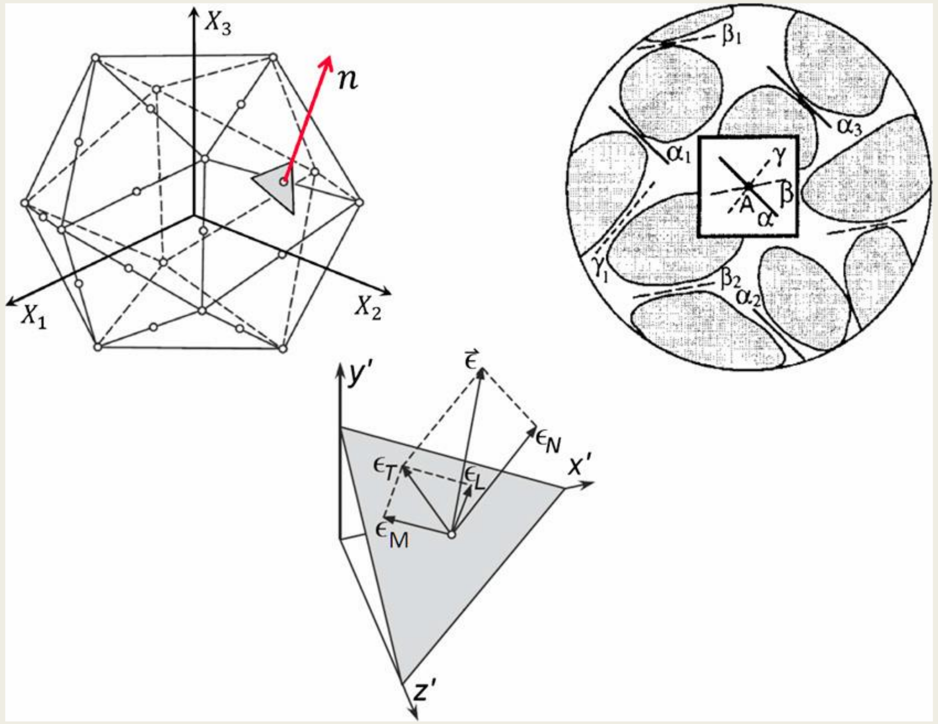
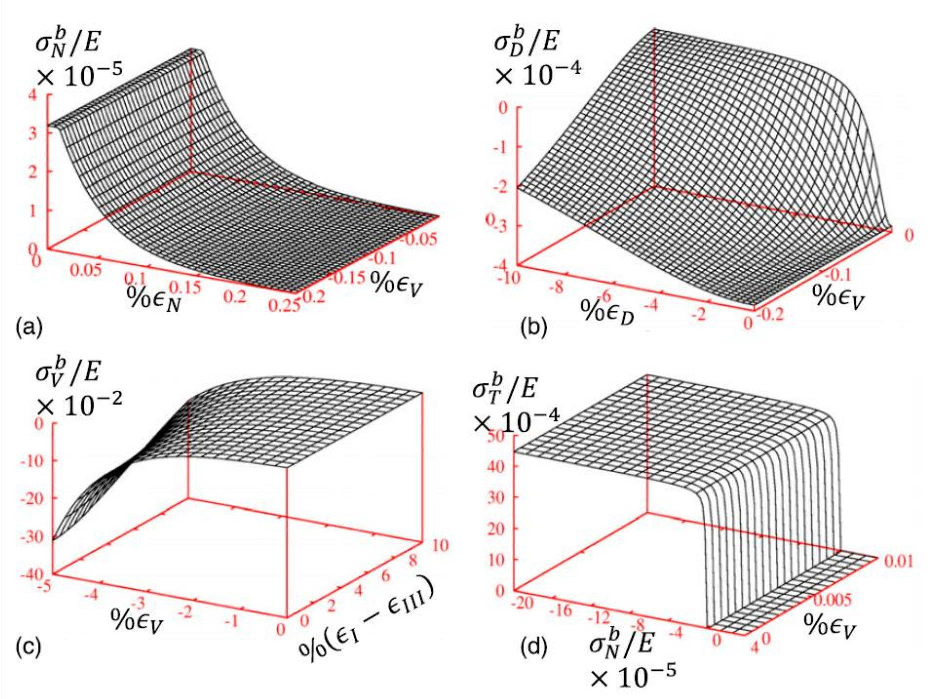
MICROPLANE MODELLING OF CONCRETE DYNAMICS

Ferhun C. Caner

Microplane Model M7: What did it achieve?

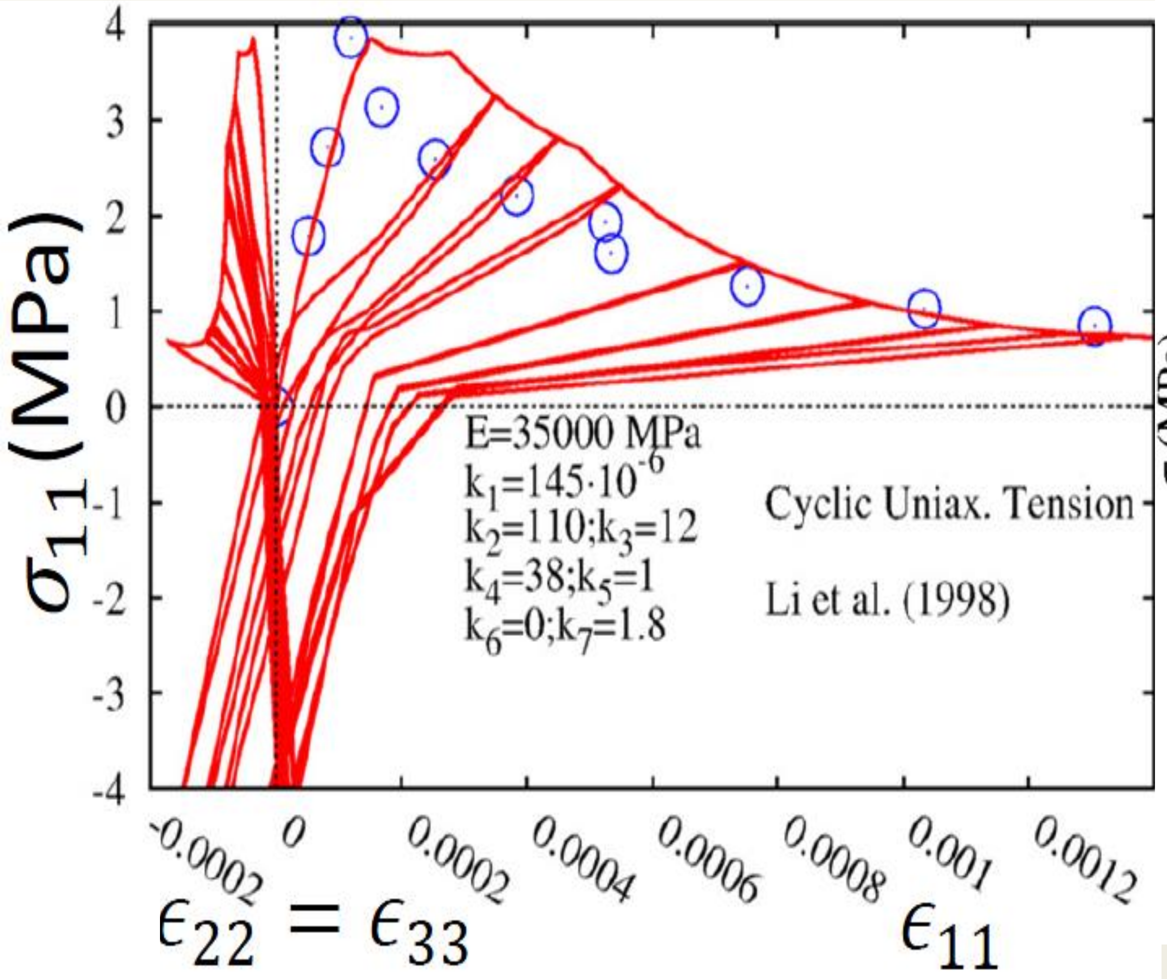


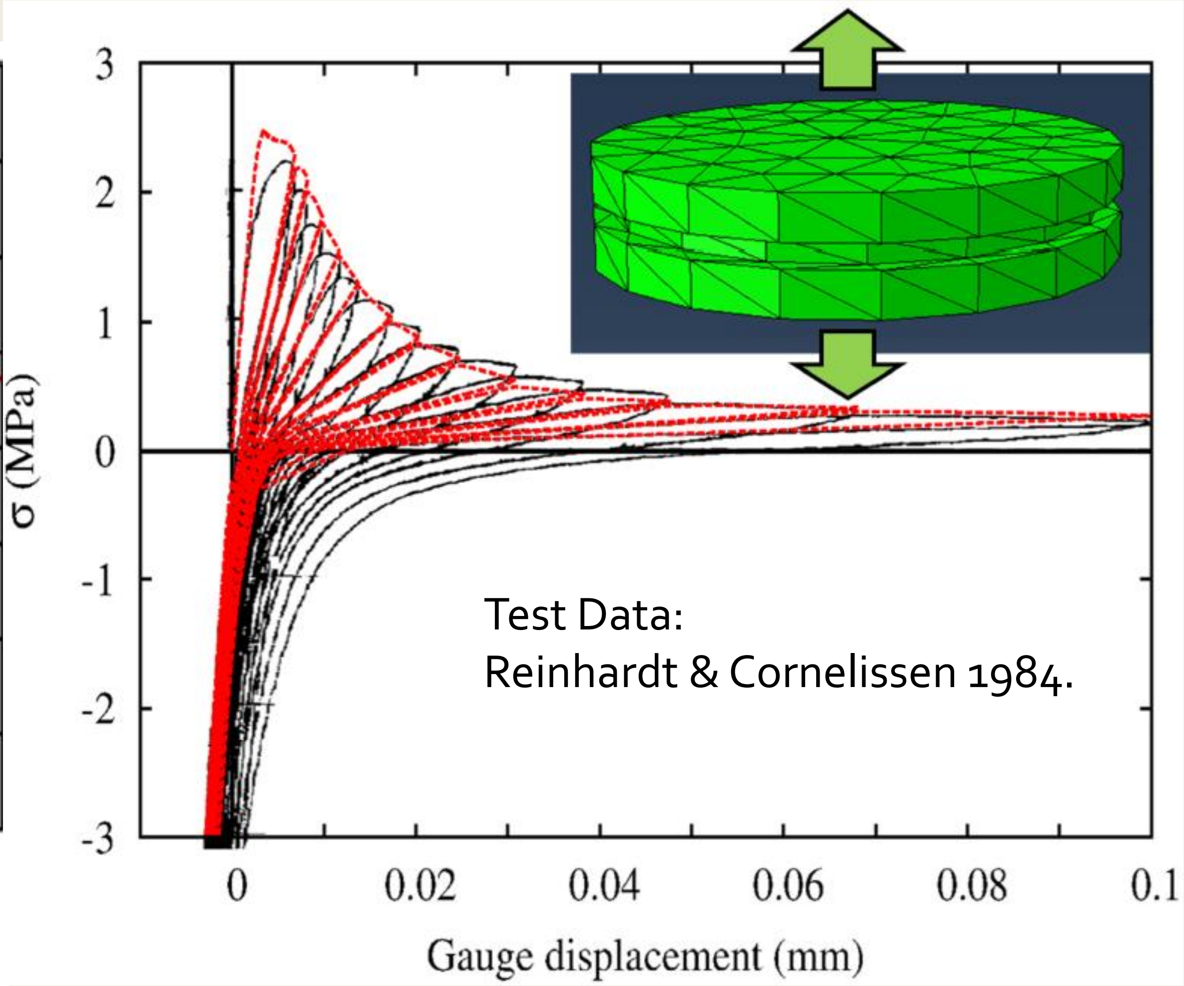


$$\sigma_{ij} = \frac{3}{2\pi} \int_{\Omega} (\sigma_N N_{ij} + \sigma_M M_{ij} + \sigma_L L_{ij}) d\Omega$$

Caner & Bažant (2013). “Microplane Model M7 for plain concrete. I. Formulation”, ASCE JEM 139(12):1714-1723.

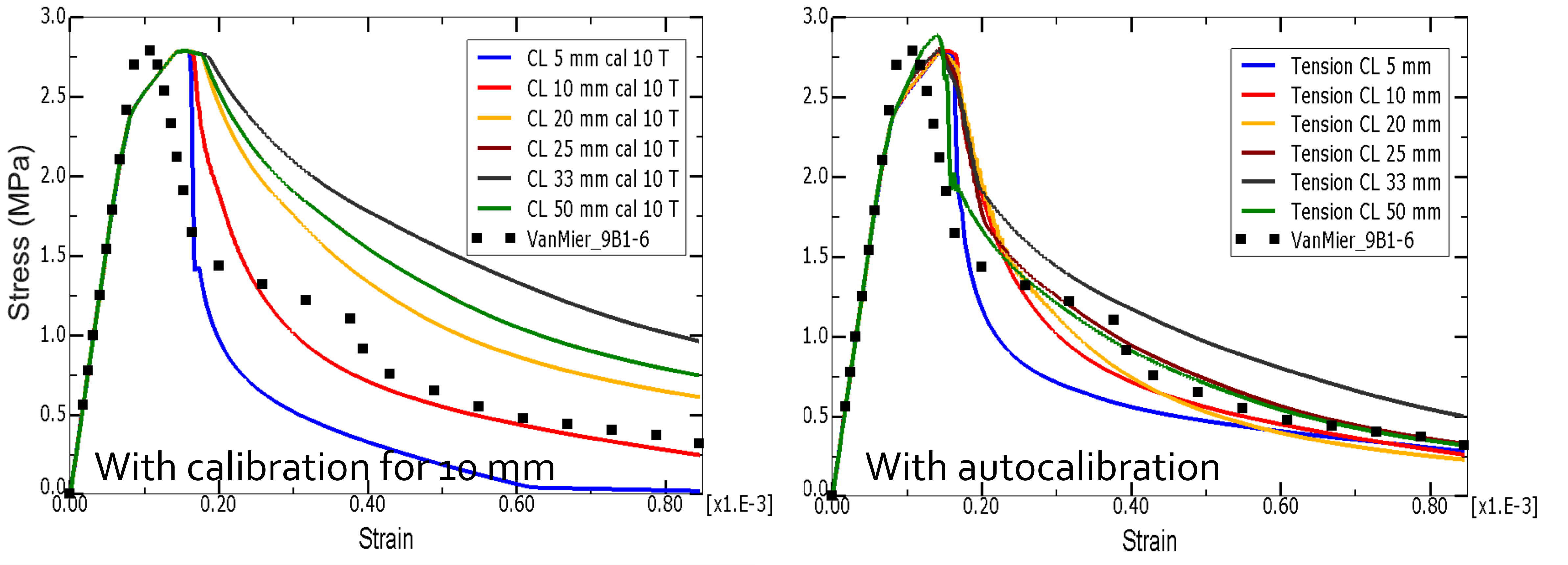
What Did Microplane Model M7 Achieve?





