REFERENCE

e=MSC engineering. education. enterprise. 2009VPD virtual product development conference

Blast Protection of Pylon of Cable-Stayed Bridge

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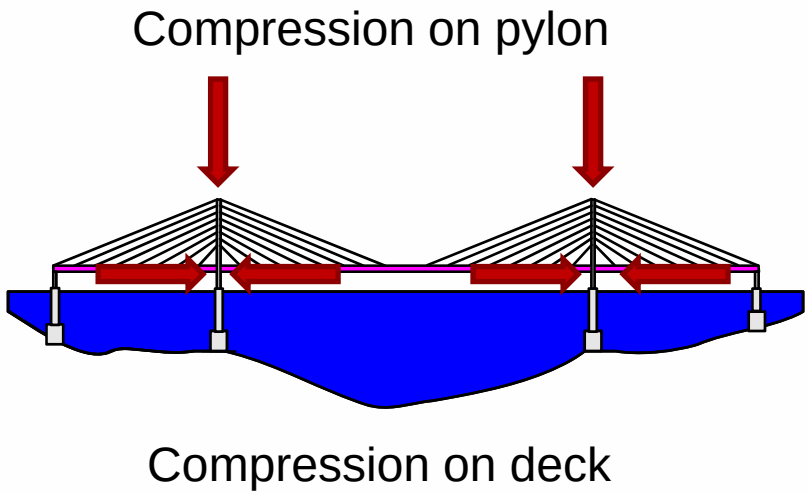
MSC Software

Research Objectives

- Investigate behavior of cable supported bridges subjected to car bombs
- Develop and recommend technologies to increase blast-resistance of bridges
- Depending on the response, develop technologies and recommendations to improve the response in terms of limiting local damage and preventing global progressive collapse.
- Investigate the performance of two types of pylon under blast loading. (hollow and concrete-filled)

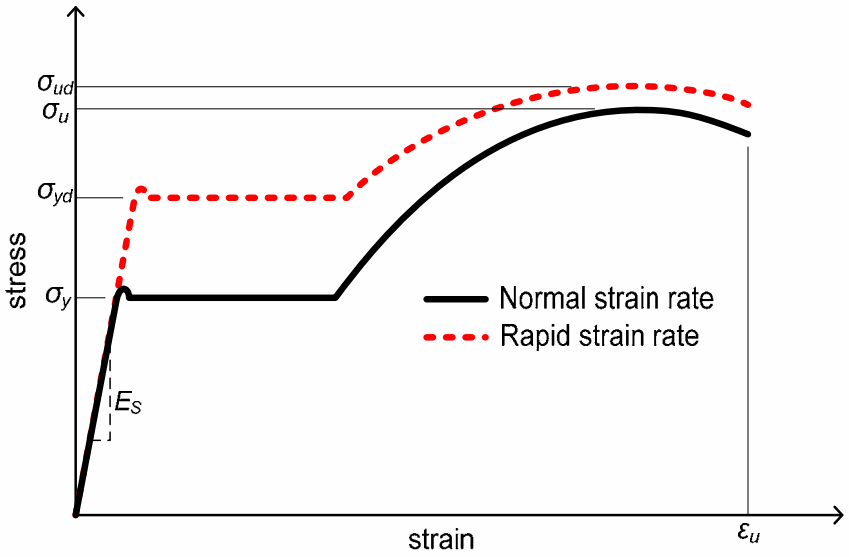
Study Bridge

- Cable-Stayed Bridge

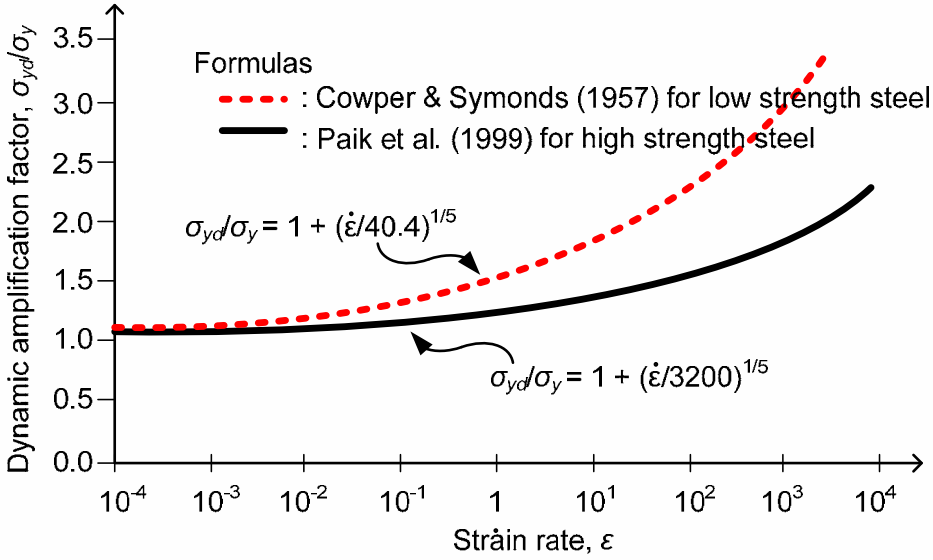


Material – steel (strain rates effect)

- No effect on elastic modulus and ultimate strain
- Yield and ultimate stress are depending on strain rates



