EHTC 2010

Impact of concrete structures

Reinforced Slabs and Beams

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- Drop Test on a slab
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Goals

- **Define the right modelling of reinforced concrete slab perforation under RADIOSS.**

- **Identificate important variables:**
  - **Influence of concrete law**
  - **Influence of elements and size mesh**
  - **Influence of reinforcement modelling**

- **Comparison with tests of Heriot Watt University performed by Prof I. M. May et al. and with others calculations under LS DYNA.**

Geometry of the slab

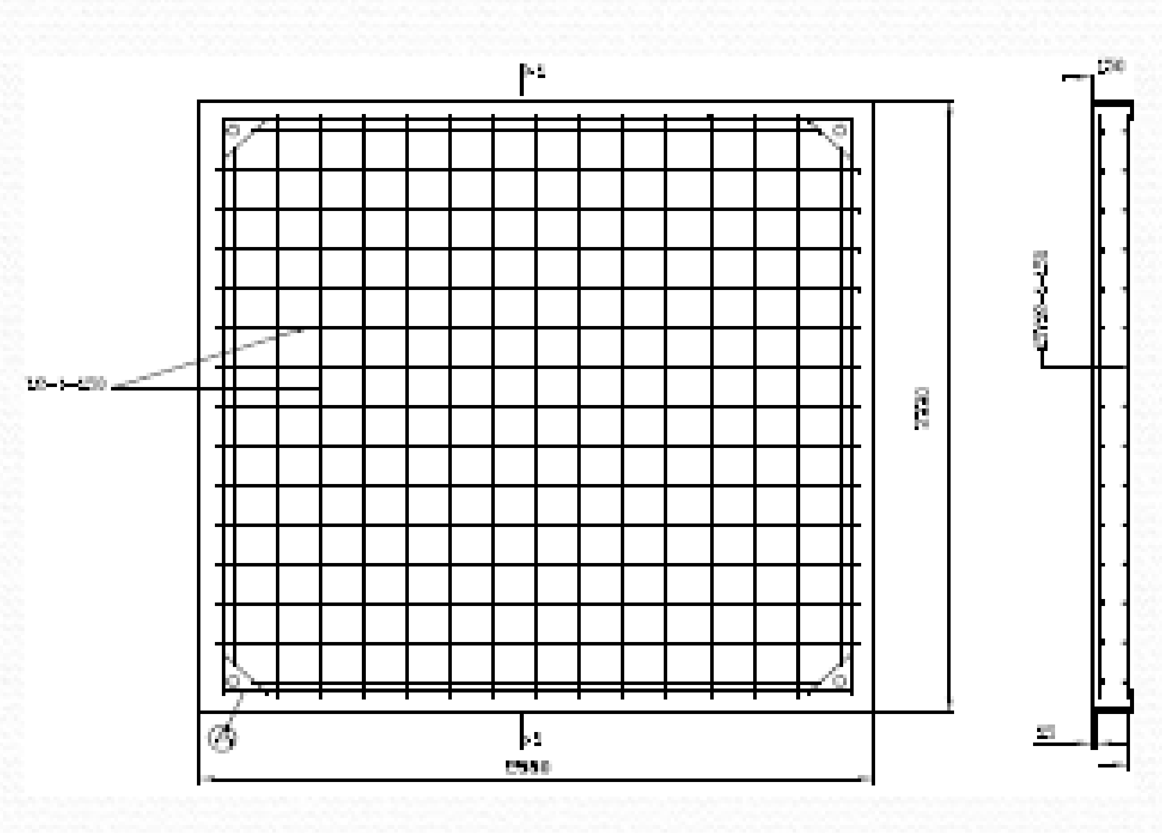
Square reinforced concrete slab in a U-type steel frame maintained at each corner

External dimensions :

- Length = 2,33 m
- Width = 2,33 m
- Height = 0,15 m

Reinforcement :

- 2 layers
- Ø12 150 x 150 mm



Presentation of the slabs

Three different modellings are tested :

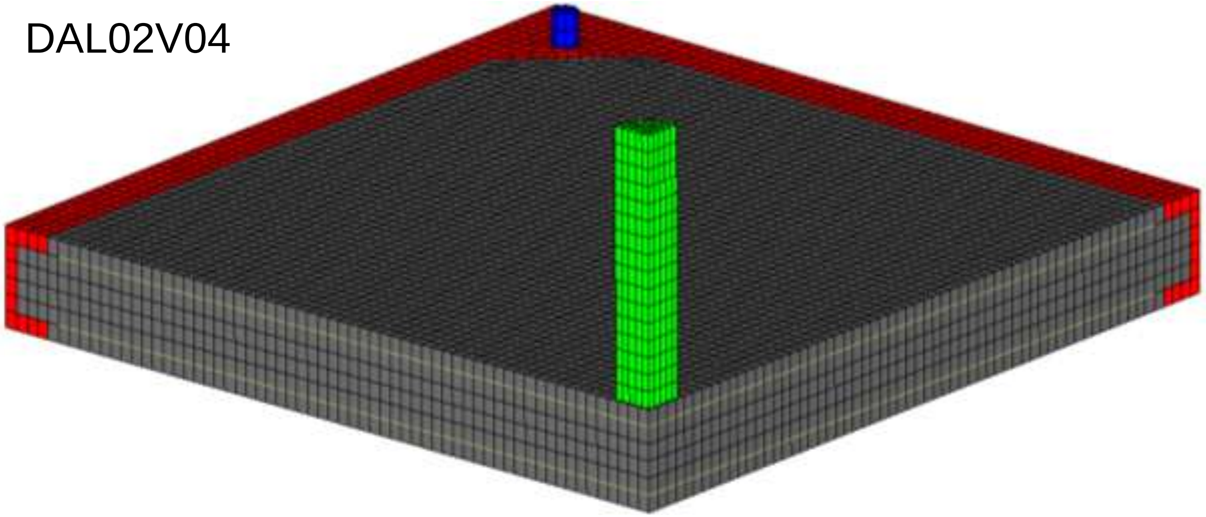
- Large meshing size
- Medium meshing size
- Small meshing size

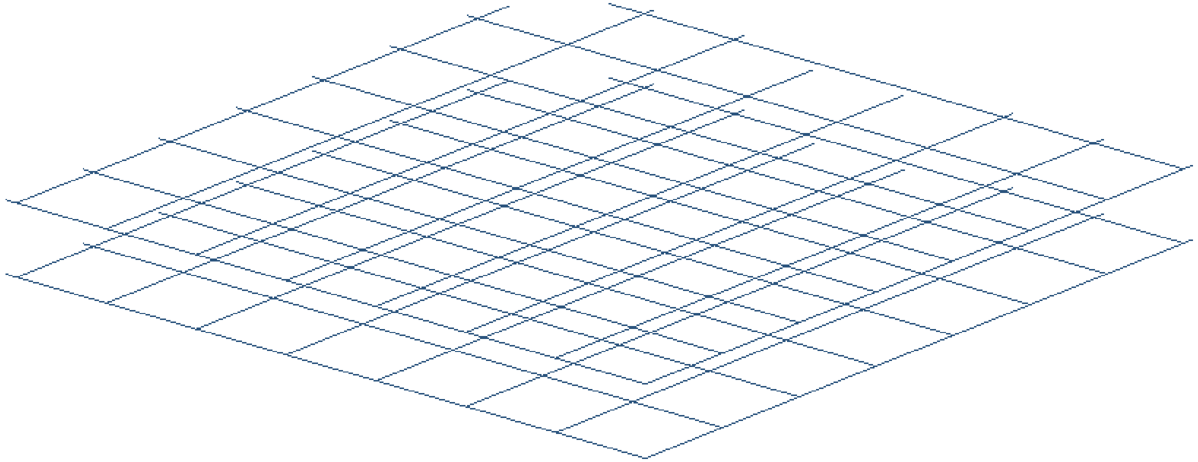
Within these modellings, the influence of the reinforcement modelling is explored :

- 1D common-node with the concrete
- 3D common-node with the concrete
  - Reinforcement grid in a single plan
  - Reinforcement grid with neutral fiber gap