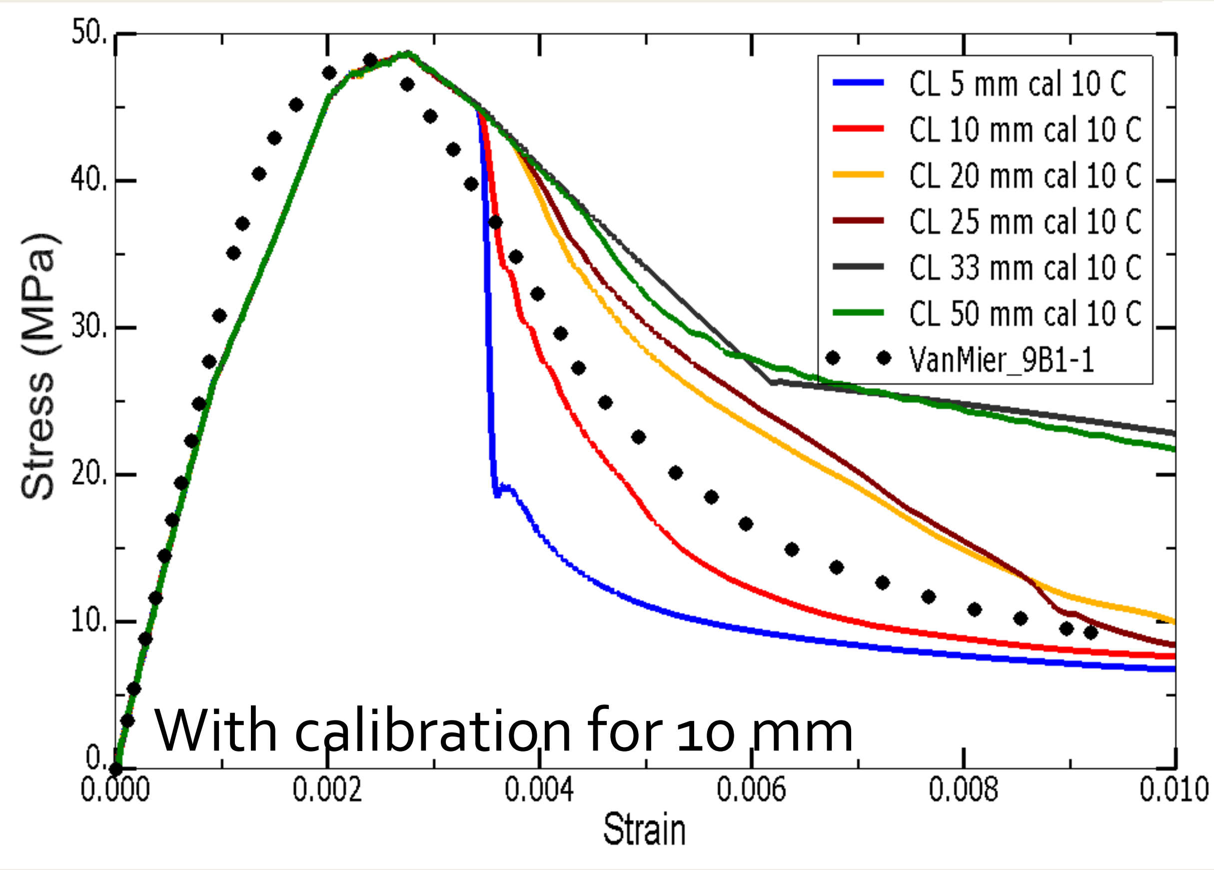
Caner & Bažant (2013). "Microplane Model M7 for plain concrete. II. Calibration and verification", ASCE JEM 139(12):1724-1735.

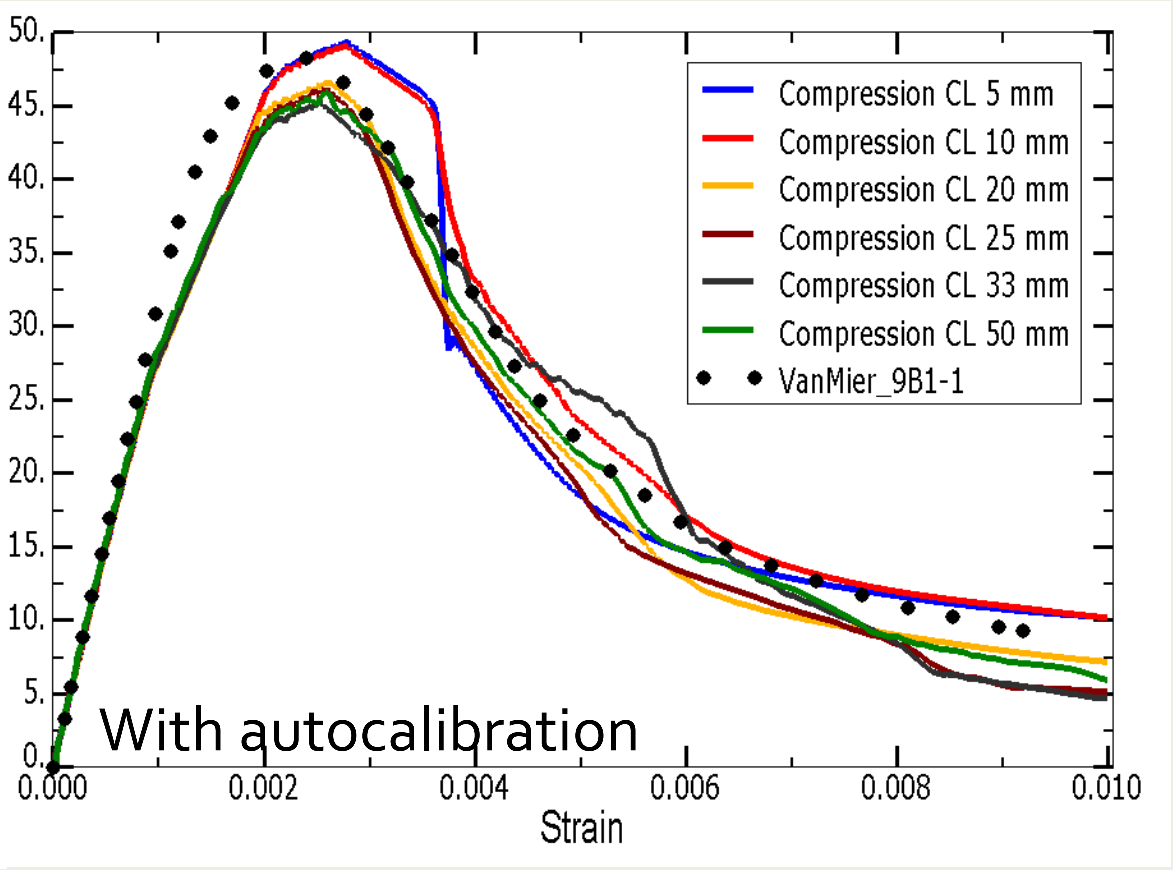
Autocalibrating Microplane Model M7 – Uniaxial Tension



Test data: van Mier, J.G.M. (1984) "Strain-softening of concrete under multiaxial loading conditions", PhD Thesis, Univ. of Eindhoven, The Netherlands.

Autocalibrating Microplane Model M7 – Uniaxial Compression



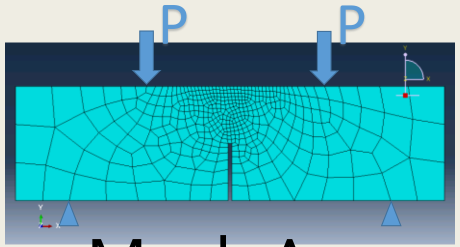


Test data: van Mier, J.G.M. (1984) "Strain-softening of concrete under multiaxial loading conditions", PhD Thesis, Univ. of Eindhoven, The Netherlands.

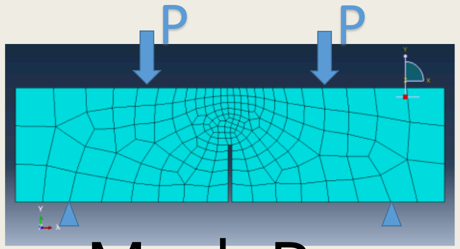
Autocalibrating Microplane Model M7. Application to 4 pt Bending