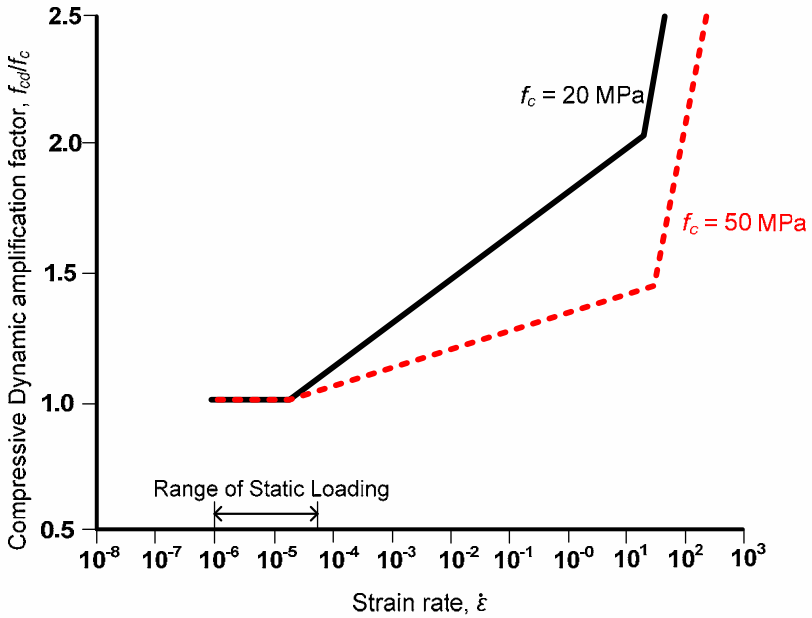
Typical stress-strain curves



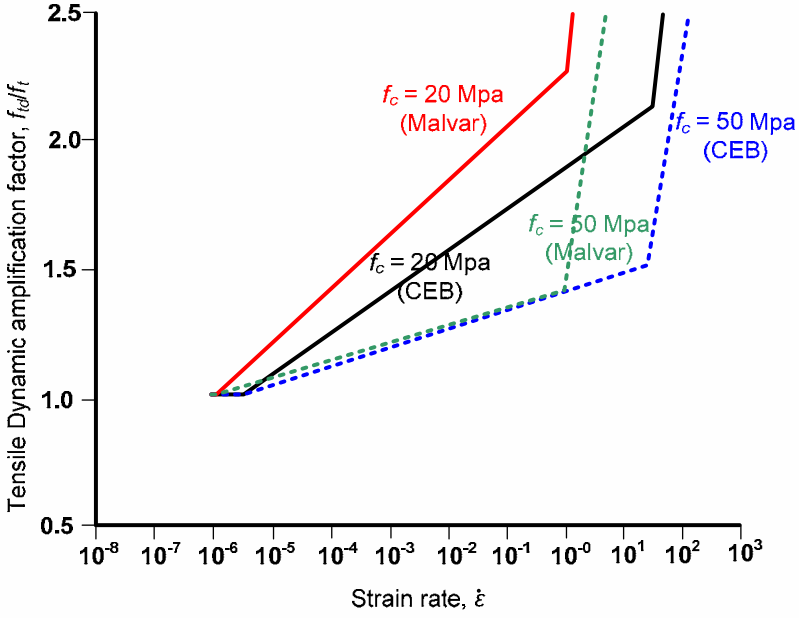
Strain rate effect

Material – concrete (strain rates effect)

- Different behavior under tension and compression
- Yield and ultimate stress are depending on strain rates



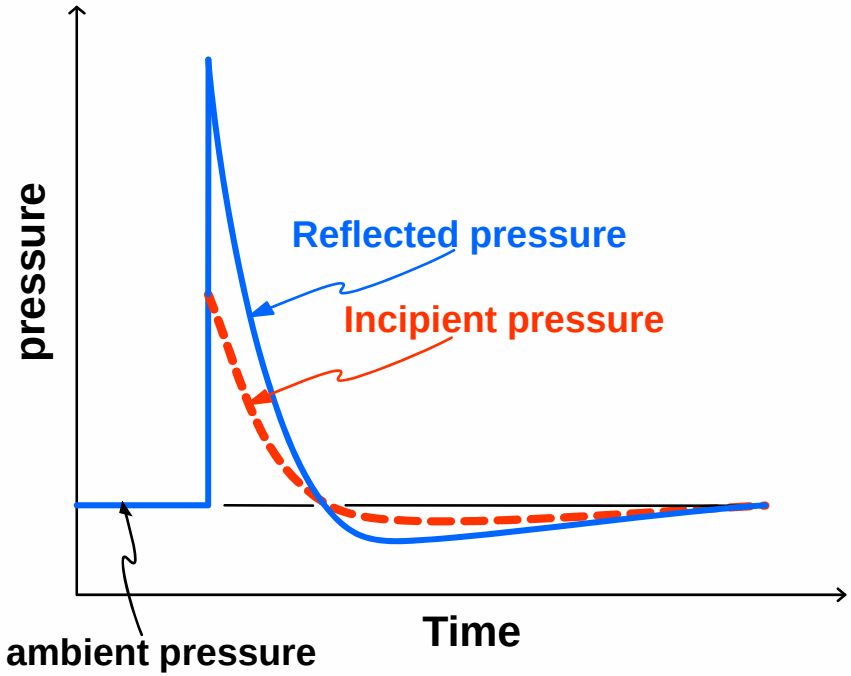
Strain rate effect (compression)



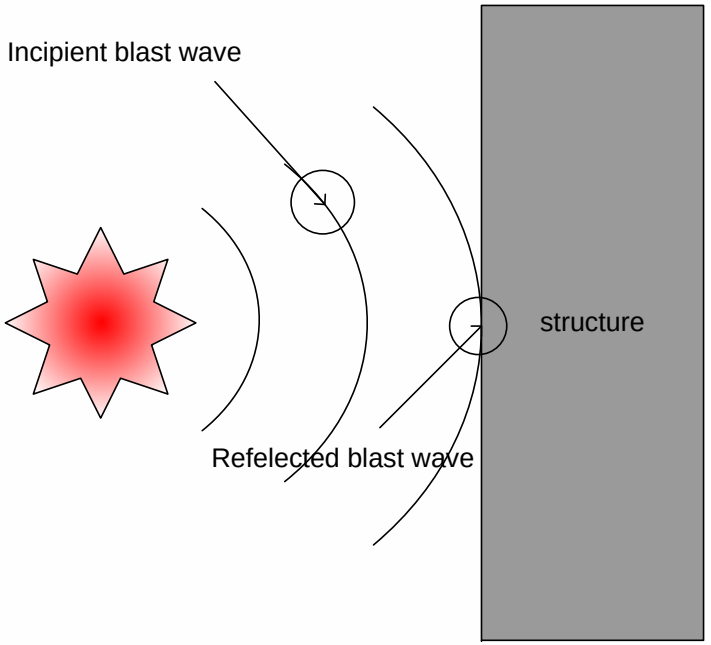
Strain rate effect (tension)

Effect of Blasts on a Structure

- Explosion is the process of a rapid energy release which generates a blast wave
- Two types of blast waves
  - Incipient blast wave: generated pressure wave in the free air after explosion
  - Reflected blast wave: the pressure wave hitting a solid structure