Presentation of the large meshing-size slab S10

DAL02V04





Size : ~ 25 mm

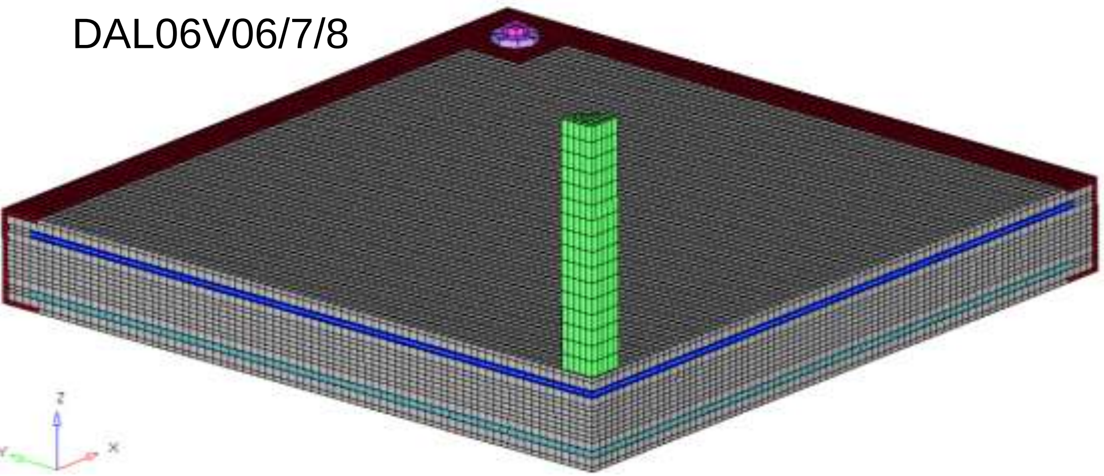
25 316 elements

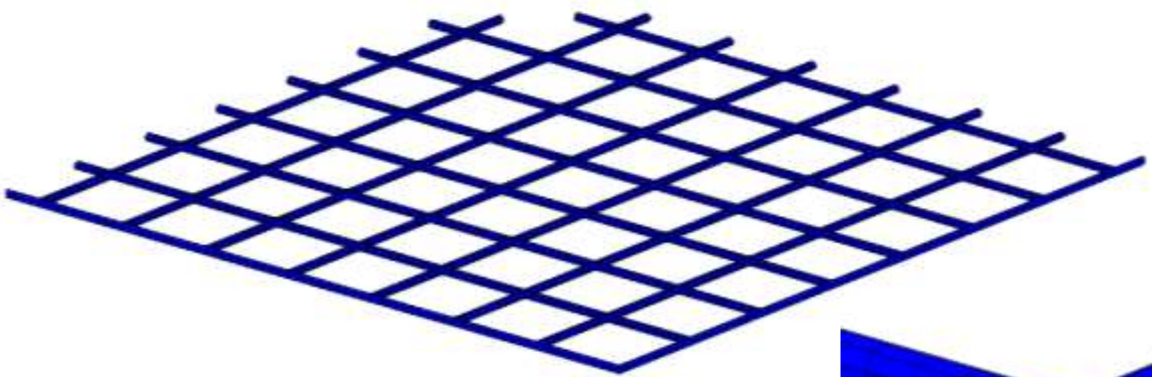
Reinforcement : Beam CN*

** CN = Common nodes*

Presentation of the medium meshing-size slab S2i

DAL06V06/7/8





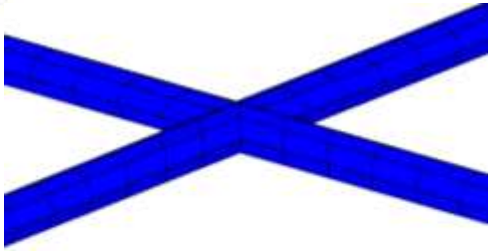
Size : ~ 10 mm

139 960 elements

S21 Reinforcement : Beam CN*

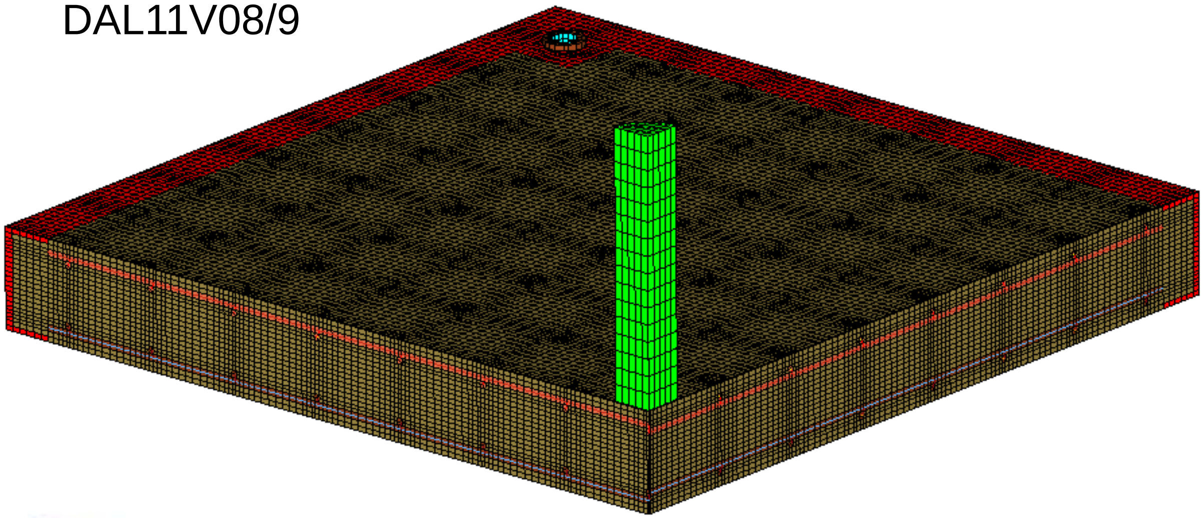
S22 Reinforcement : Solid CN*

S23 Without Reinforcement



Presentation of the small meshing-size slab S3i

DAL11V08/9

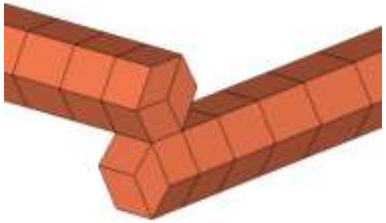


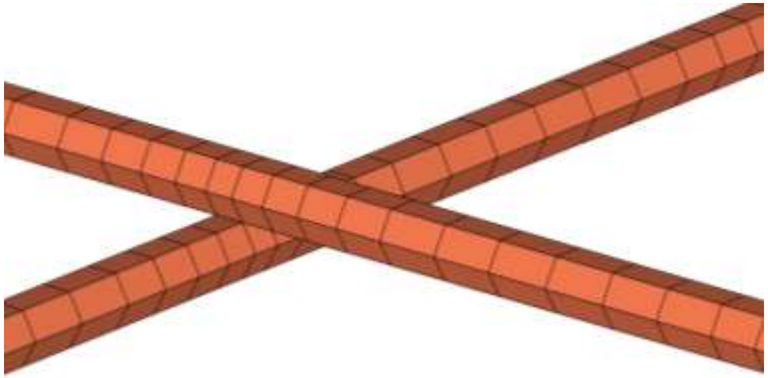
Size : ~ 6 mm

316 890 elements

S31 Reinforcement : Beam CN*

S32 Reinforcement : Solid CN*





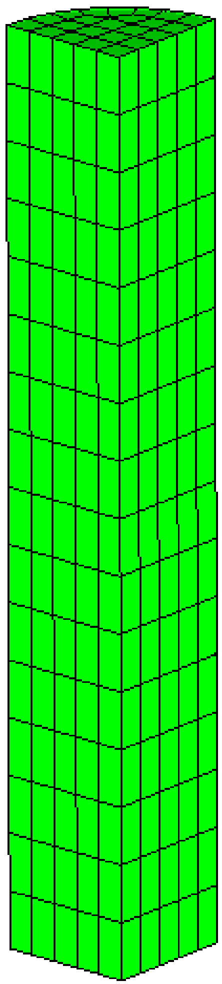
Impactor definition

Material : Steel

Diameter : 120 mm

Mass : 380 kg (full)

Impact Velocity : 8,3 m/s (3,5 m drop off)



Materials

Steels : /MAT/PLAS_JOHNS

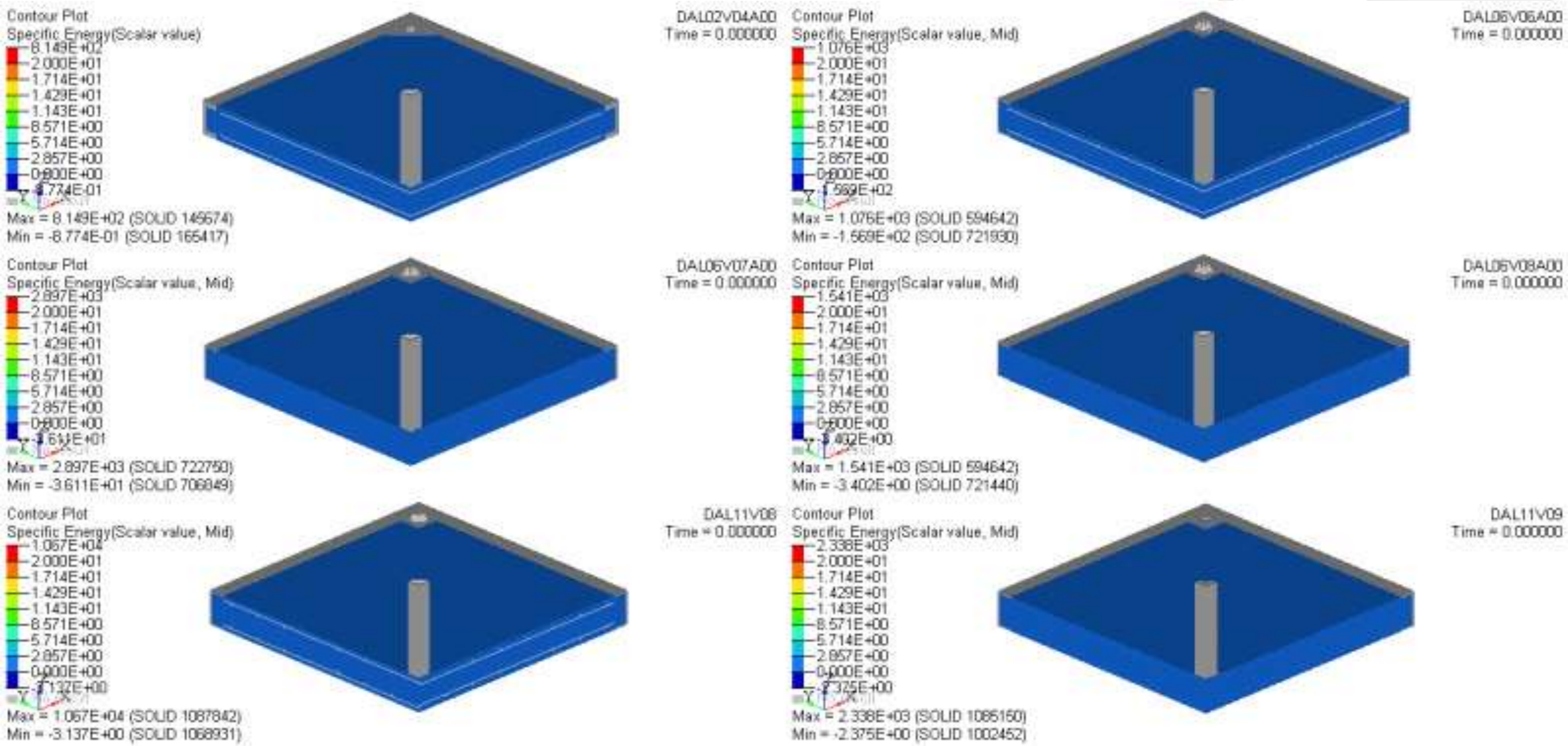
	Frame / Impactor	Reinforcement
ρ (kg/m³)	7850	7850
E (GPa)	210	210
ν	0,3	0,3
σ_e (MPa)	235	500
σ_{max} (MPa)	340	640

