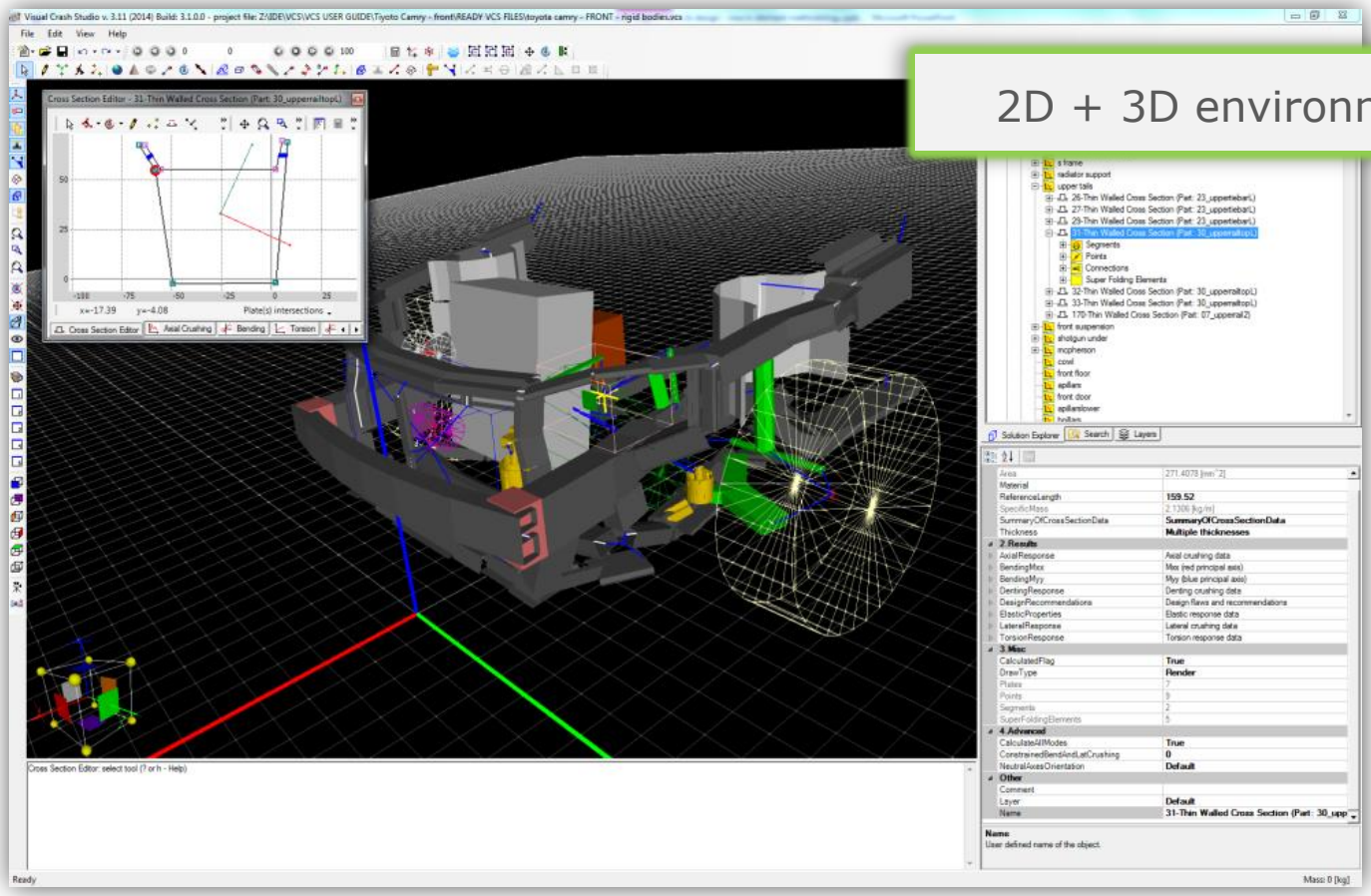
VISUAL CRASH STUDIO

general information

Visual Crash Studio – all-in-one environment

VISUAL CRASH STUDIO (VCS) is an all-in-one environment for early design, virtual testing and optimization of complex crashworthy structures.
It includes the functionalities of the 2D environment for analyzing and design of thin walled prismatic members as well as a complex 3D virtual design space for modeling and testing of individual beams, subassemblies and complete structures.
VCS is based on **Macro Element Method** worked out (among others) by T. Wierzbicki and W. Abramowicz in late eighties of the XX century. The computerized version of the current macro element theory is based on the works of Wlodek Abramowicz.

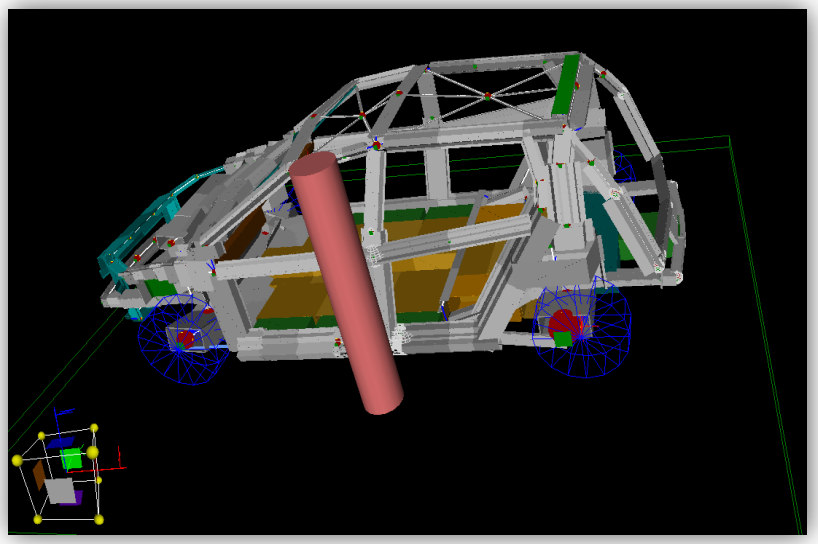


About Macro Element method

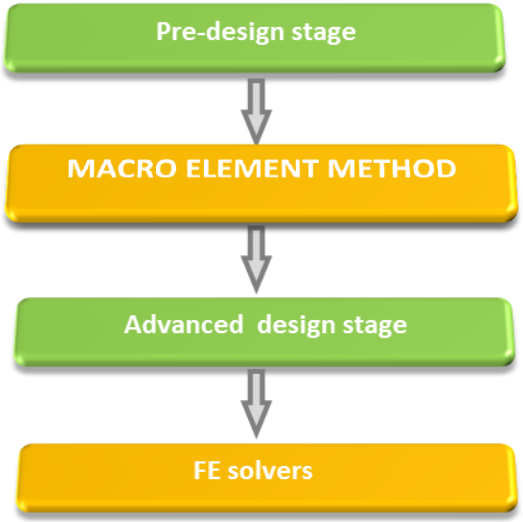
- MACRO ELEMENT METHOD is based on **simplified modeling**.
  The concept of **Super Folding Element** at the cross sectional level and **Super Beam Element** in case of a 3D structure, enable the creation of simplified models of variety of design concepts.

- The Macro Element models take over the main load of simulation work at the intermediate level of the design process when basic dimensions of the structure undergoes frequent modifications.

- The Macro Element method is especially useful at early stages of the design process when fast assessment of various design concepts substantially speeds up product development process.



Calculation time for this Model is 125 [s] !



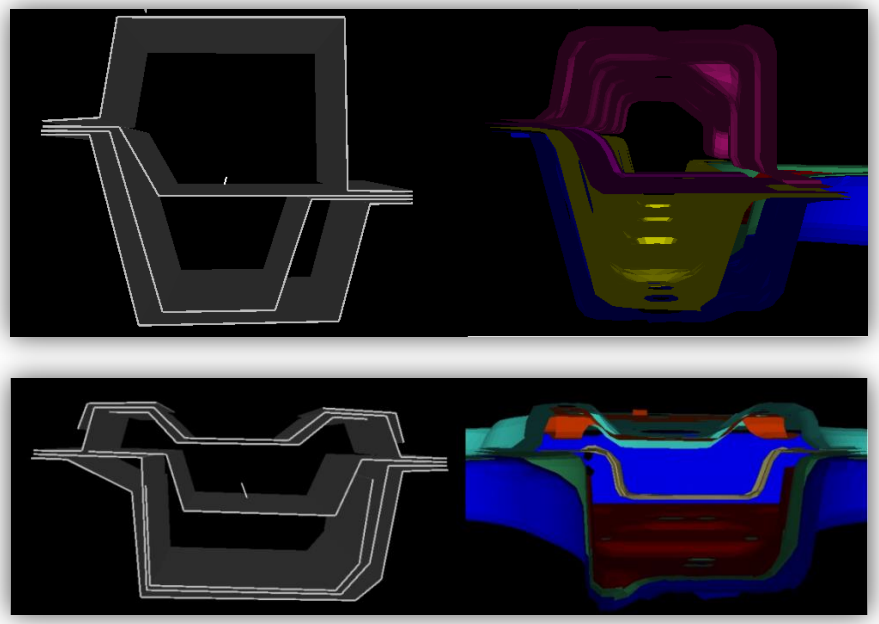
- The main benefit of Macro Element Method - very fast calculation process.

- A consequence of simplified modeling approach, most significant for the optimization purpose, is the possibility of easy modification of a structure

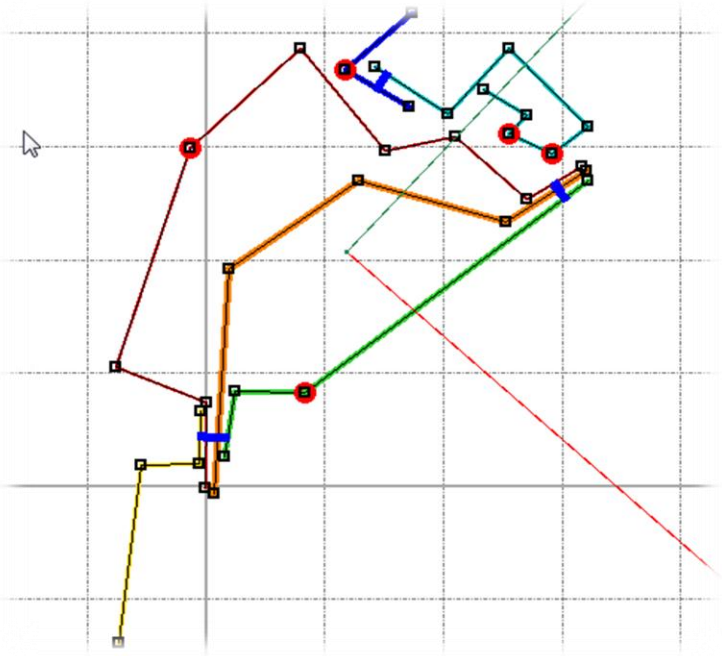
- Compared to a FE model the CCC or VCS Macro element model gives similar results in substantially shorter period of time (seconds).

Macro Element 2D simplified models - CROSS SECTIONS

Simplicity of cross section modeling by means of macro elements (on the left – a Macro Element simplified model; on the right – the original FE geometry a the cross section)



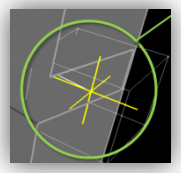
- The Macro Element calculation routines require as input
  - **overall dimensions** of the cross –section
  - **tensile characteristic of the material**
- The calculation process takes **only few seconds** on a standard PC.



- Accordingly to the Macro Element Method VCS software enables the creation of a **simplified cross section model** build of Plates and Segments based on Points.
- As an output of the calculation process (for the cross-section on the left the calculation time was 1sec.) the user receives 7 blocks of results. Modifications of the design can be easily made by changing the coordinates of Points, thickness of plates and/or material characteristics.

Macro Element simplified models – 3D STRUCTURES

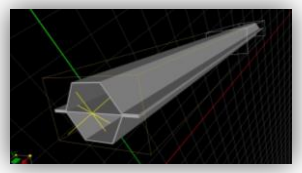
Nodes



The ***Node*** is used as a spatial reference point for all VCS objects

The Node encompasses number of data necessary for dynamic simulation

Beams

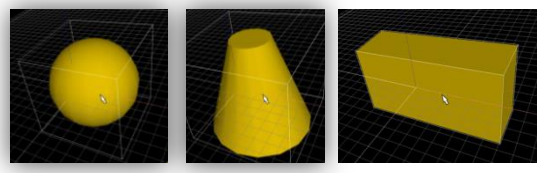


Super Beam - Defined by 2 Thin Walled Cross Sections

Solid Beam - Defined by a singe Solid Cross Section

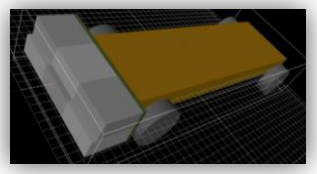
User Defined Beam - The mechanical response of the Beam defined by 2D Characteristics

Rigid Bodies



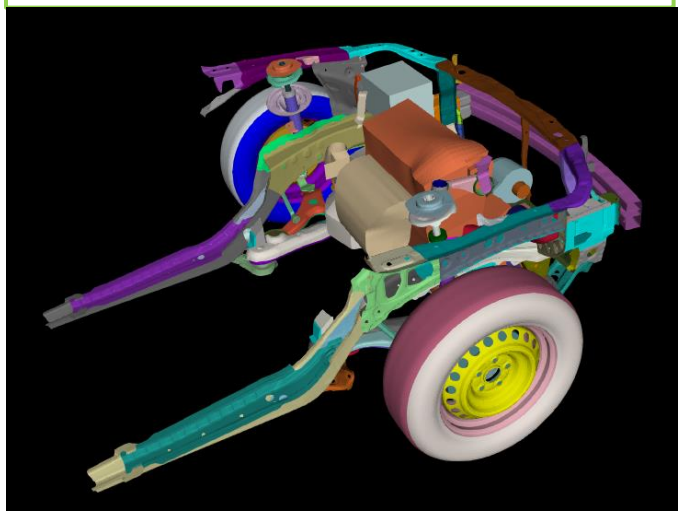
Rigid bodies: sphere, cone, cylinder and box (cube) are created as objects attached to a Node.

Barriers

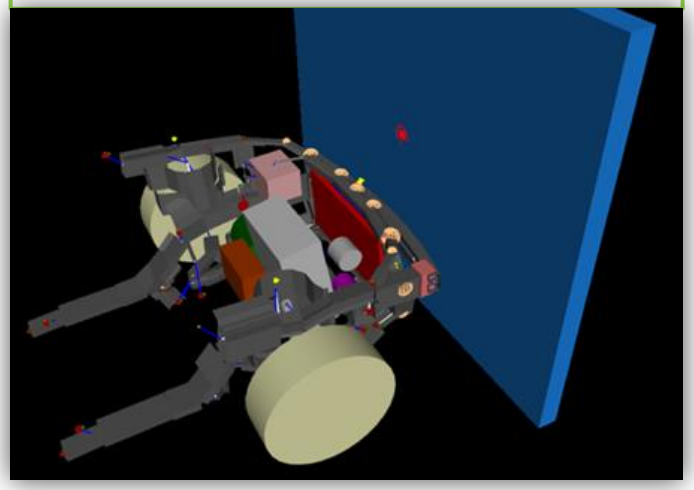


VCS implements three deformable barriers according to the following specifications: MDB FMVSS 214; MDB 96/27/EC; ODB IIHS/EEVC

Finite Element Model



Macro Element Model – VCS

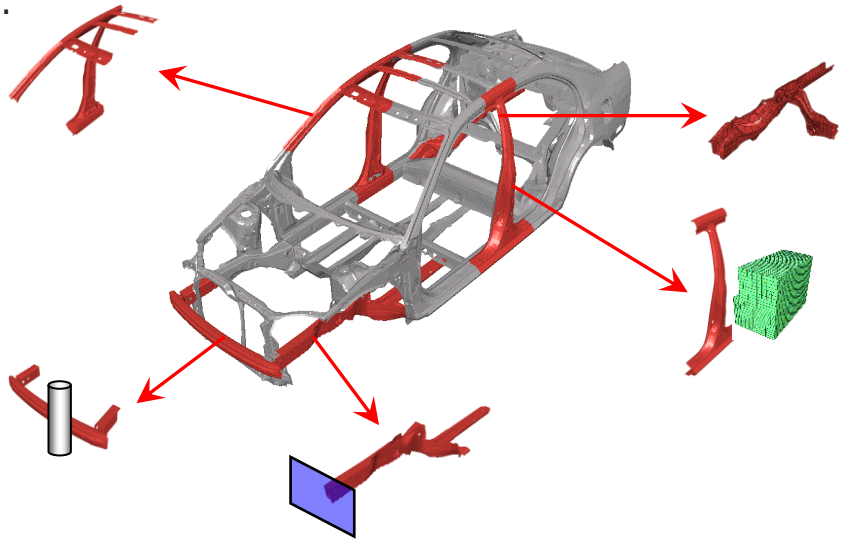


MEM applications – Cross Sections

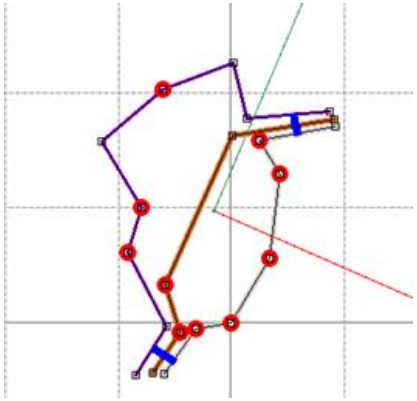
The design of a structural member at the cross - sectional level is especially important at the pre - design and early design stages when the proper shape and optimal dimensions of a member are sought and the design concept undergoes frequent modifications.

In automotive industry Macro Element Method can be successfully used for design and optimization of cross sections of various assemblies of a vehicle structure.