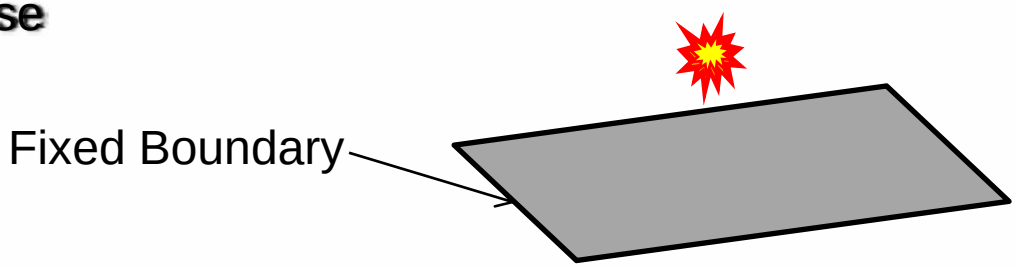


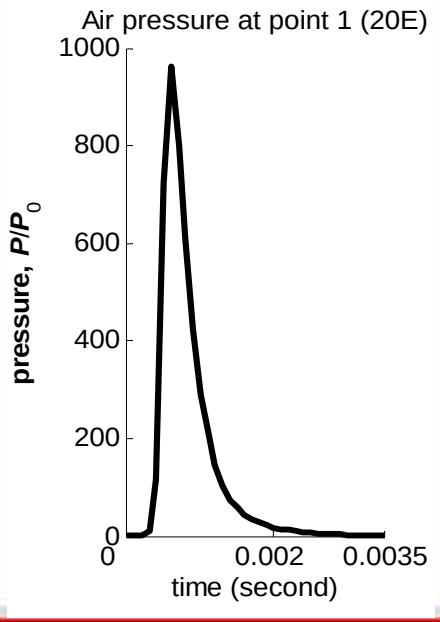
Blast wave profile

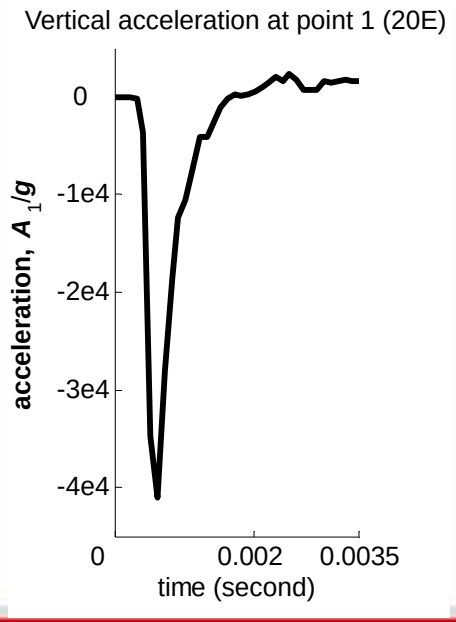


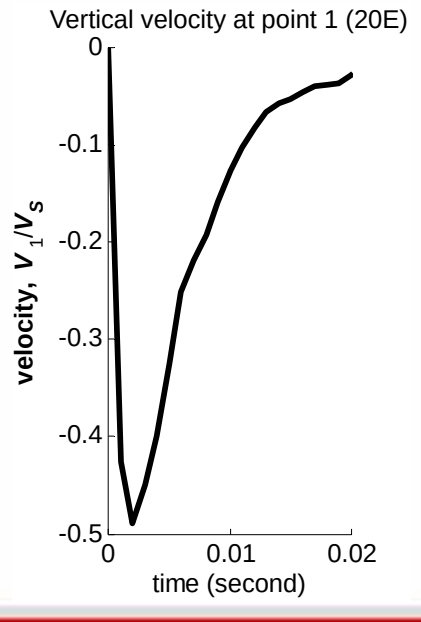
Simple test of blast on plate

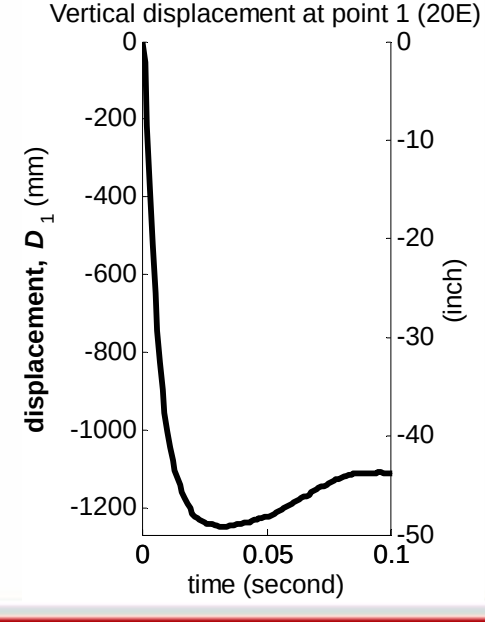
- Pressure profile is almost the same as acceleration profile.
- Other responses such as velocity and displacement reached peaks quite later than acceleration response





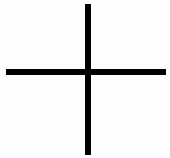






MD Nastran SOL700

- Dytran
  - General Coupling and Fast Coupling Algorithm
  - Roe Solver technique
  - Adaptive Euler mesh, etc

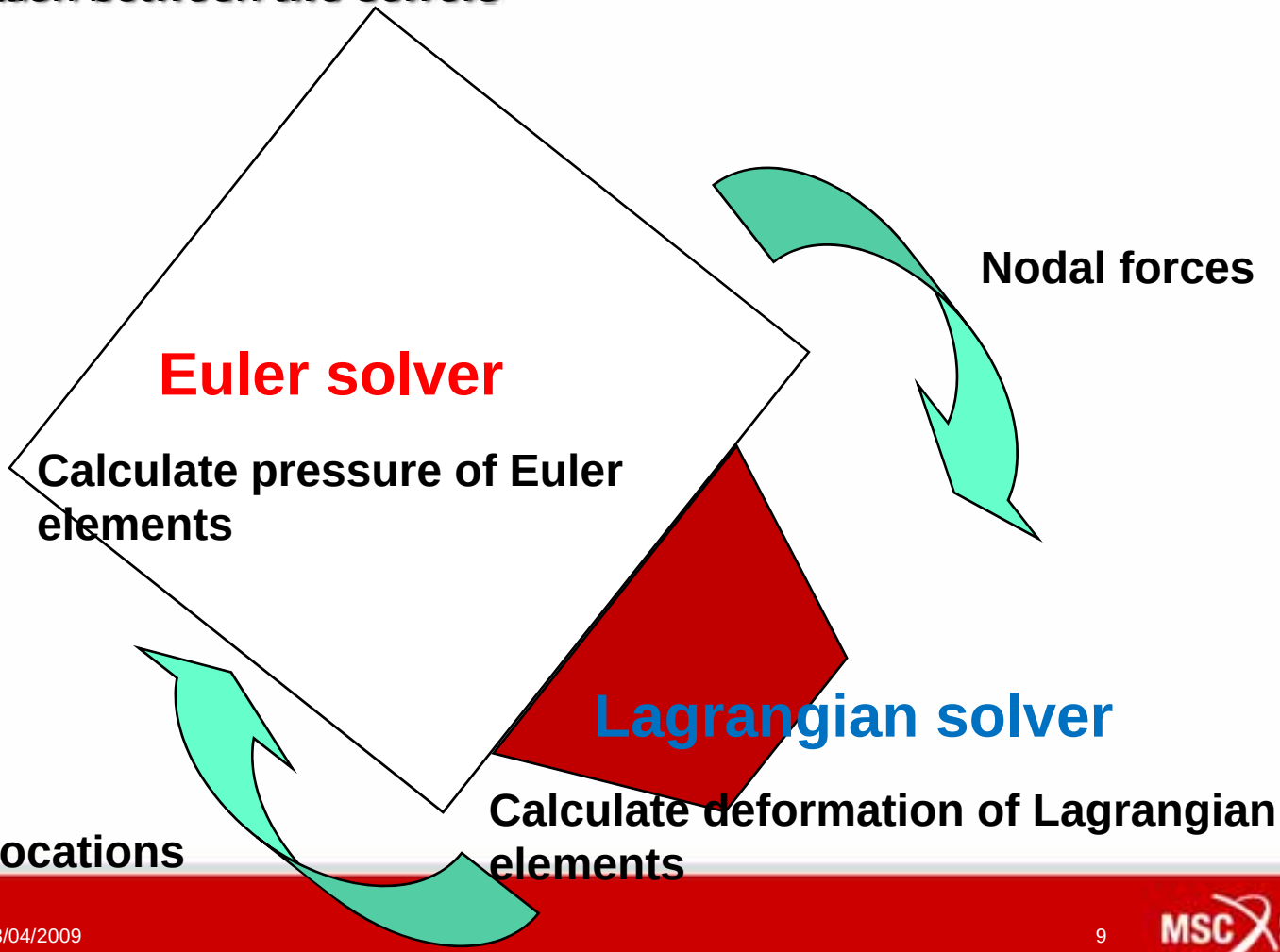


= MD SOL700

- LS-Dyna
  - Around 200 material properties
  - Over 100 element formulation
  - Advanced contact algorithm