Concrete : /MAT/CONC

	Concrete
ρ (kg/m³)	2400
E (GPa)	40
ν	0,2
fc (MPa)	60

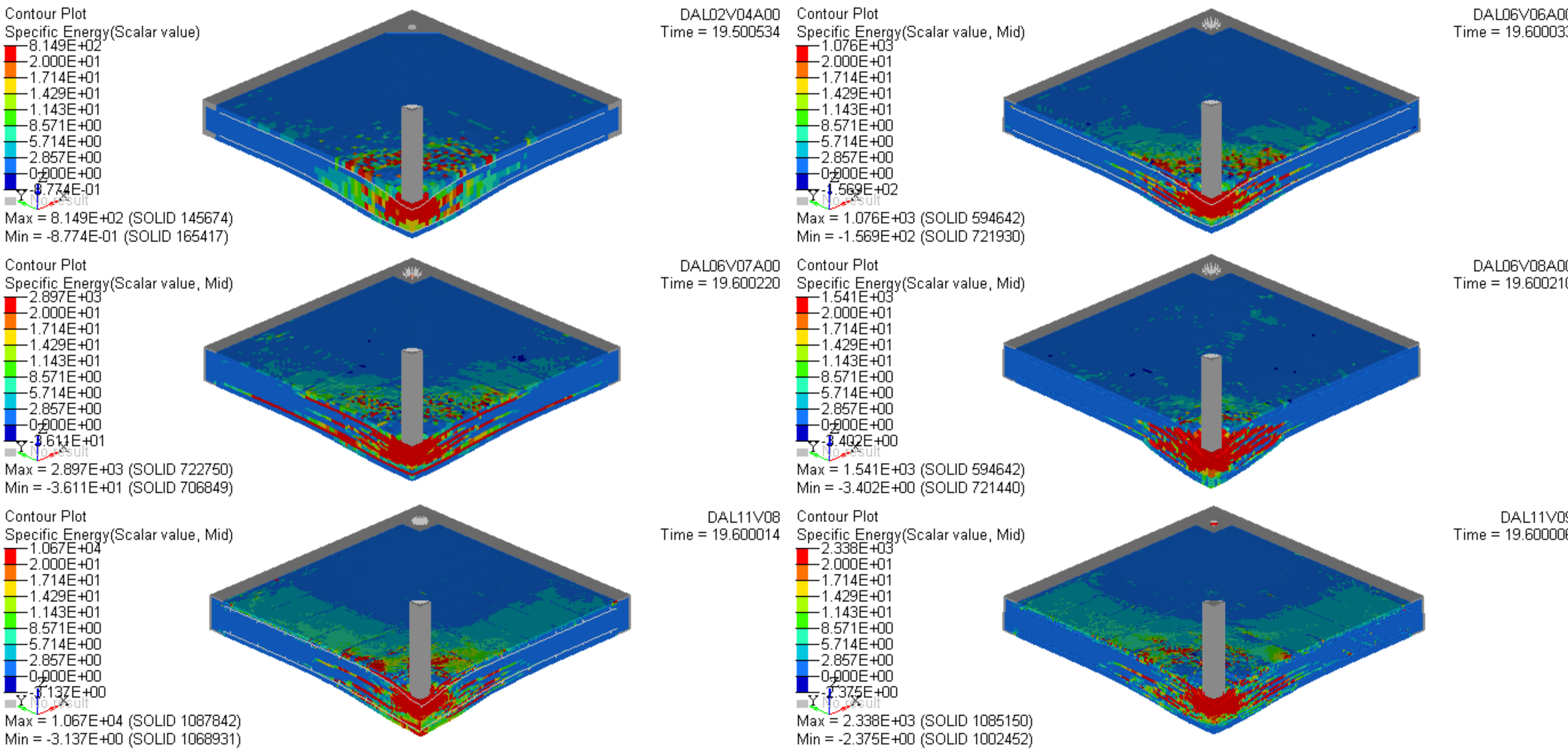
Simulation Results

Evolution of Specific Energy (mJ)



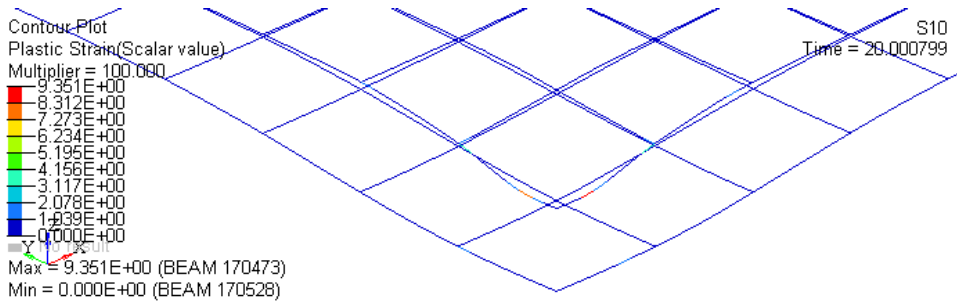
Simulation Results

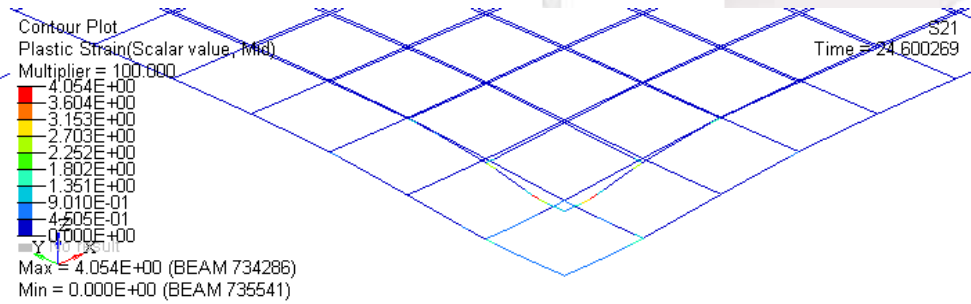
Specific Energy at t ≈ 20 ms (mJ)

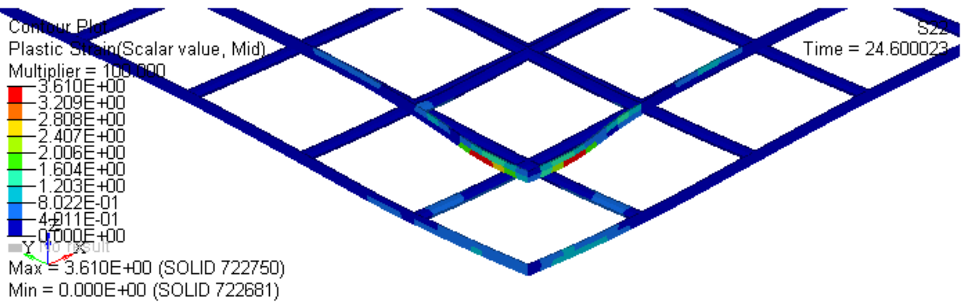


Simulation Results

Plastic Strain of the reinforcement at t ≈ 20 ms (%)







