UNIVERSITÉ LIBRE DE BRUXELLES, UNIVERSITÉ D'EUROPE

Introduction to nonlinear finite element modeling

Péter Z. Berke

1.1. Introduction

Inspired and adapted from the 'Nonlinear Modeling of Structures' course of Prof. Thierry J. Massart at the ULB

Outline

Motivation & Application field

Examples of non-linear phenomena

Course objectives

Course outline

Motivation

A large number of practical problems are non-linear

Various software used but their use can be dangerous

- their scope >> average knowledge of engineers
- software are often not documented in detail

Still the subject of intensive research

NL computations often used as complement of experimental procedures (e.g. crash tests)

Computational investigation are often required

Application fields

Structural mechanics (buildings, civil engineering)

Mechanical engineering (engines, composites, …)

Mechanics of Materials (forming, link between the texture of materials and their properties)

Soil mechanics, geotechnical applications

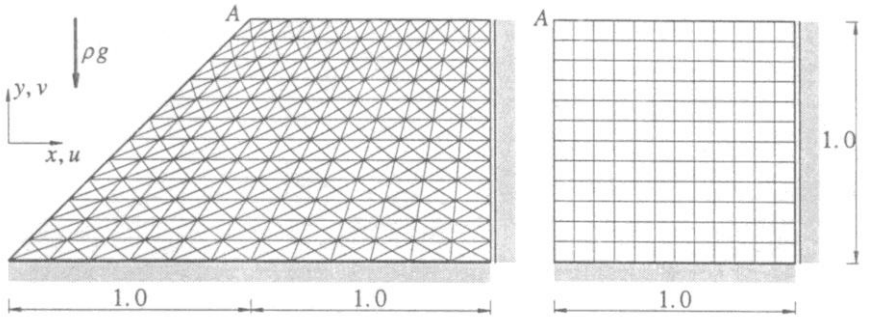
Moisture transport, thermal problems, …

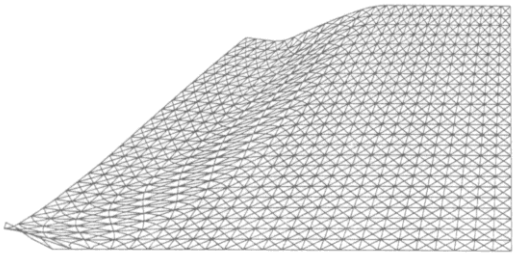
Multi-physical coupled problems

In this course: **Mechanical and civil engineering problems**

Slope stability

Ouro Preto, 2012



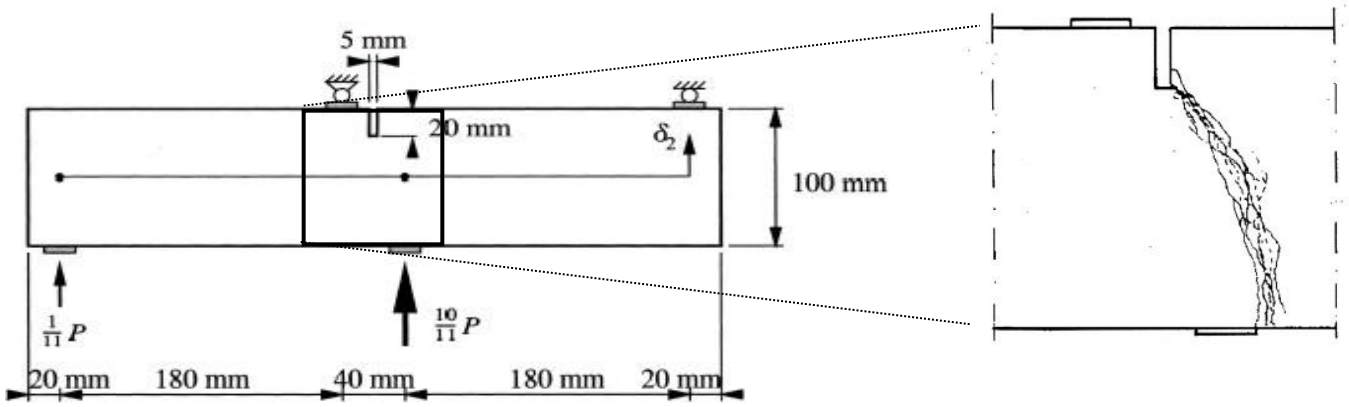


Ph.D. Jerzy Pamin (TUDelft, 1994)

[unknown source]