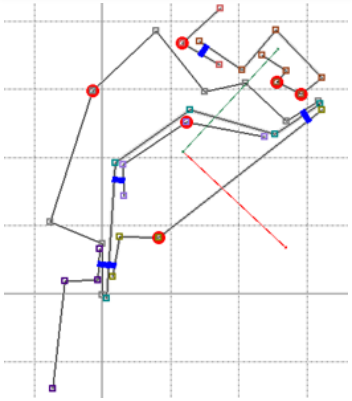
Thanks to import / export possibilities, simplified modelling, and very fast and adequate calculations, VCS is perfect for optimization routines at early stages of product development.



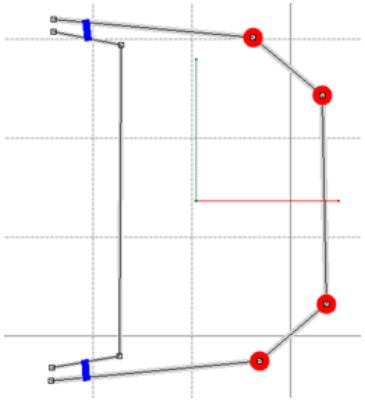
A-pillar



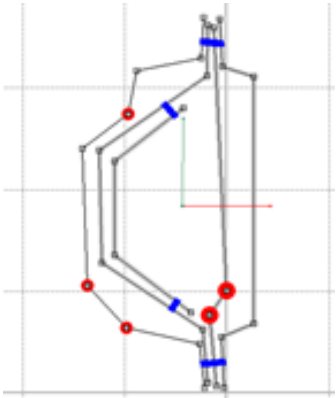
Side roof rail



crash box



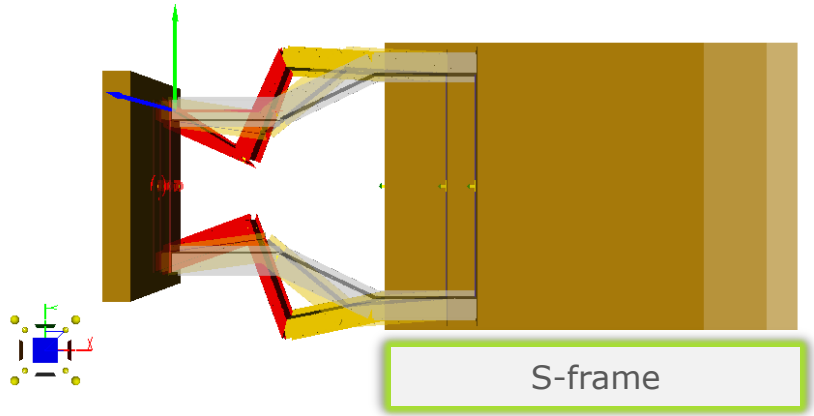
B-pillar



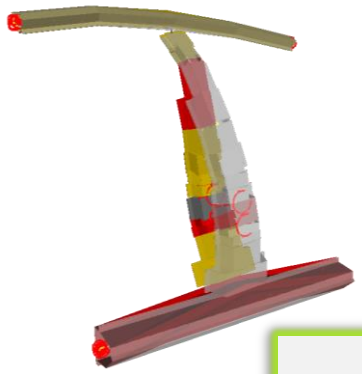
ME applications – 3D Structures

The Macro Element Method is especially successful in the field of large deformations of thin sheets and thin walled elements made of variety of materials

- Sub-assemblies

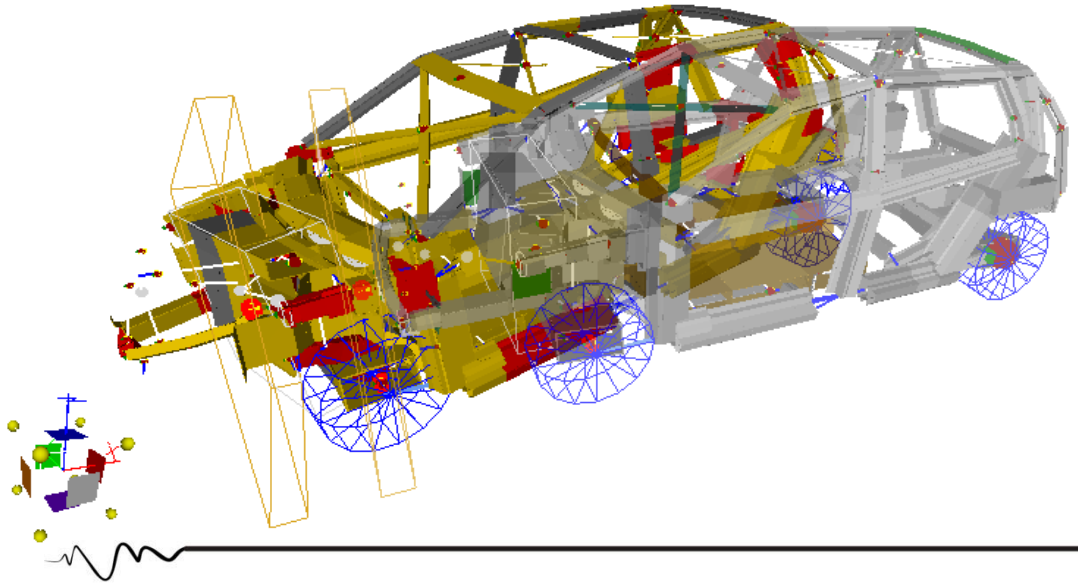


S-frame



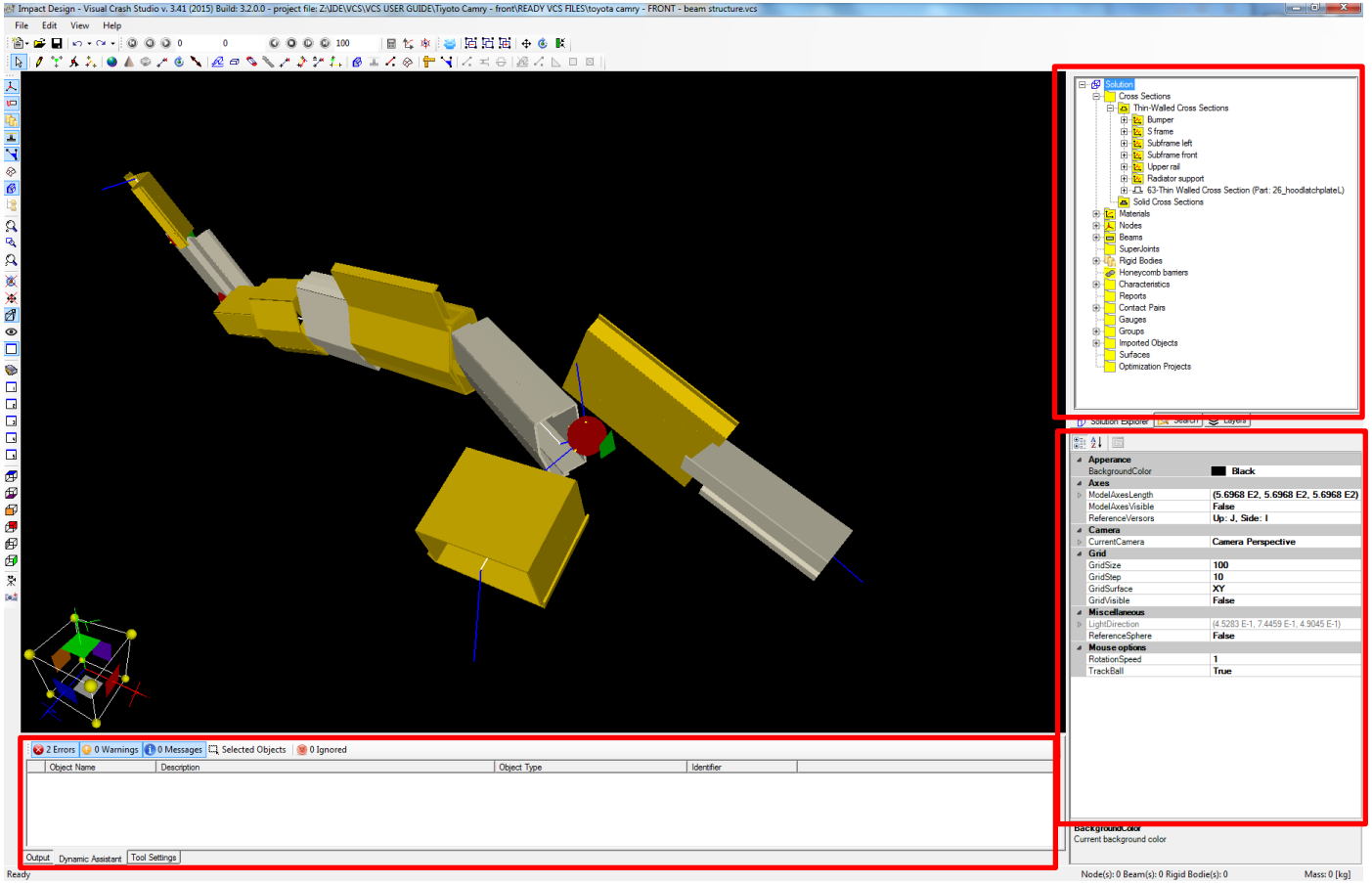
B-pillar

- Full Vehicle Structures



VCS – main view

On the top of the screen you can find the **MAIN TOOLBAR** where you have easy access to most of the VCS main features.
On the left hand side of the screen you will find **3D VIEW TOOLS** dedicated for the edition of the 3D view. This icons will enable you to control appearance of the main 3D view



Solution Explorer

In the Solution Explorer window located on the right hand side of the screen you will find folders containing each and every object created in the Solution.

Properties

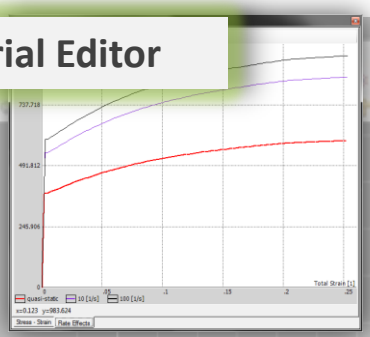
The Properties window on the right hand side gives the possibility to edit an object. In the properties window you will find the properties and results for the currently selected object

Output & Dynamic Engineering Assistant

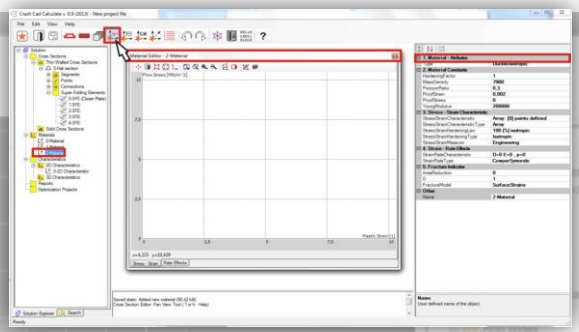
In the Output window on the bottom of the screen you will find additional information about the current status of any selected tool. This window also includes basic help information for the selected tool
Dynamic Engineering Assistant provides a list of errors, warning and useful messages detected in the VCS solution.

VCS software – main functionalities

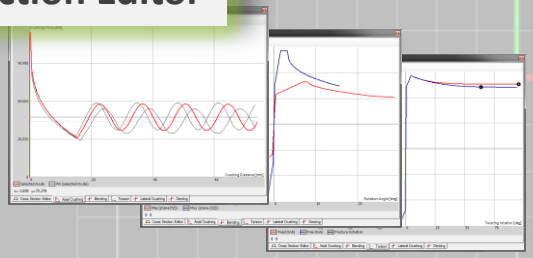
Material Editor

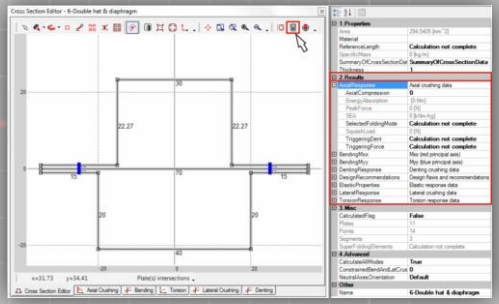


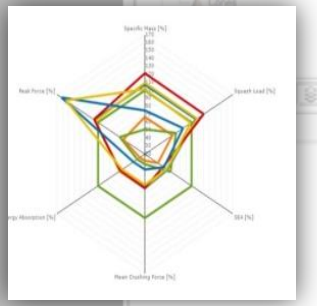
1. Material - Atributes	
Type	DuctileIsotropic
2. Material Constants	
HardeningFactor	1
MassDensity	7890
PoissonRatio	0.3
ProofStrain	0.002
ProofStress	380
YoungModulus	200000
3. Stress - Strain Characteristic	
StressStrainCharacteristic	Array: [10] points defined
StressStrainCharacteristicType	Array
StressStrainHardeningLaw	100 [%] isotropic
StressStrainHardeningType	Isotropic
StressStrainMeasure	True
4. Strain - Rate Effects	
StrainRateCharacteristic	D=8 E+3 , p=8
StrainRateType	CowperSymonds
5. Fracture Indicator	
AreaReduction	0
D	1
FractureModel	SurfaceStrains
Other	
Comment	
Layer	Default
Name	Steel - 380 MPa - 2000122 (LS_DYNA)