Mesh A: Finer mesh

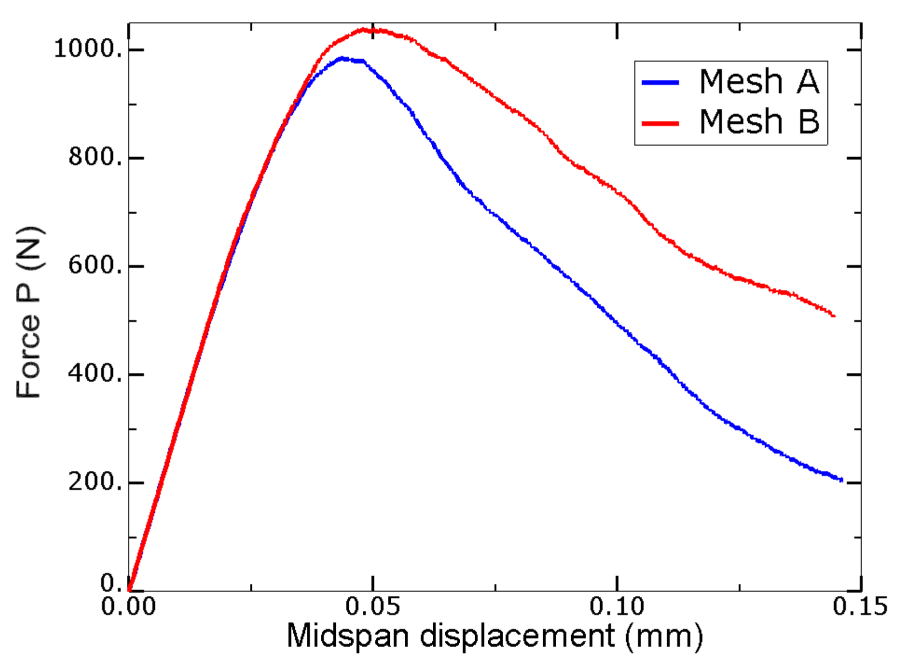
Mesh B: Coarser mesh

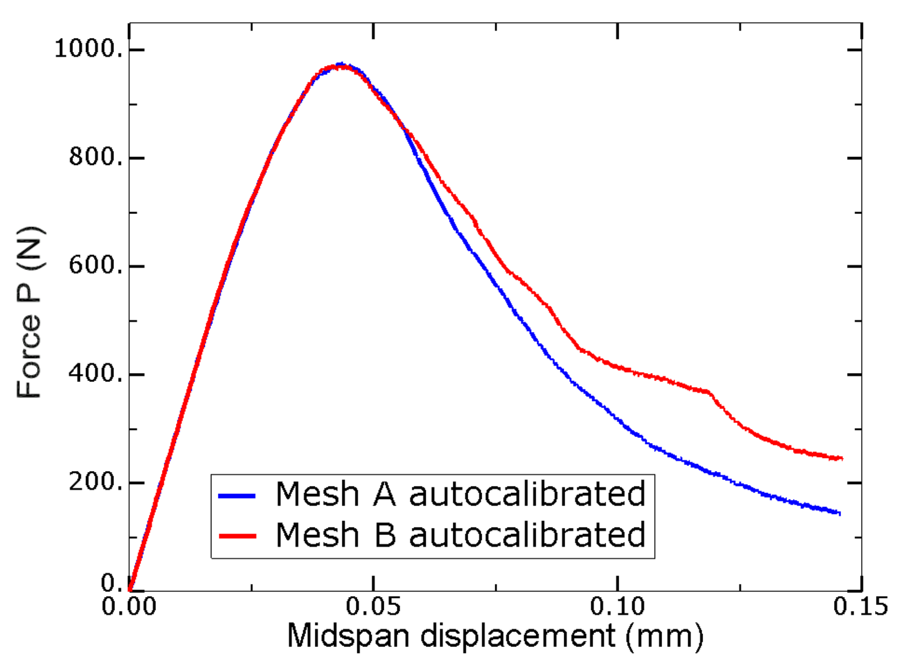


Mesh A

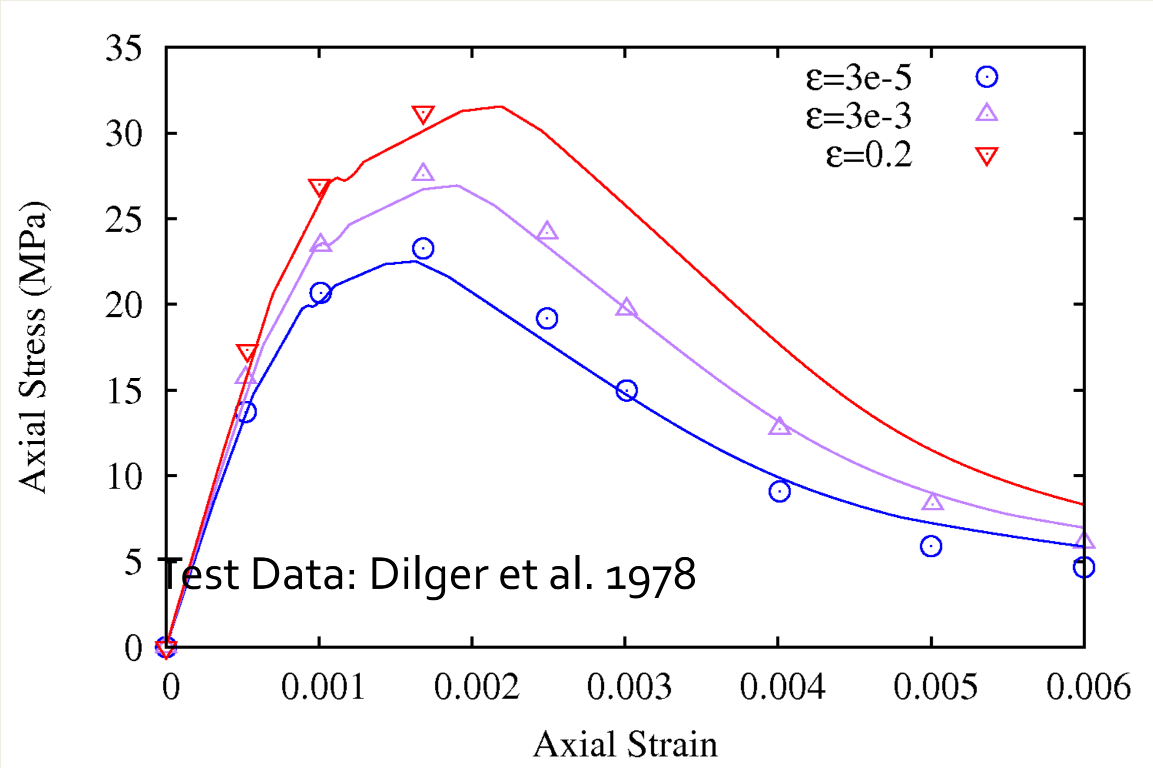


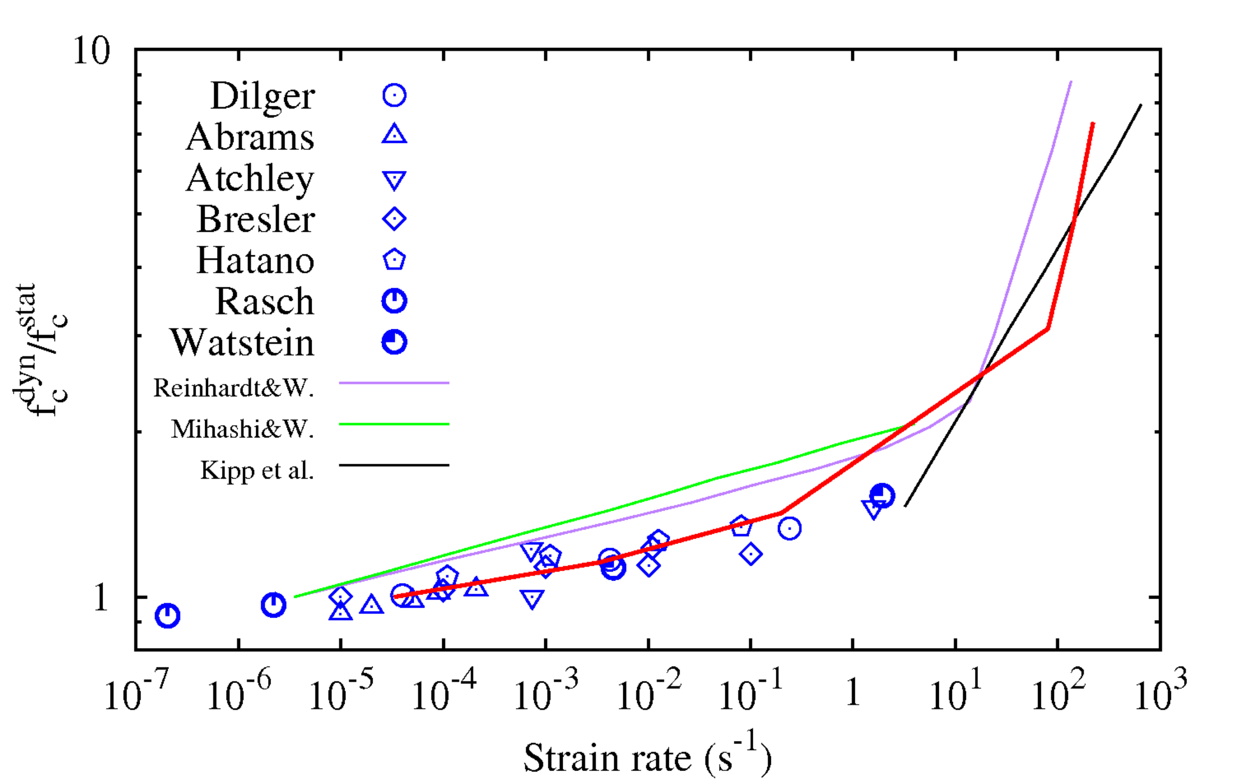
Mesh B



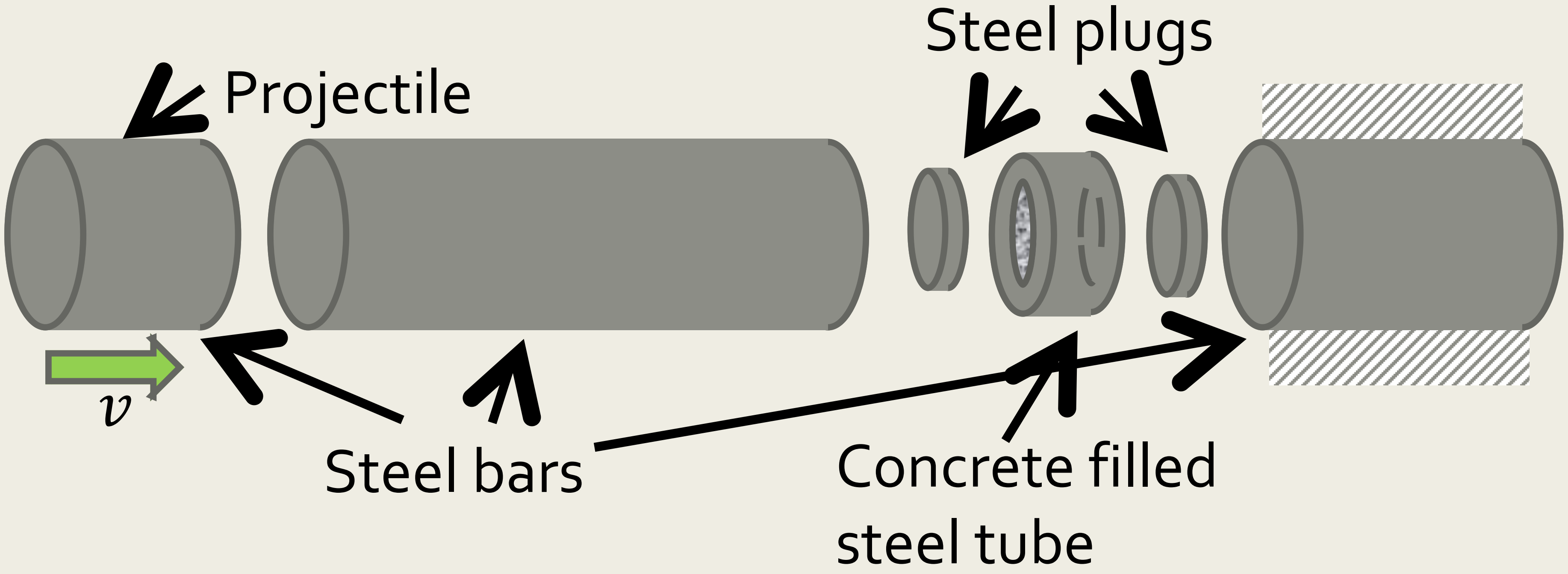


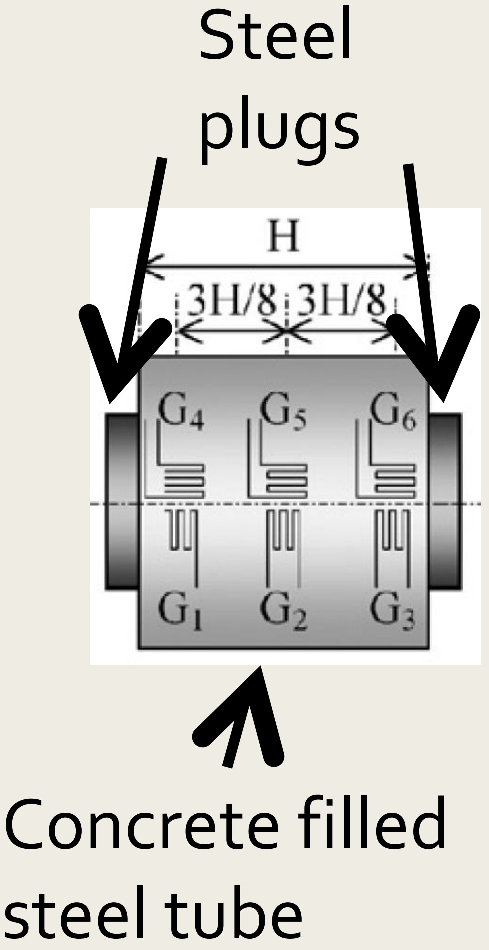
Rate-Dependent Microplane Model M7R – Uniaxial Compression





Rate-Dependent Microplane Model M7R – Triaxial Compression: "Hopkinson Pressure Bar Test"



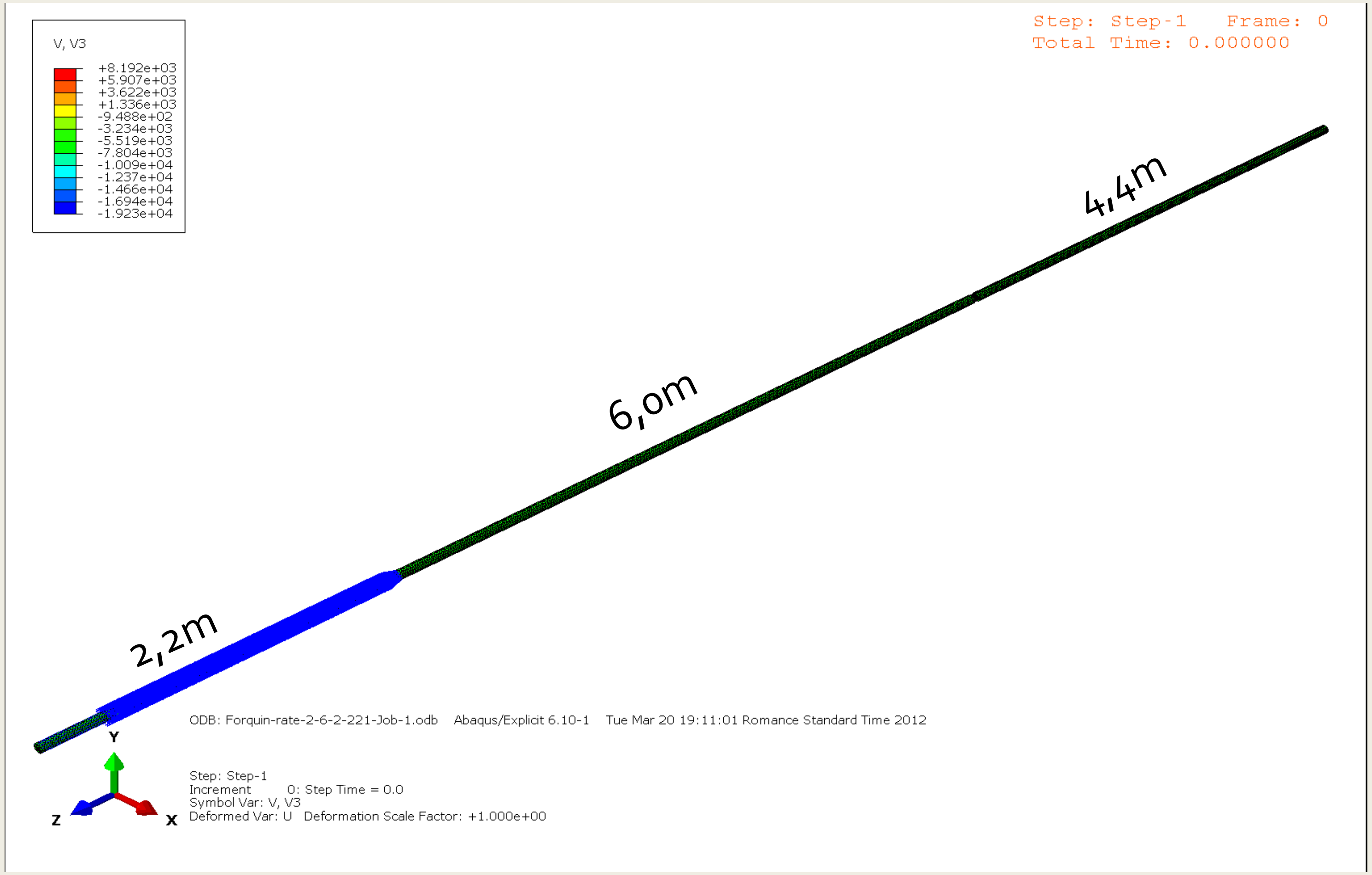


3 tests at 3 projectile speeds:

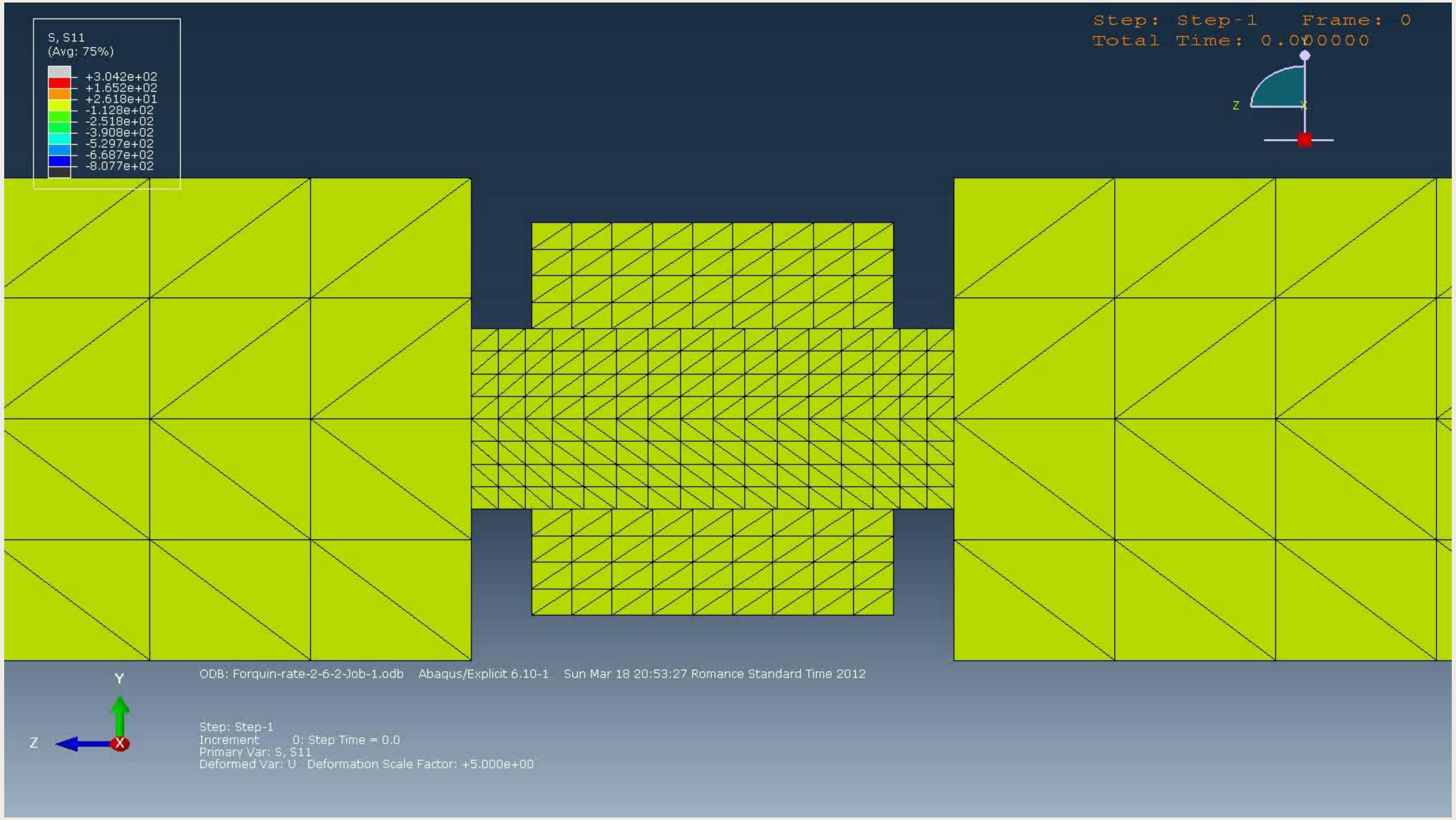
- $v = 6{,}13\ m/s$
- $v = 12{,}5\ m/s$
- $v = 19{,}23\ m/s$