MD Nastran SOL700 FSI scheme

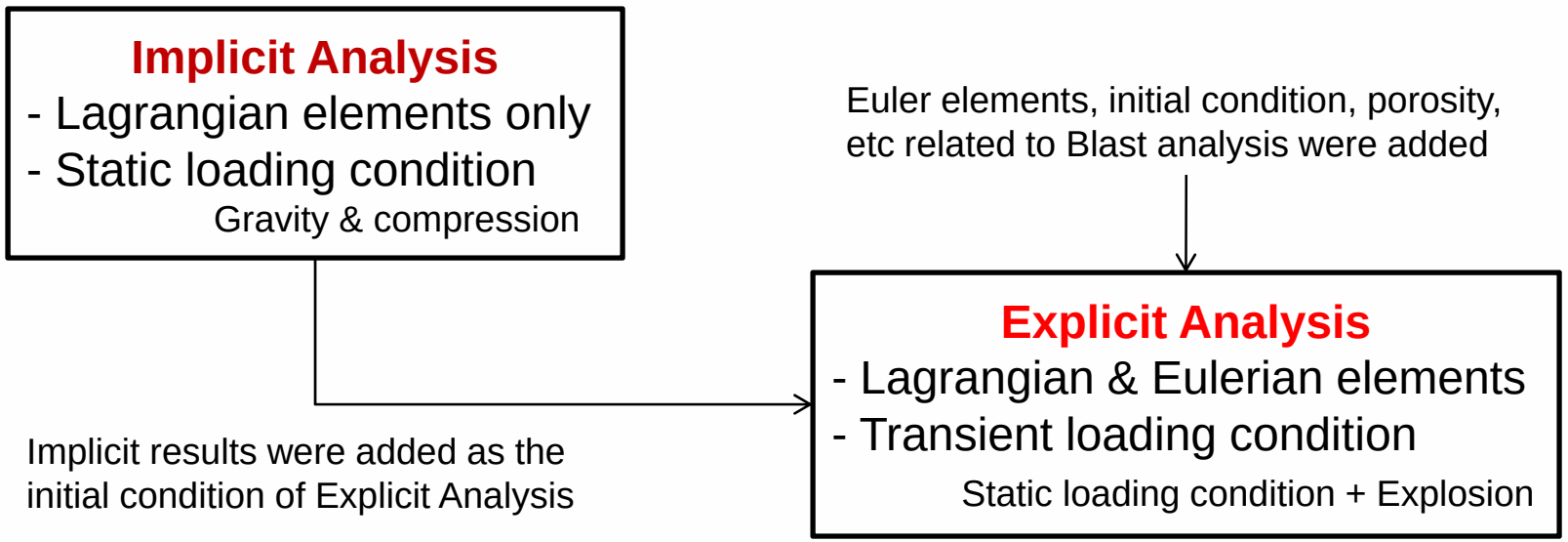
- Full integration of Two solvers (Eulerian and Lagranian)
- Communication between two solvers



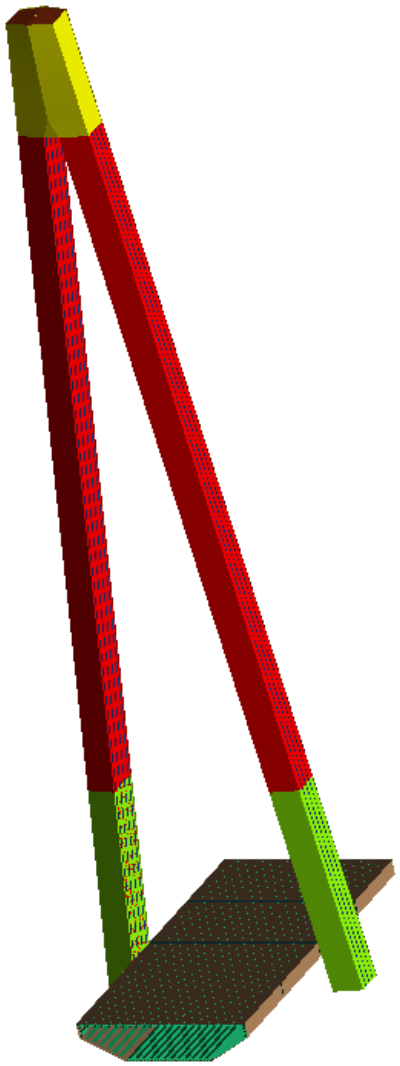
Analysis scheme

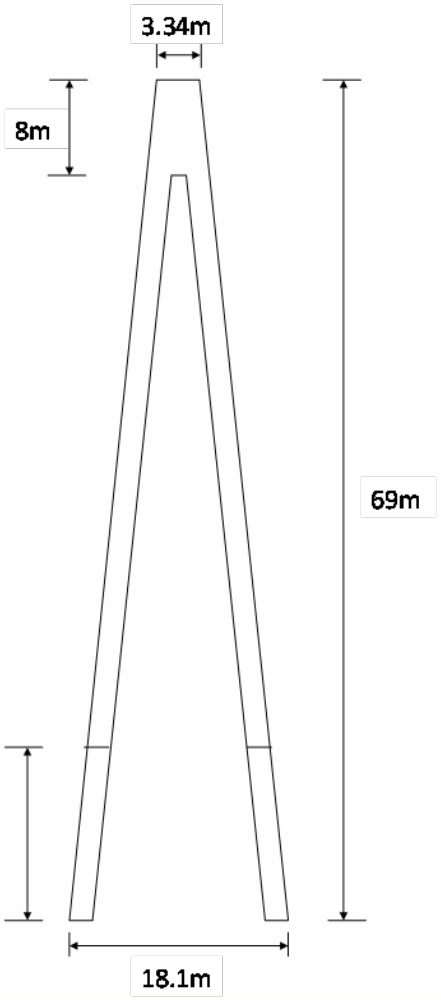
- Two models were compared:
  - hollow pylon (general)
  - concrete-filled pylon (reinforced)

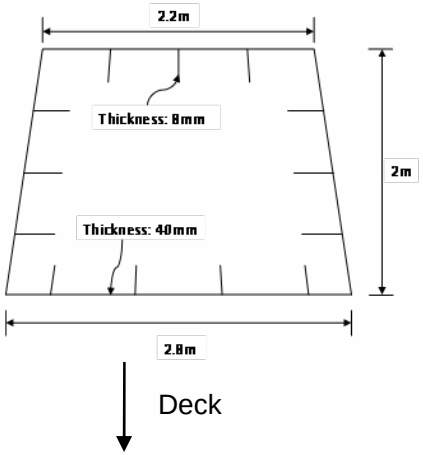
- For both cases, the same analysis scheme was used.