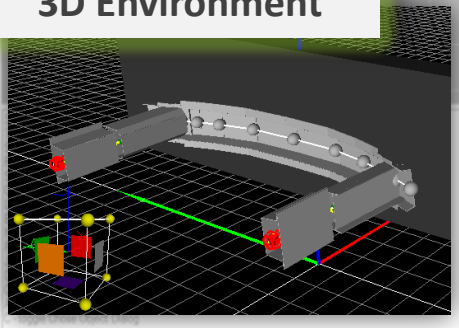
Cross Section Editor

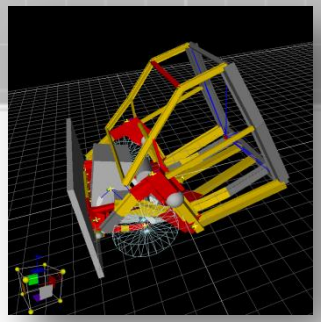


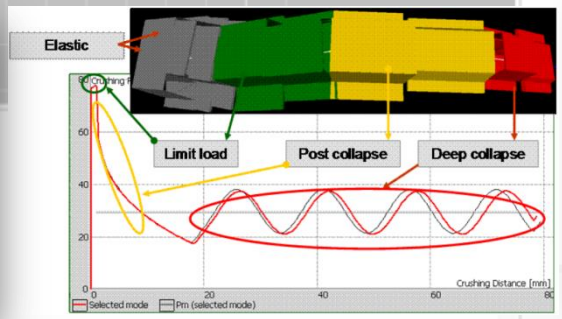


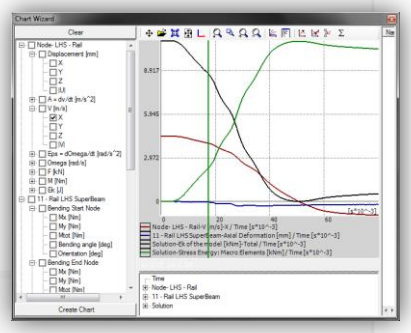


3D Environment



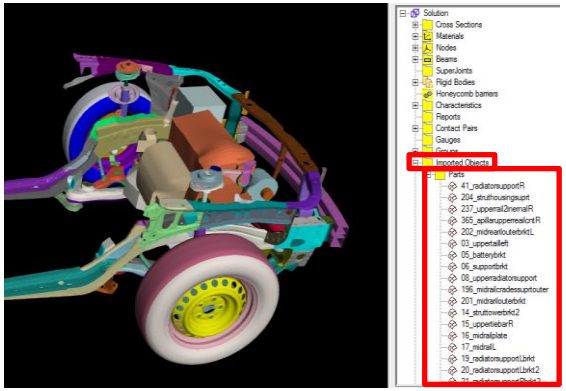




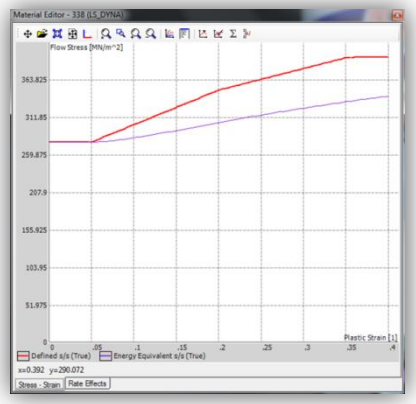


ME method work scheme – general information

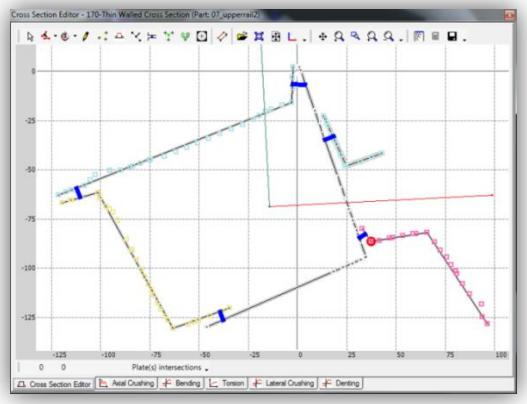
1. mesh/initial geometry import



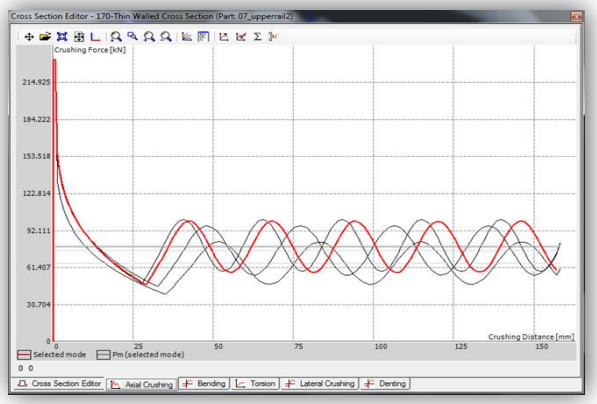
2. Material definition



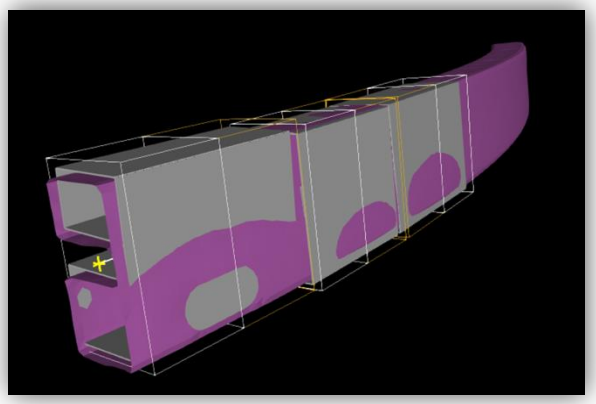
3. 2D Structure – Cross Sections



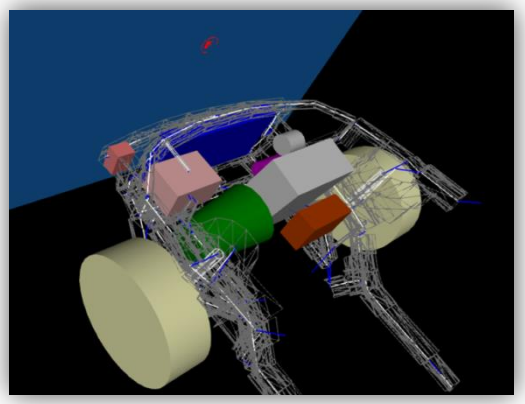
4. Cross Section analysis



5. 3D Structure – Super Beams

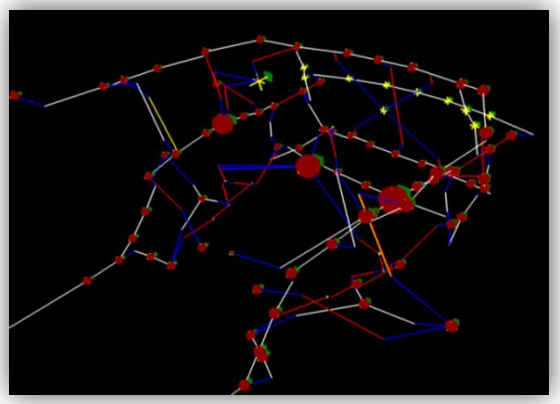


6. 3D – additional elements

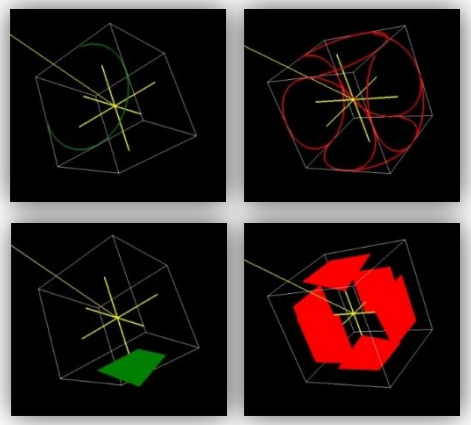


ME method work scheme – general information

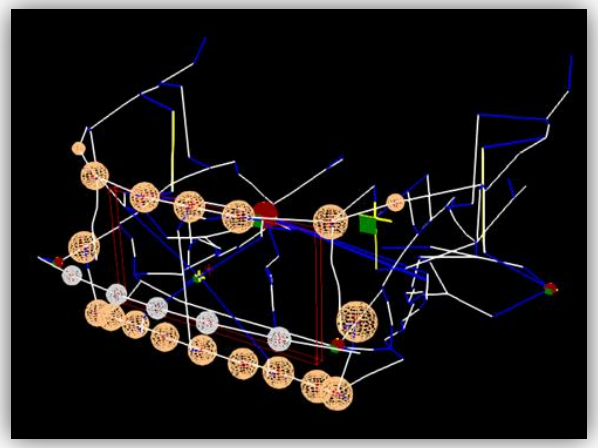
7. Mass distribution



8. Initial & Boundary conditions



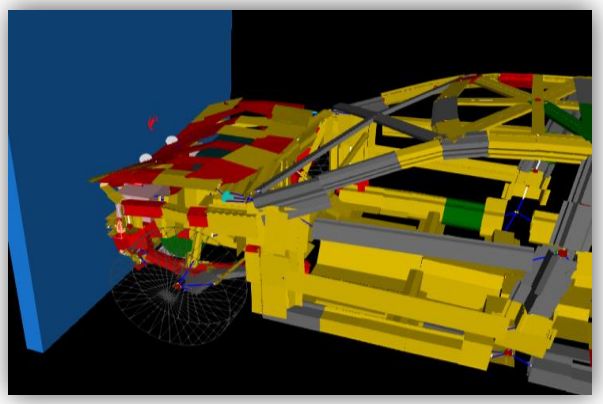
9. Contact settings



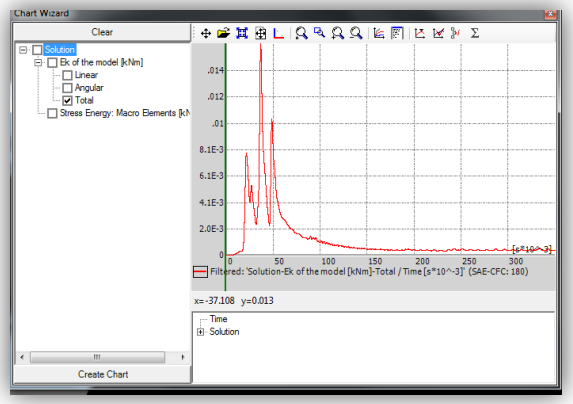
10. Solution Settings

⊞ 1. Attributes	
⊞ 2. Animation Progress	
⊟ 3. Time Stepping Routine	
ElapseTime	50
OutputFrequency	1
TimeIncrement	0.01
TimeStepCritical	0.01
TimeSteppingRoutine	StandardExplicit
TimeUnits	Milliseconds
TotalTimeSteps	5000
⊞ 4. Fields and global parameters	
⊞ 5. Settings	
⊞ Other	
⊞ Statistics	

11. Calculations and animation

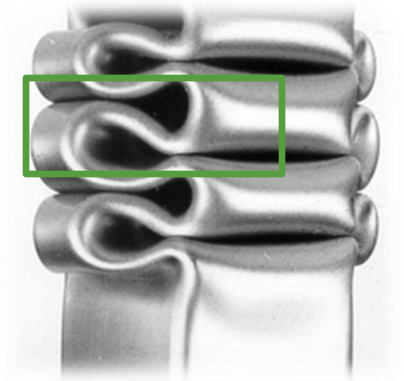


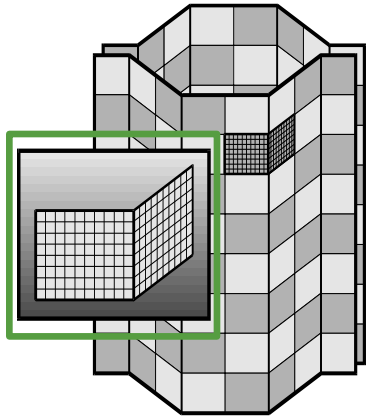
12. Results – Chart Wizard



Super Folding Element

The very core of the theoretical background of Cross Section Editor is the **Super Folding Element (SFE)**.
The SFE represents the segment of a corner line off a prismatic column.
One SFE is cut off from a column by a set of two parallel horizontal planes. The distance between planes, 2H, equals the length of the plastic folding wave of the column. The vertical boundaries of a SE are defined by a set of two vertical planes equally distanced from the neighboring corners and/or vertical edges of a column





SFE is cut by set of two horizontal, parallel planes

The distance between the horizontal planes equals the length of the plastic folding wave of a column

The vertical boundaries – planes equally distanced from the neighboring corners

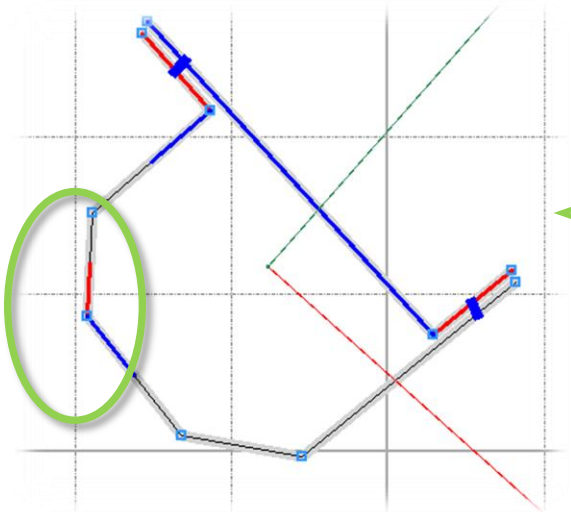
The initial geometry of a Super Folding Element is defined by four parameters:

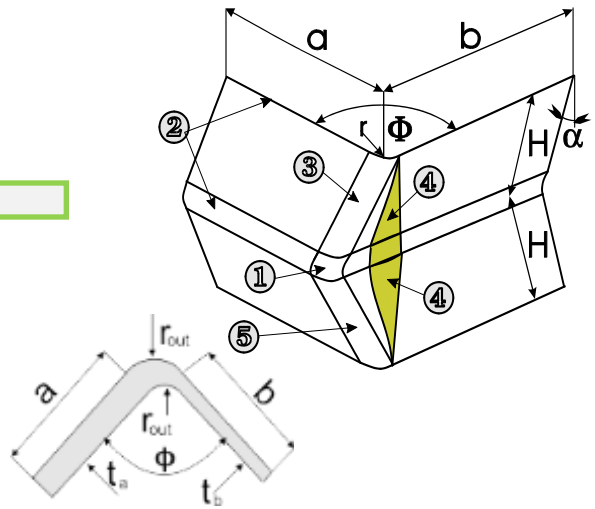
1. total length, C, of two arms of a SE, C = a + b,

2. central angle, Φ

3. wall thickness t^a of the arm of the length a

4. wall thickness t^b of the arm of the length b

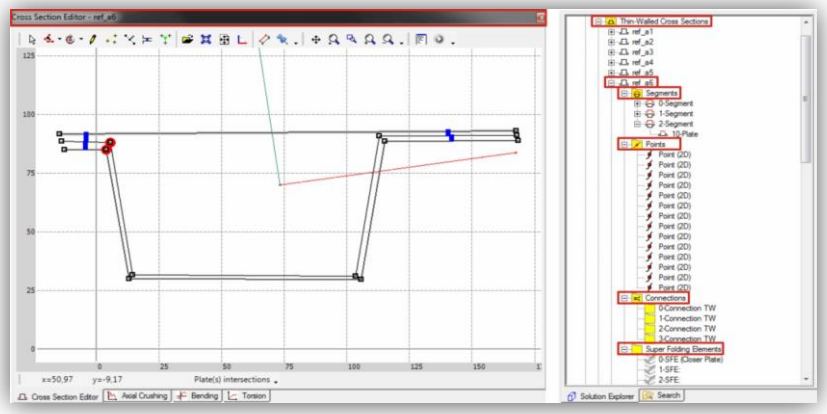


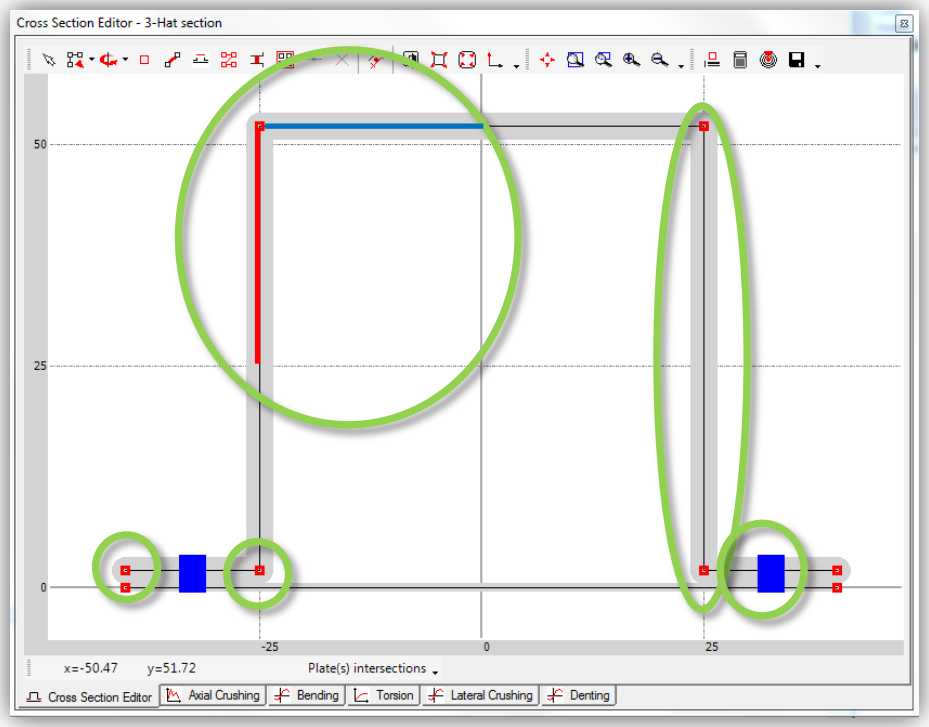


Cross Section Editor – simplified modelling

The **Cross Section Editor** is used to design, calculate and optimize Thin Walled Cross-Sections for best crash performances.

Cross-Sections processed by the *Cross Section Editor* are then used to build 3D prismatic and tapered Super Beams.

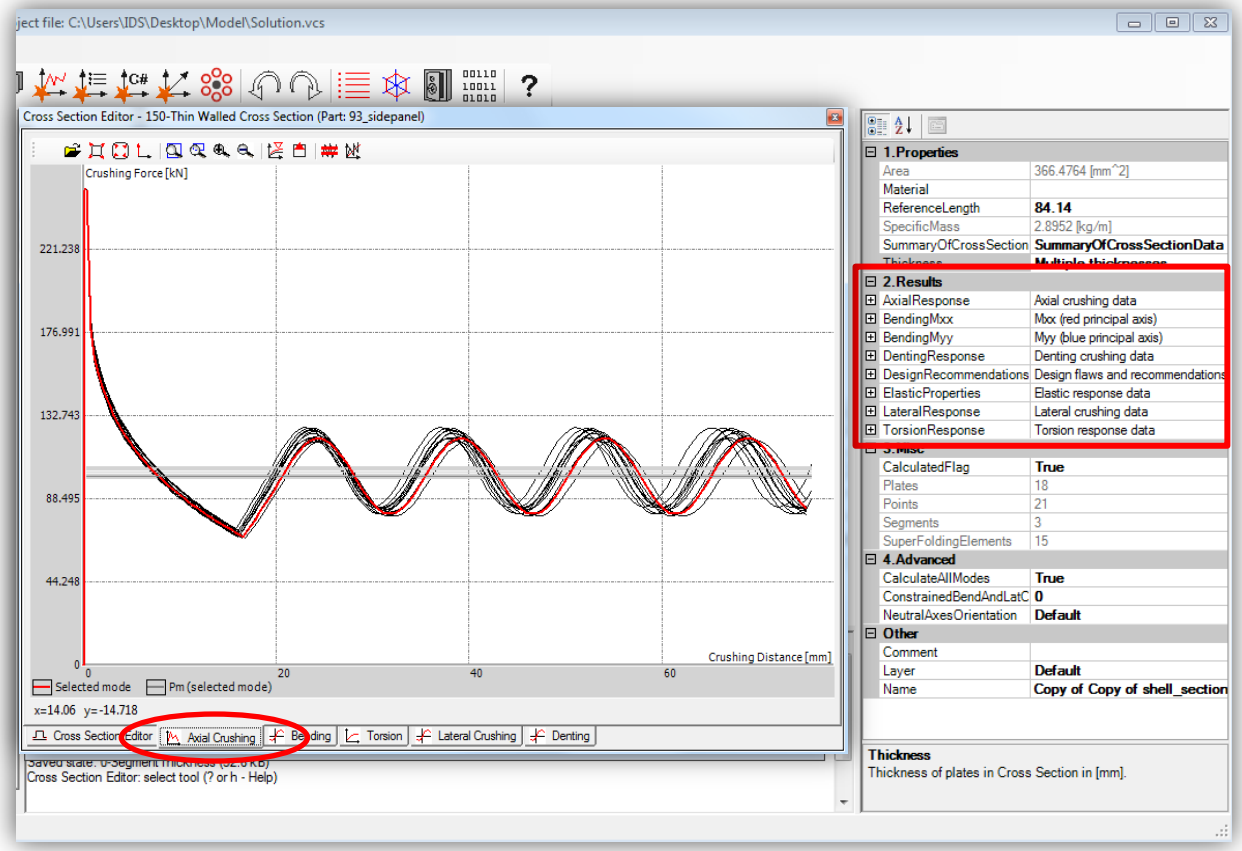




All Cross Sections created in VCS consist of Points, Plates – created by connecting two Points, Segments – build of Plates, Super Folding Elements and possibly Connections.