Tests: Forquin et al. 2008

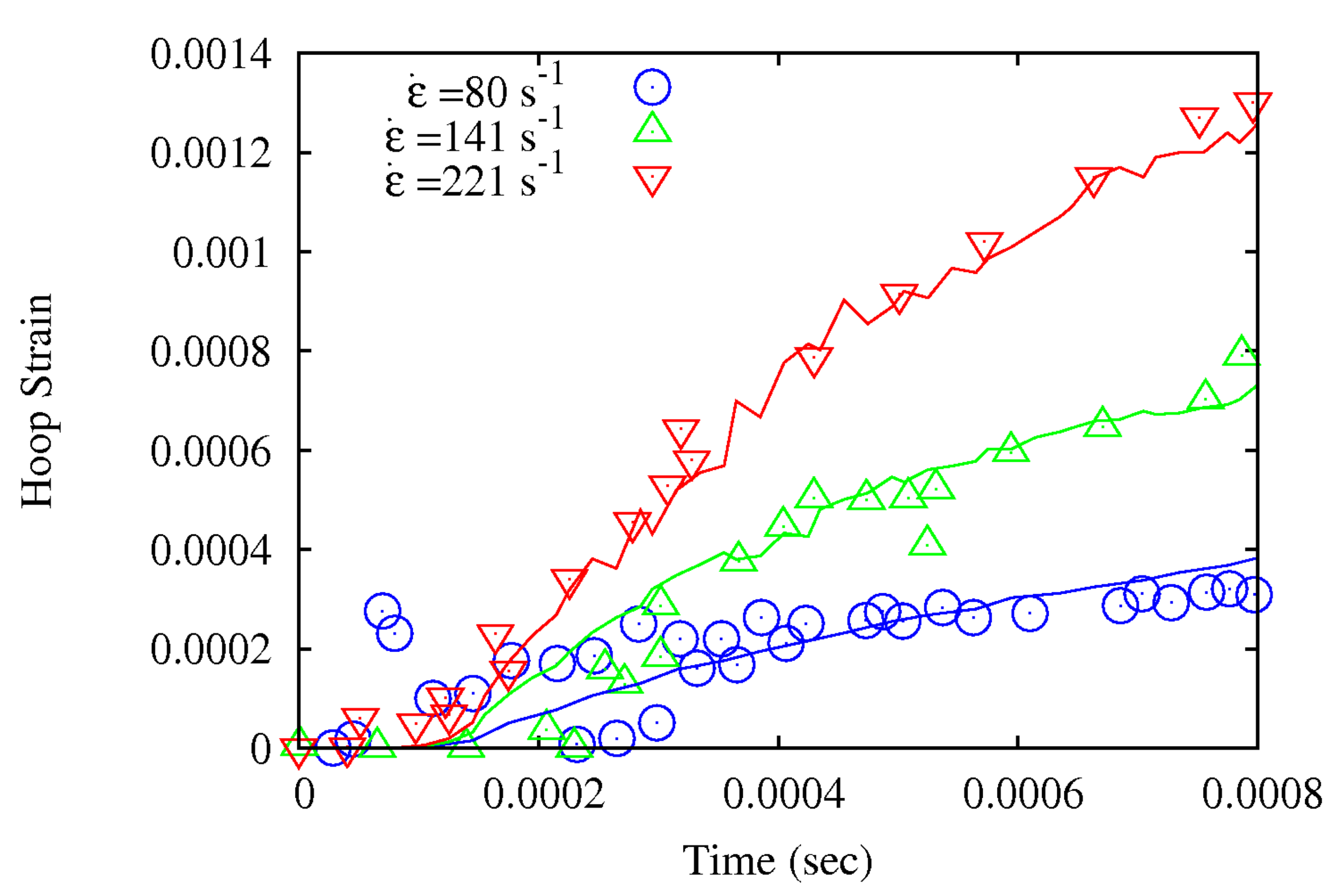
Rate-Dependent Microplane Model M7R – Triaxial Compression: "Hopkinson Pressure Bar Test"



Rate-Dependent Microplane Model M7R – Triaxial Compression: "Hopkinson Pressure Bar Test"



Rate-Dependent Microplane Model M7R – Triaxial Compression: "Hopkinson Pressure Bar Test"

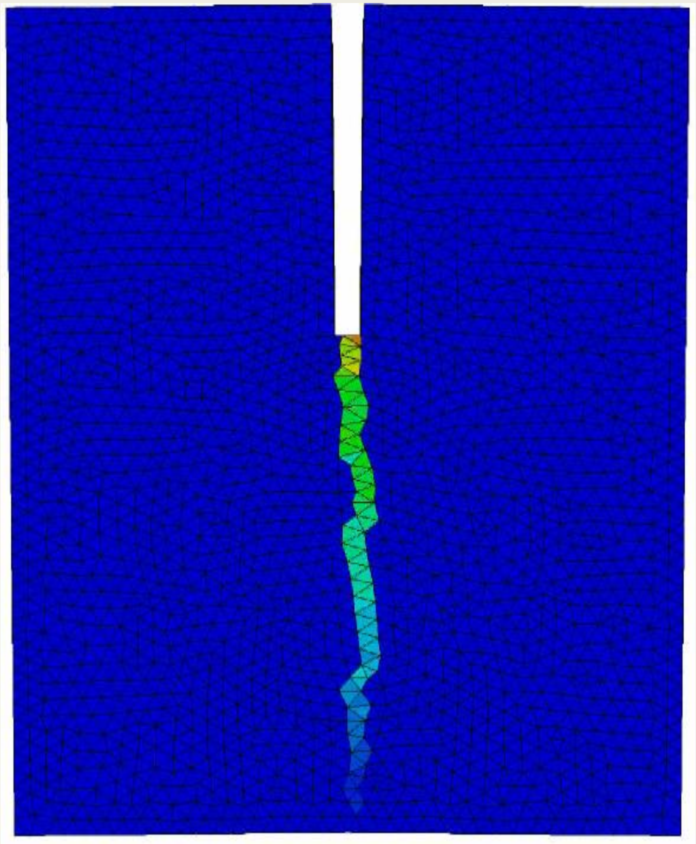


Caner & Bažant (2014). "Impact comminution of solids due to local kinetic energy of shear strain rate: II. Microplane model and verification", JMPS 64:236-248.

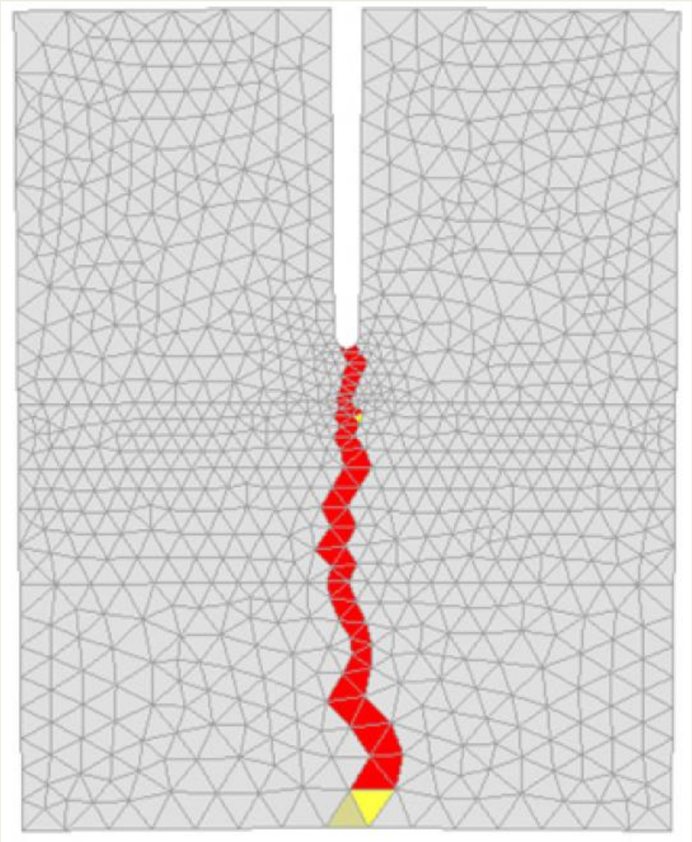
Rate-Dependent Microplane Model M7R – CTT

$$v = 100mm/s$$

Model M7R

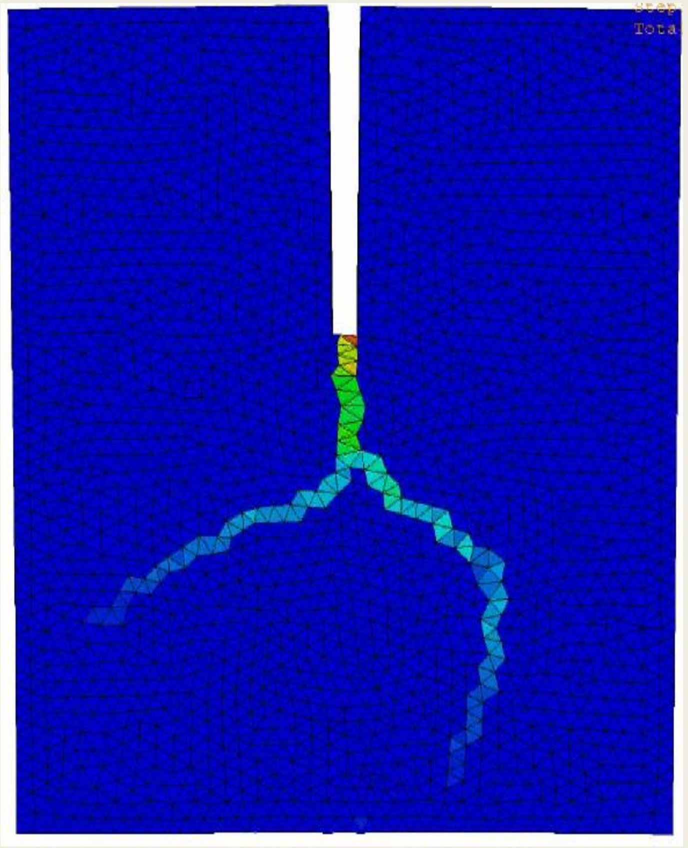


Ožbolt et al 2011

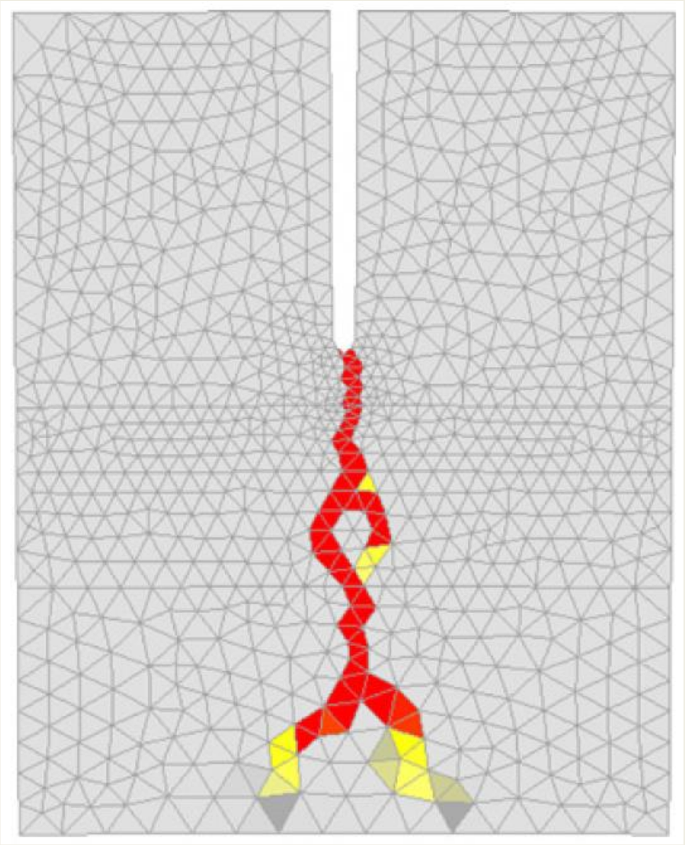


Rate-Dependent Microplane Model M7R – CTT
$$v = 500mm/s$$

Model M7R



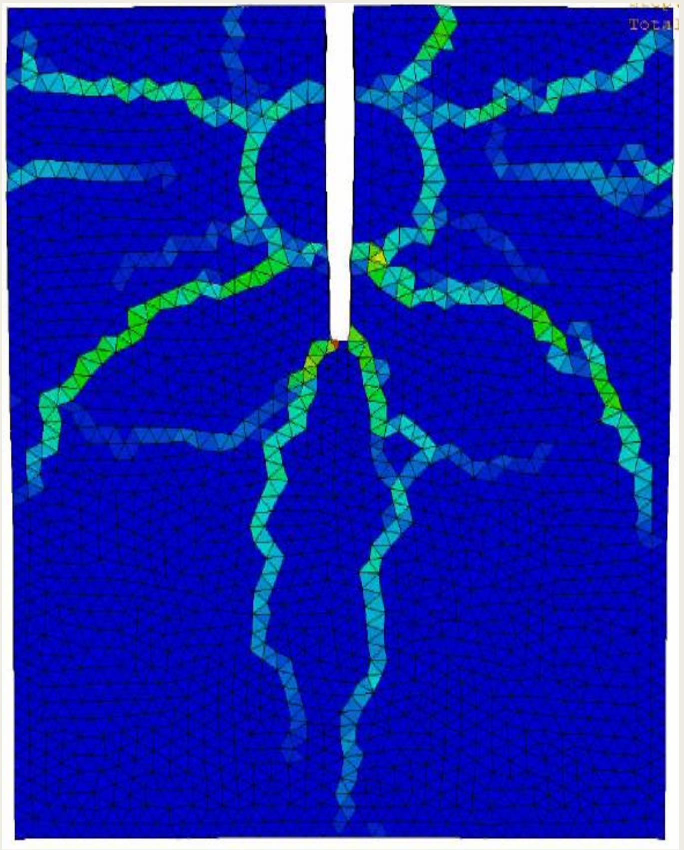
Ožbolt et al 2011



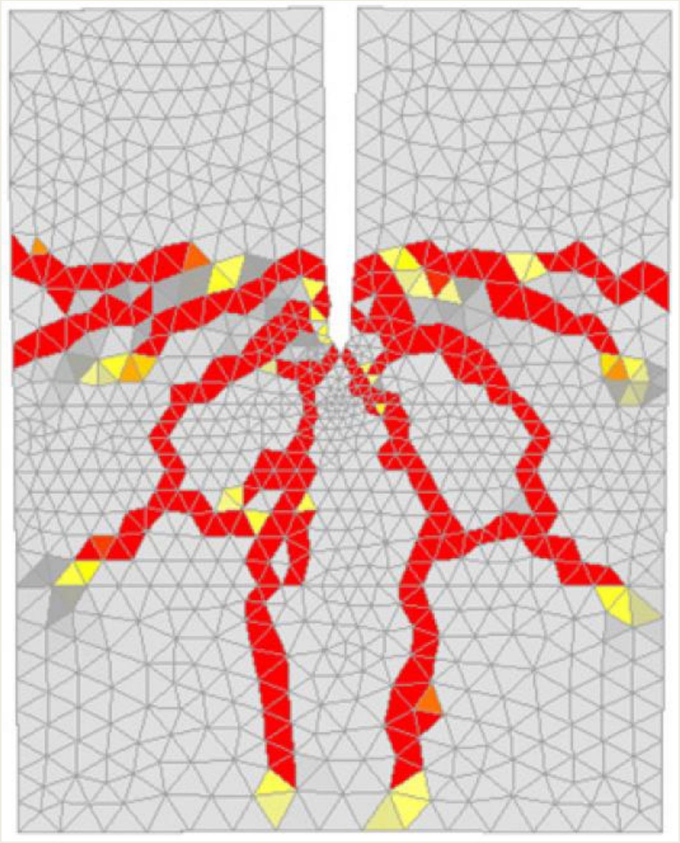
Rate-Dependent Microplane Model M7R – CTT