Model (pylon)

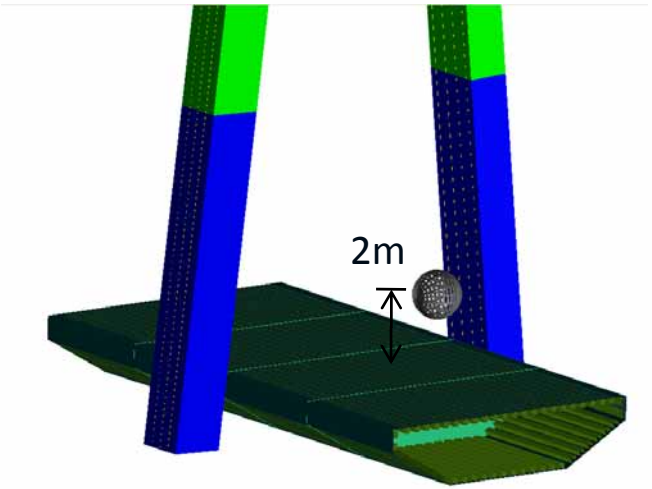



3.34m
8m
69m
14.2m
(Concrete filled case)
18.1m

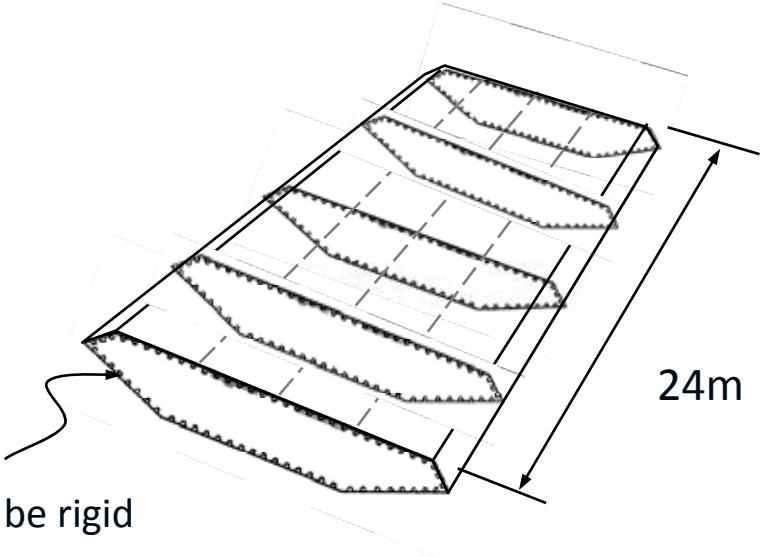

2.2m
Thickness: 8mm
2m
Thickness: 40mm
2.8m
Deck

Model (deck & explosive)

- Explosive
  - modelled by sphere
  - Explosive type: TNT
  - Radius: 1m



- Deck



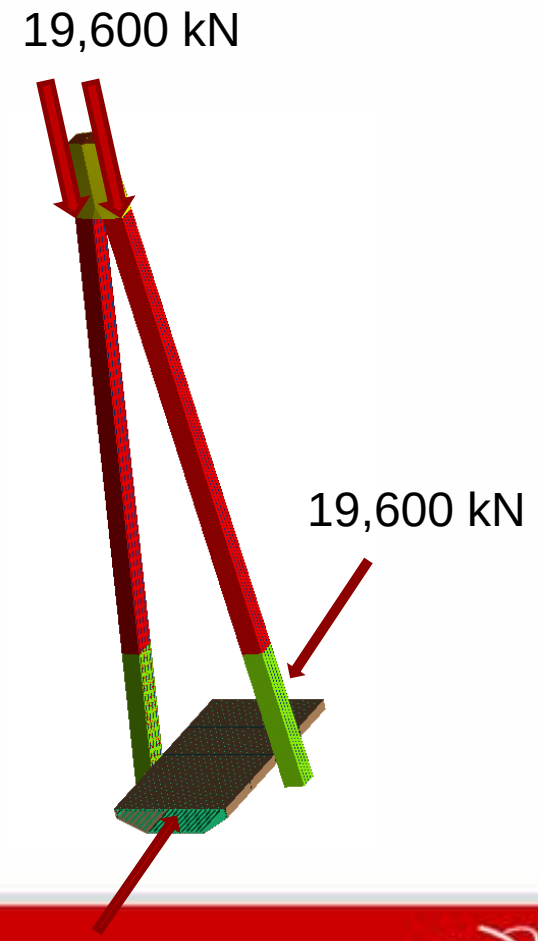
Ends were
considered to be rigid

Applied techniques

- Implicit to Explicit Chaining Analysis
- SOL700 FSI
- Control activation of Euler elements and coupling surfaces
- Porosities between Euler domains
- Adaptive (Erode) Contacts between Lagrangian elements

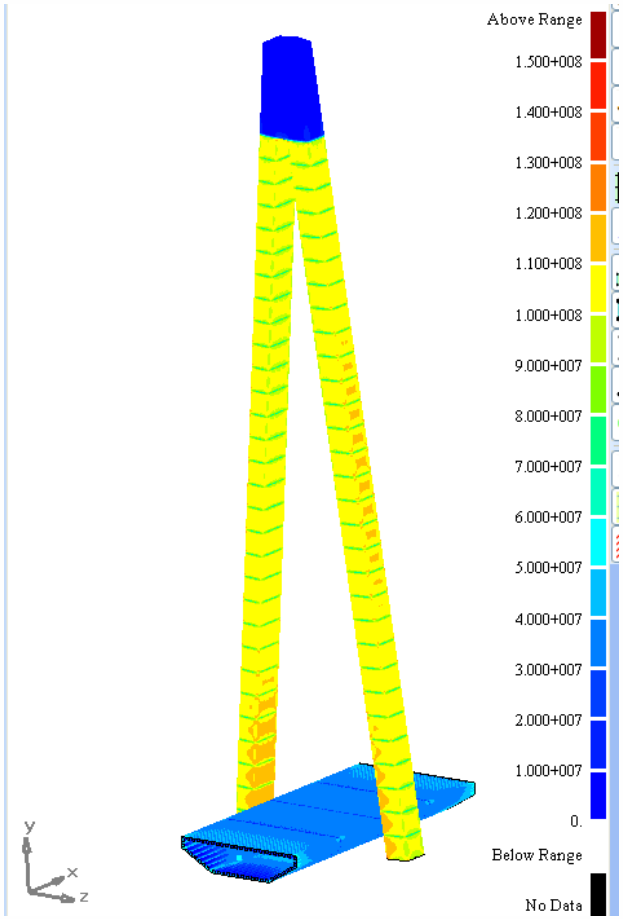
Implicit Analysis

- Applied compression on pylon: 19,600 kN on each pylon
- Applied compression on deck: 19,600 kN
- Applied gravity loading
- Boundary condition
  - Bottom of both pylon legs were fixed
  - Two support points of deck were fixed