- Points
- Plates
- Segments
- Connections
- Super Foldng Elements

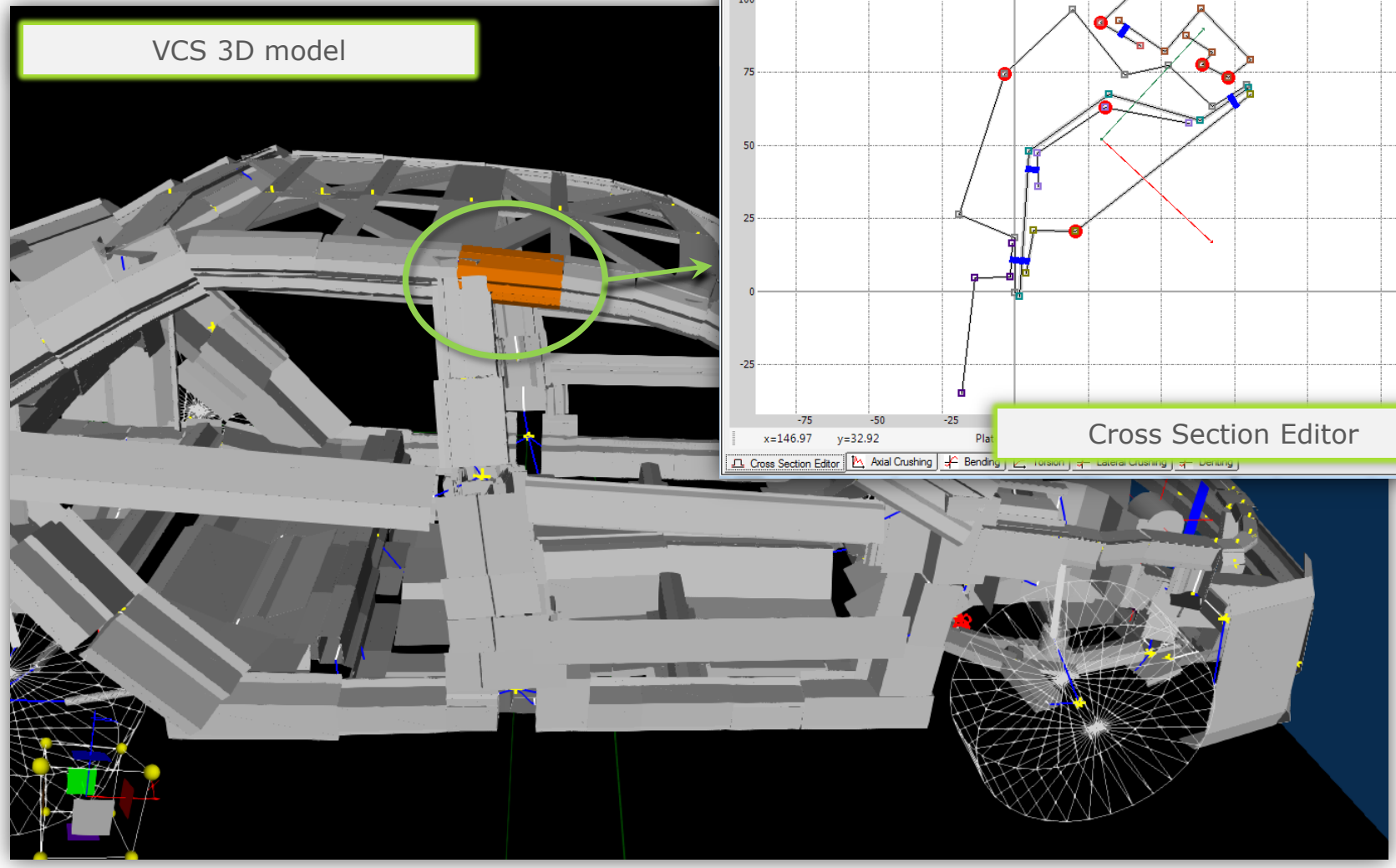
Cross Section analysis - RESULTS



- Axial Response
- Design Recommendations
- Bending Response
- Elastic Properties
- Lateral Response
- Denting Response
- Torsion Response

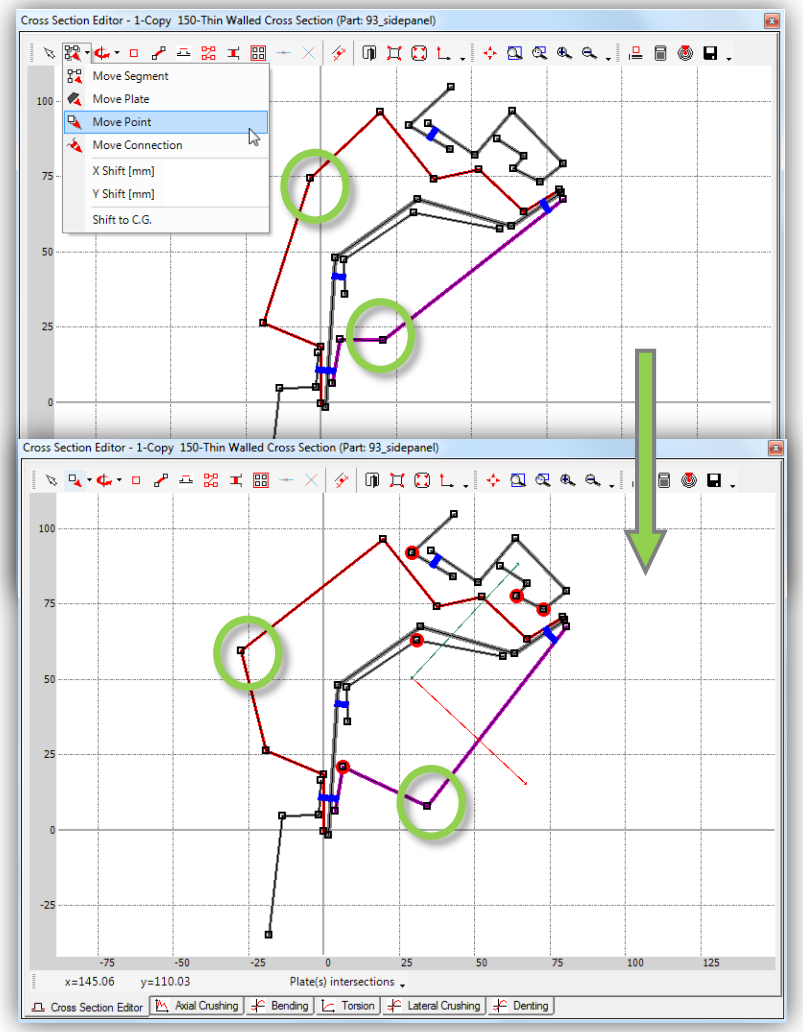
- Results of calculations for a cross section are grouped in 7 expandable containers in the section **Results** of the properties window
- Each container lists characteristic parameters for a given crushing response mode such as maximal value of force or moment, energy absorption capacity, limiting value of a deformation such as total rotation in bending hinge or jamming rotation in torsion crushing.

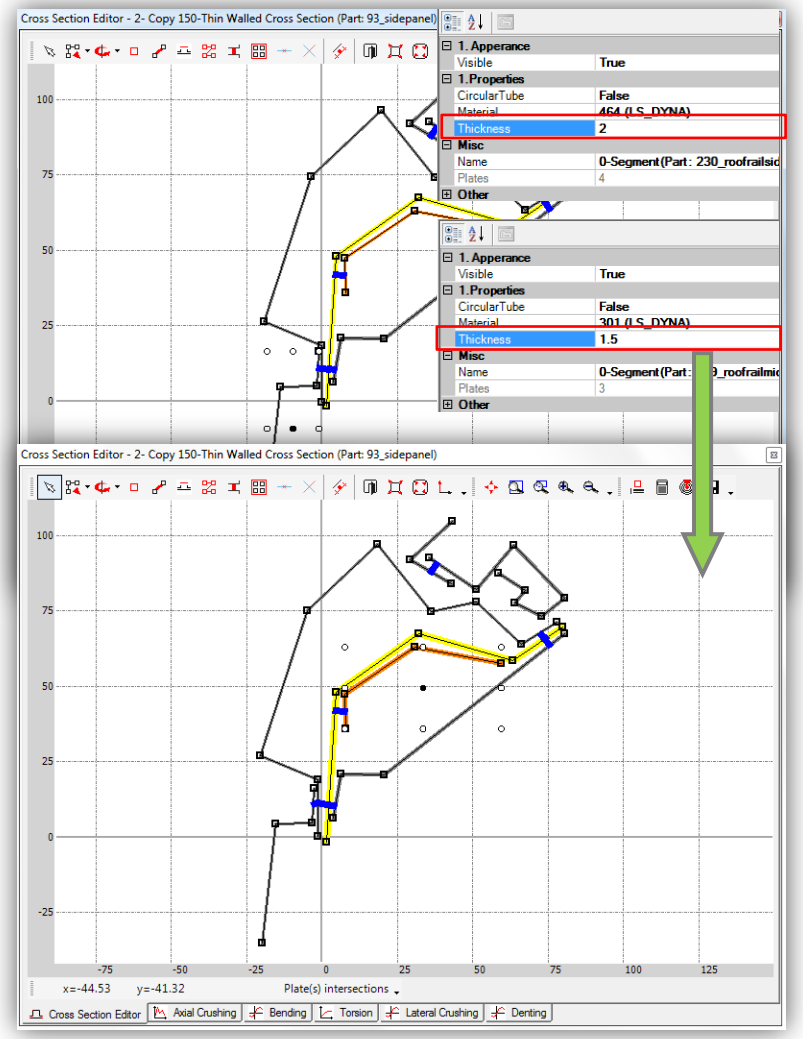
VCS – examples of application – side roof rail



VCS – examples of application – side roof rail

Basic edition possibilities available in the Cross Section Editor:

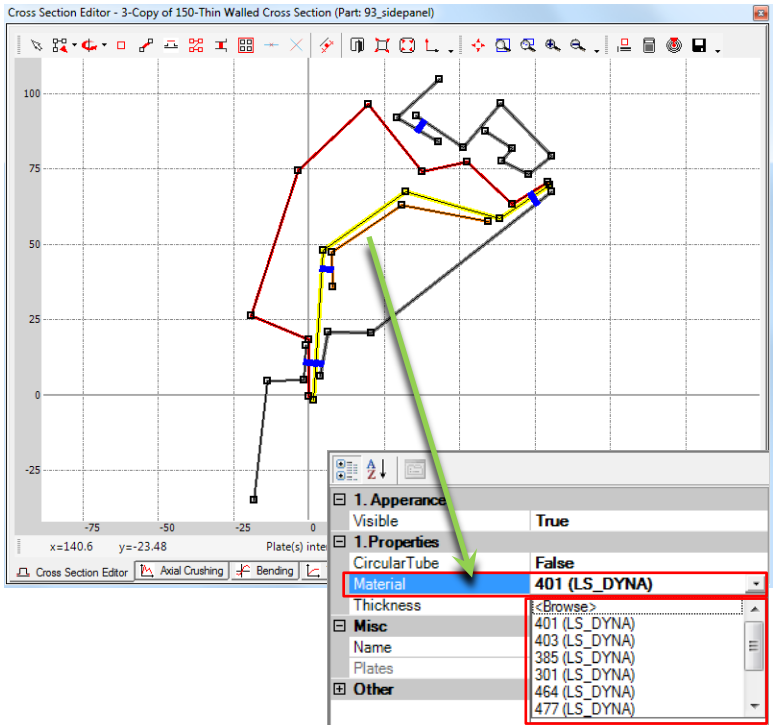


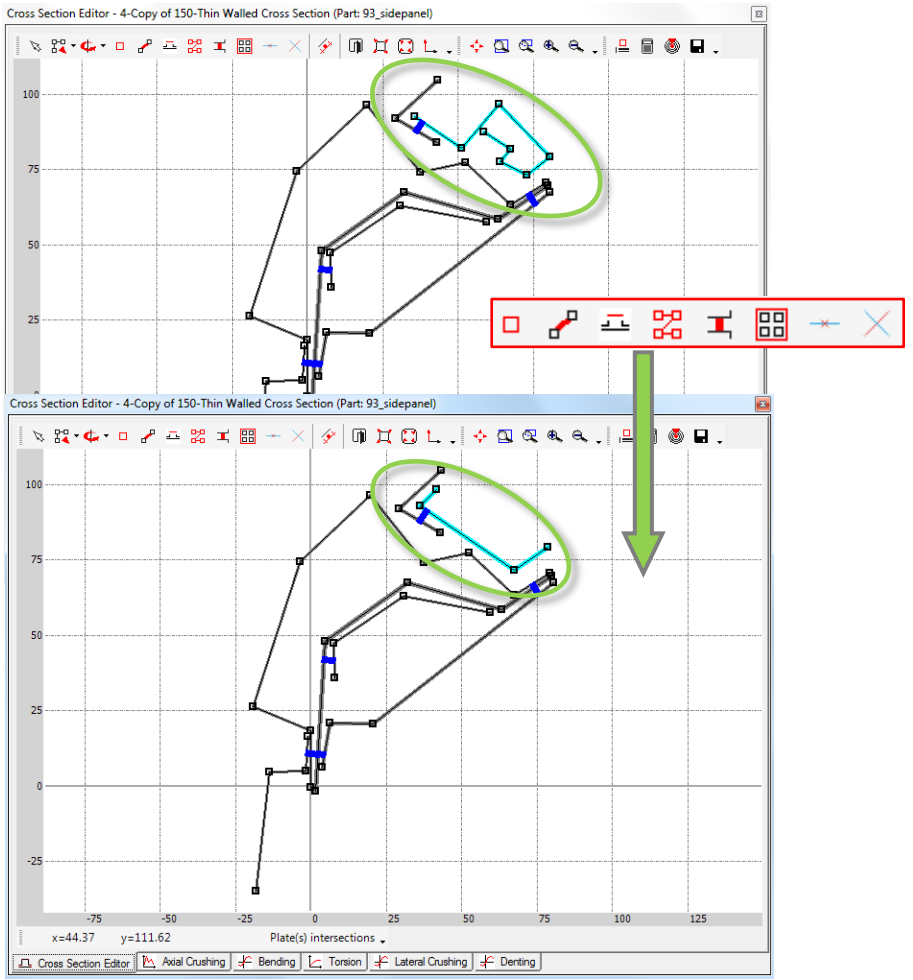


- Modification of coordinates of Points
- Modification of thickness of Plates and/or Segments

VCS – examples of application – side roof rail

Basic edition possibilities available in the Cross Section Editor:

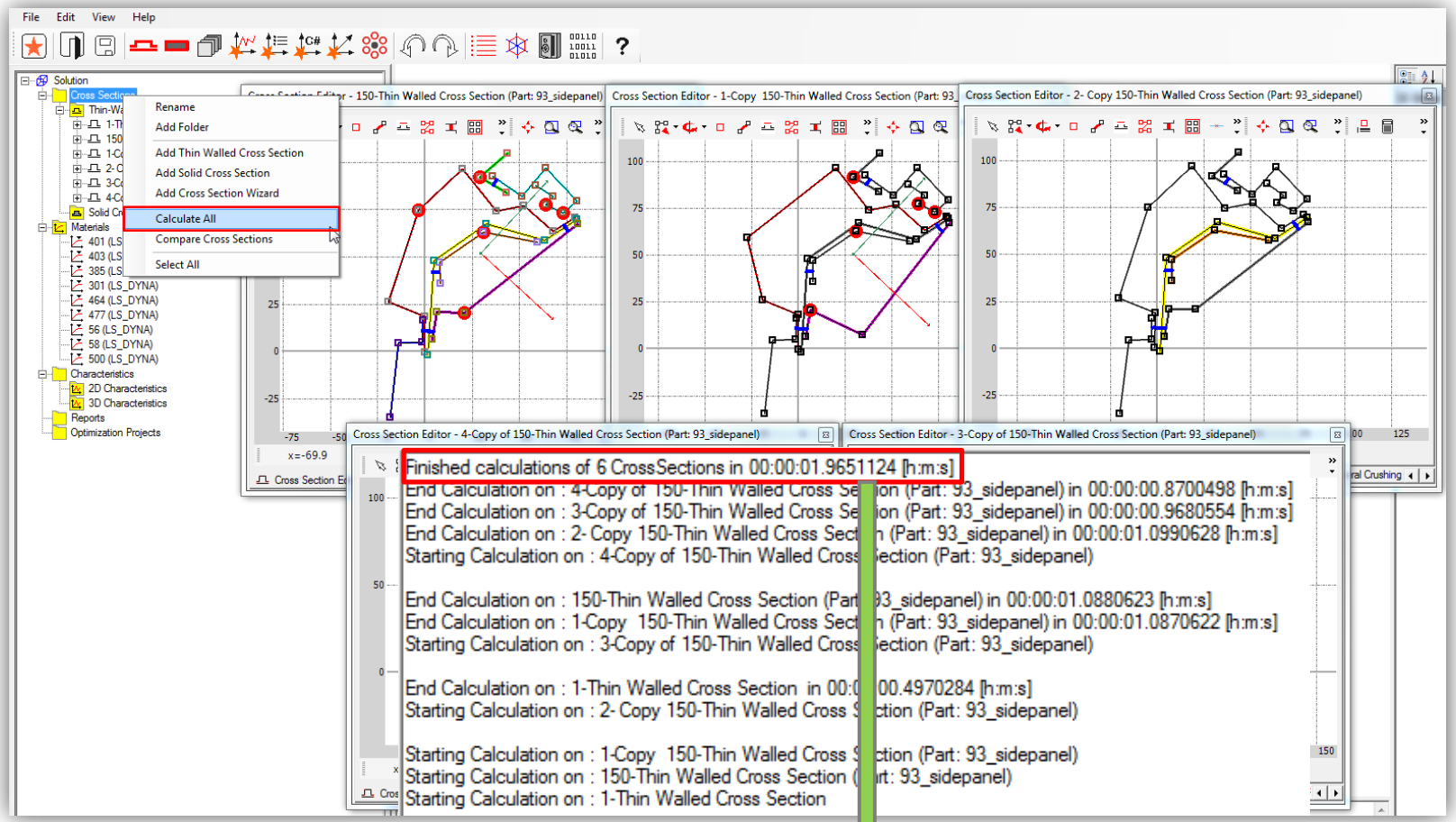




- Modification of material assigned to a Plate or a Segment
- Modification of Segment's geometry; creation of a new Plate or Segment