S23
Time = 19.600210

S10 : 9,35 %

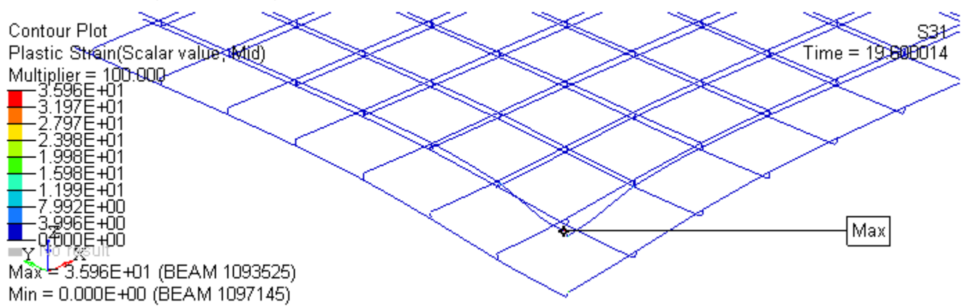
S21 : 4,05 %

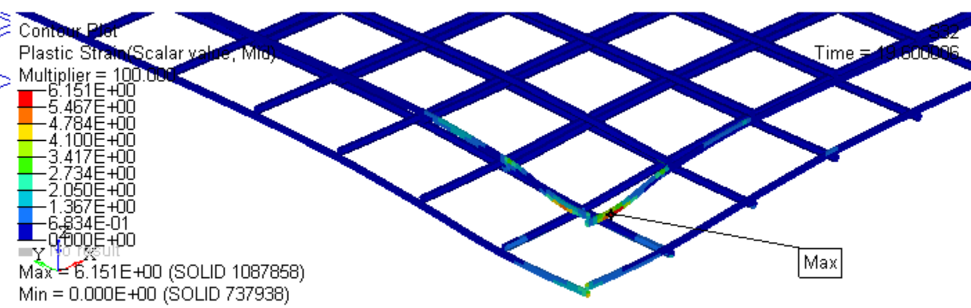
S22 : 3,61 %

S23 : ----

S31 : 3,60 %

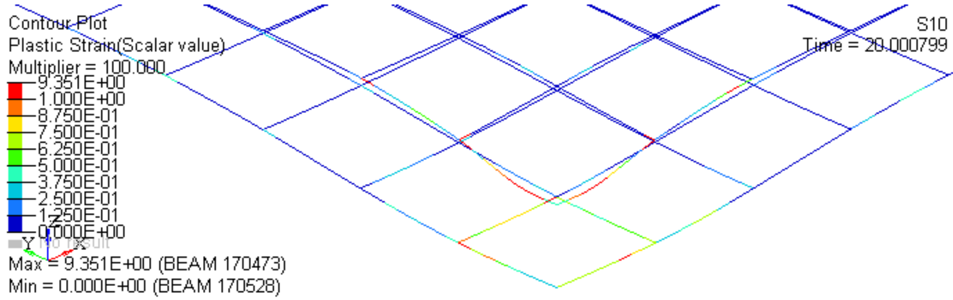
S32 : 6,15 %

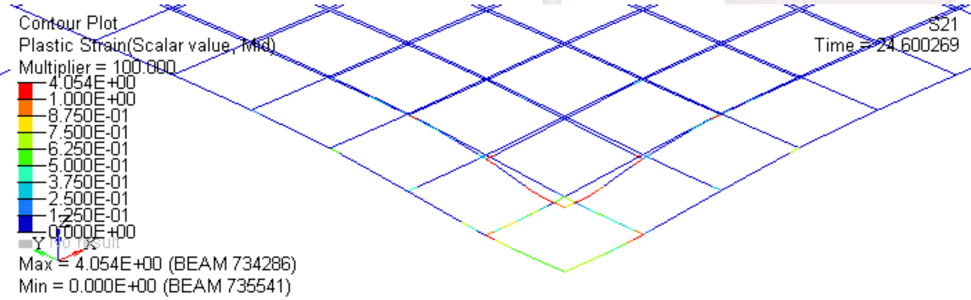


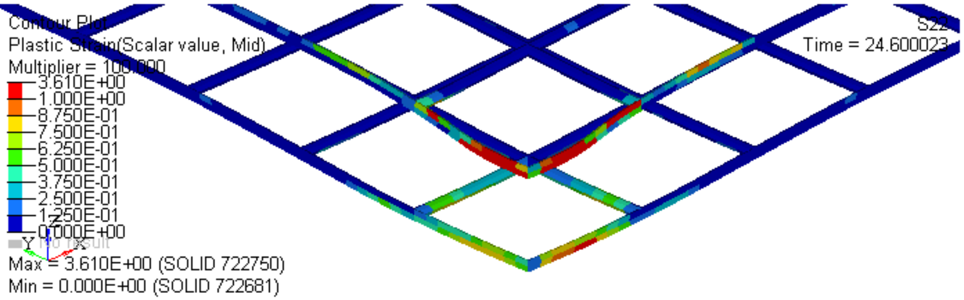


Simulation Results

Plastic Strain of the reinforcement at t ≈ 20 ms (max 1 %)







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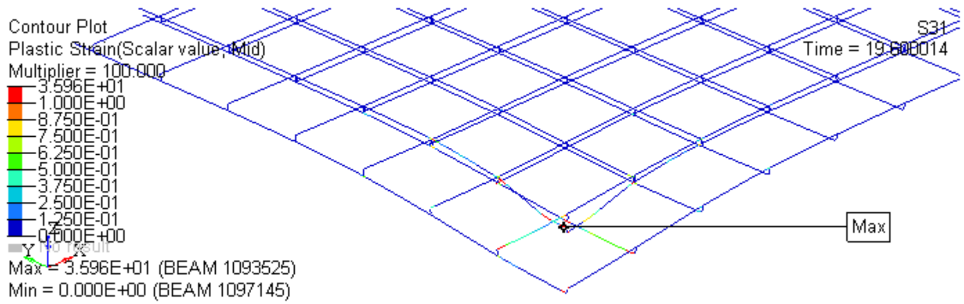
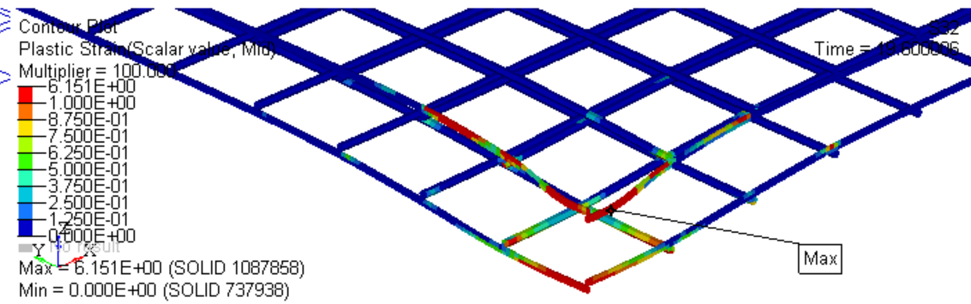
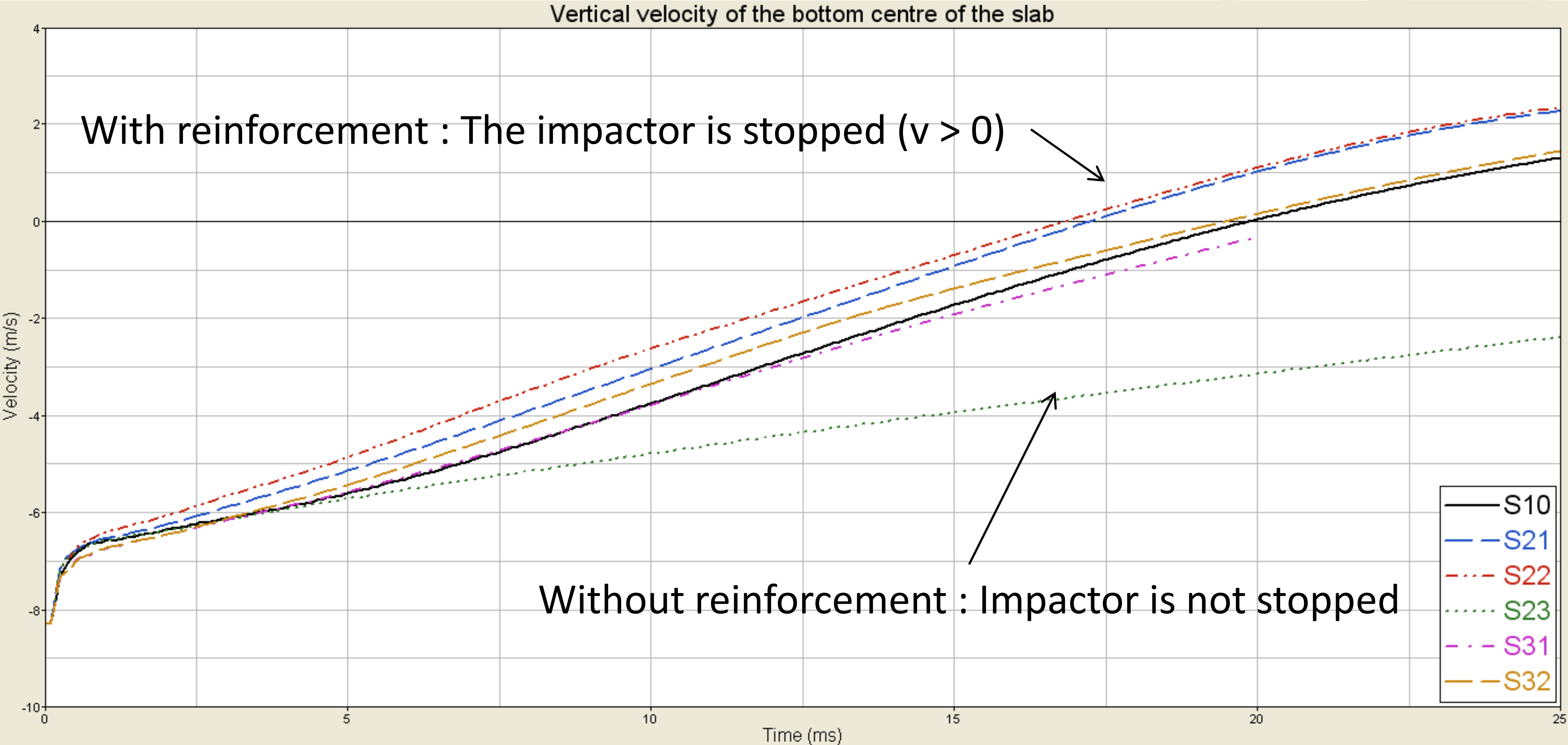