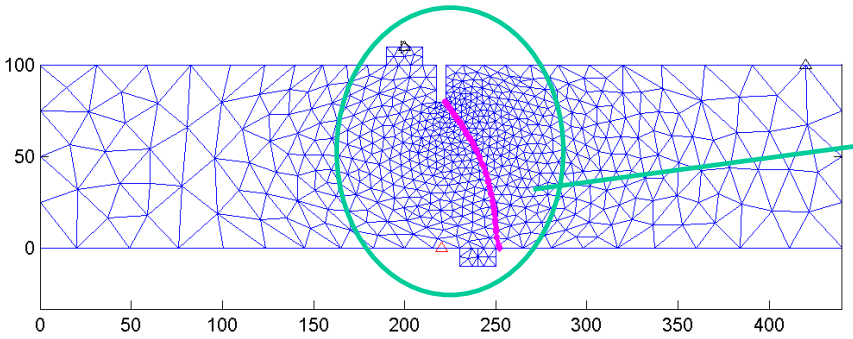
Materials characterisation - Failure

de Borst & Van Der Giessen eds, 1998

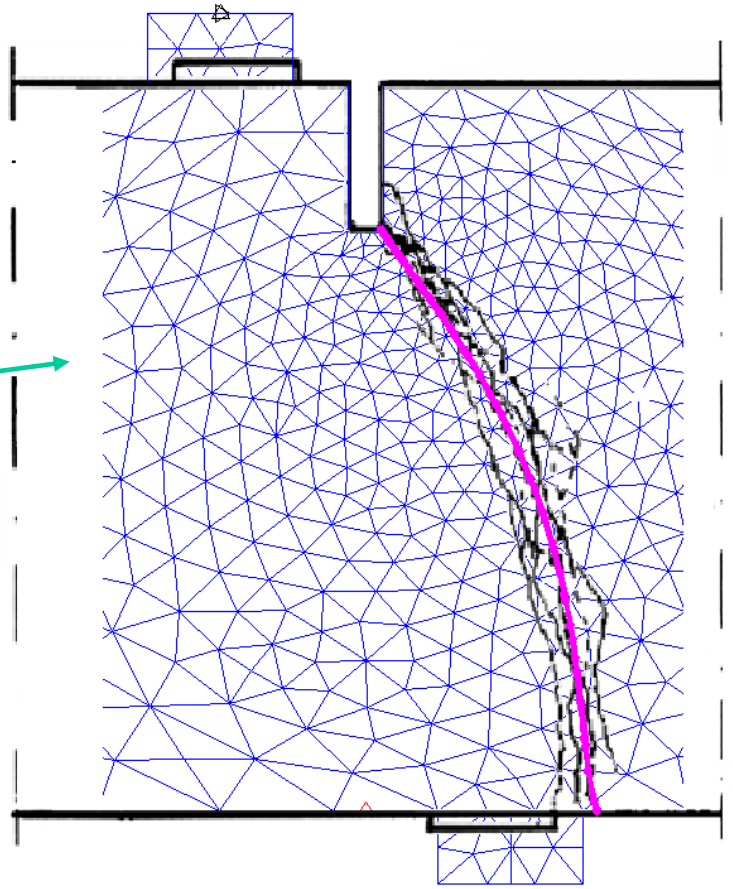


Geers, de Borst, Peerlings, 2000

Materials characterisation - Failure



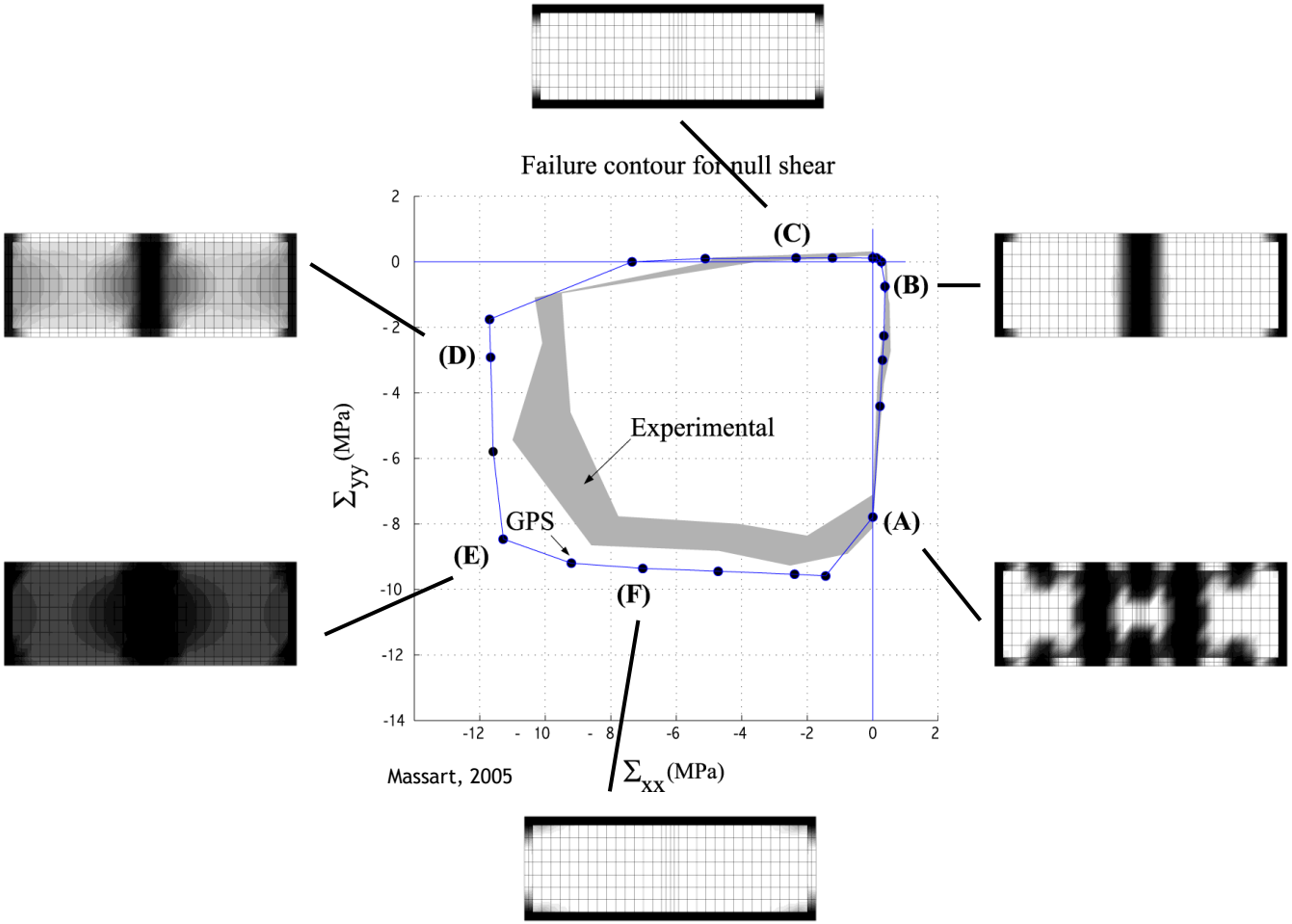
G.N. Wells, 2001



Schlangen – 1993