VCS – examples of application – side roof rail

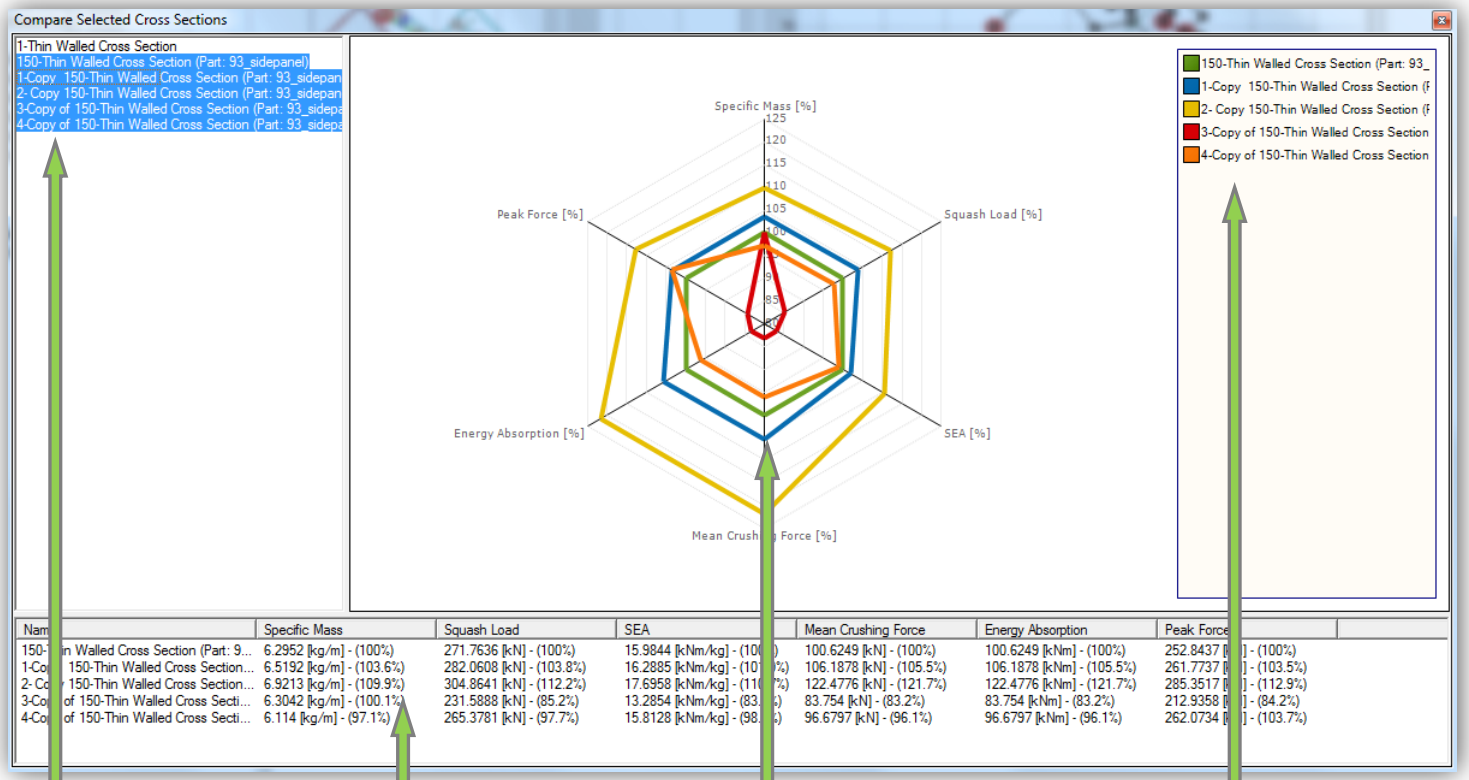
All cross sections created in a VCS Solution can be calculated simultaneously.



Calculation time for ALL Cross Sections is 1.96 [s]

“Compare Selected Cross Sections” tool

Results of all calculated cross sections can be compared with the usage of the “Compare Selected Cross Sections” tool.



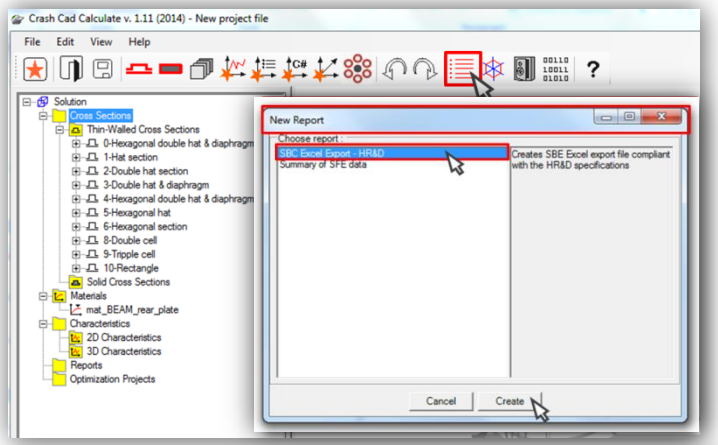
List of all Cross Sections created in the Solution.

List of selected Cross Sections and their results

Diagram illustrating the results of selected Cross Sections

Each Cross Sections results will be illustrated by a line of a different color

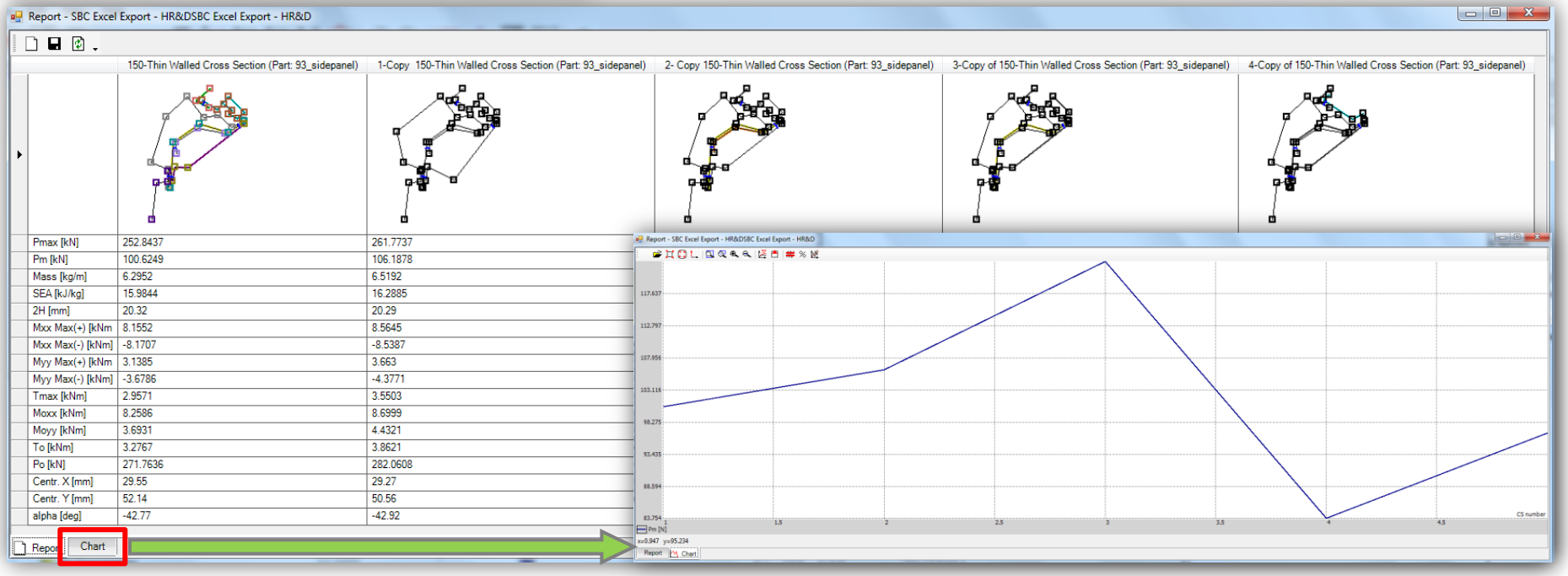
Results Report



The "Report" functionality enables the User to semi-automatically generate report summarizing results of various Cross Sections, and to view the summary of result data for each Super Folding Element of a one chosen Cross Section.

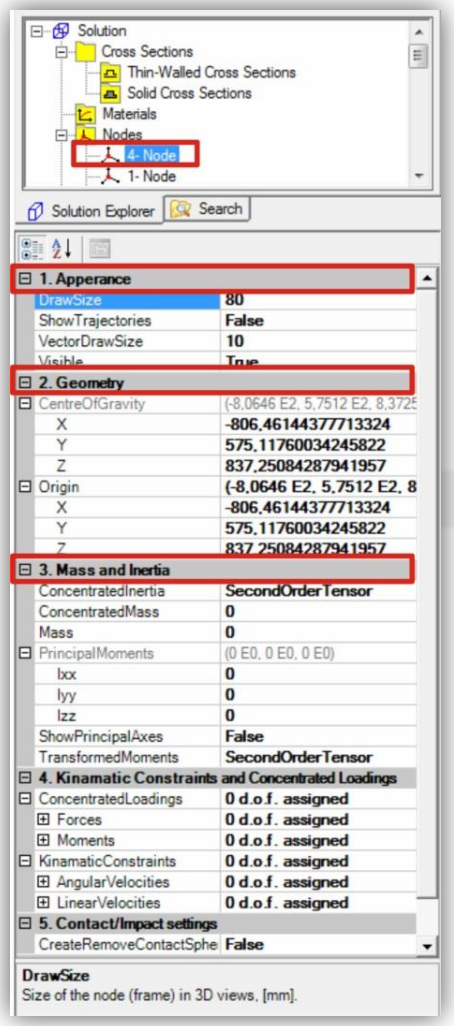
In the Report table you will be able to view and compare each cross sections geometry and data for each of the selected parameters.

After clicking on the "Chart" bookmark you will be able to view a graph visualizing the comparison of cross sections (marked here as cross section 1, 2, 3 and so on).

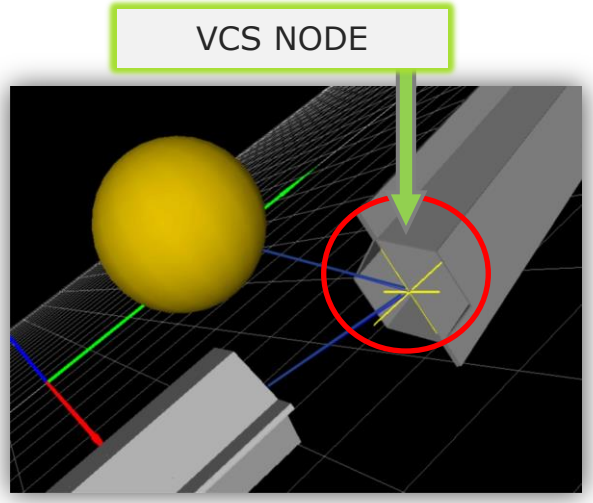


3D environment objects - NODES

NODES - Properties



- The ***Node*** is used as a spatial reference point for all VCS objects
- Several elements can be attached to one Node
- The Node encompasses number of data necessary for dynamic simulation
- The Node encompasses number of data necessary for dynamic simulation



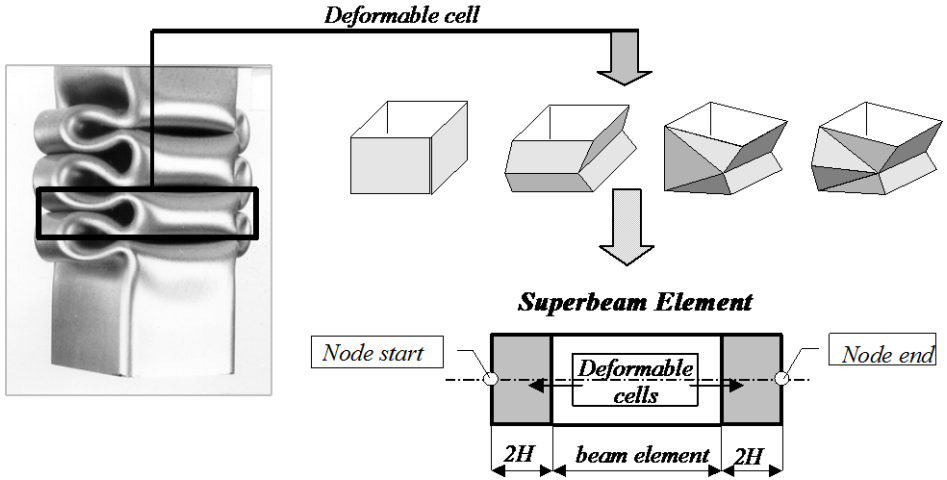
NODES - Properties

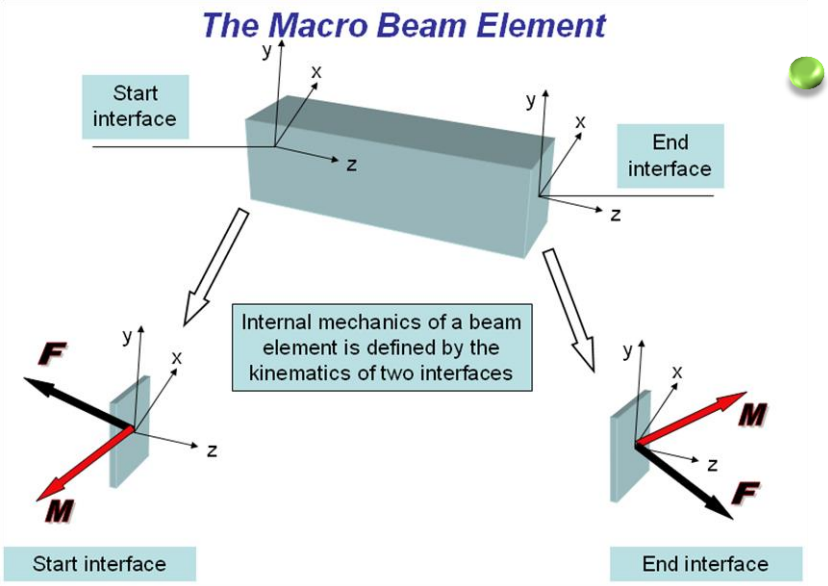
- Node Appearance
- Geometry
  - center of gravity
  - origin
- Mass and Inertia
  - Mass
  - Concentrated Mass
  - Concentrated Inertia
  - Principal Moments
  - Transformed Moments

Macro Element 3D Structure - SUPER BEAM ELEMENT

The Super Beam Element models large deformations of thin walled structures
Two major features of the Super Beam Element (SBE) must be kept in mind during any modeling procedure involving those elements:

- The Super Beam Element is build up from a collection of Super Folding Elements (SFE).
  Each SFE has the length of the plastic folding wave 2H and models crushing response of single corner line of a prismatic or tapered segment of thin walled cross section. Therefore, the smallest size of Super Beam Element in any VCS model should not be smaller than the length of the plastic folding wave. Since each Super Beam has two deformable sections (referred to as deformable cells) the smallest recommended length of a Super Beam Element equals **4H.**





- The Super Beam Element models large deformations of thin walled structures, however, it follows standard definition of a beam due to Love & Kirchhoff. In particular the segment of thin-walled structure modeled by a SBE is limited by two planes perpendicular to the initially straight centroid line. During any deformation these planes remain perpendicular to the deforming centroid line. All the loadings exerted onto the SBE must be applied to the limiting surfaces referred to as SBE interfaces. These basic features of the beam formulation impose several restrictions on to the SBE response in crashworthiness calculations.

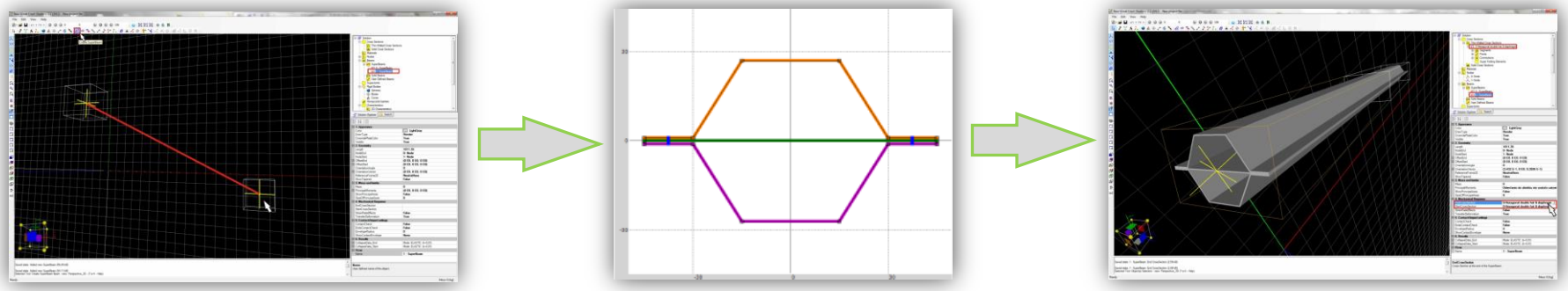
  For example:
  - Rotation (bending angle) of each interface cannot be larger than 90 deg.
  - Local Shell-like response of SBE in contact impact events must be modeled separately using contact envelopes and contact characteristics

3D environment objects - BEAMS

The *Beam Element* is spanned between two *Node Objects*. VCS offers four types of beam elements:

Super Beam Element

Two Thin Walled Cross Sections define a Super Beam Element.
If the same cross section is defined at the start and end Nodes the prismatic Super Beam Element is created.
In case of different cross sections a stepped Super Beam element is created.



Solid Beam

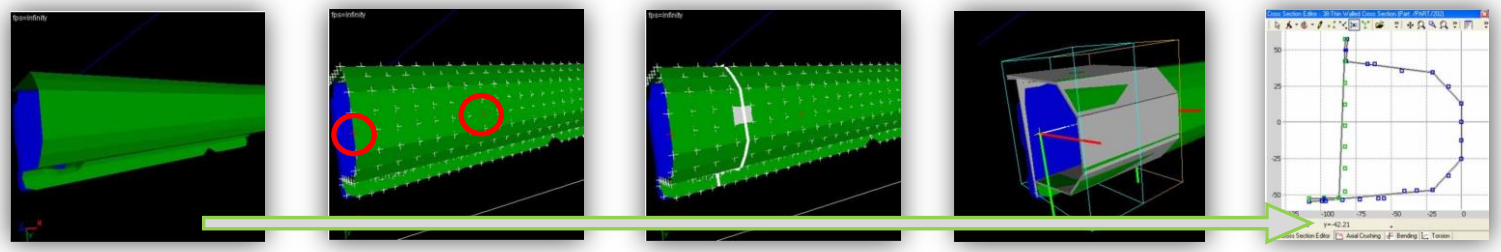
A Solid Beam is defined by a single Solid Cross Section

User Defined Beam

The mechanical response of a User Defined Beam is defined by six 2D Characteristics (plus set of scalar parameters).