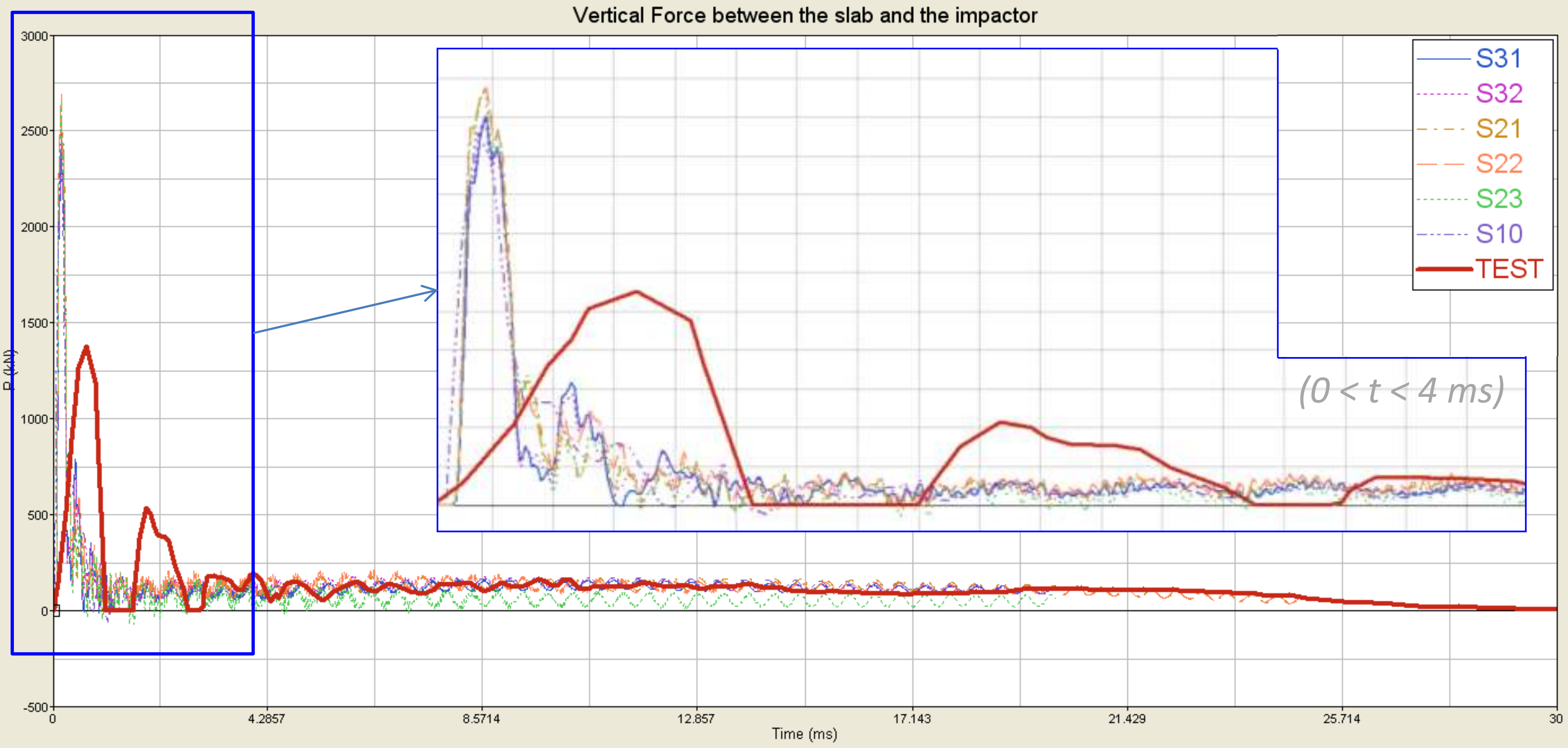
Simulation Results

Velocity of the impactor



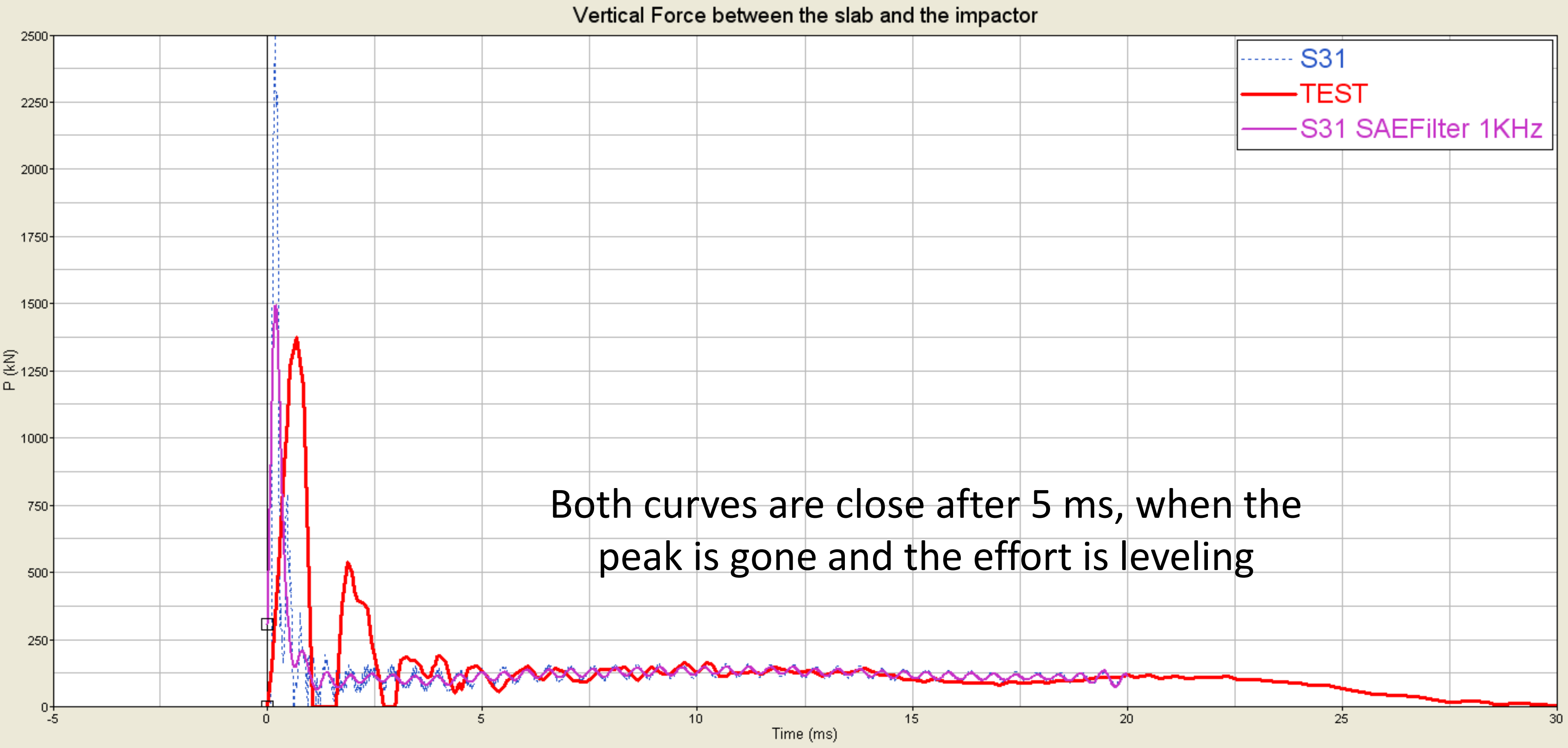
Simulation Results

Force between the impactor and the slab (kN)

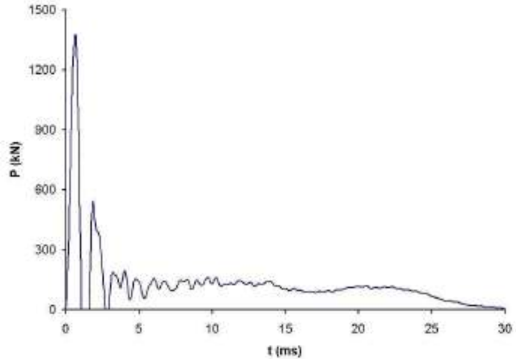


Simulation Results

Force between the impactor and the slab (kN)