Materials characterisation – Failure of masonry

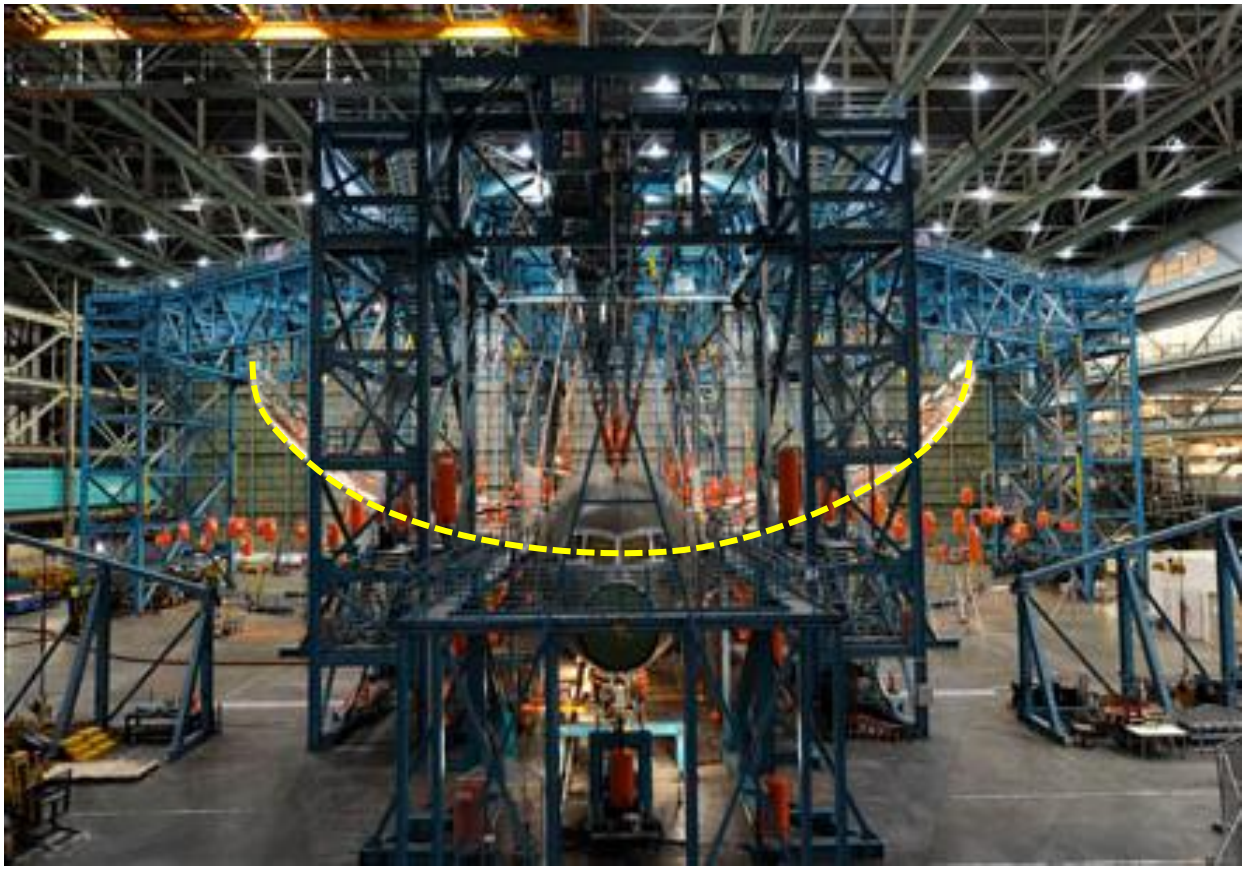
[http://wehavea.name/Photo.ashx/434ef4e5c599456fb2a460a6dbbcedde]



Anisotropy, damage, plasticity…

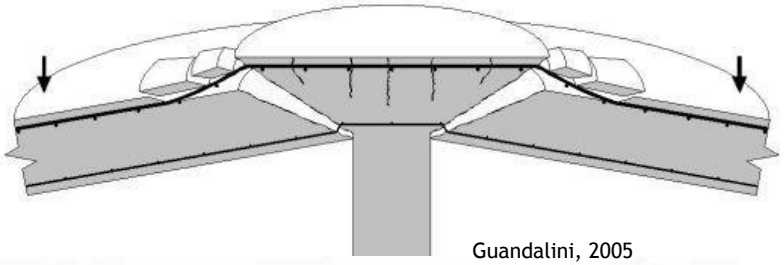
Structural failure

Boeing 787



[http://www.boeing.com]
[http://www.youtube.com/watch?v=sA9Kato1CxA]