Create Super Beam from FE Part

A tool dedicated to enable the User to build complex Super Beam geometry from FE models



VCS - 3D SIMULATIONS

3D Simulation animation

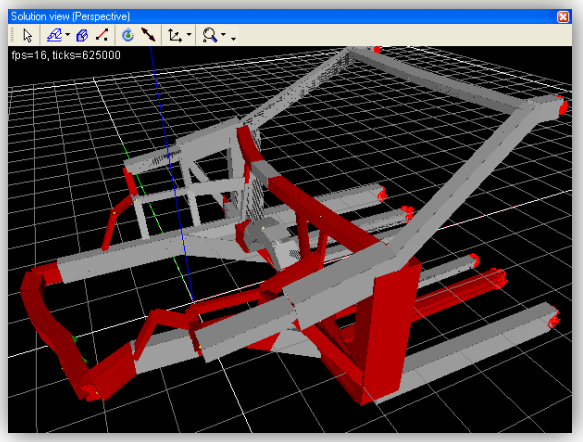


Chart Wizard

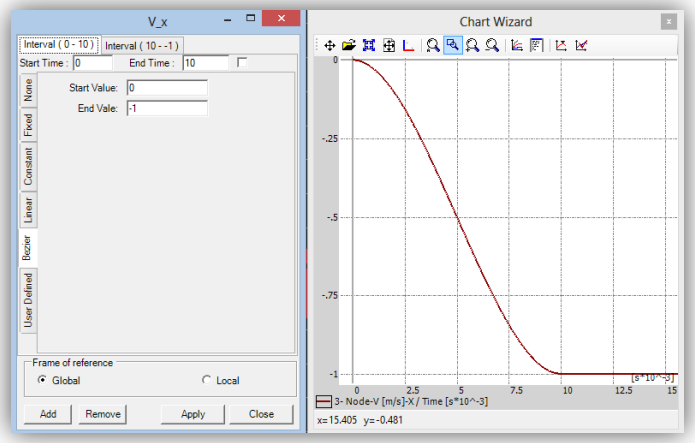


Chart Wizard is used to create various graphs.
For VCS results the user can select any object of the Solution.
It is also possible to view results for a group of VCS objects.

The following color scheme is implemented in order to simplify interpretation of simulation results

- **Dark gray**: macro elements which remain in elastic range
- **Dark green**: elements that have reached limit load carrying capacity (under a combined loading).
- **Dark Yellow (golden)**: elements in the post collapse range
- **Red**: elements in deep collapse region,

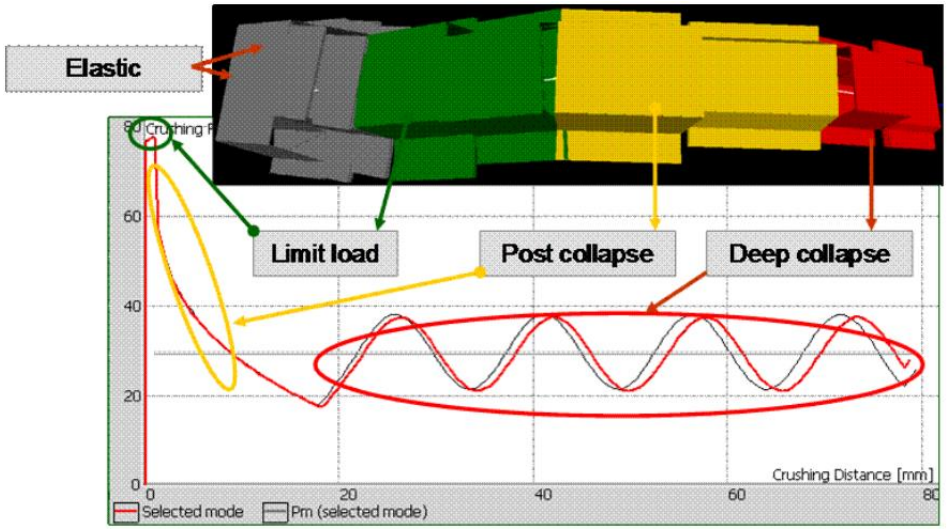
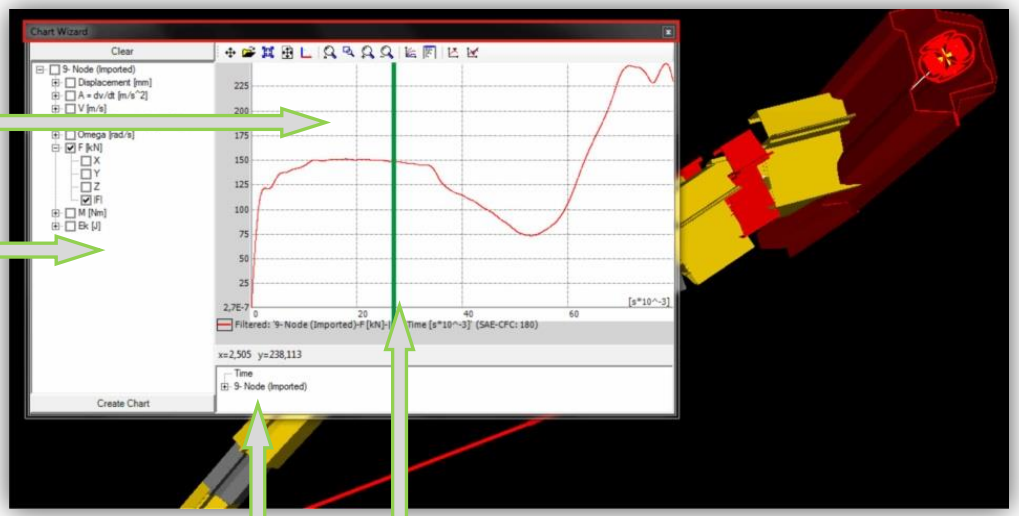


CHART WIZARD – creating various graphs

Chart wizard window is divided into three sub-windows.

The main window presents the function chart.

List window at the left side of the chart wizard is a selection window for dependent variable (ordinate).
The default independent variable
(X-axis) is time.

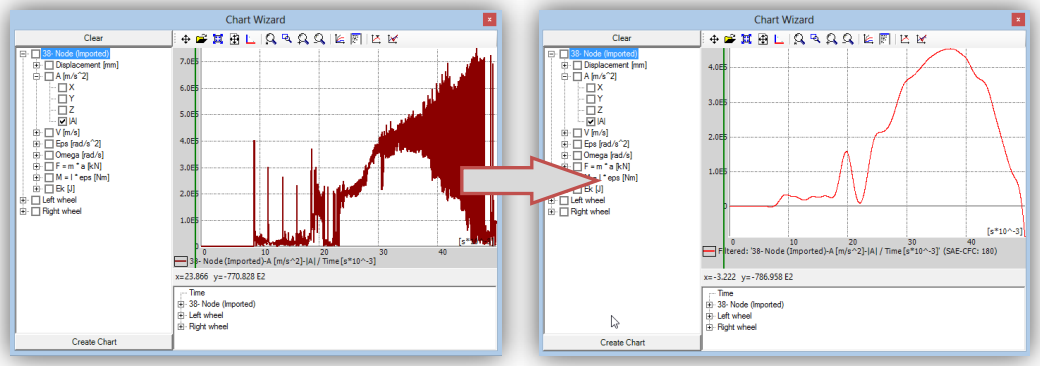


The list window at the bottom enables selection for function domain.

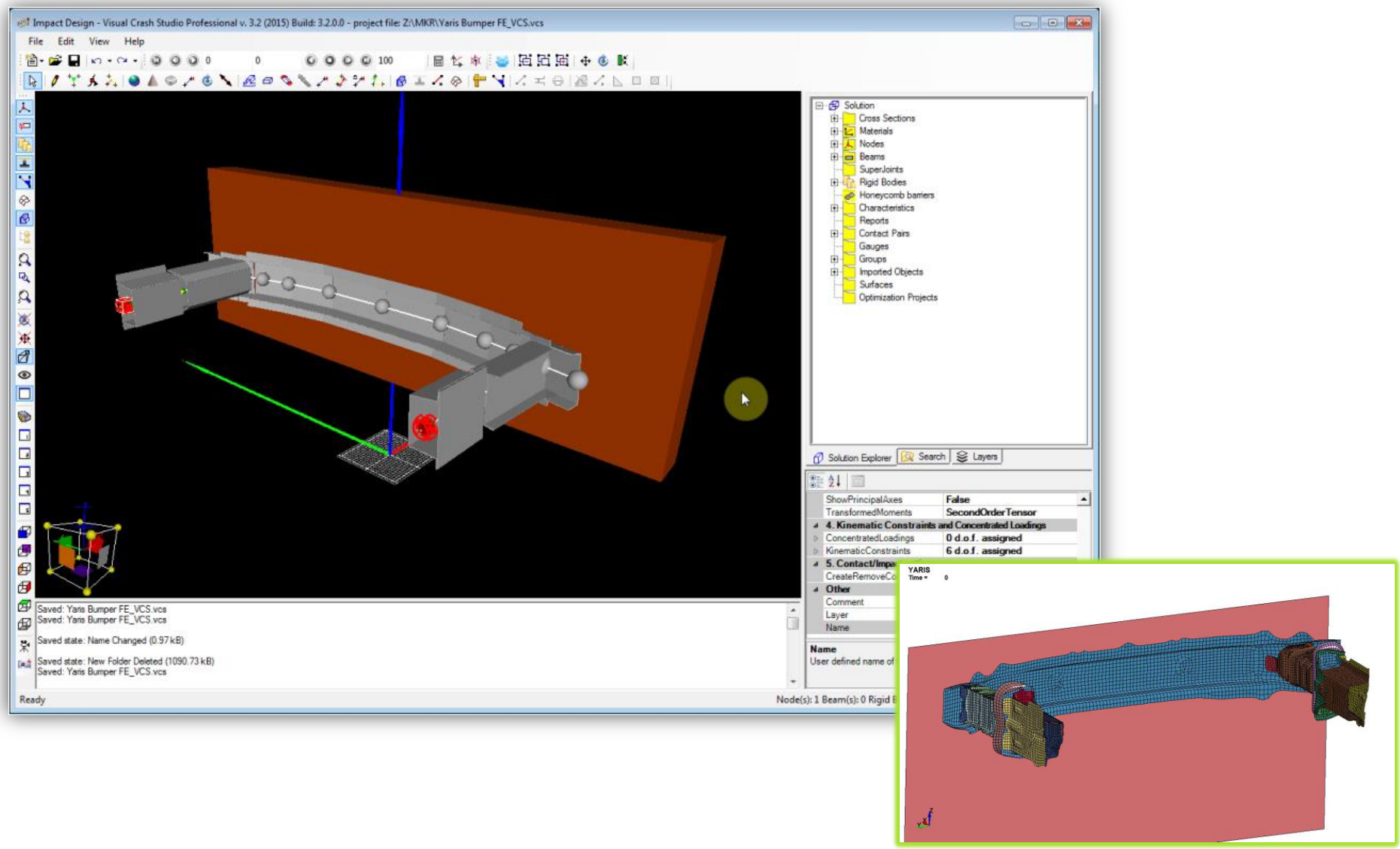
Green time marker –
This line illustrates the movement of the load case simulation

in Chart Wizard a number of filters designed for converting the diagram curve are available.

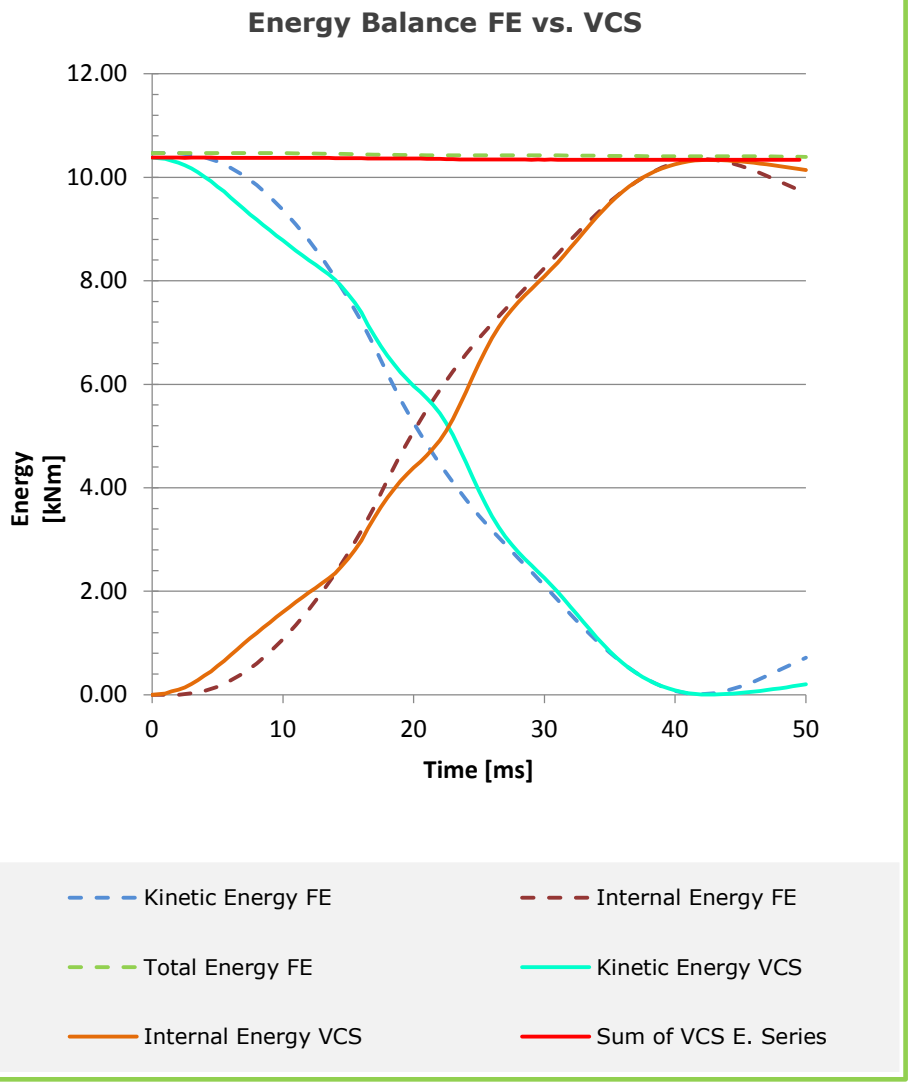
- **SAE Filters**
- **Low pass 2nd order Butterworth**
- **Filter (BF)**
- **Turncated Fourier Series (FFT)**
- **Moving Averages (MA)**

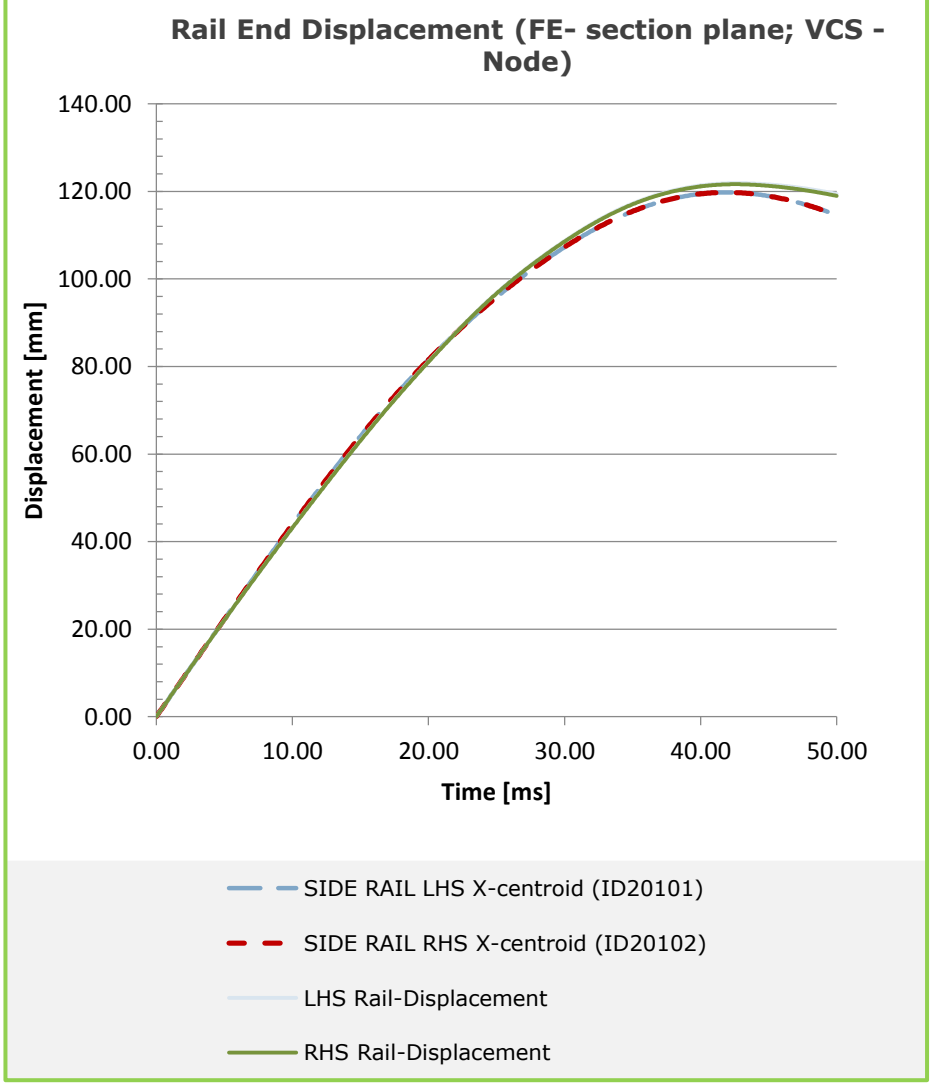


Comparison between FE simulation and Macro Element simulation



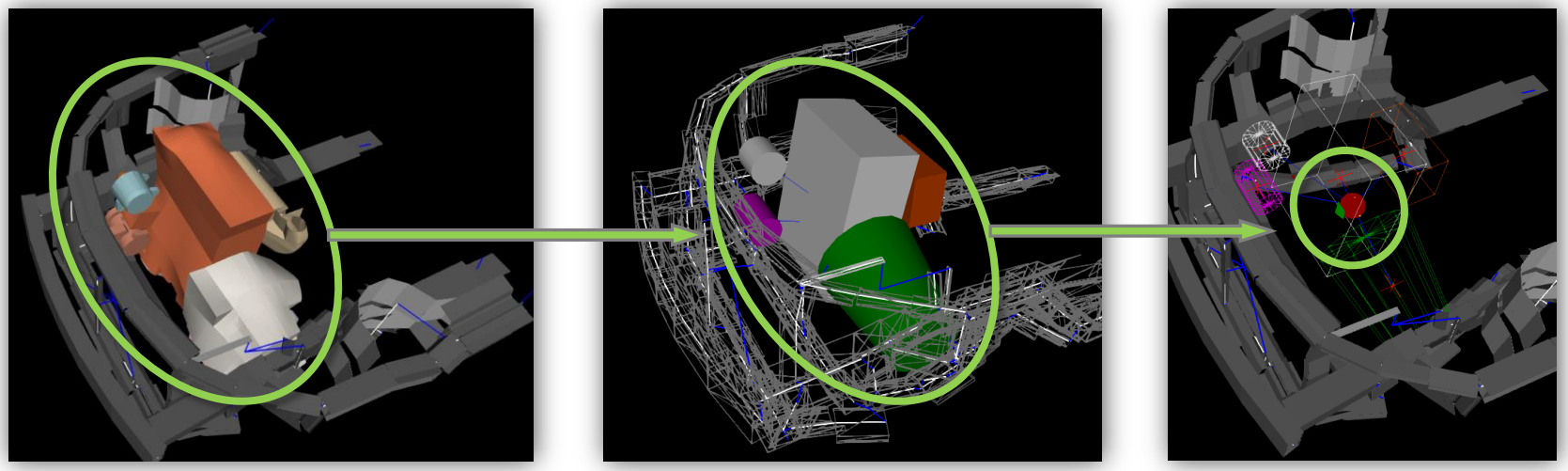
Comparison between FE simulation and Macro Element simulation