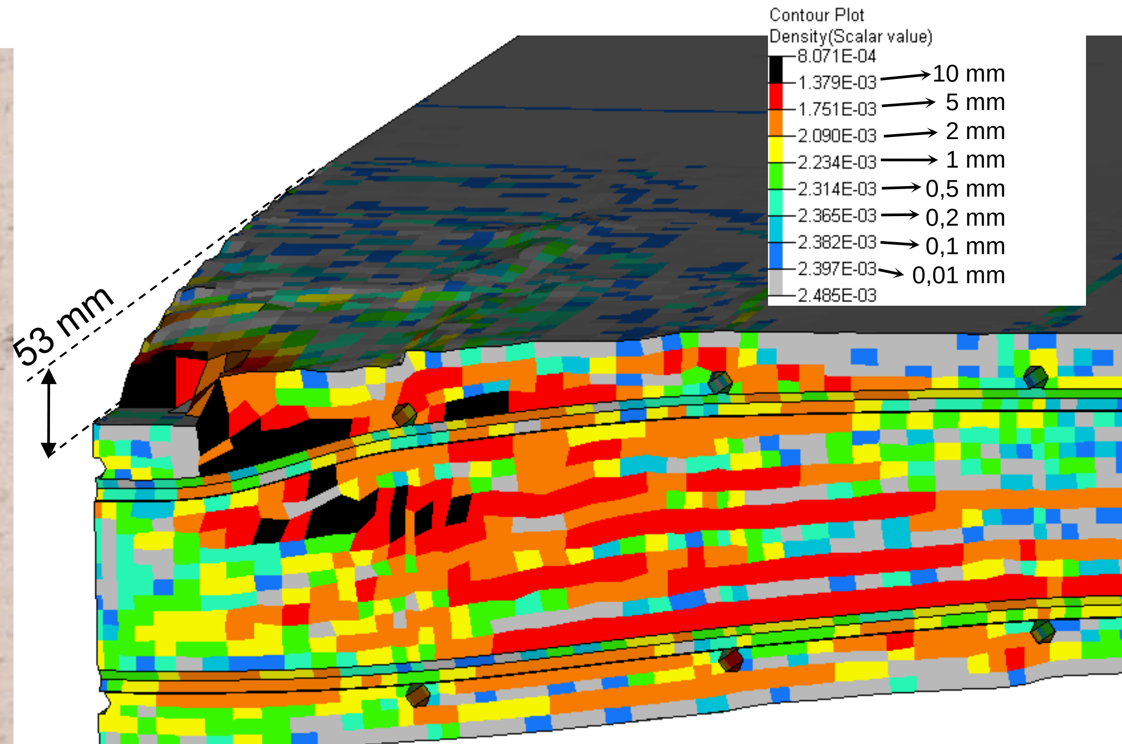
Drop Test Installation



Simulation Results

Estimation of the cracking of slab S31 – comparison with test

Top face

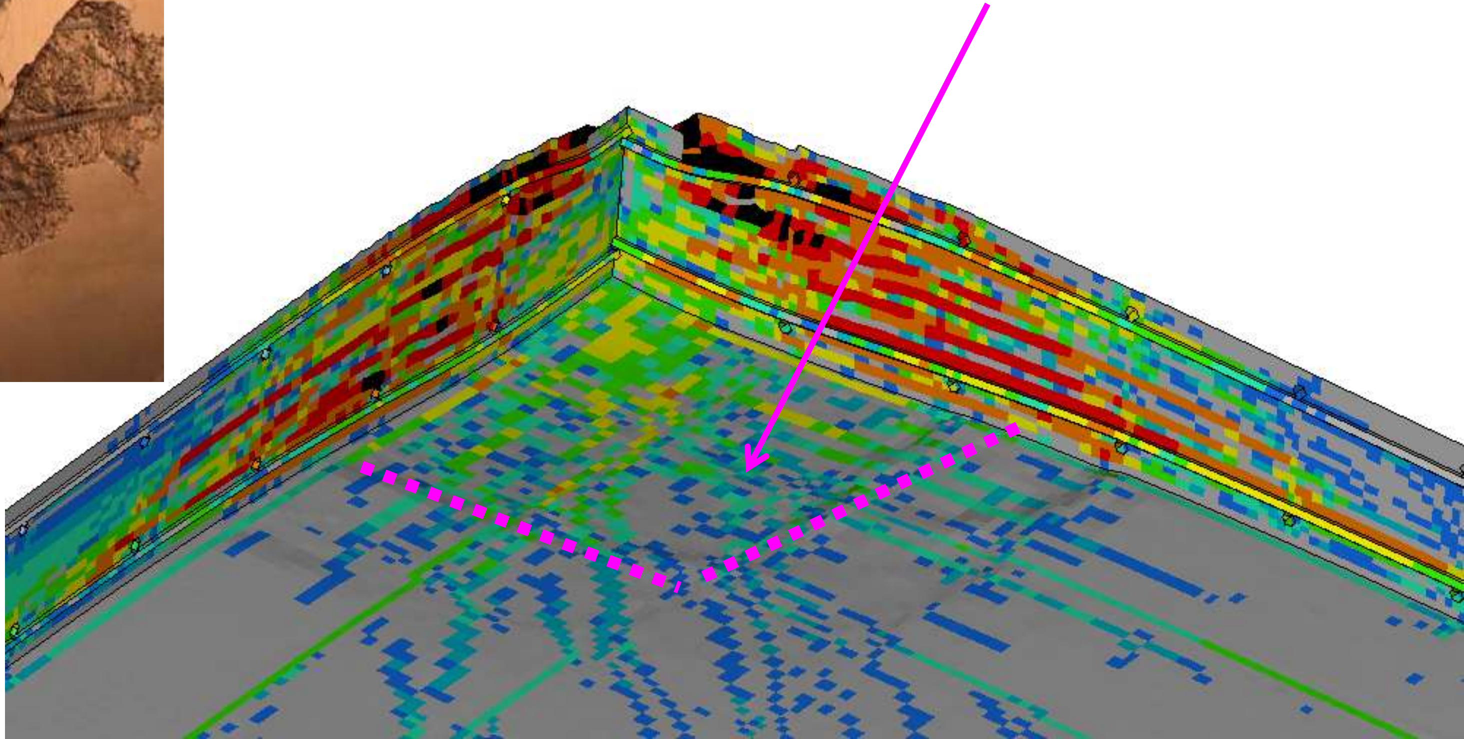


Simulation Results

Estimation of the cracking of slab S31 – comparison with test

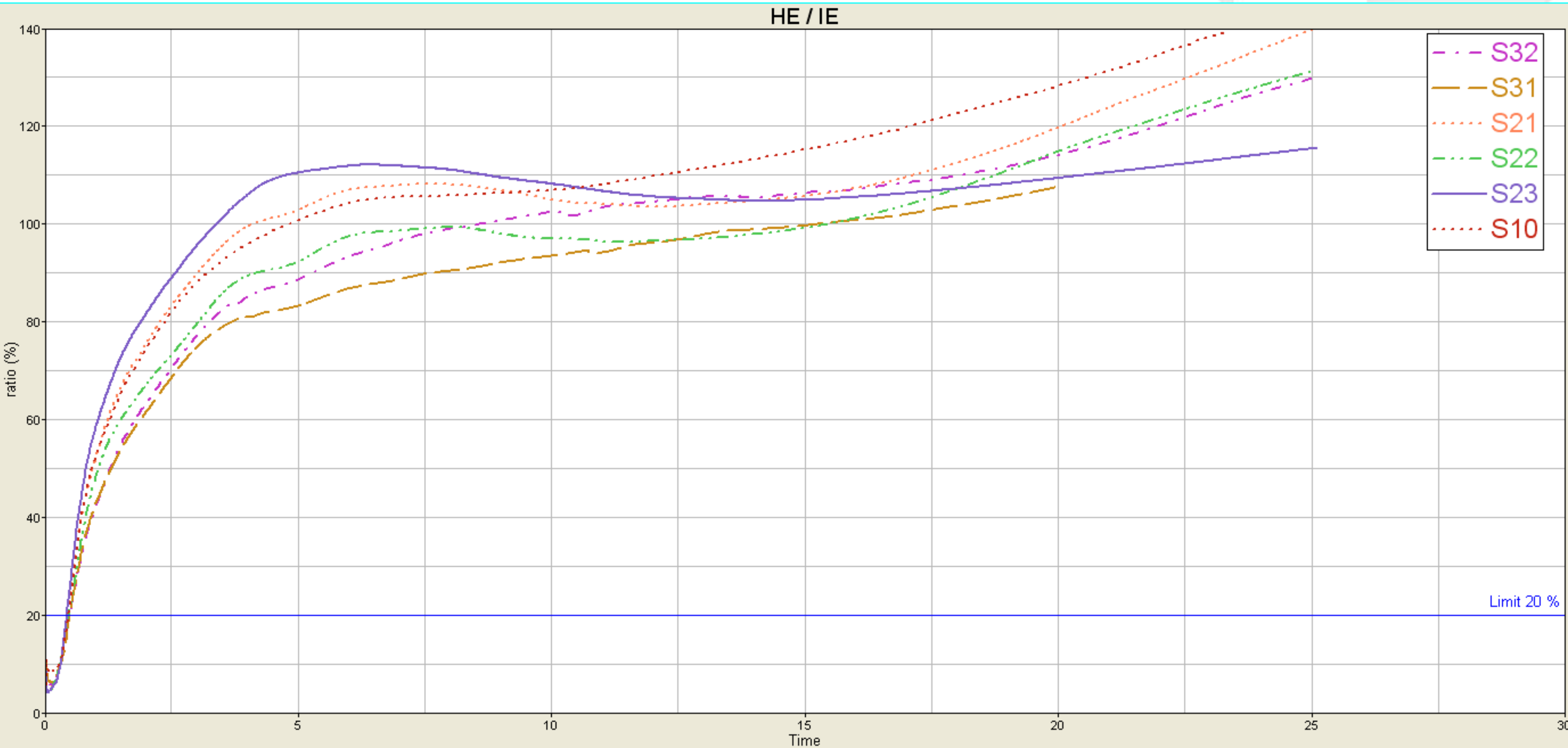
Bottom face

Area of massive cracks in the test



Simulation Results

Comparison between Hourglass and Internal Energies



Conclusions of the impact simulation on a slab

Whatever the modelling is, global variables of the problem stay almost the same.
The simulation ables the user to see the cracking cone inside the thickness of the slab and its propagation along the reinforcement.
The maximum plastic deformation is in the same range for a 1D or a 3D modelling even if the neutral gap can increase a bit the deformation on the external wires.

Although the Hourglass Energy is really important (> IE), the model seems to be close to the real test in terms of vertical force and cracking, except at the beginning of the impact when the rigidity is really different.
This sequence should probably be influenced by the structure above the slab during the test.

Other tests should be runned on simple structure to improve the knowledge like reinforced beams.

Perspectives

Perform calculations under simpler structures and smaller models to make many iterations

Use other elements like TETRA and SPH

Comparison with LS DYNA results using other concrete laws

APPENDIX 1: Crack opening assessment by density contours

Simulation Results

In order to estimate the cracking, we are using the density contour.
Mostly, cracking appears where the structure is in traction. Considering an element can be in traction 1 to 3 directions, and neglecting the deformations on the other directions (Poison effects), the volume variation is directly linked to potential of cracking.

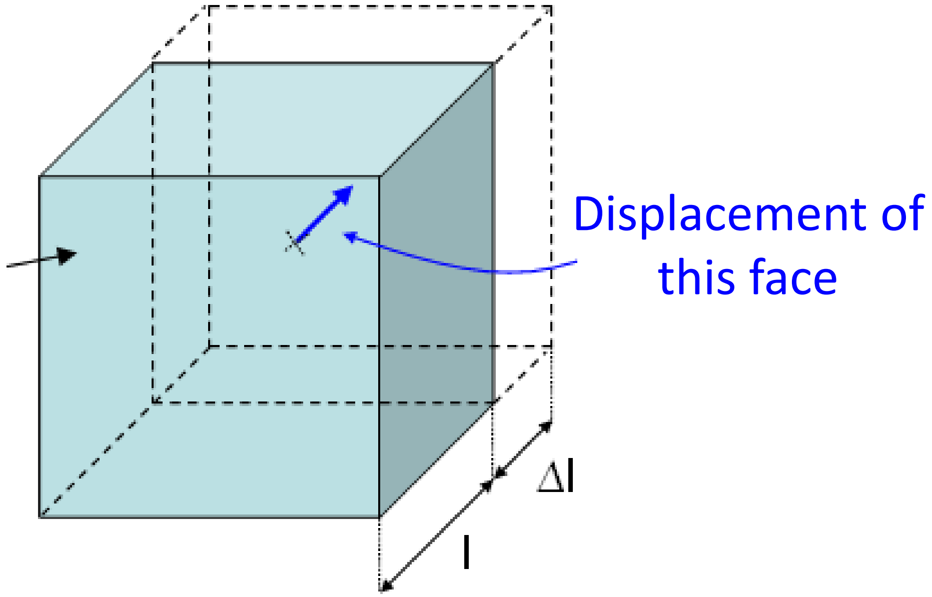
Example & Hypothesis for uniaxial traction :

Elements as perfect cubes
(length = width = height = L)