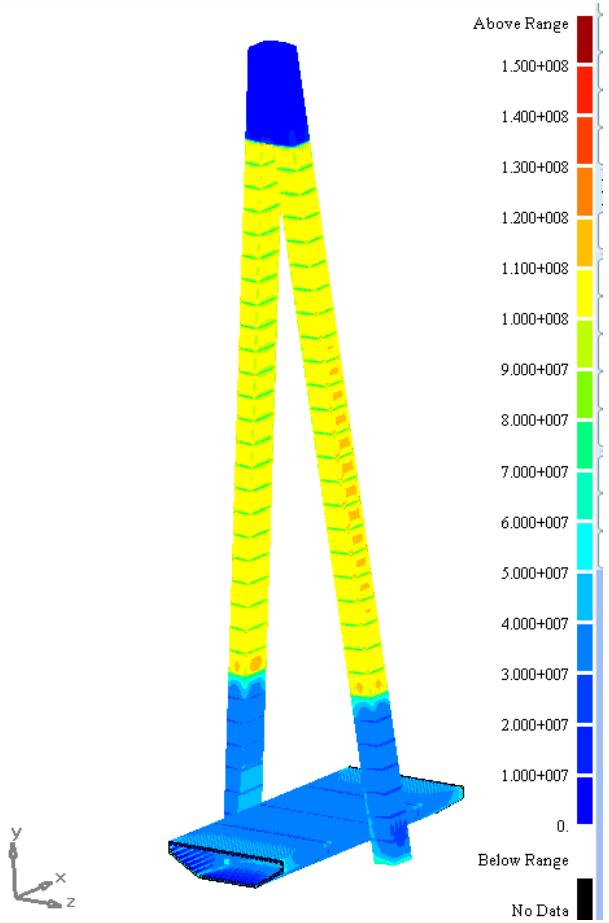


Implicit Results

- Hollow

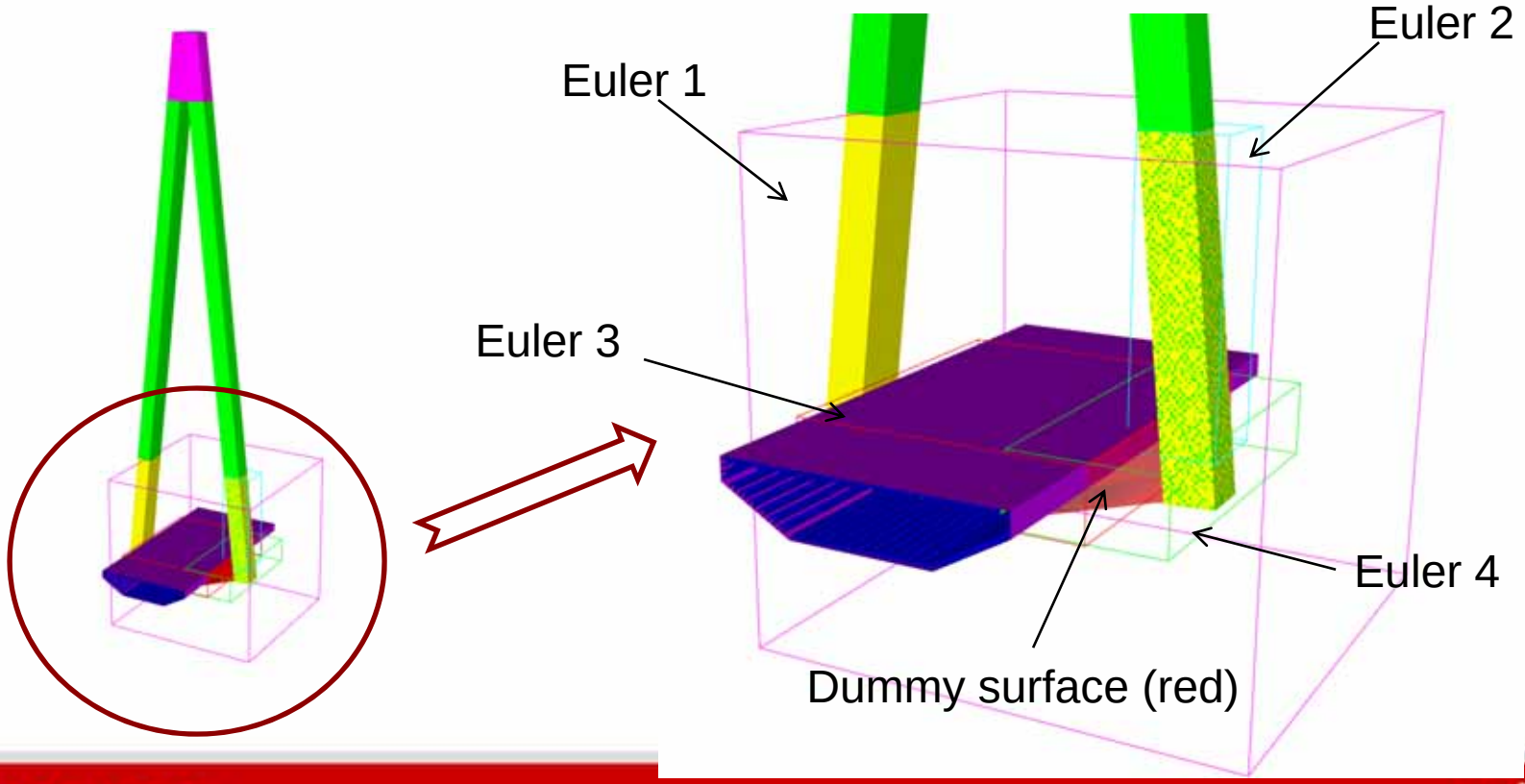


Concrete filled



Explicit Analysis

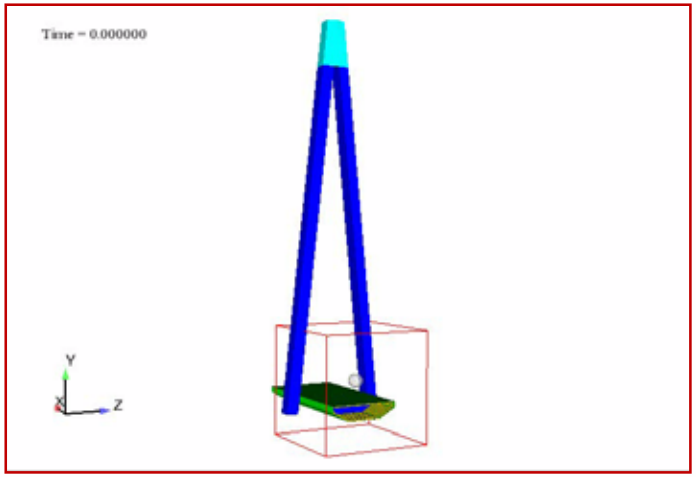
- Four Euler domains
  - Euler 1: Outer Air & Explosive, Material can flow out through boundary
  - Euler 2: Air, Inside of pylon
  - Euler 3: Air, Inside of deck
  - Euler 4: Air, Inside of dummies
  - Dummy surfaces: using porosity, air can flow between Euler 1 and Euler 4 freely



