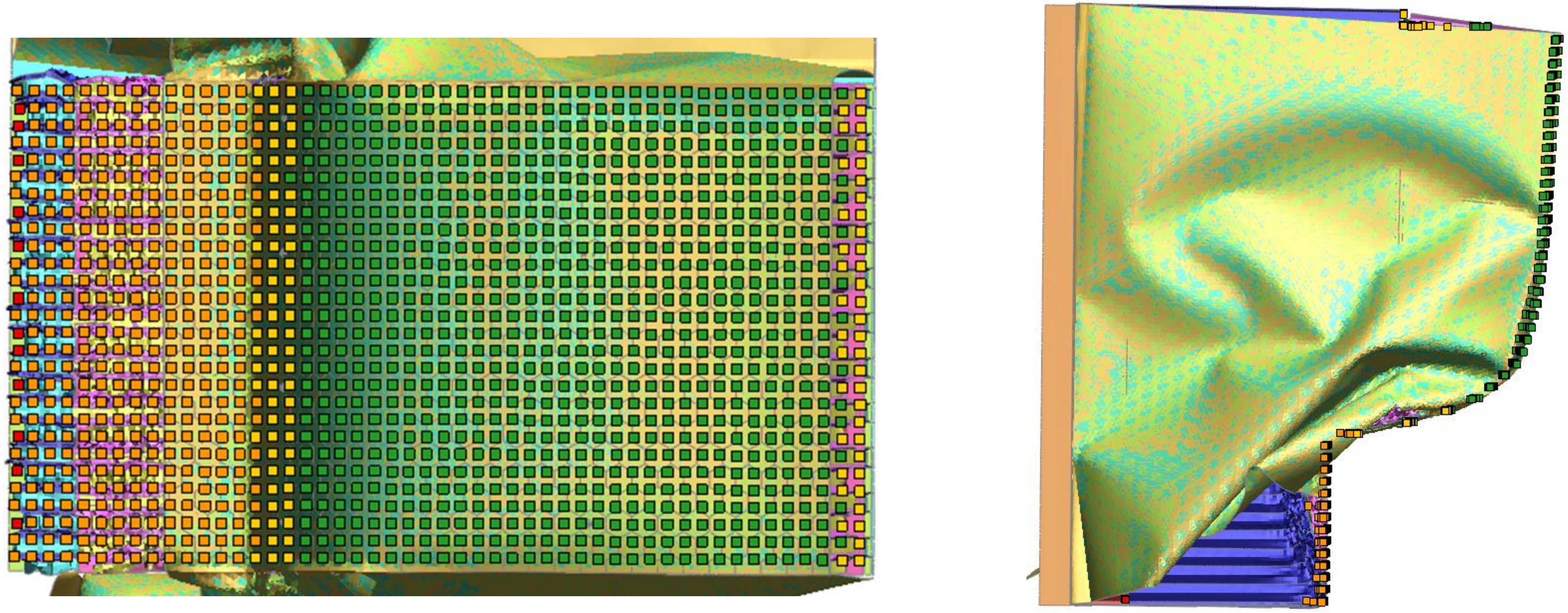
The Protocol requires that deformation depths be calculated along the projection of each grid point.

Once outliers have been corrected, for each grid point, find first the Shell element which projects onto the grid point and is at the same distance or closer to the backplate than previously calculated winner.