Initial density = 2400 kg/m3

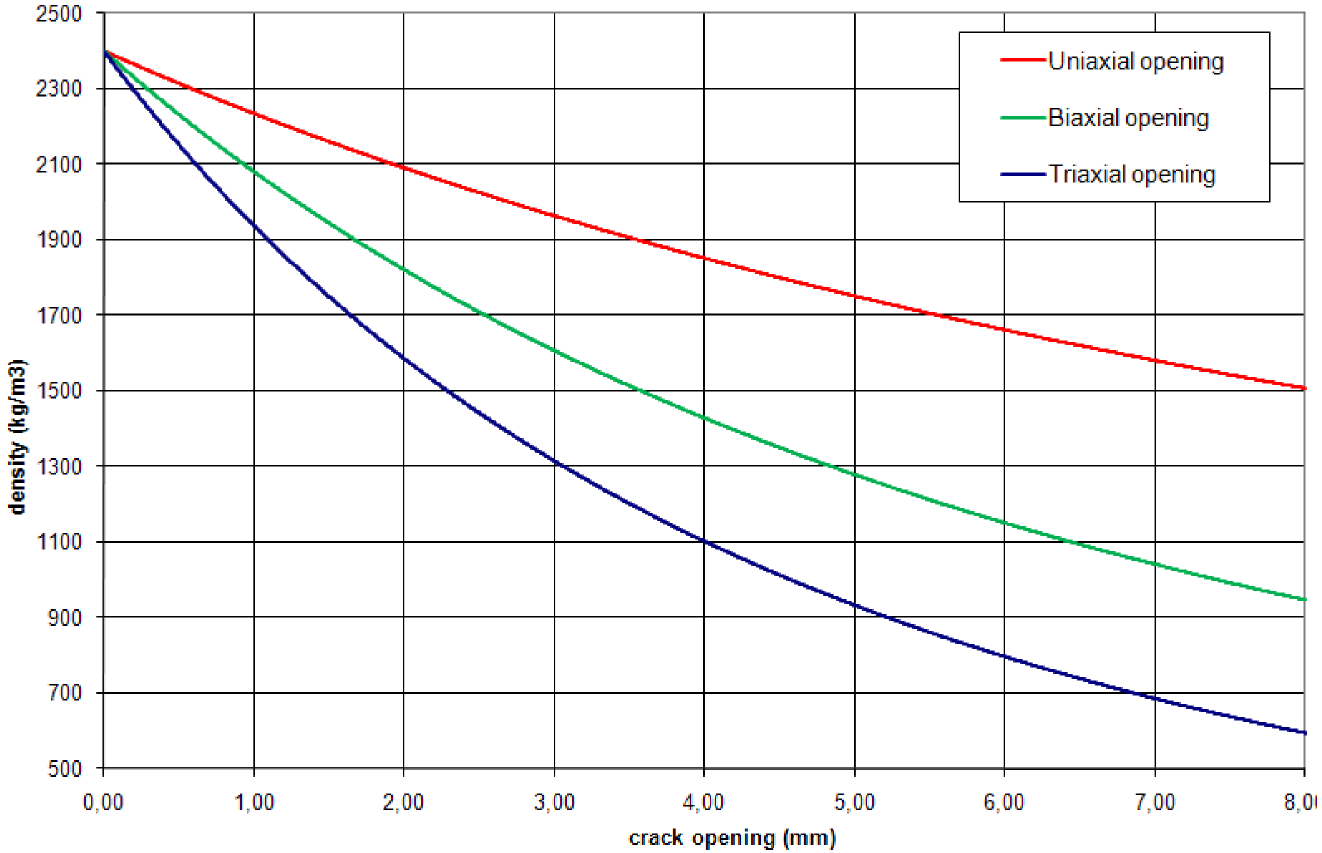
Initial volume = L^3

Final volume = $(L + \Delta L)^3$



Simulation Results

For the 3 kinds of solicitations, the crack opening can be estimate by the density contour, considering the uniaxial opening as the worst for a fixed density.



APPENDIX 2: Drop tests on reinforced beams

DOE of drop tests on reinforced beams:

Variables:

Beam modelling: 8 types

2 impactor shapes : cylinder and hemispheric

Concrete properties: fc= 32, 60, 90MPa

Impactor speed: 2, 5 and 8 m/s

$\Rightarrow$**Complete DOE leads to 144 calculations**

Responses:

max of force, acceleration and displacement,

Speed at simulation end

Ratio Hourglass energy on Internal energy (HE/IE)

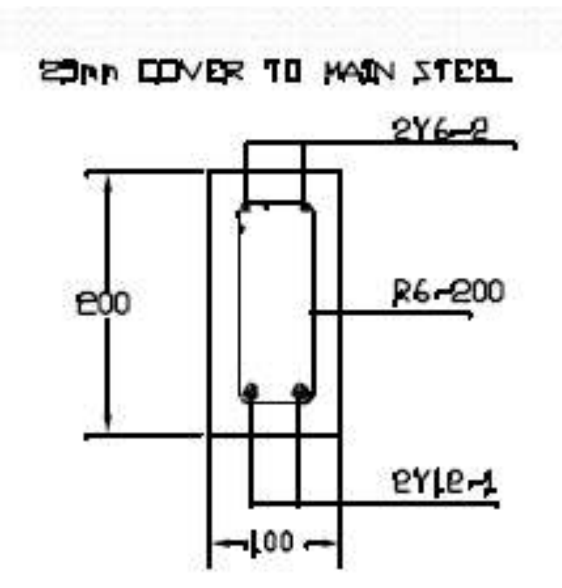
Max plastic deformation of reinforcement

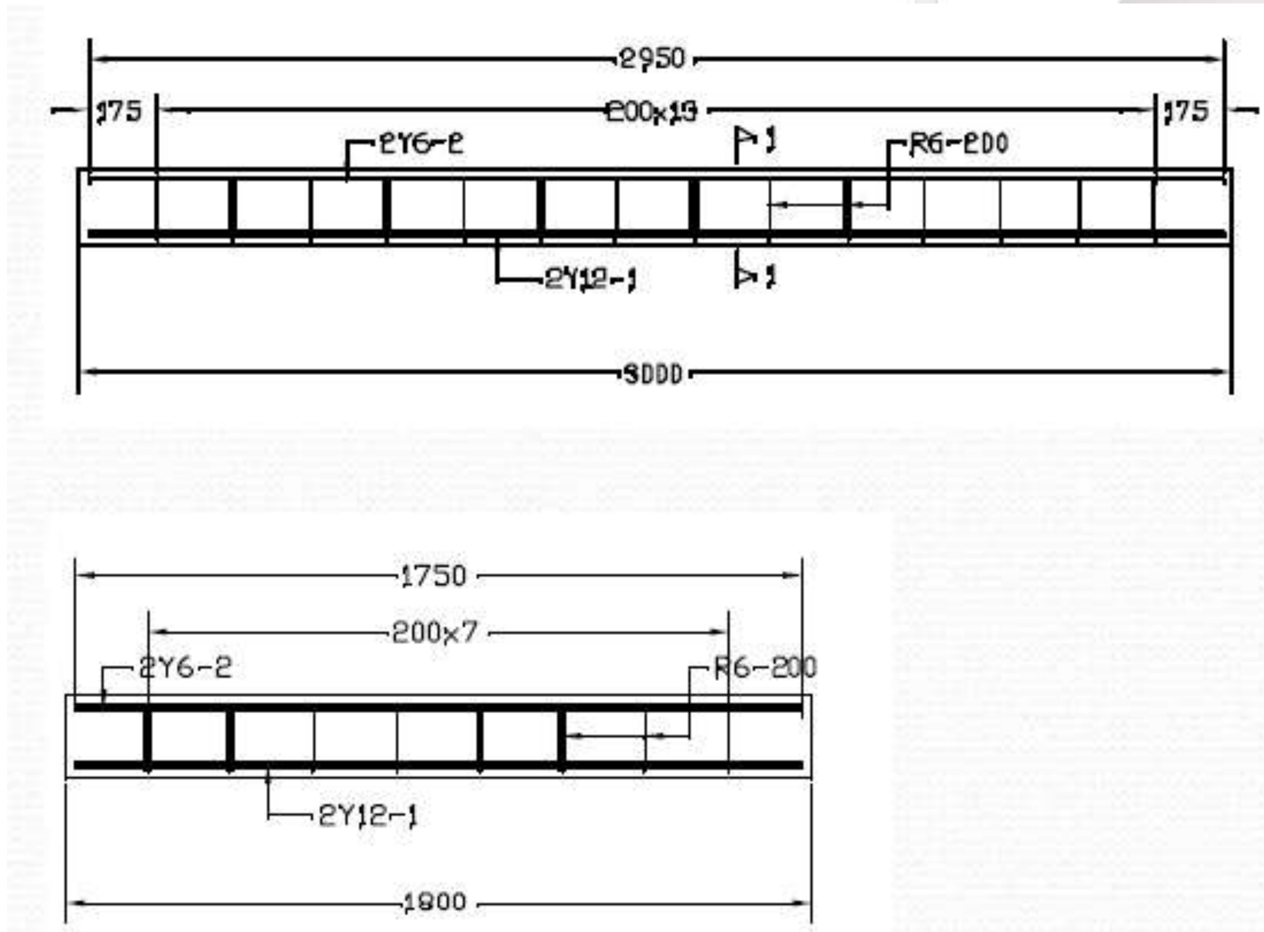
Tools and analysis:

All calculations made with RADIOSS

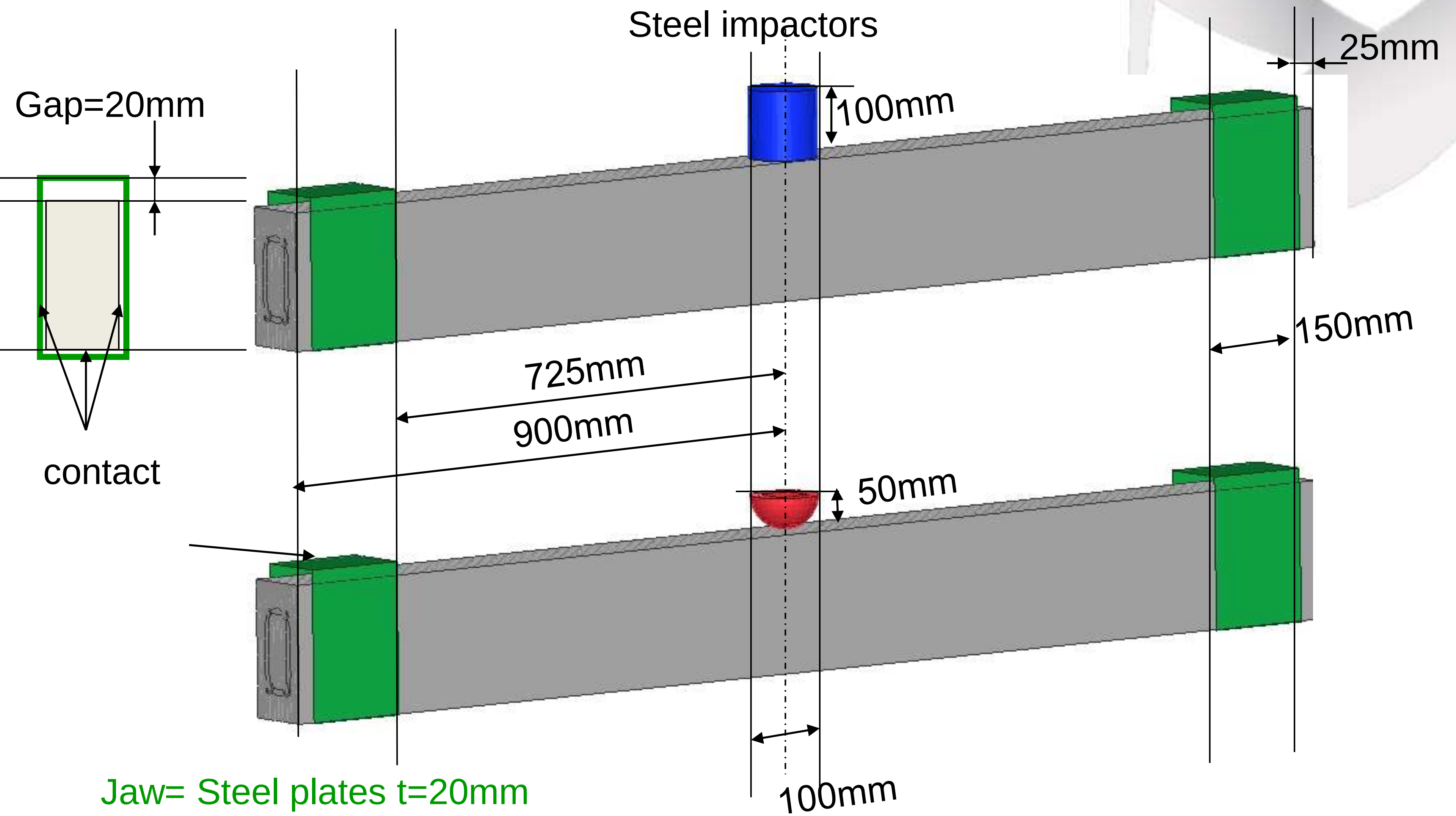
DOE built and analysed with HyperstudyDSS