$$v = 5000mm/s$$

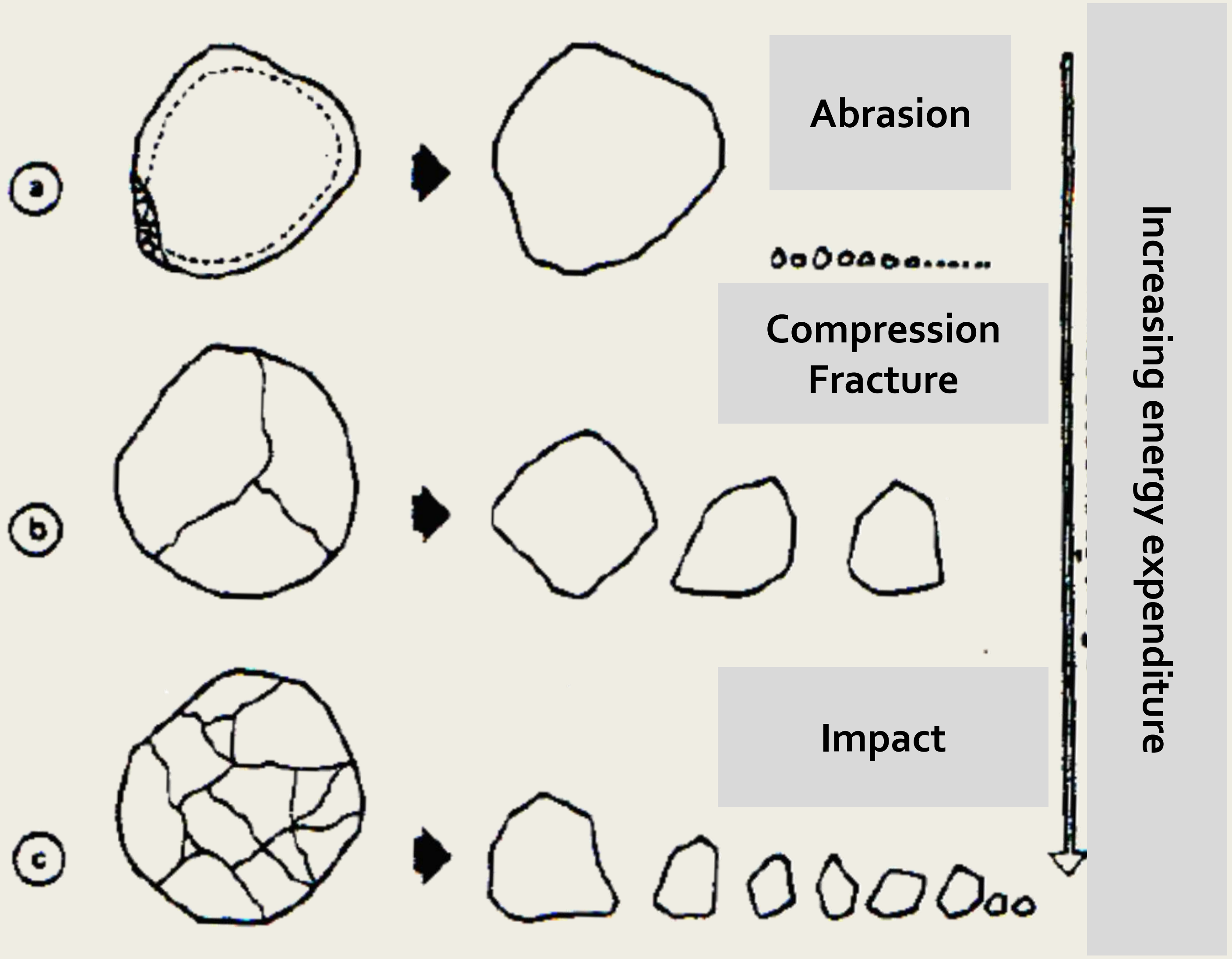
Model M7R



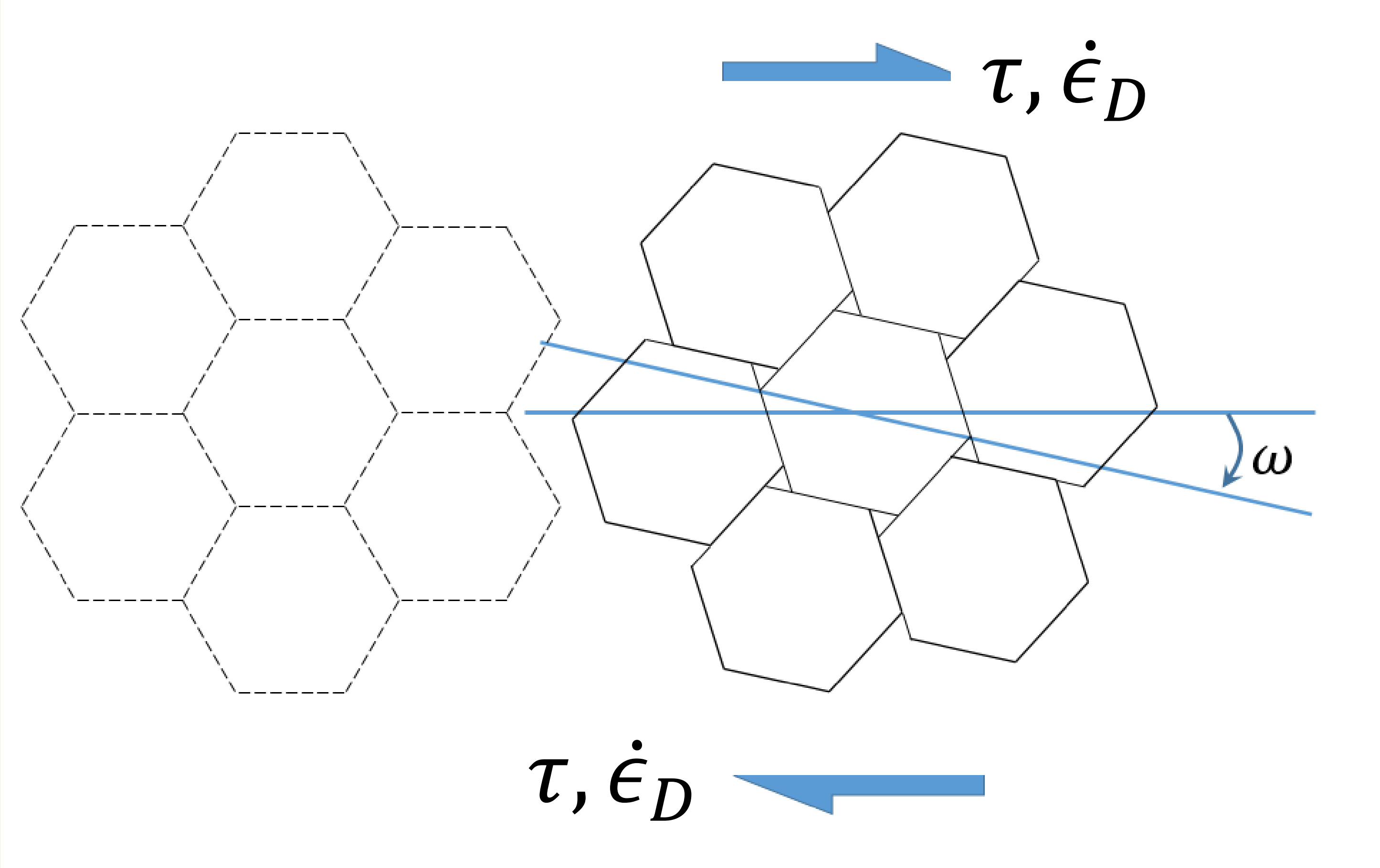
Ožbolt et al 2011



Comminution Theory of Concrete



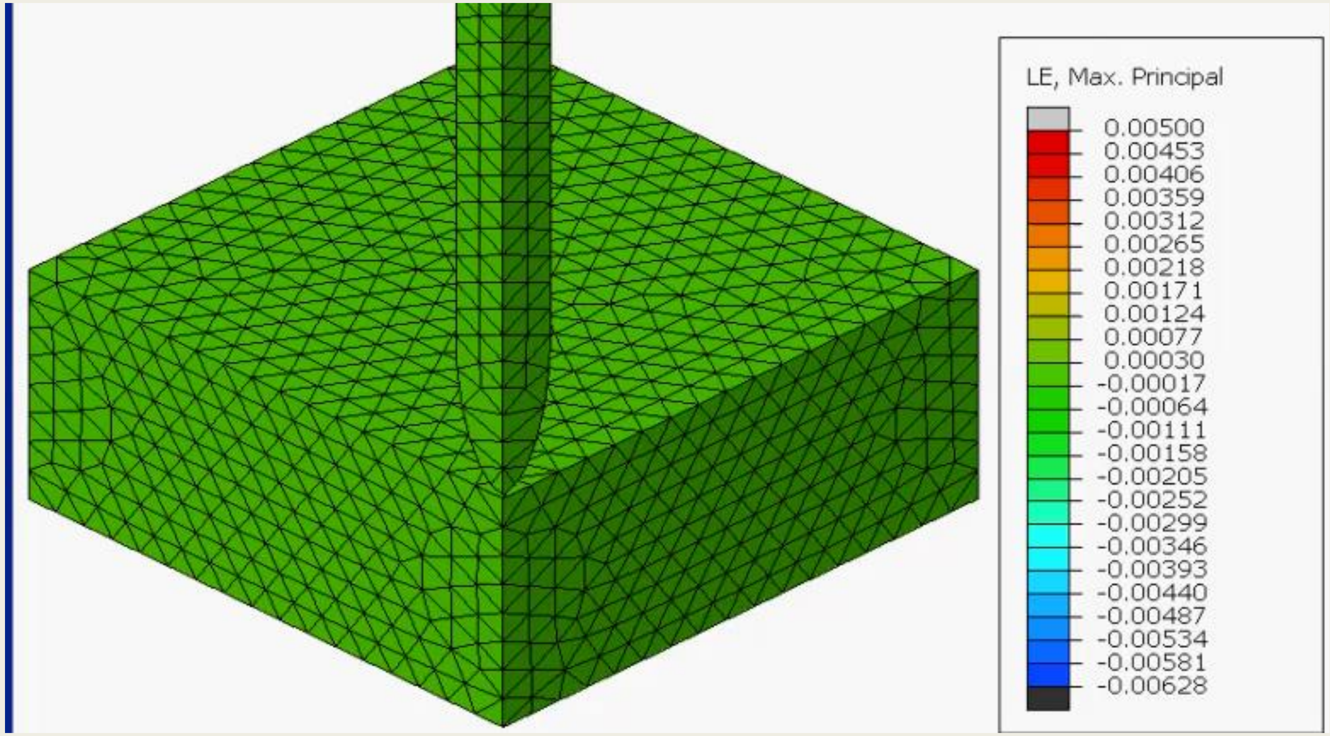
Comminution Theory of Concrete – Basic Concept



$$\boxed{\tau \propto \dot{\epsilon}_D^{2/3}}$$

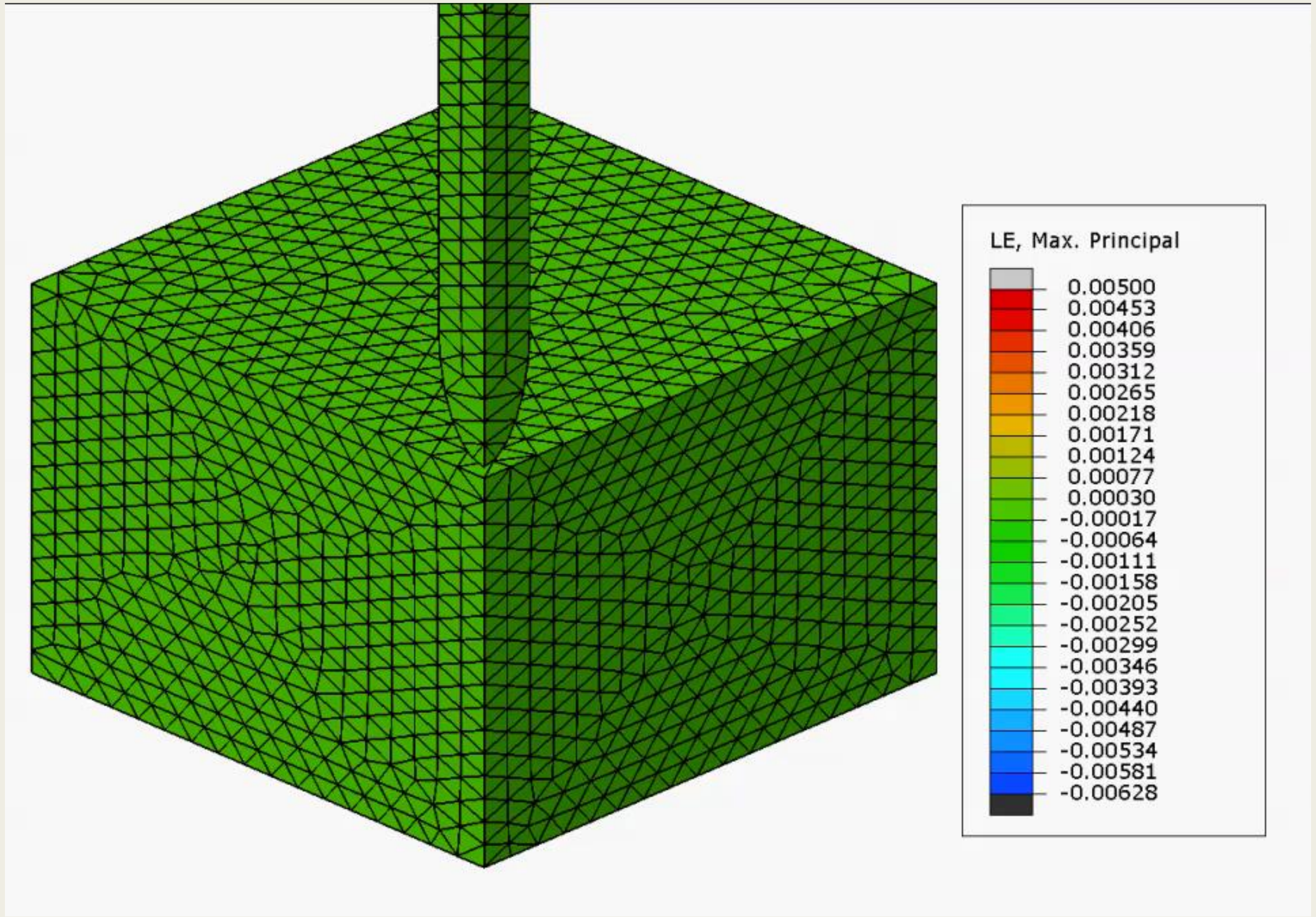
Bažant & Caner (2014). "Impact comminution of solids due to local kinetic energy of shear strain rate: I. Continuum theory and turbulence analogy", JMPS 64:223-235