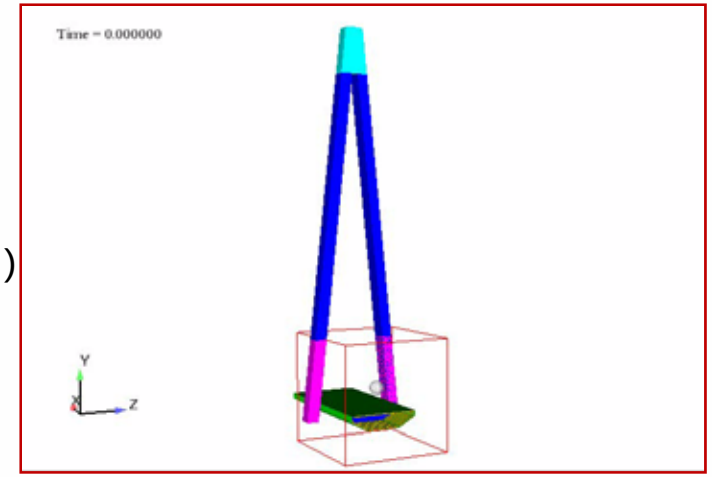
Explicit Results

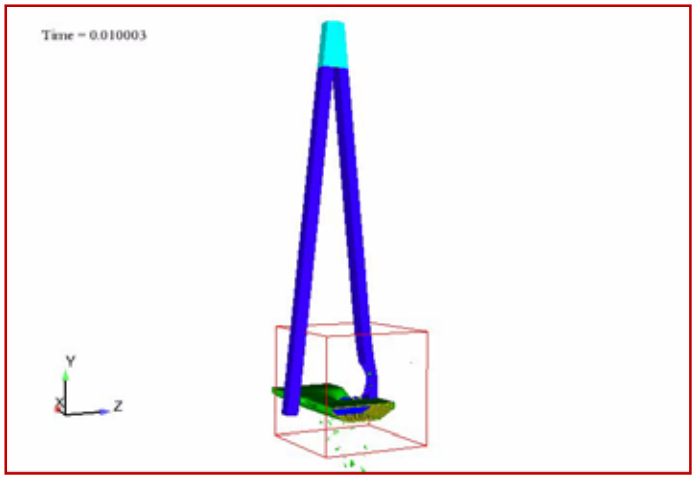
- **Hollow**

Concrete filled

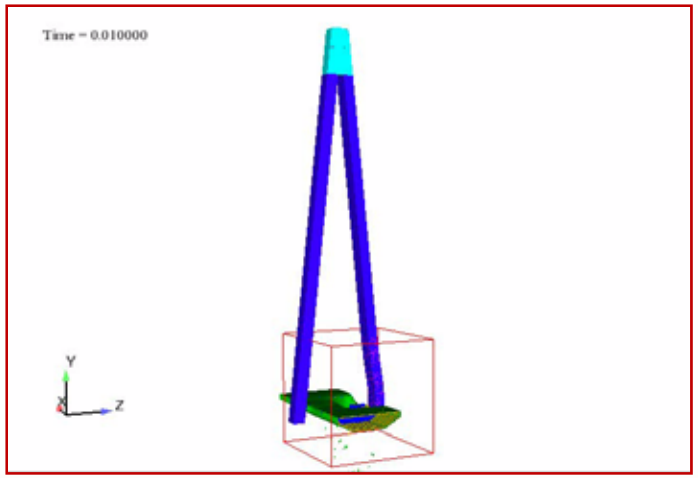


0~4ms
(step size: 0.1ms)





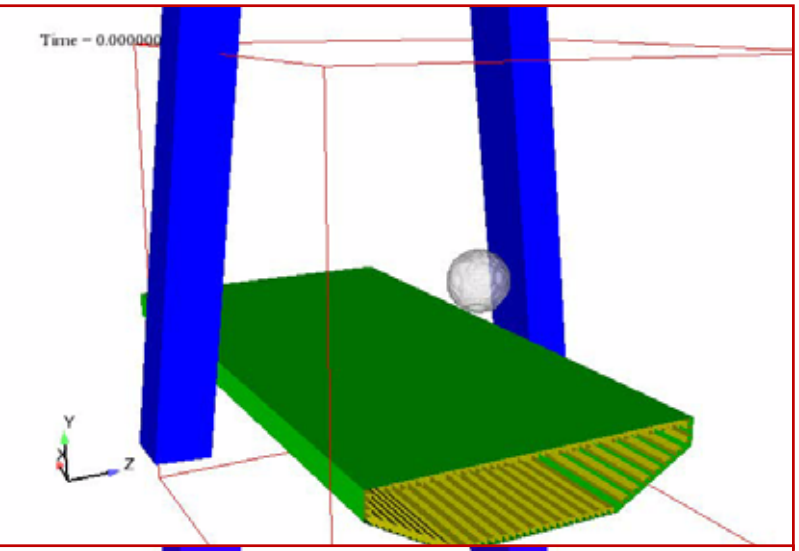
4ms~1000ms
(step size: 10ms)