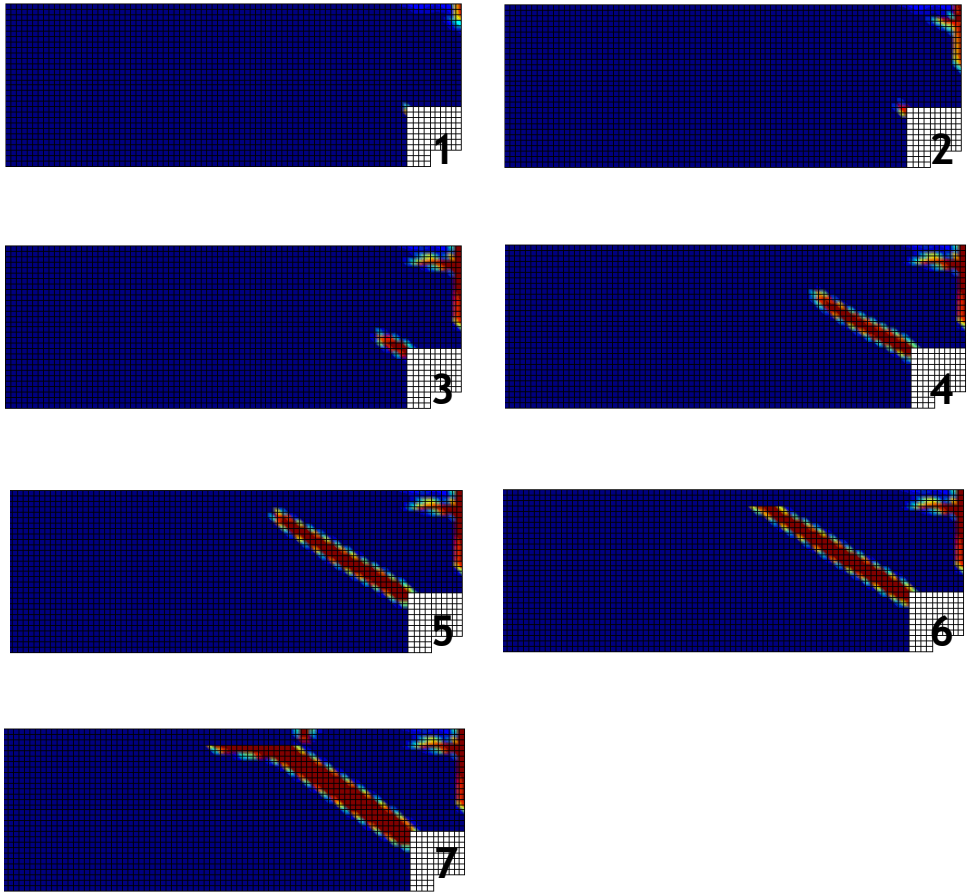
Structural failure (punching failure)