Example – impact with obstacle

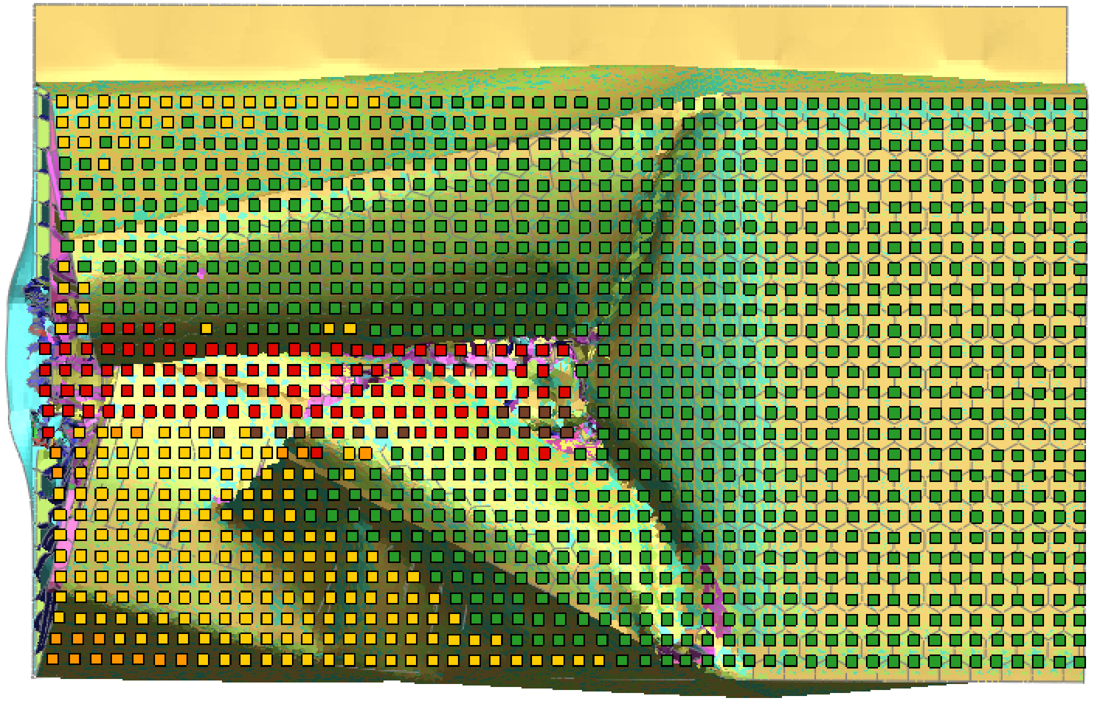
Correctly identifies deformation profile.

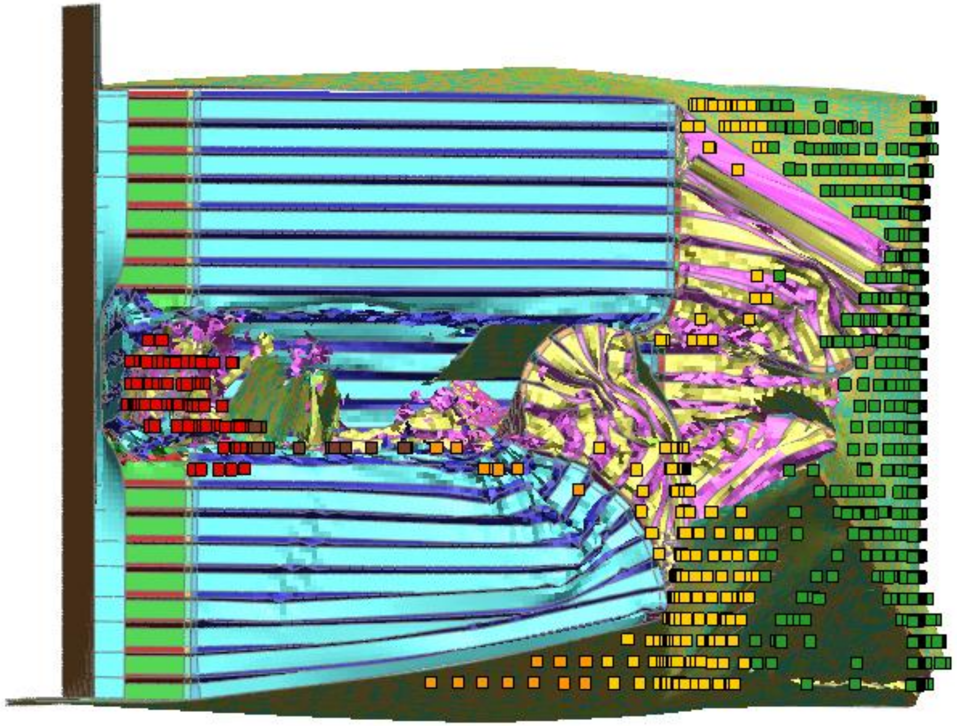


(L) Front view of showing Blob plot on barrier after impact.
(R) Aerial view of the same.