Two geometries: one section and two lenghts





Loadcase and boundary conditions

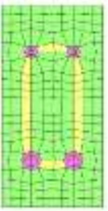


Jaw= Steel plates t=20mm

Beams modelling:

0. Direct in the law n°24: volumic percentage of steel /concrete by direction

1 .No reinforcement: only concrete



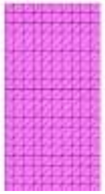
2. Reinforcement modelized by brick elements: common nodes between steel and concrete

3. Reinforcement modelized by beam elements: common nodes between steel and concrete

4. Reinforcement modelized by beam elements fixed on concrete bricks by a type 2 interface

5. Perfect Brick mesh + reinforcement modelized by beam elements: common nodes between steel and concrete

6. TETRA mesh + reinforcement modelized by beam elements fixed on concrete bricks by a type 2 interface



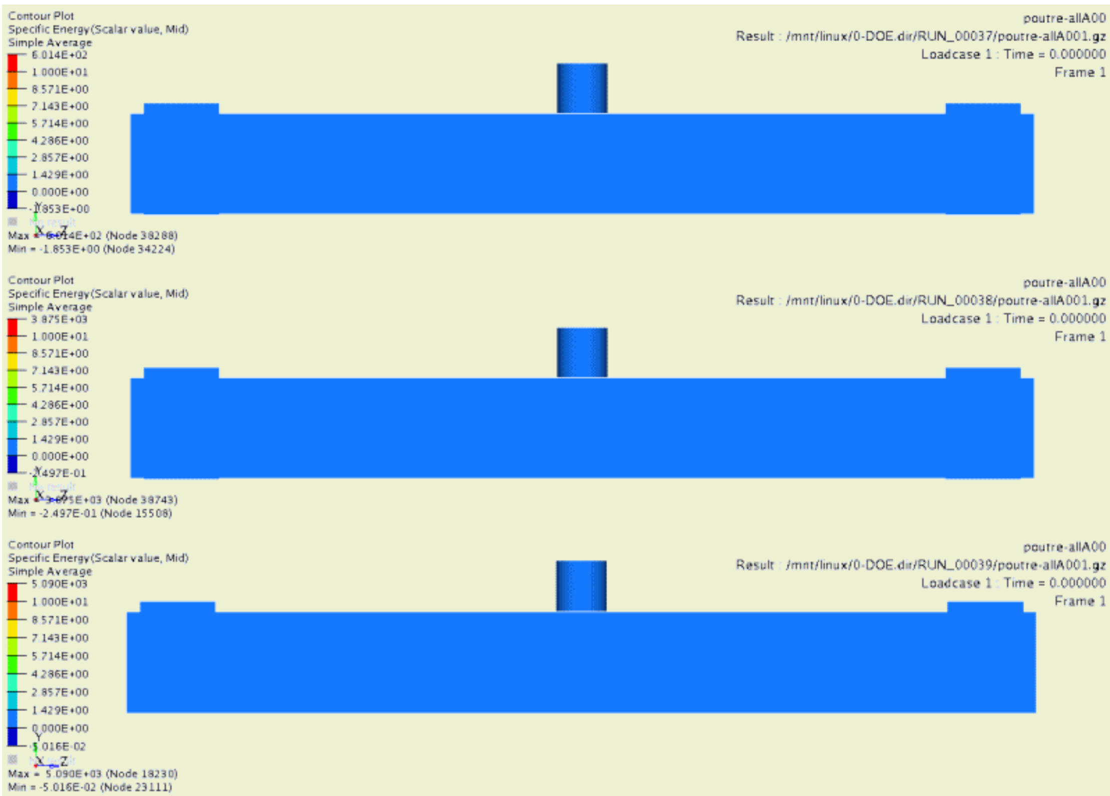
7. SPH mesh for concrete + Reinforcement modelized by bricks elements. SPH are fixed on concrete bricks by a type 2 interface

Animation: contour specific energy (mJ/g)

2m/s

5m/s

8m/s



- Punching at the top face
- Oblique cracks
- Propagation of cracks near the bottom reinforcement
- Beam bending
- Concrete burst at the bottom face

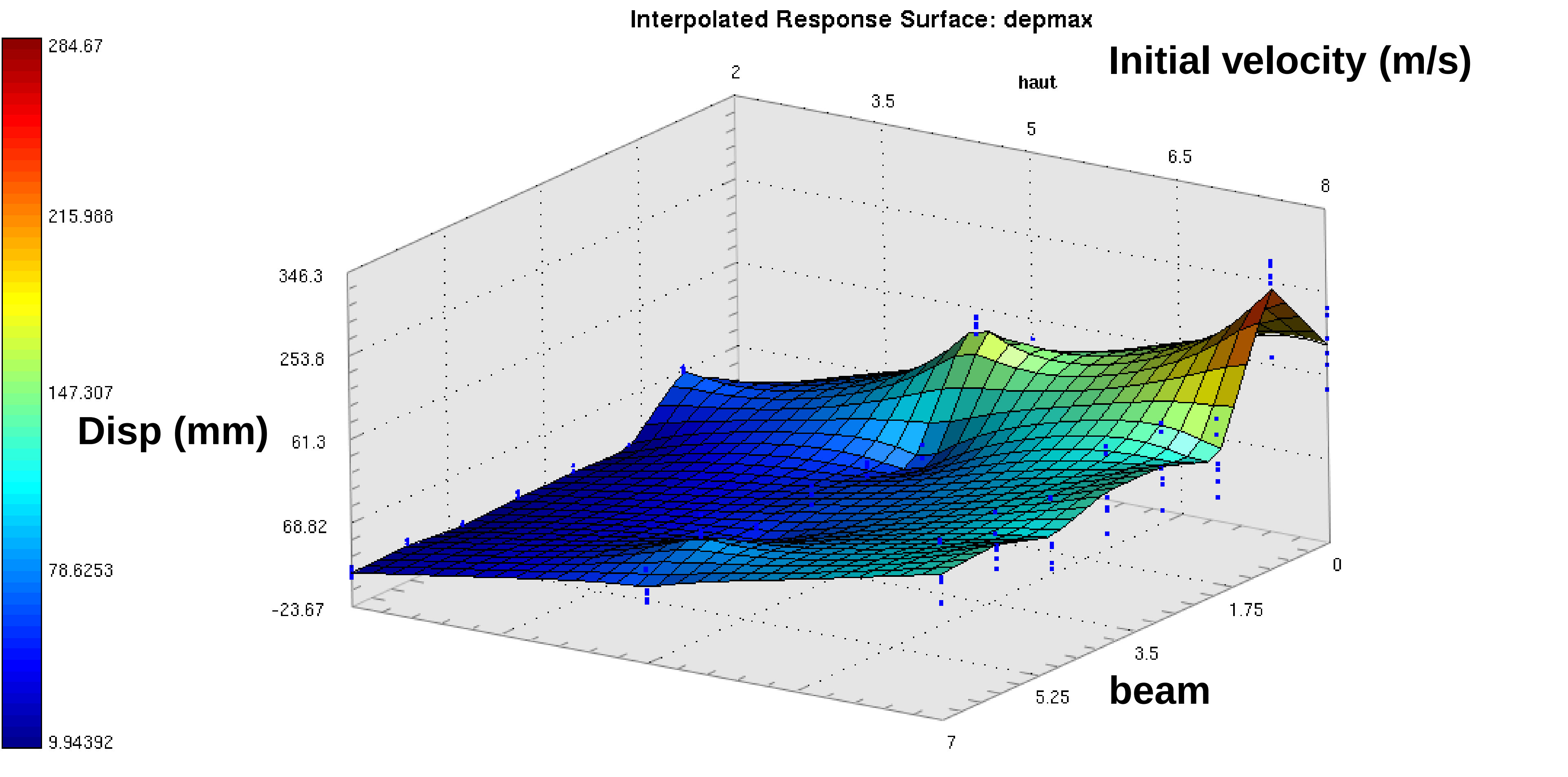
Impactor= cylinder

BEAM 2: all in bricks: concrete and reinforcement (Isolid=1 and Iframe=2)

Concrete fc=32MPa

Response surface :

Impactor max displacement=f(beam, initial velocity)



Response surface of HE/IE=f(beam, initial velocity)

1= 100% !!!