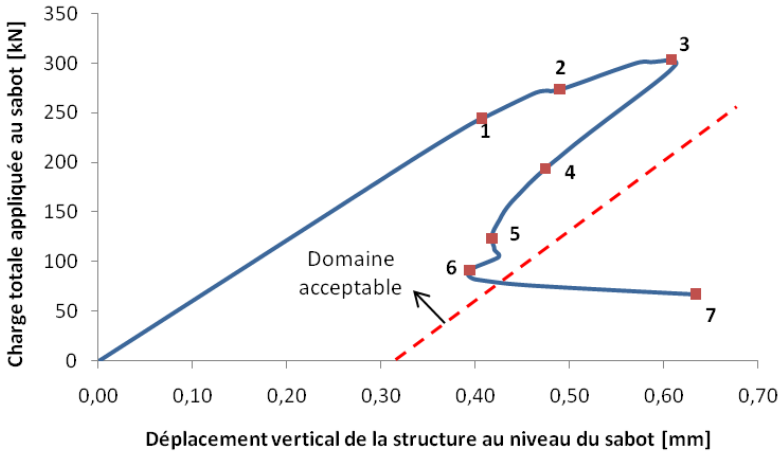
Guandalini, 2005

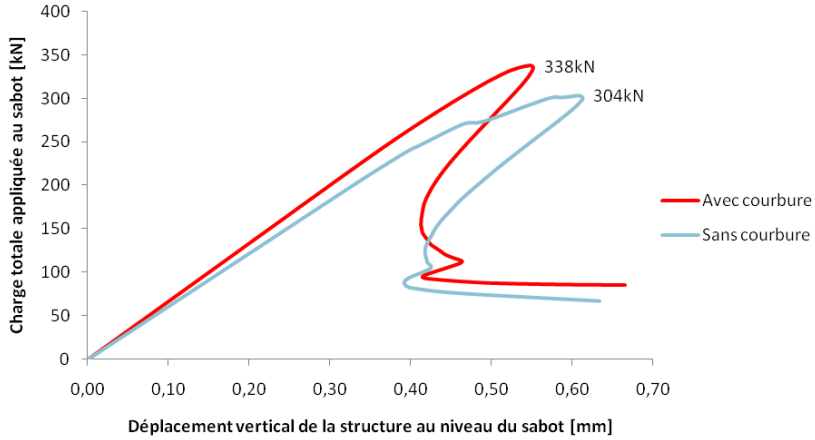
J.G.M. Wood, 2007

Punching of planar shell - modelling

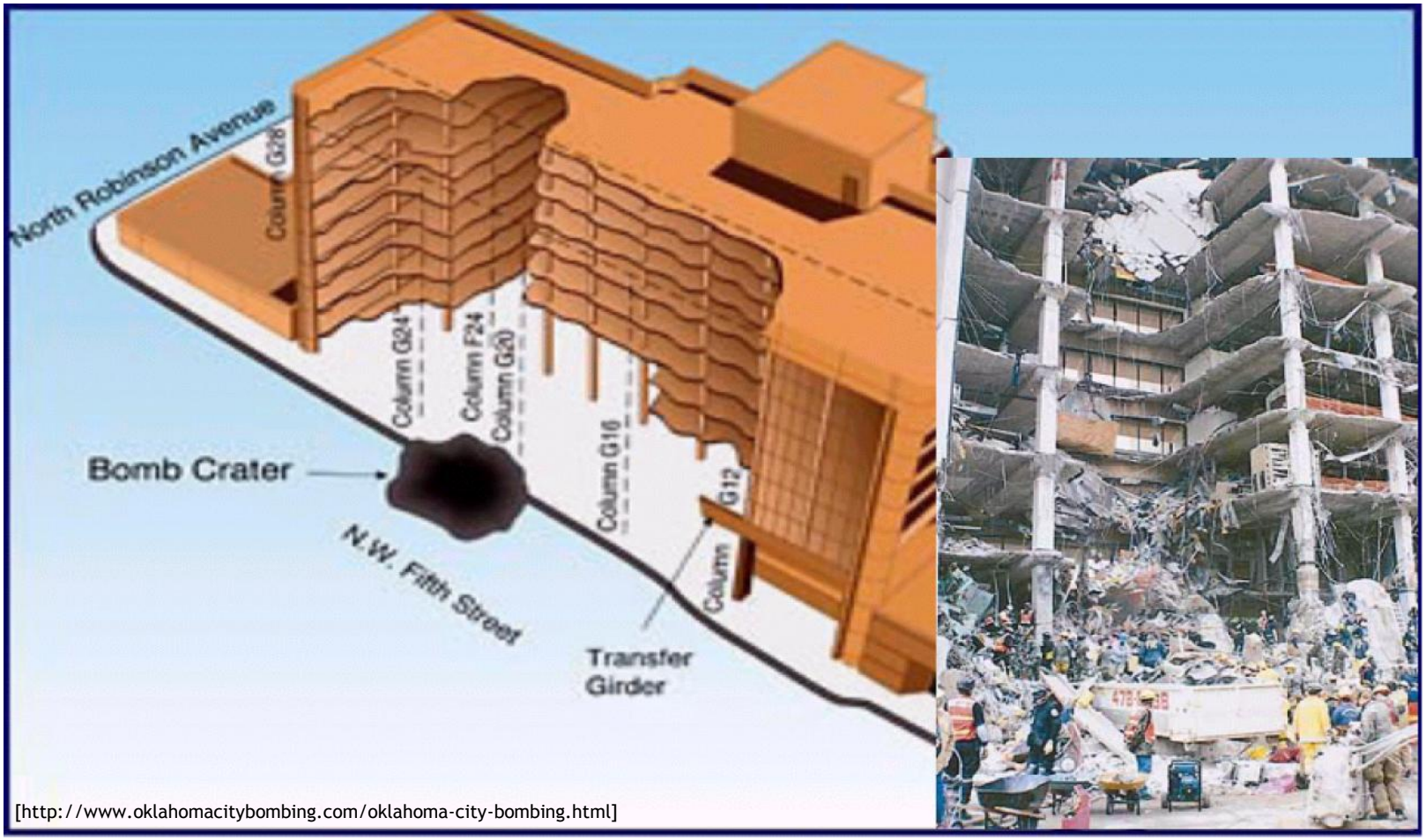


M. Syed Ali Azor, MFE grad. damage, 2008





Structural failure (progressive collapse)



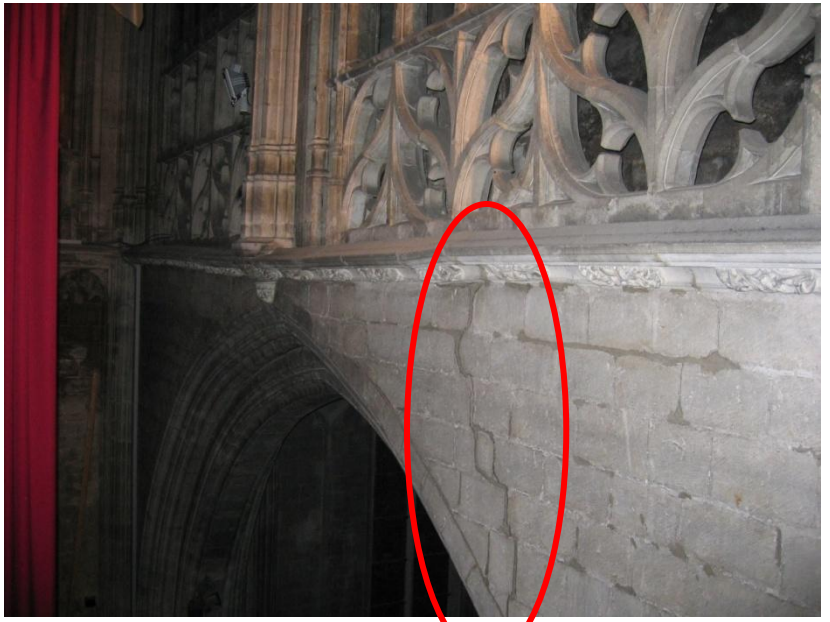
[http://www.oklahomacitybombing.com/oklahoma-city-bombing.html]

Structural failure (geometrical effects)

[unknown source]