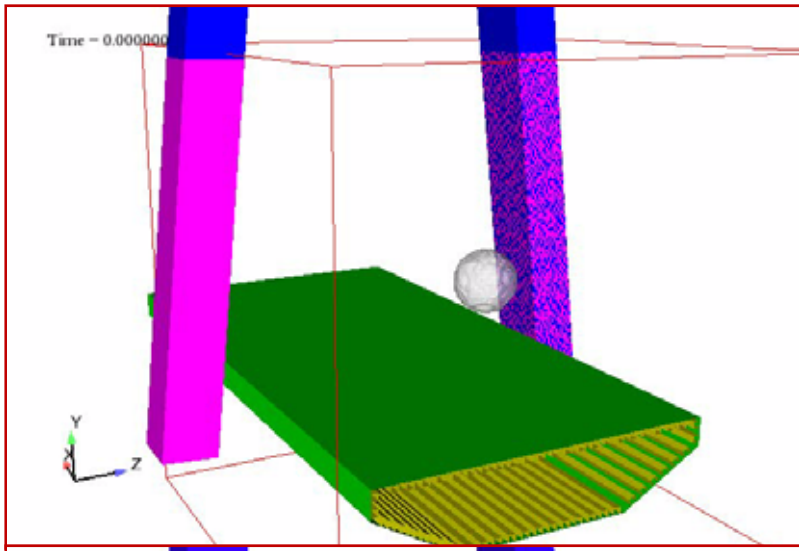


Explicit Results

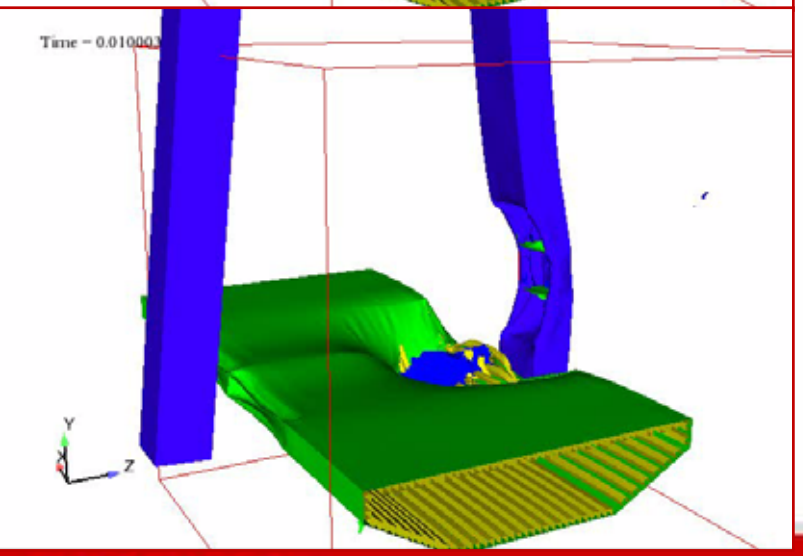
- Hollow

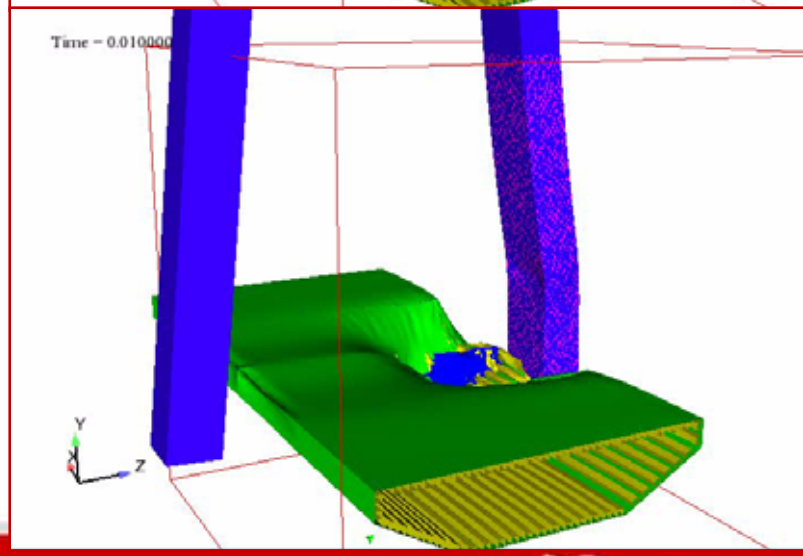
Concrete filled





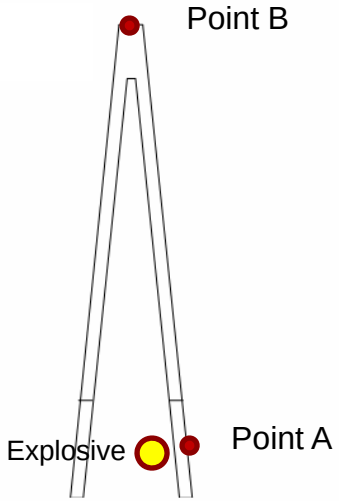
0~4ms
(step size: 0.1ms)





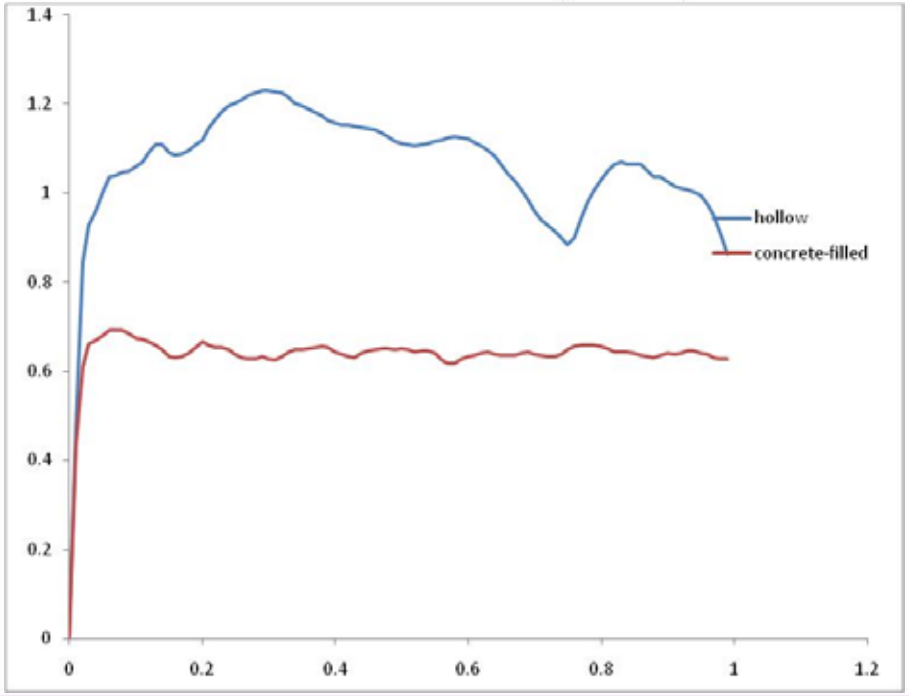
4ms~1000ms
(step size: 10ms)

Explicit Results

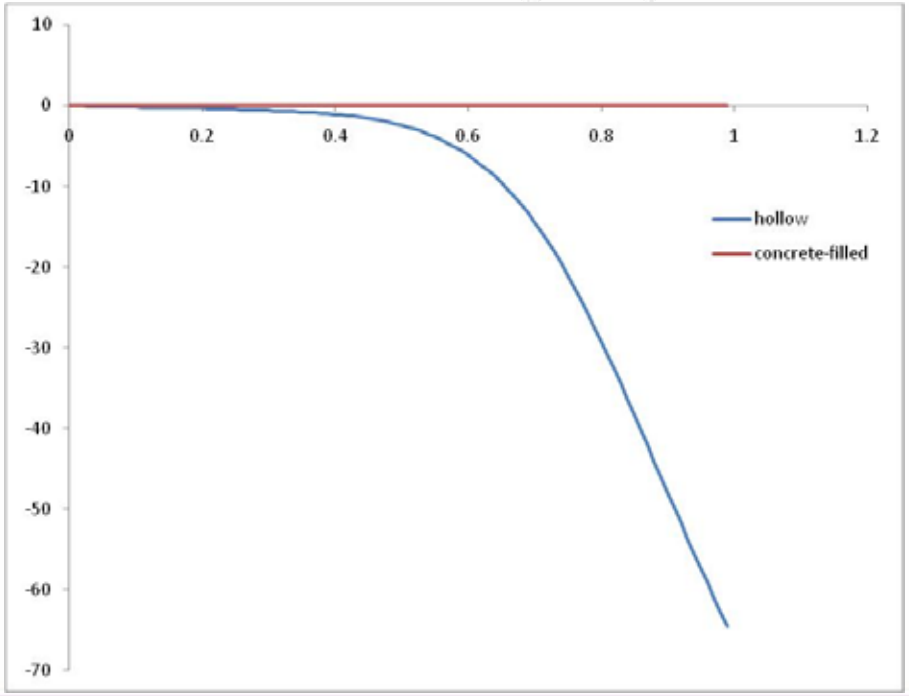


- Displacement time history

- Transverse direction (point A)



- Vertical direction (point B)



Conclusion

- Acceleration response was the earliest and the most important physical response under blast loading
- Composite section guaranteed the reaction of the cross section as a whole.
- P-delta effect was the main factor of the collapse under compression loading.
- The compression loading had effects (Vertical time history at point B) on the pylon quite later than the blast loading (Horizontal time history at point A) did.

Questions?

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- For further information please contact

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