Example – bumper beam with 'hook'

Correctly identifies cavity or 'hook' on left side and calculates deformation depth reaching to back of barrier.



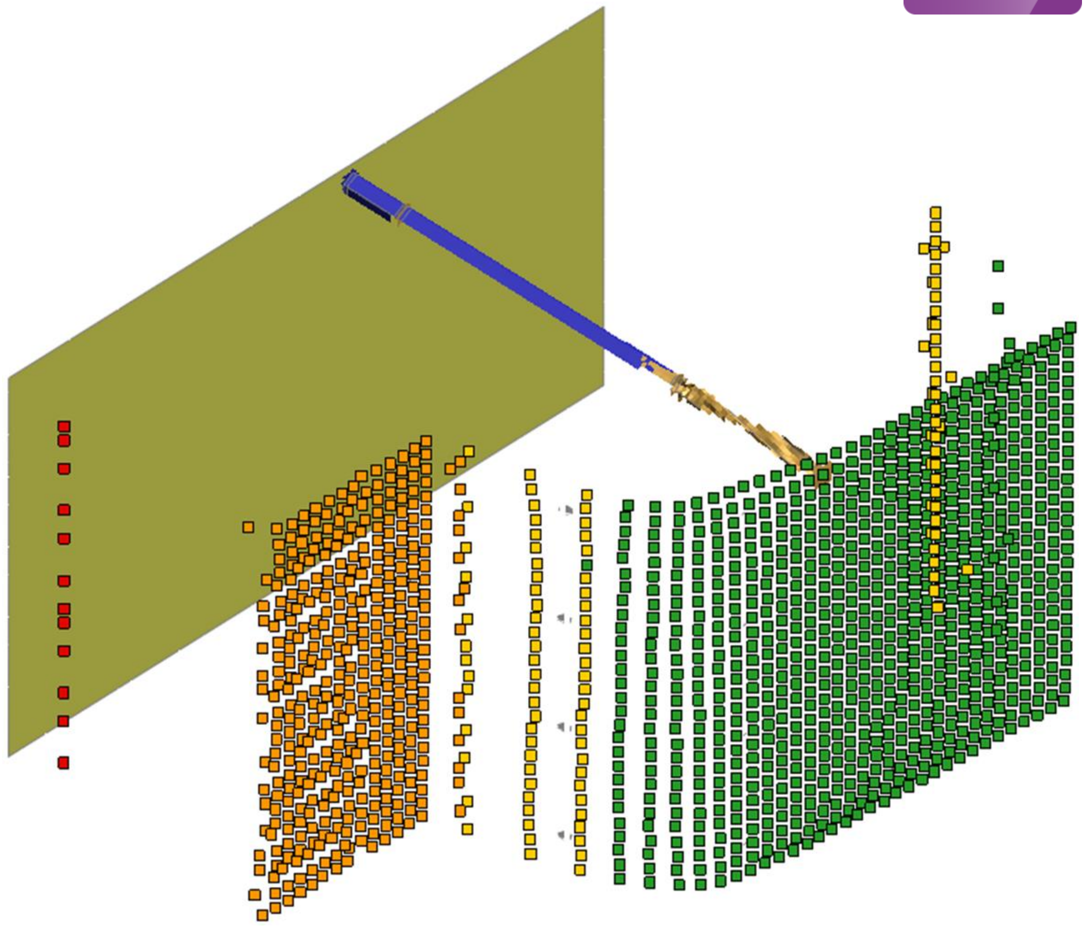


(L) Front view of showing Blob plot on barrier after impact. Note the cavity on the left.
(R) Elevation of the same.

Additional features

When run in D3PLOT through the user interface, the Inspect tool can be used to show which Shell elements were considered when calculating the deformation depth at a grid point. The elements are temporarily recoloured: undeformed in blue, deformed in orange.

By default, a Blob plot will be active to reveal which won, and the GUI presents useful information, like deformation depth.



The Inspect tool can be used to view which shells were used to calculate the deformation depth at a grid point.

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