Historical structures: local cracking

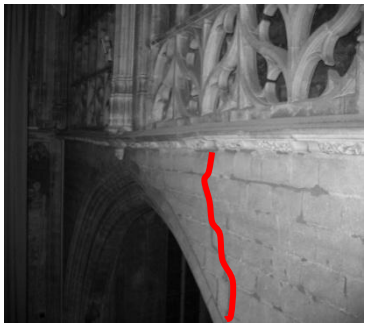
M. Provost

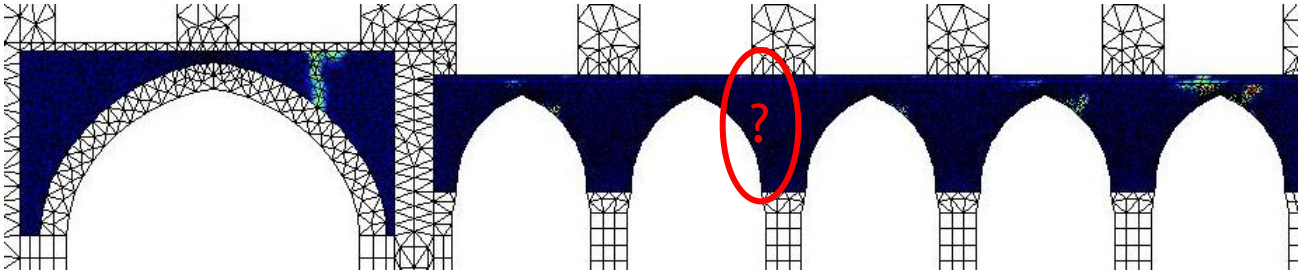


Historical structures: local cracking

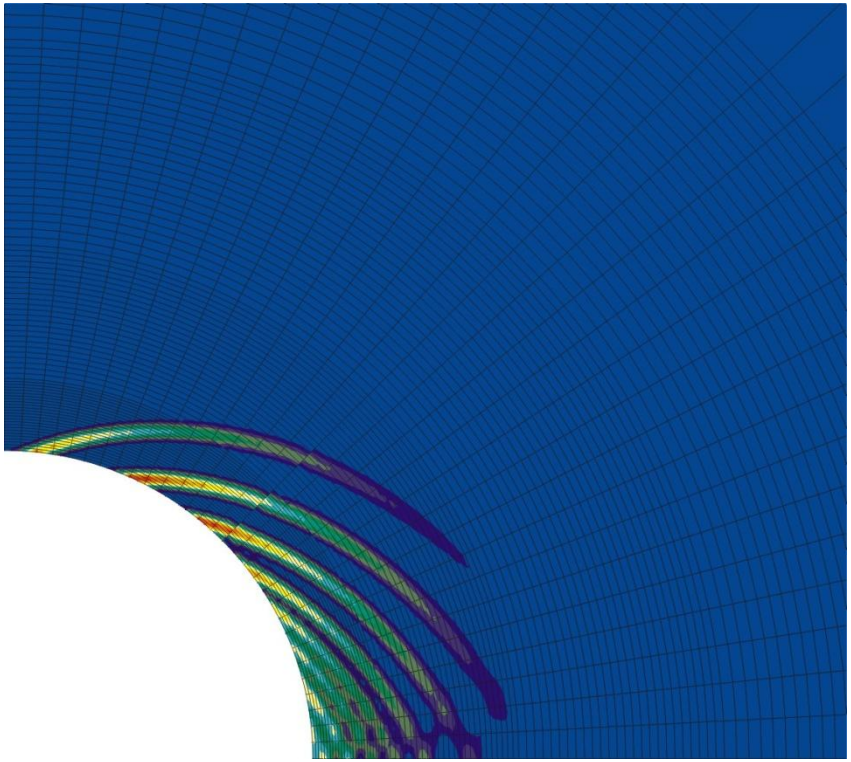
M. Provost

Computational results vs. observations



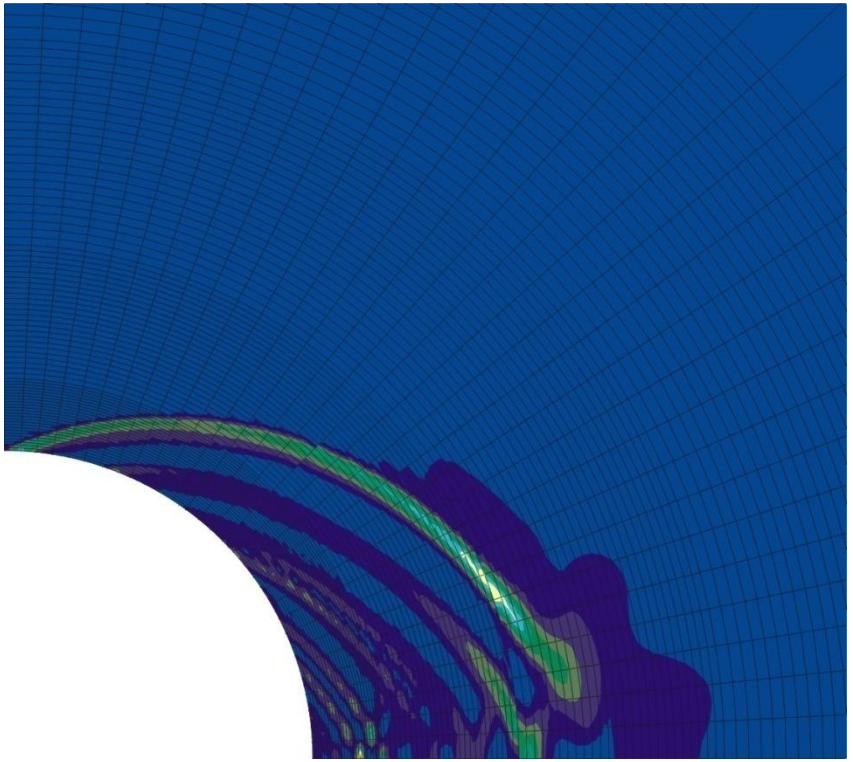


Tunnelling