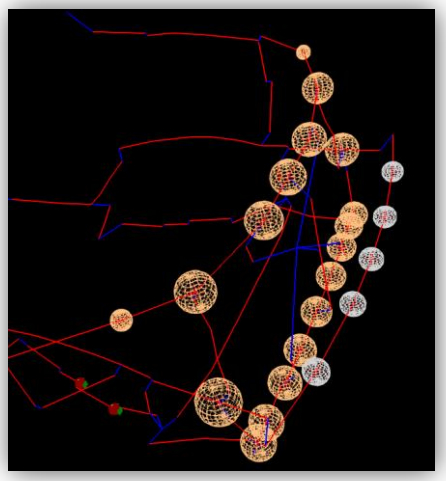


Body in white – additional elements – Rigid Bodies

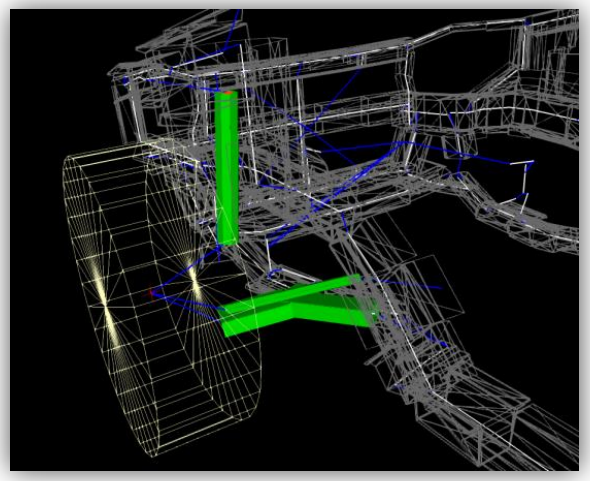
- Engine, gearbox, intake manifold, water pump, alternator – **Rigid Bodies**



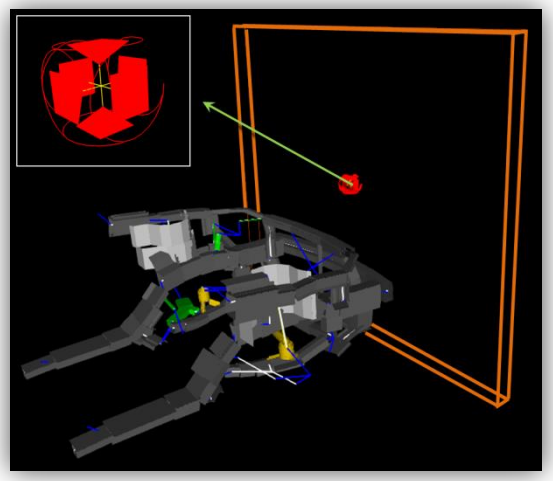
- Contact Bodies



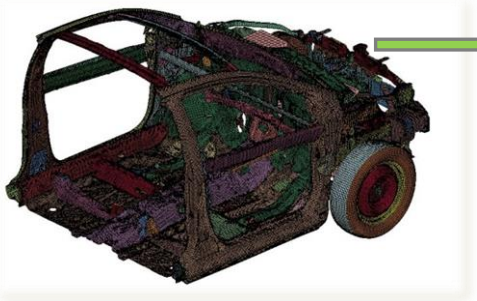
- Wheels and suspension

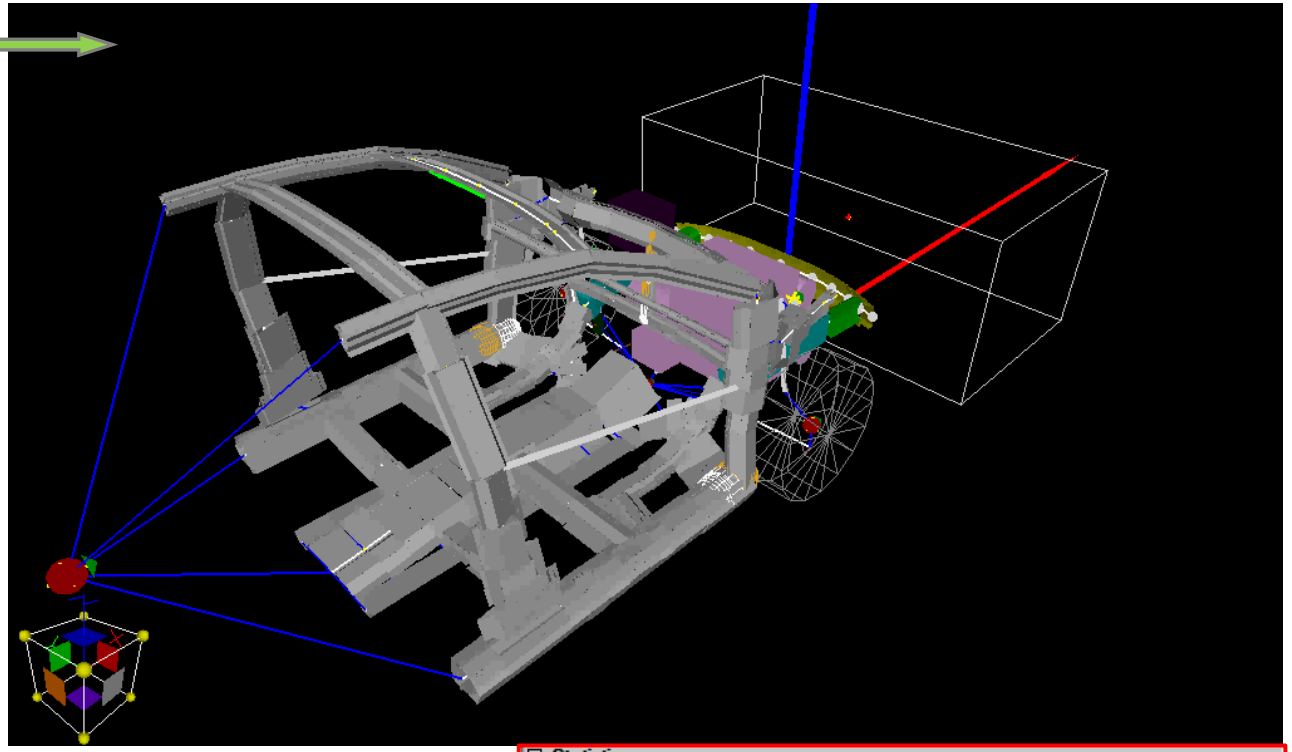


- Barriers



VCS – Space Frames





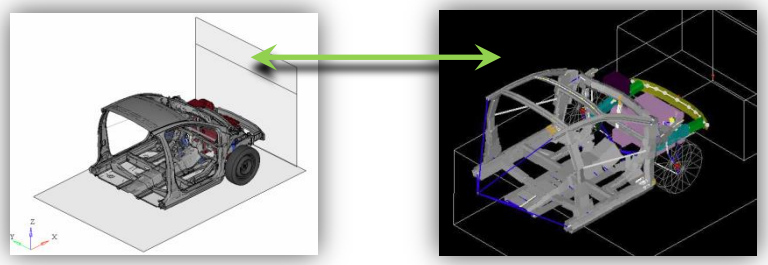
```
Integration routine: StandardExplicit
  Time units: Milliseconds
  Time step: 0.0100
  Total time steps: 5,000

Model consistency check.
Model consistency check complete.
Initialization of objects:
  - Nodes
  - Macro Elements
  - Barriers
  - Contact processor
    - Reference (maximal) contact stiffness: 5.3759 E9 [N/m]
  - Contact pairs
Initialization of objects complete.
Stability check/settings.
  - Maximal time step (no added mass/inertia): 0.01026 [s*10^-3]
Stability check/settings complete.
Processing main iteration loop.

Post-processing operations
Elapse time [s] : 74
Model consistency check.
Model consistency check complete.
Initialization of objects:
  - Nodes
  - Macro Elements
  - Barriers
  - Contact processor
    - Reference (maximal) contact stiffness: 5.3759 E9 [N/m]
  - Contact pairs
Initialization of objects complete.
Stability check/settings.
  - Maximal time step (no added mass/inertia): 0.01026 [s*10^-3]
Stability check/settings complete.
Processing main iteration loop.

Post-processing operations
Elapse time [s] : 33
```

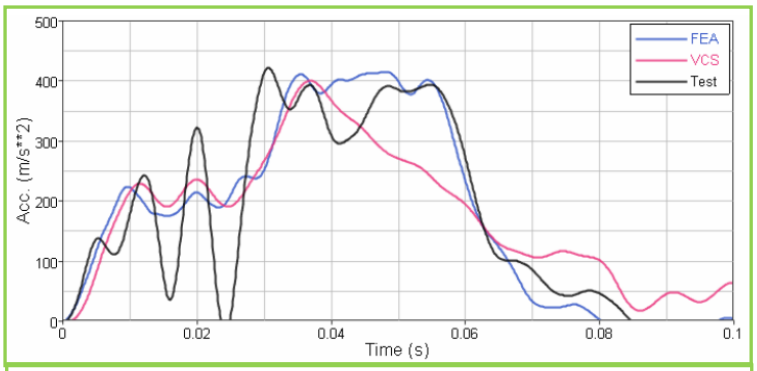
Statistics	
BeamElements	115
⊞ CenterOfGravity	(4.1888 E2, -1.5756 E1, 8.3789 E2)
CrossSections	30
Materials	36
Nodes	84
Reports	0
RigidBodies	37
TotalMass	2382.8418
TotalMassBeams	216.104
TotalMassRigidBodies	966.7379

Calculation time for this Assembly is 33 [s] !

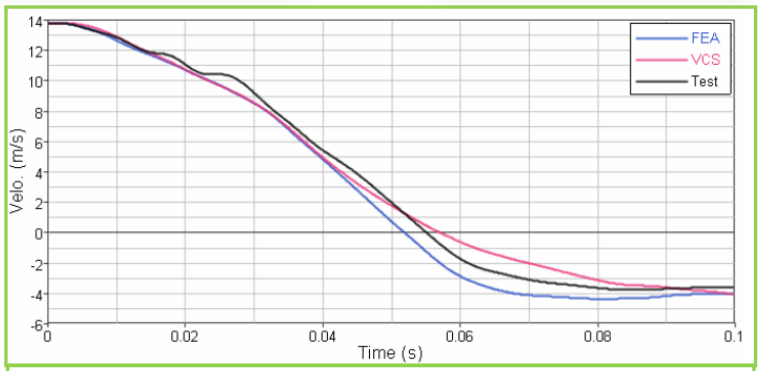
Comparison between VCS simulation and FE simulation

Results:
Acceleration vs. Time
Velocity vs. Time
Displacement vs. Time
Acceleration vs. Displacement

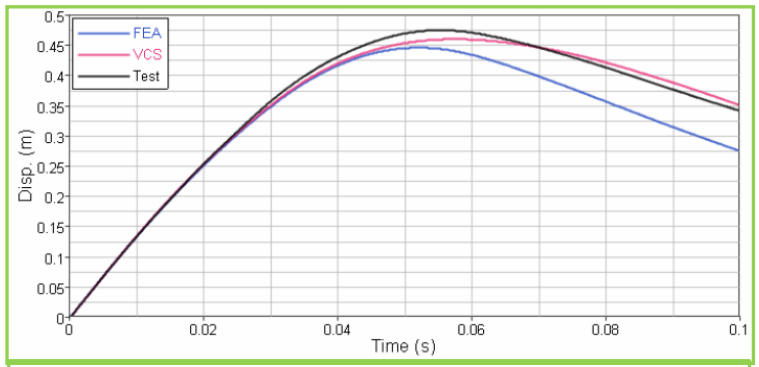




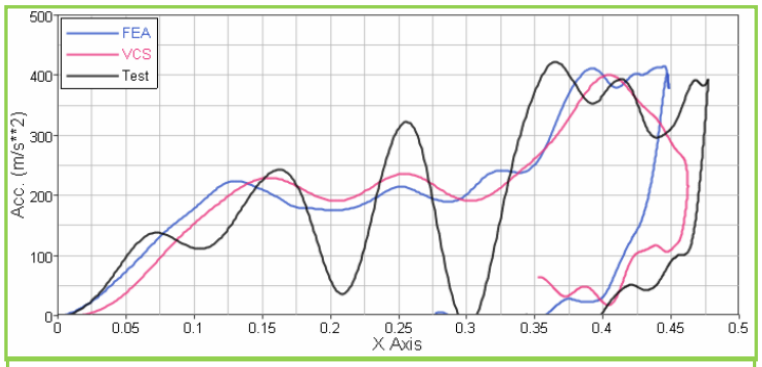
Acceleration vs. Time



Velocity vs. Time



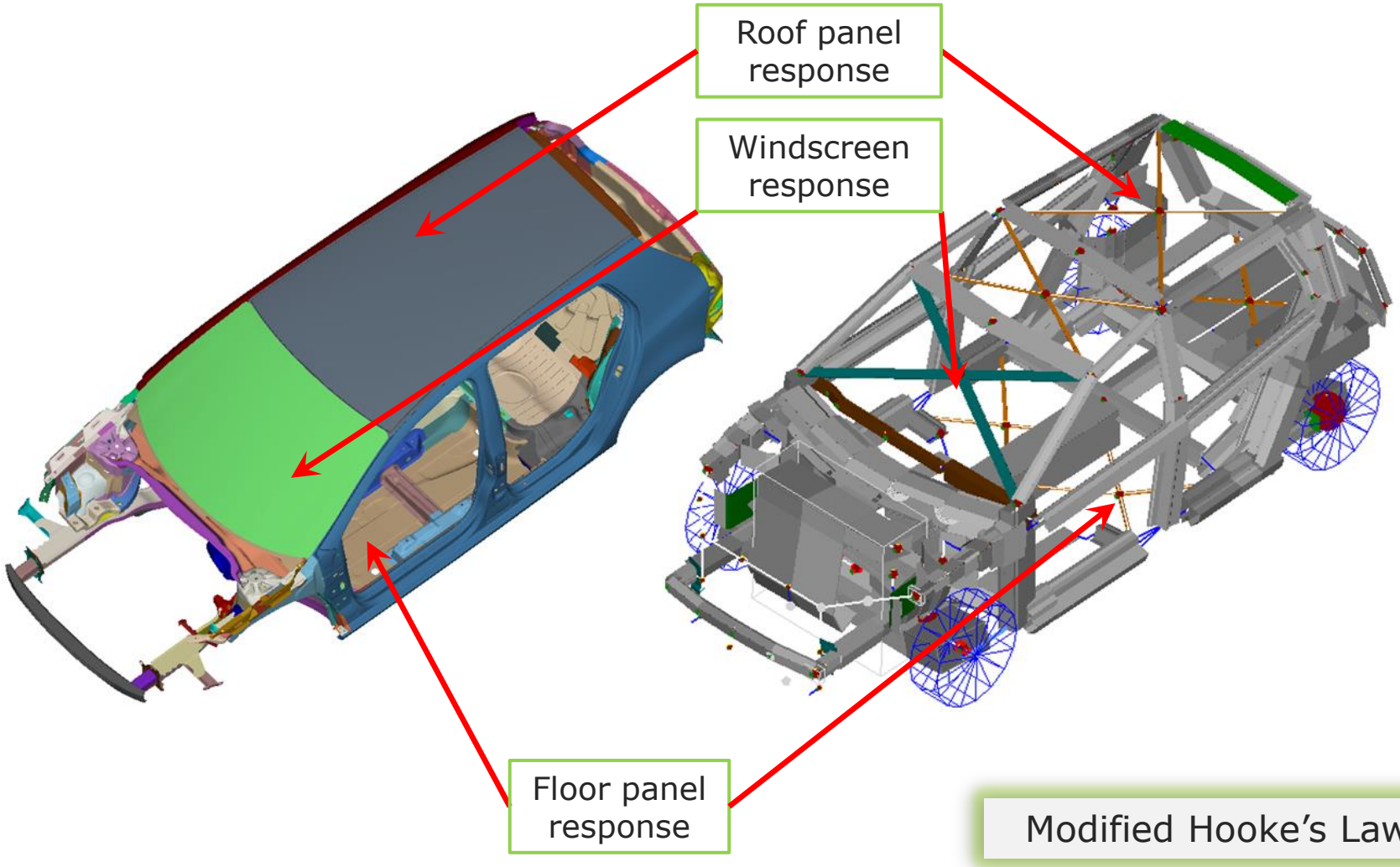
Displacement vs. Time



Acceleration vs. Displacement

Modeling of flat panels response

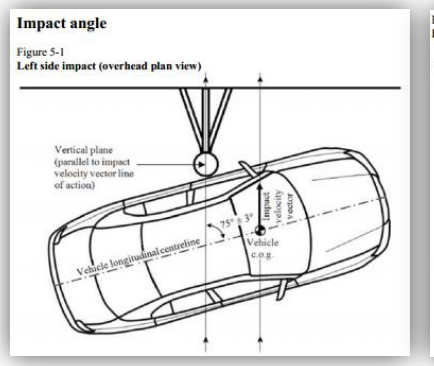
The shear panels increase vehicle's body stiffness.
In VCS shear response is modelled by means of crossing super beam elements