Comminution Theory Applied to Projectile Penetration - 127mm Wall



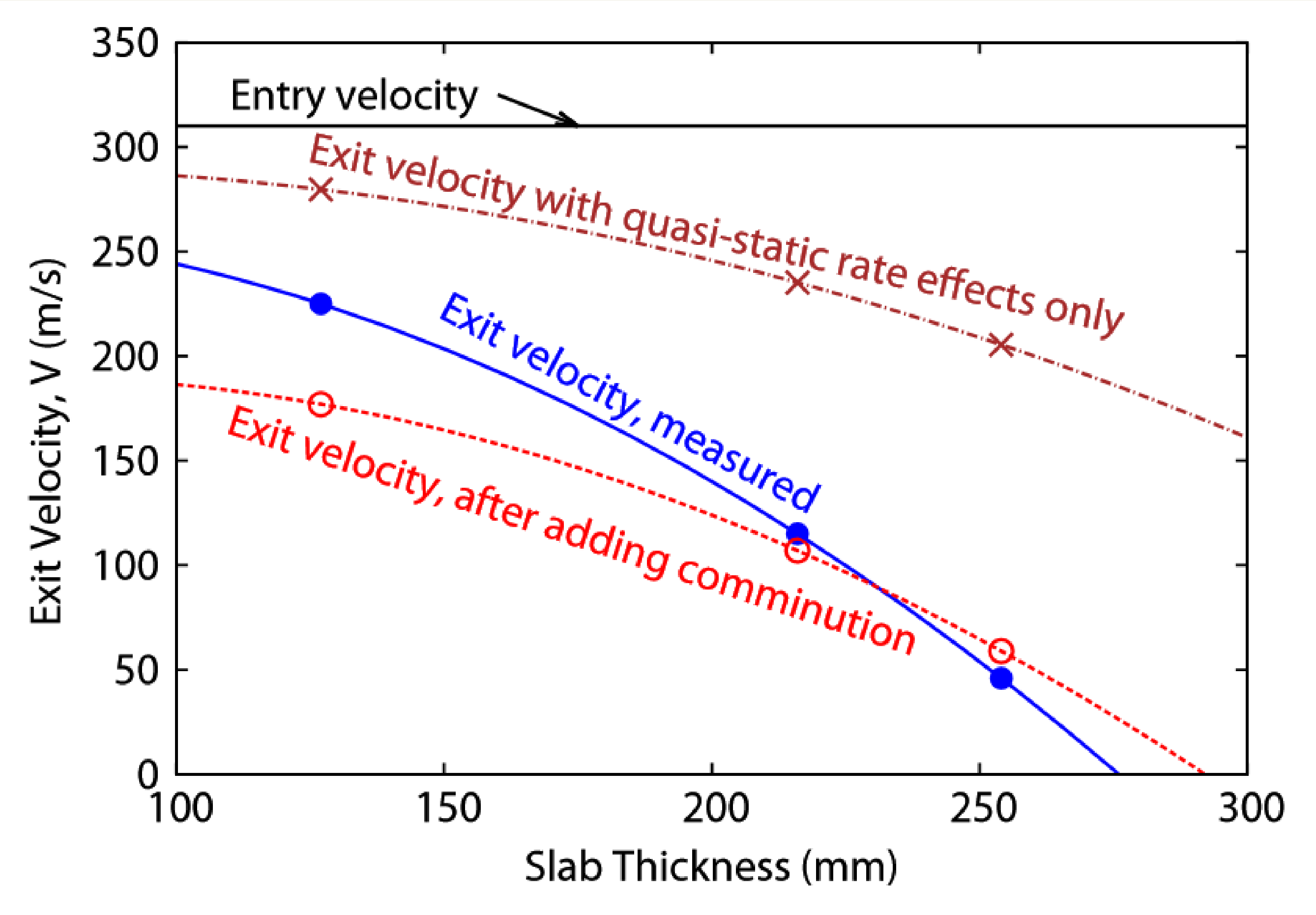
Caner & Bažant (2014). “Impact comminution of solids due to local kinetic energy of shear strain rate: II. Microplane model and verification”, JMPS 64:236-248.

Comminution Theory Applied to Projectile Penetration - 254mm Wall



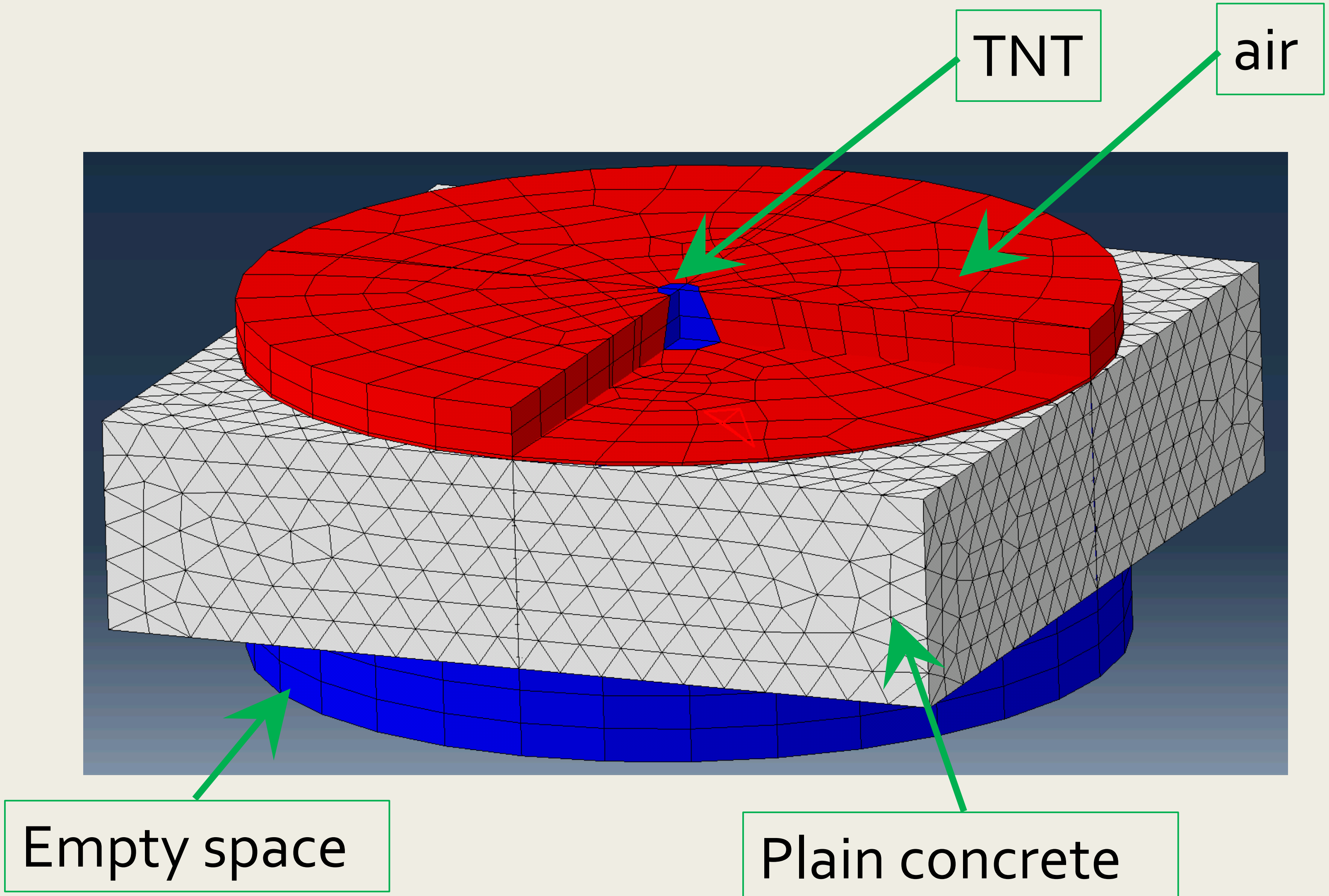
Caner & Bažant (2014). "Impact comminution of solids due to local kinetic energy of shear strain rate: II. Microplane model and verification", JMPS 64:236-248.

Comminution Theory Applied to Projectile Penetration – Exit velocities

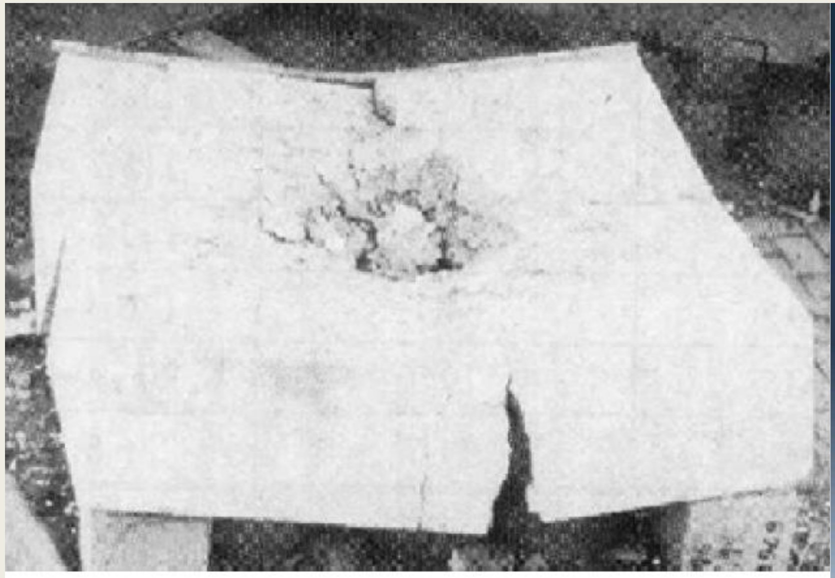


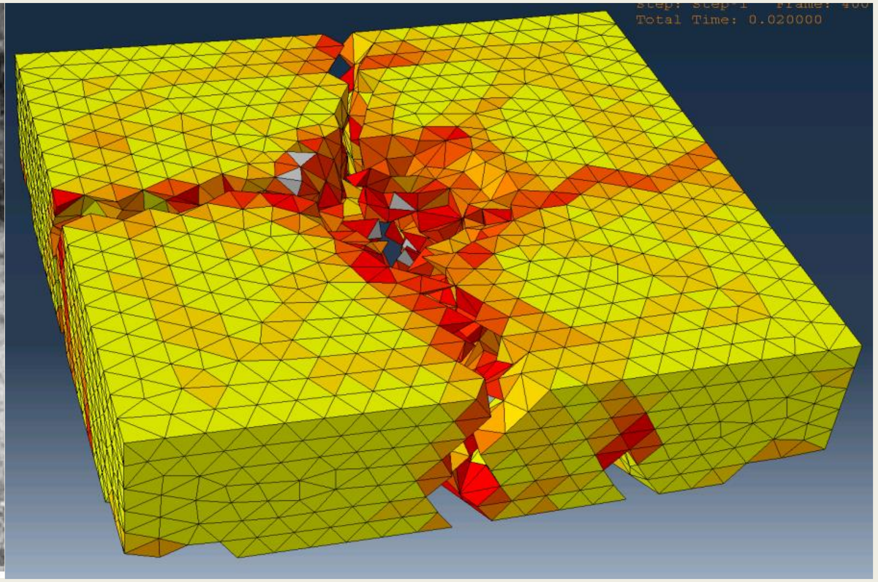
Caner & Bažant (2014). "Impact comminution of solids due to local kinetic energy of shear strain rate: II. Microplane model and verification", JMPS 64:236-248.

Simulation of Explosion of 400g TNT on A Plain Concrete Plate



Simulation of Explosion of 400g TNT on A 30cm Thick Plain Concrete Plate



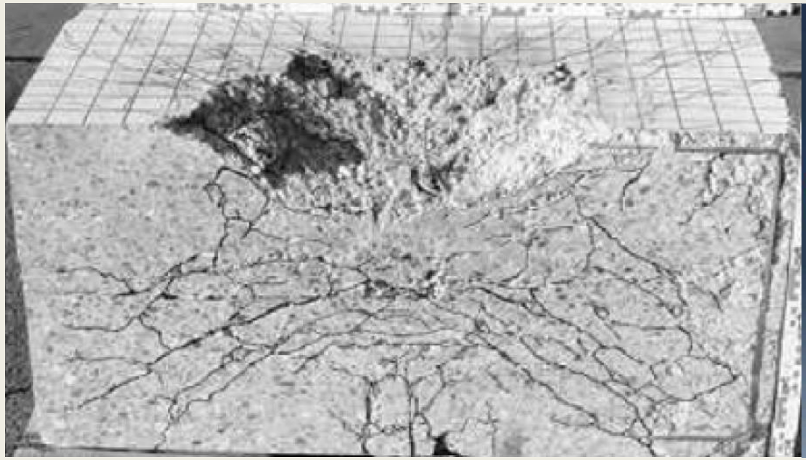


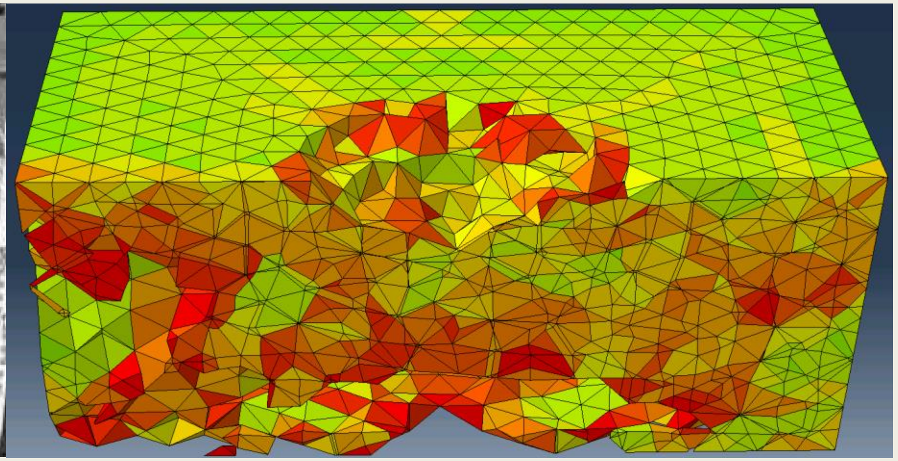
Test

Simulation

Test data: Rabczuk, T and Belytschko, T. (2007) “A tree-dimensional large deformation meshfree method for arbitrary evolving cracks”, Comput. Methods Appl. Mech. Engrg. 196:2777-2799.