F. Collin, ULg

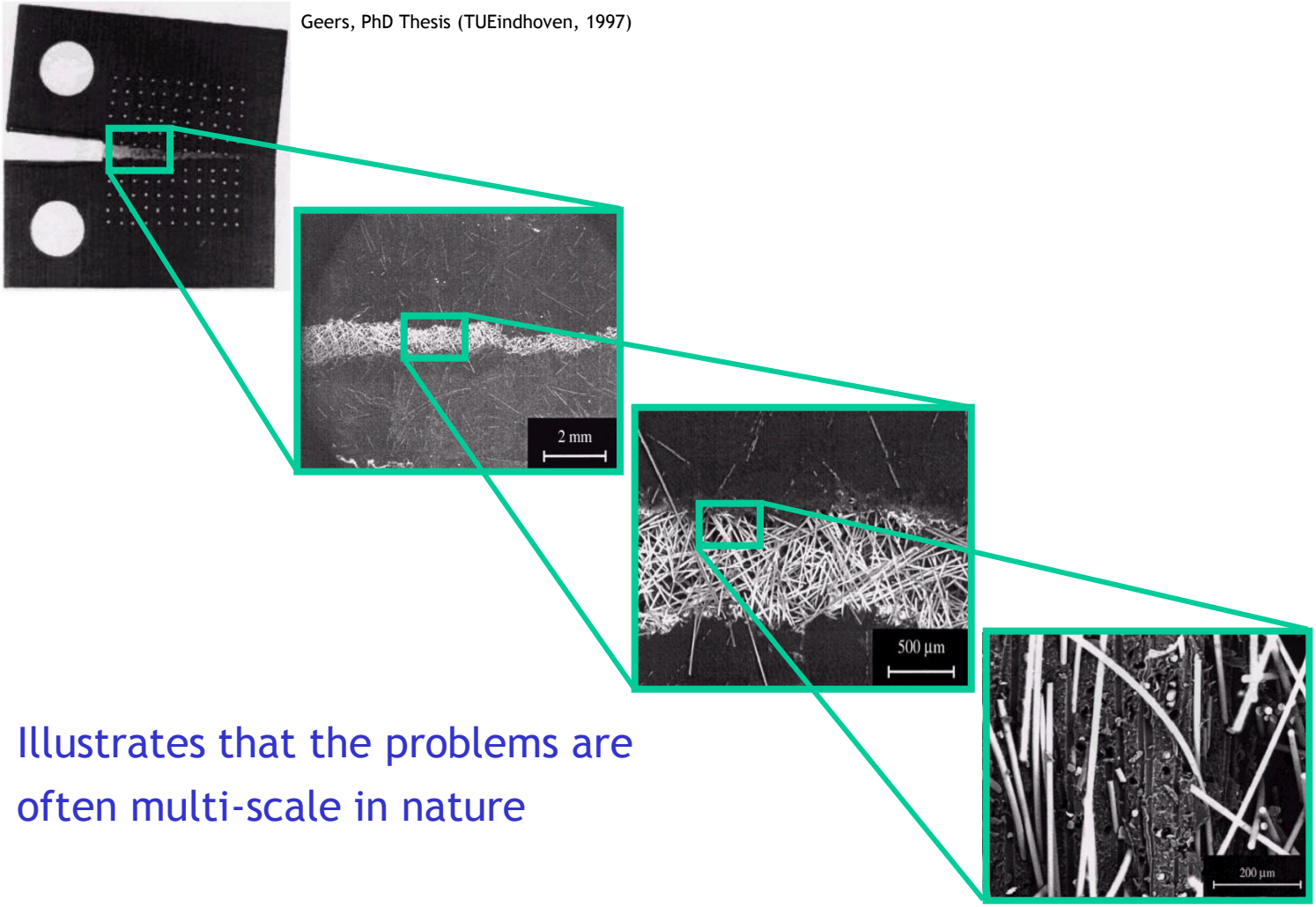
Deviatoric deformations



Deviatoric deformation gradients

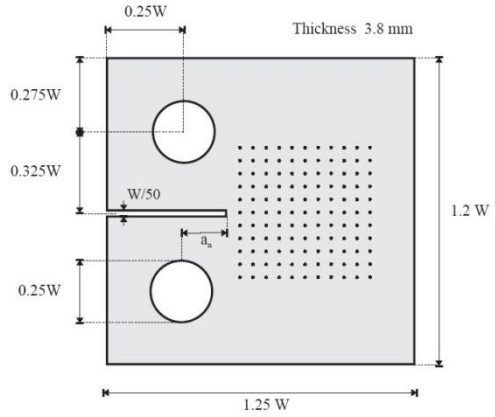
Cracking changes mater. Properties (e.g. permeability)

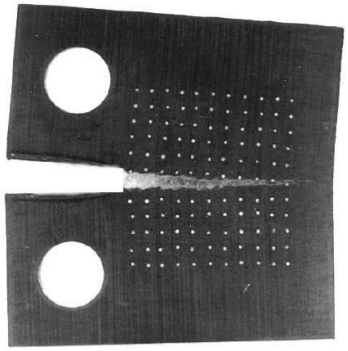
Composite failure (short fibers reinforced polypropylene)