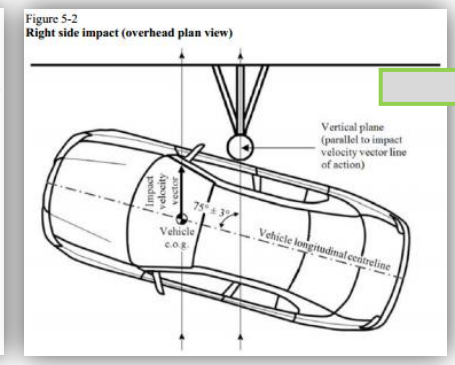


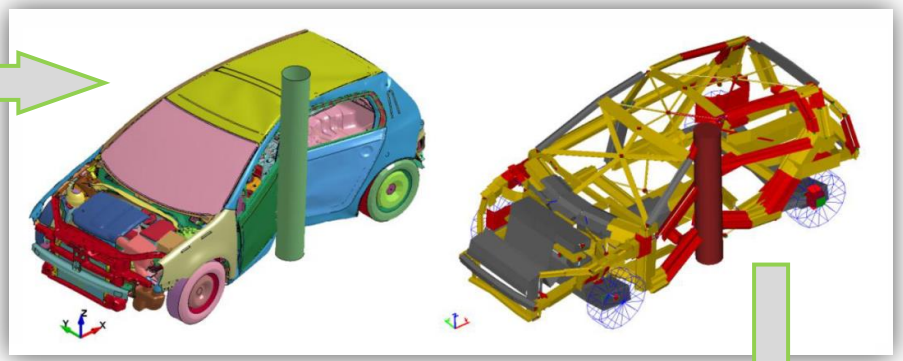
Modified Hooke's Law

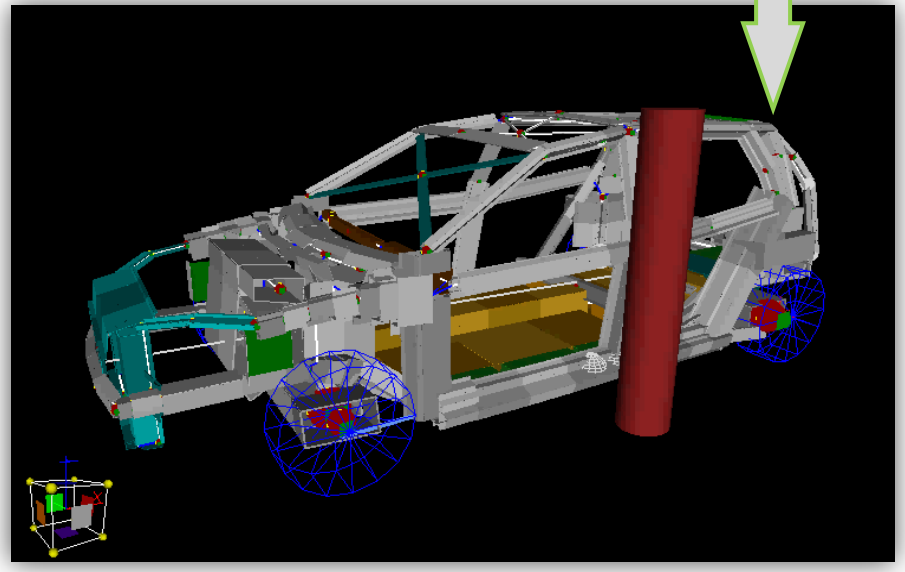
Load case definition – Pole Side Impact

Technical regulation on Pole Side Impact









Source: GLOBAL NCAP (www.crashnet1.com); UNECE

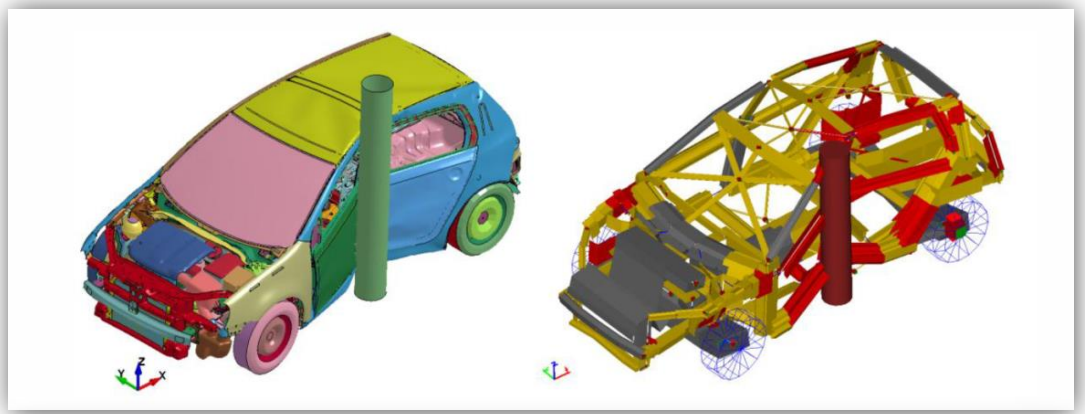
VCS – Full Crash Simulation – the SmartBatt project

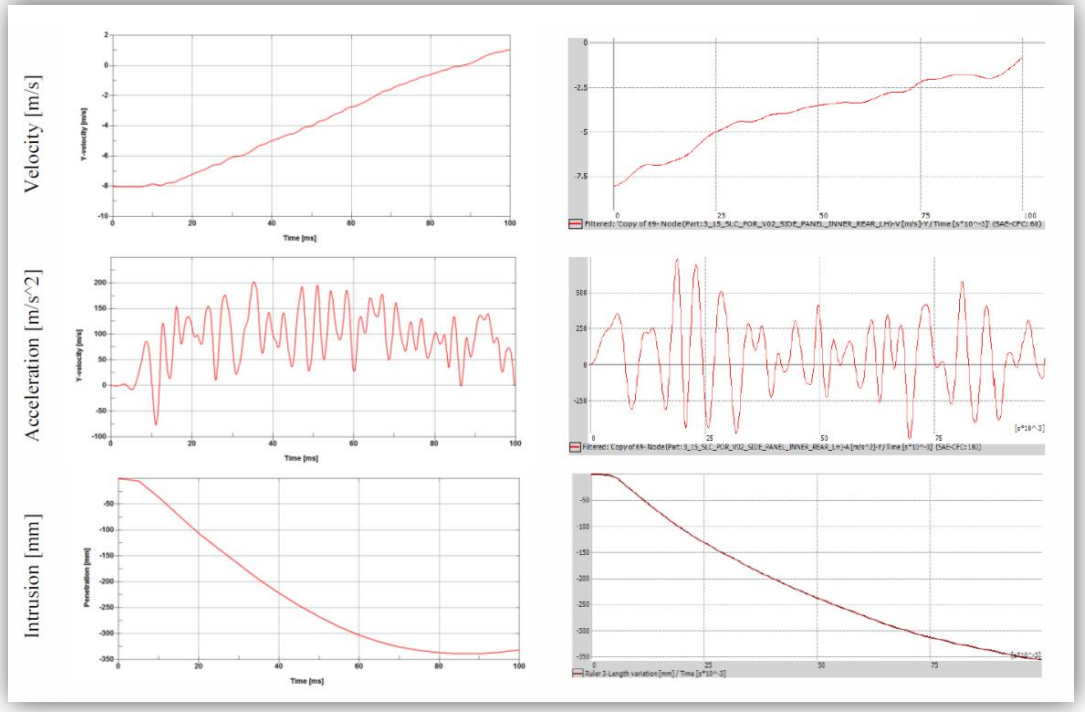
Comparison between FE and Visual Crash Studio models results for pole crash. From the top:

- velocity [m/s] of node of lower B-pillar on side opposite to impact;
- acceleration [m/s^2] of node of lower B-pillar on side opposite to impact;
- penetration [mm] measured between lower parts of B-pillars.

All curves displayed as a function of time [ms].

Results from finite elements on left, results from macro elements on right





Load case definition – Front Impact

Example 1: **Regulation No. 33**

E/ECE/324)Rev.1/Add.32/Rev.1
E/ECE/TRANS/505)
Regulation No. 33
page 26
Annex 4

FRONTAL-IMPACT TEST AGAINST A BARRIER*

1.1. Testing ground

1.2. Barrier

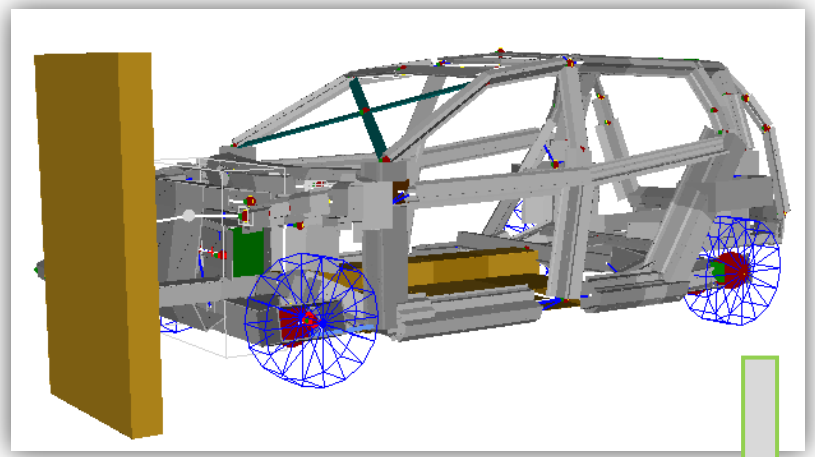
The barrier consists of a block of reinforced concrete not less than 3 m wide in front and not less than 1.5 m high. The barrier must be

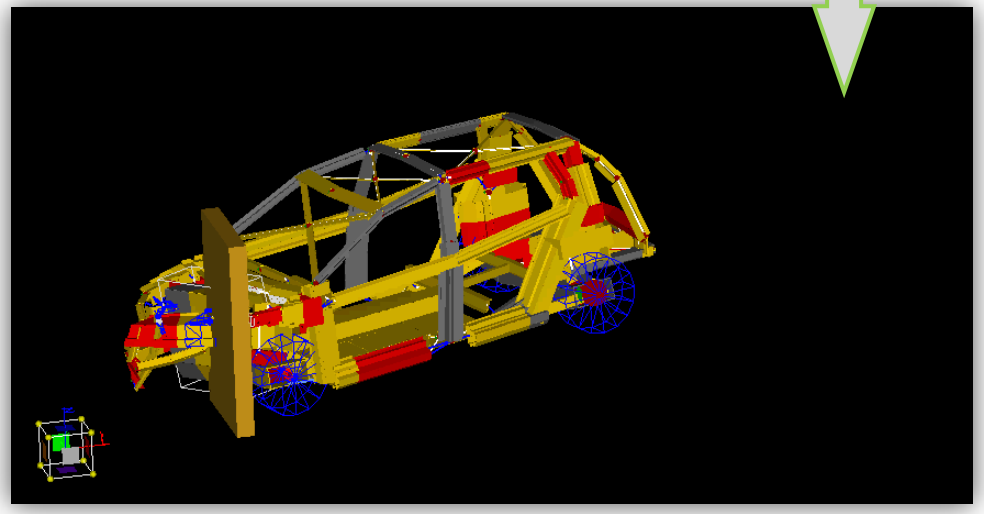
1.3. Propulsion of vehicle

At the moment of impact the vehicle must no longer be subject to the action c
the obst
maximum
line of
collisio

1.4. State of vehicle

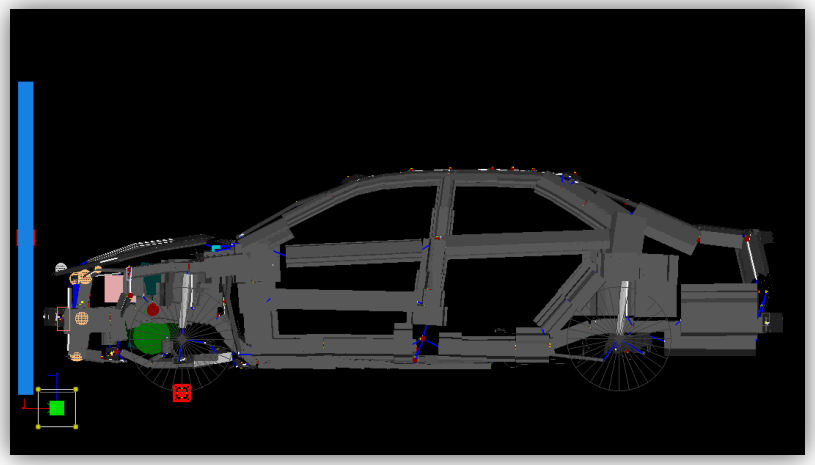
1.4.1. The vehicle under test must either be fitted with all the normal components and equipment included in its unladen kerb weight or be in such a condition as to fulfil this requirement so far as the components and equipment of concern to the passenger compartment and the distribution of the weight of the vehicle as a whole, in running order, are concerned.

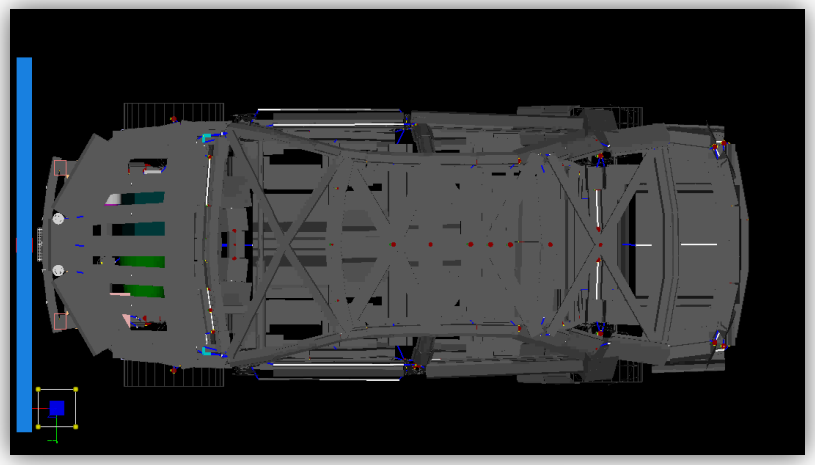


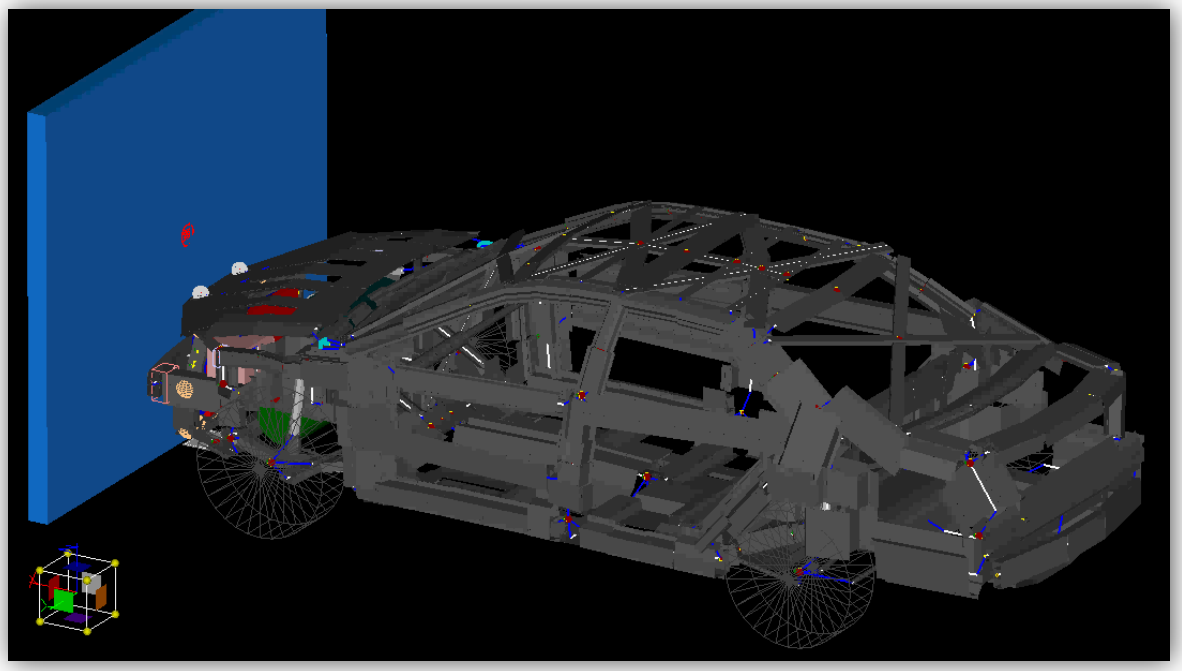


Source: GLOBAL NCAP (https://www.youtube.com/watch?v=En2X4V3LPt4 ; www.crashnet1.com); UNECE

Body in white – Toyota Camry







Thank you
for your kind attention

Impact Design Europe
ul. 3 Maja 18
05-816 Michalowice
POLAND
www.impactdesign.pl

Contact:
Agata Abramowicz Sokoll
CEO
mail: as@impactdesign.pl