Simulation of Explosion of 400g TNT on A 50cm Thick Plain Concrete Plate



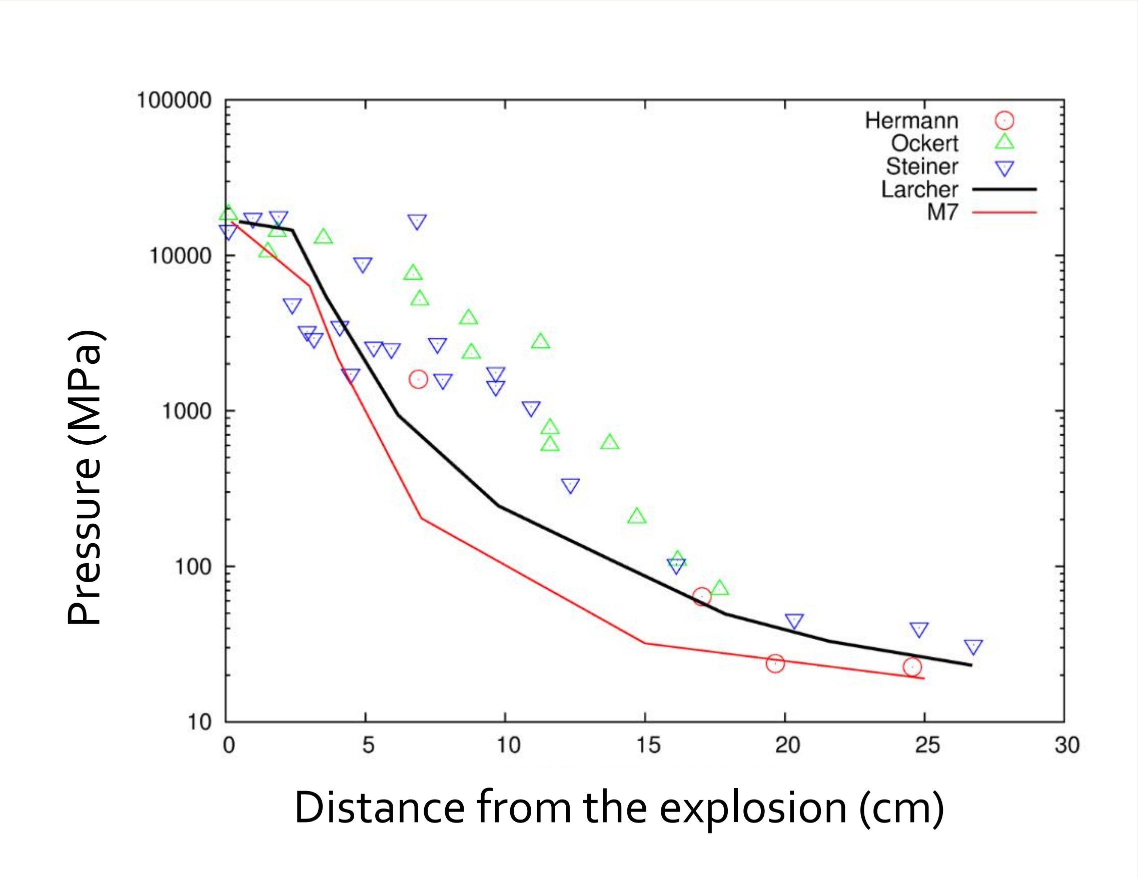


Test

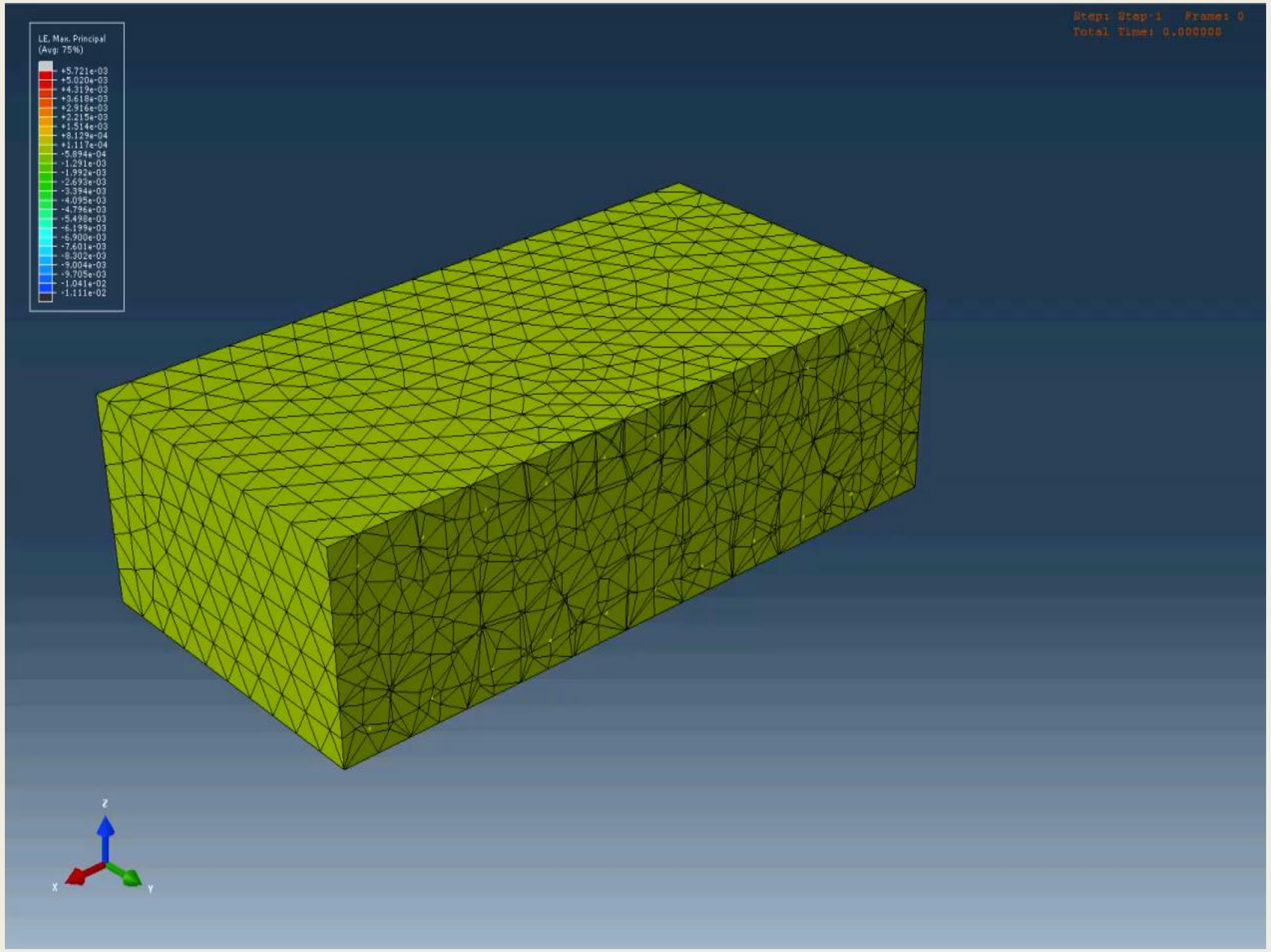
Simulation

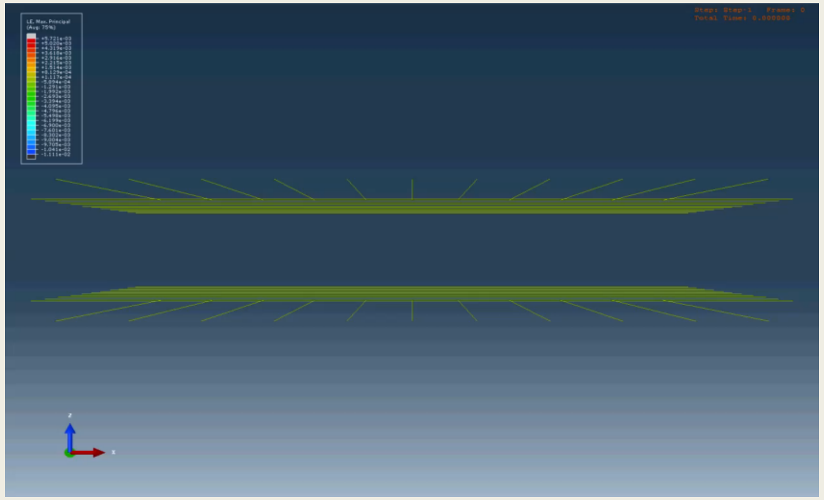
Test data: Rabczuk, T and Belytschko, T. (2007) “A tree-dimensional large deformation meshfree method for arbitrary evolving cracks”, Comput. Methods Appl. Mech. Engrg. 196:2777-2799.

Simulation of Explosion of 400g TNT on A 30cm Thick Plain Concrete Plate



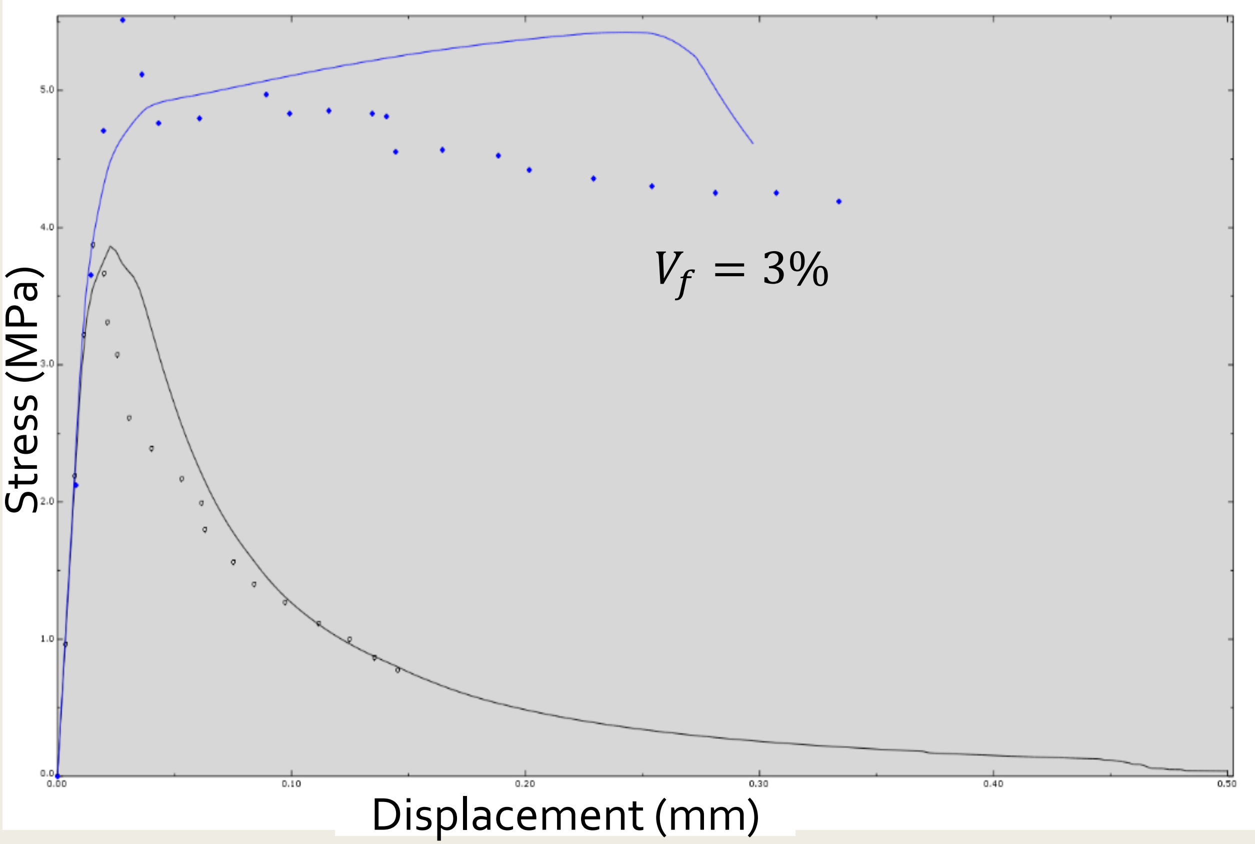
Simulation of Explosion of 400g TNT on a 30cm Thick Reinforced Concrete Plate