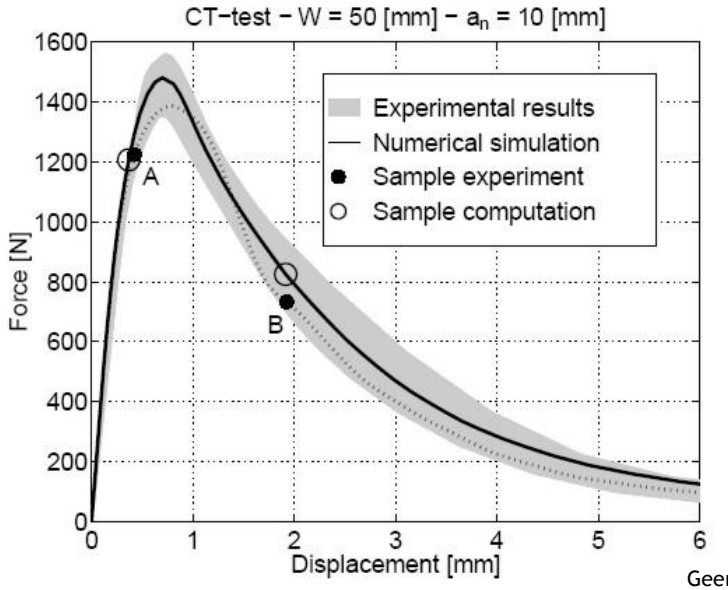


Illustrates that the problems are often multi-scale in nature

Composite failure - modelling







Geers, PhD Thesis (TUEindhoven, 1997)

Crash test simulations

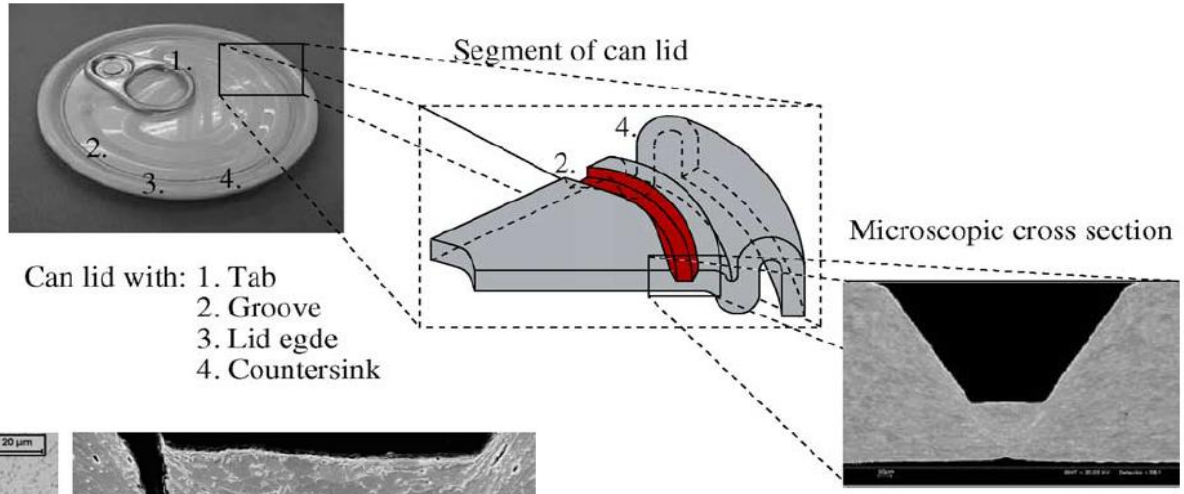
[http://www.esi-group.com/Products/Crash]

Large displacements analyses

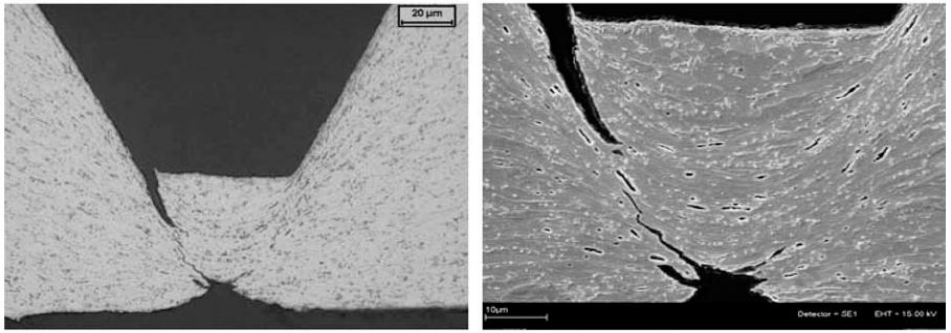

[unknown source]

Does the problem need to be formulated in the initial or deformed configuration ?

Large deformations and failure



Boers et al., 2005



→ Pre-damaging required to allow 'easy' opening

→ However the sealing should not be compromised

→ Computations can help optimising the process

Course objectives

Computational tools are required

→ Analytical approaches not always available

→ In this case, efficiency of simulations is required

But such tools are complex to formulate and use

→ Global overview of the available methods is required

→ A good end-user understanding is a key !

Course objectives and targeted competencies

→ Understand some main principles of nonlinear modeling

→ Being able to detect the key aspects of a problem

→ Being an ‘entry point’ for your future needs if any

→ Understanding the limit of applicability of the proposed methods

Course organization

- 4 Lecture sessions = 9 hours
- 1 Exercise session = 1 hour

Remarks

- This course is an introduction, yours to complete by other readings
  [Zienkiewicz, Crisfield]
- There is no stupid question, only questions you do not dare to ask
- Constructive suggestions are welcome

Outline

1. Introduction and ‘Prerequisites’
2. Geometrical nonlinearities
3. Material nonlinearities
4. Solution procedures for structural problems
5. A peak into advanced subjects