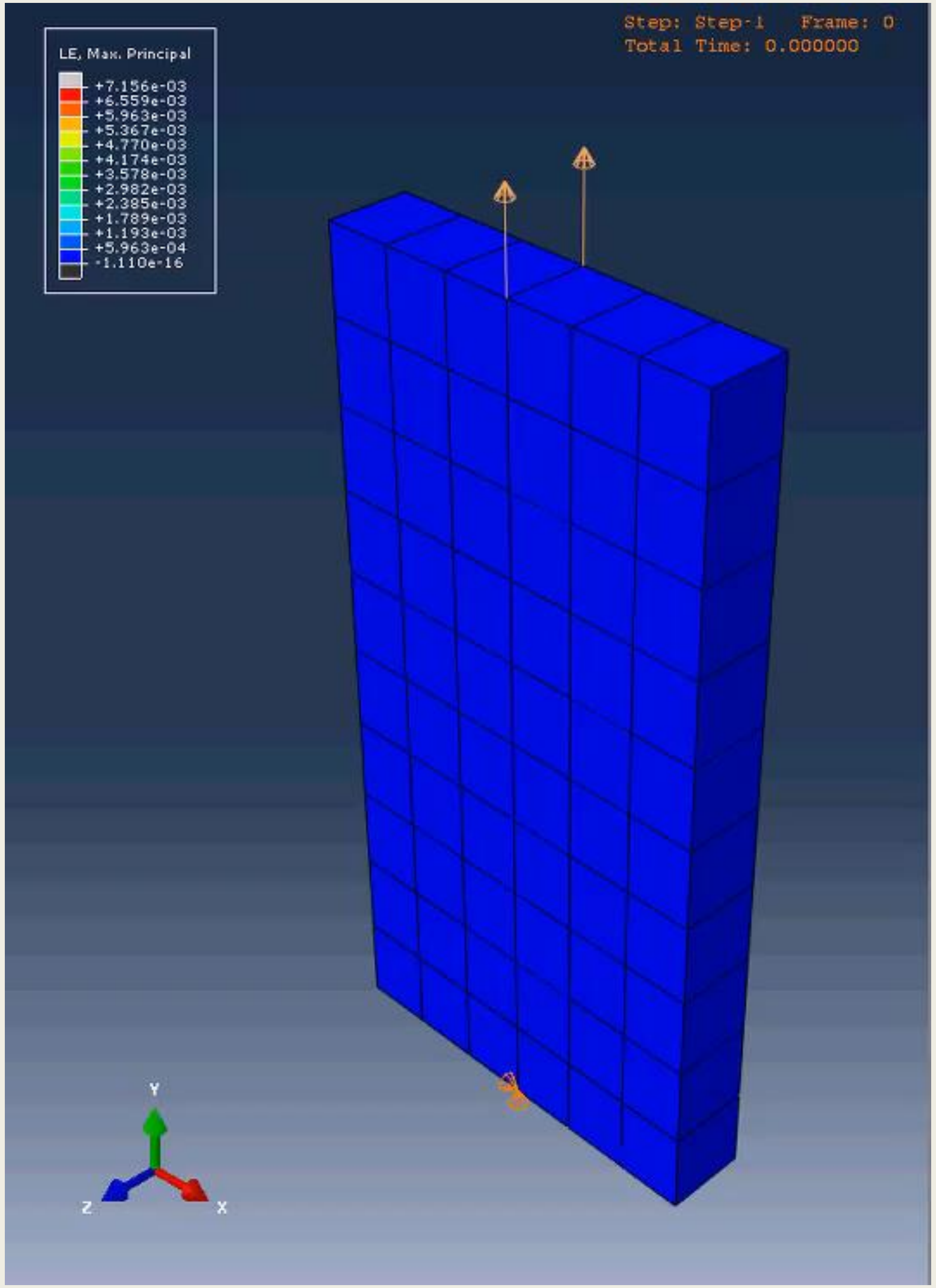




Reinforcement at upper and lower faces

Fiber Reinforced Concrete
M7F – Harex Fibers

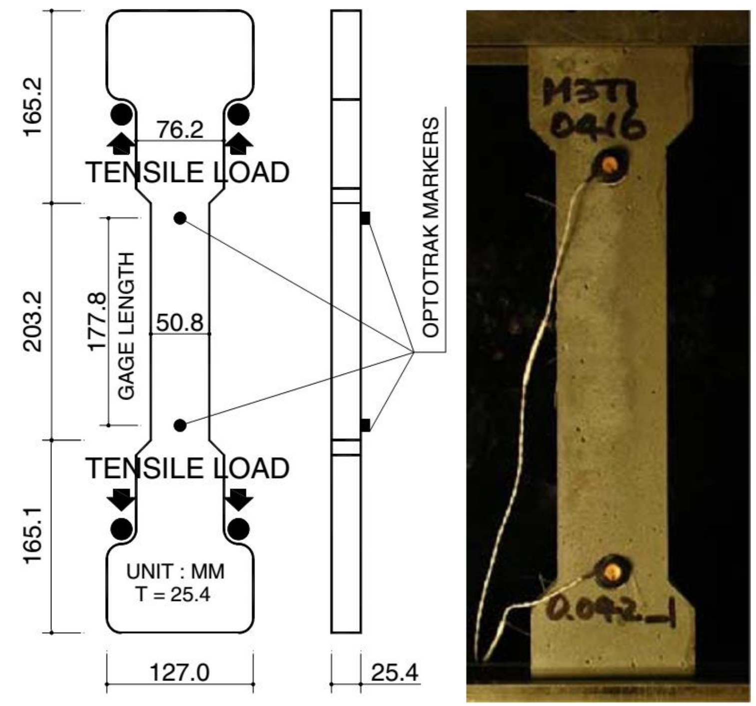




Test data: Kim DJ, El-Tawil S, Naaman AE (2009). "Rate-dependent tensile behavior of high performance fiber reinforced cementitious composites", Materials and Structures, 42:399-414.

Rate-Dependent Microplane Model for Fiber Reinforced Concrete M7FR – Torex Fibers

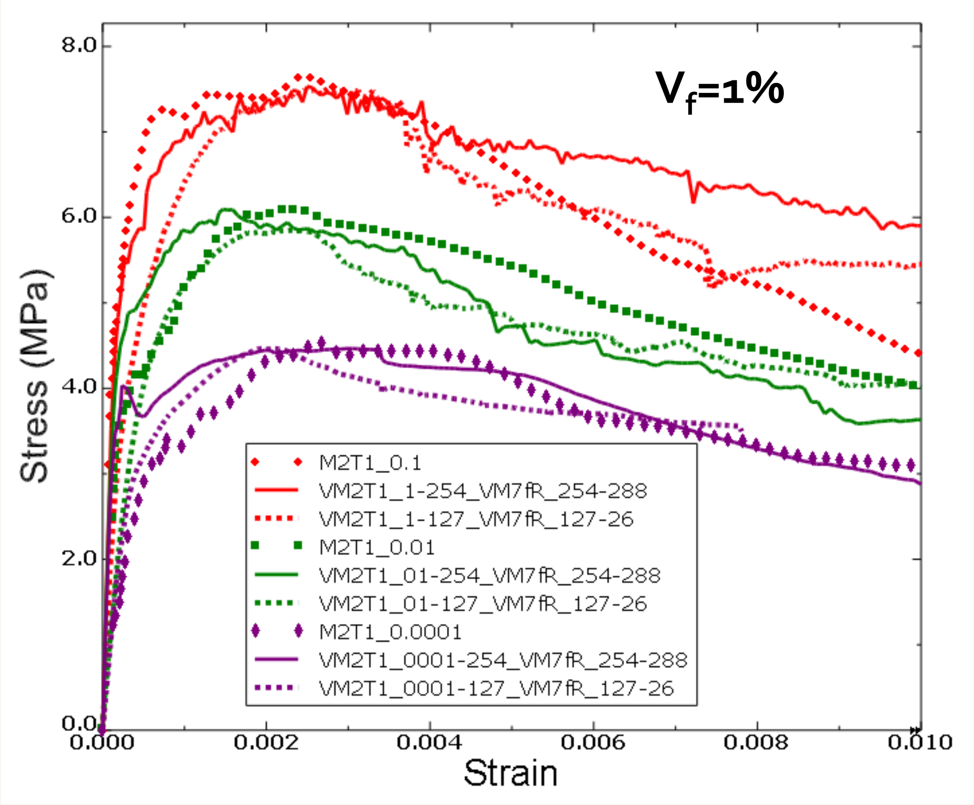
Fig. 3 Photos for hooked fiber and twisted fiber after fiber pullout. (**a**) Hooked fiber, (**b**) Twisted fiber



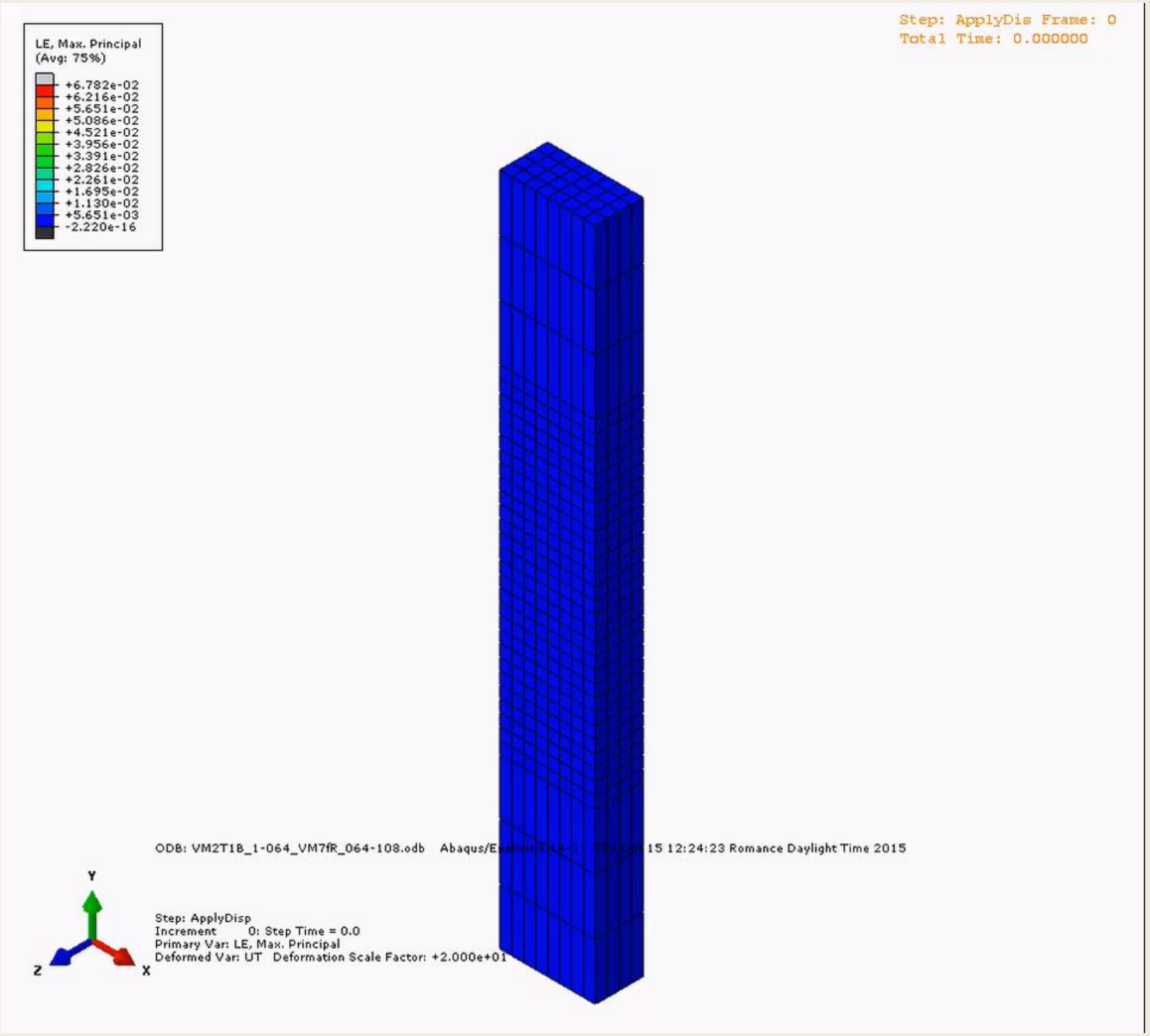
Test setup

Test data: Kim DJ, El-Tawil S, Naaman AE (2009). "Rate-dependent tensile behavior of high performance fiber reinforced cementitious composites", Materials and Structures, 42:399-414.

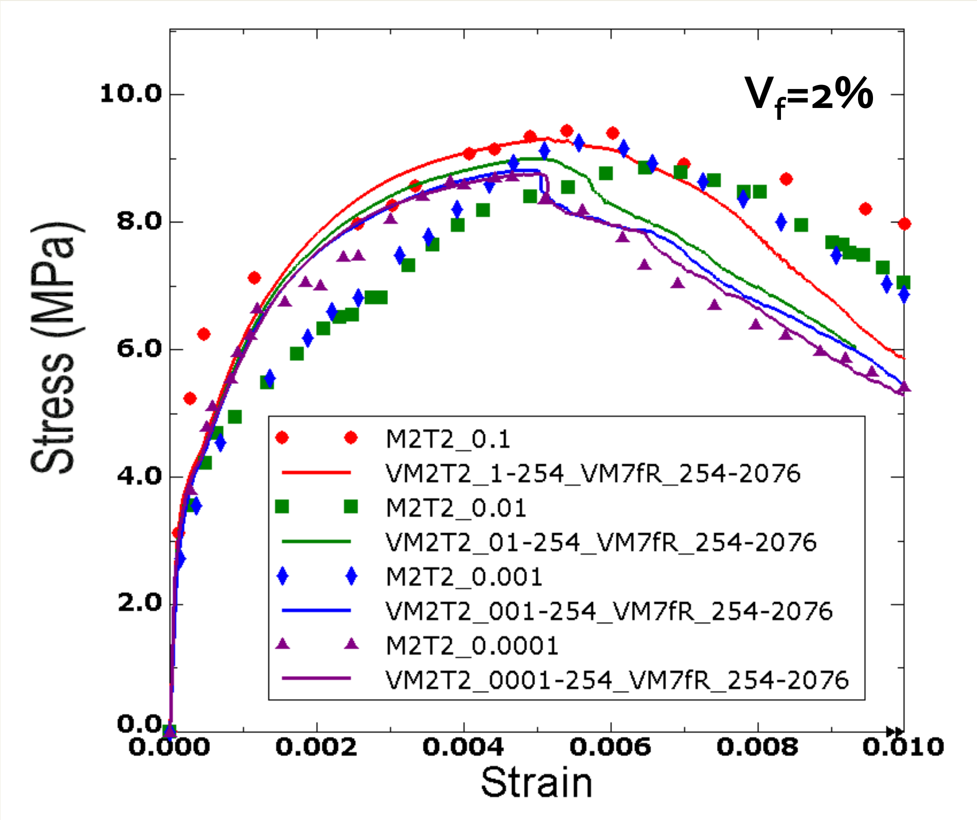
Rate-Dependent Microplane Model for Fiber Reinforced Concrete M7FR – Torex Fibers



Test data: Kim DJ, El-Tawil S, Naaman AE (2009). “Rate-dependent tensile behavior of high performance fiber reinforced cementitious composites”, Materials and Structures, 42:399-414.



Rate-Dependent Microplane Model for Fiber Reinforced Concrete M7FR – Torex Fibers



Test data: Kim DJ, El-Tawil S, Naaman AE (2009). "Rate-dependent tensile behavior of high performance fiber reinforced cementitious composites", Materials and Structures, 42:399-414.

Conclusions

The Microplane Model M7 solved **3** 20-year-old problems :

1. It removes the excessive lateral contraction in tension.
2. It correctly predicts damage in the loading/unloading stiffness in tension.
3. It reduces the number of stress-strain boundaries from five to four.

The model successfully simulates:

1. The quasi-static and dynamic behavior of plain concrete over strain rates in the range [0,0001 – 10,000]/s.
2. The quasi-static and dynamic behavior of fiber reinforced concrete over strain rates in the range [0,0001 – 10,000]/s.
3. Mesh independence by treating the element size as a material property.

Thank you for your attention.

Test

Simulation