Geometrically nonlinear finite element modelling of linear elastic truss structrures

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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 of NL models

Examples of non-linear phenomena

Course objectives and 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 vs. experiments (e.g. crash tests)

Computational investigations are often required

Application fields

Structural mechanics (buildings, civil engineering)

Mechanical engineering (engines, composites, …)

Mechanics of Materials (forming, texture vs. properties)

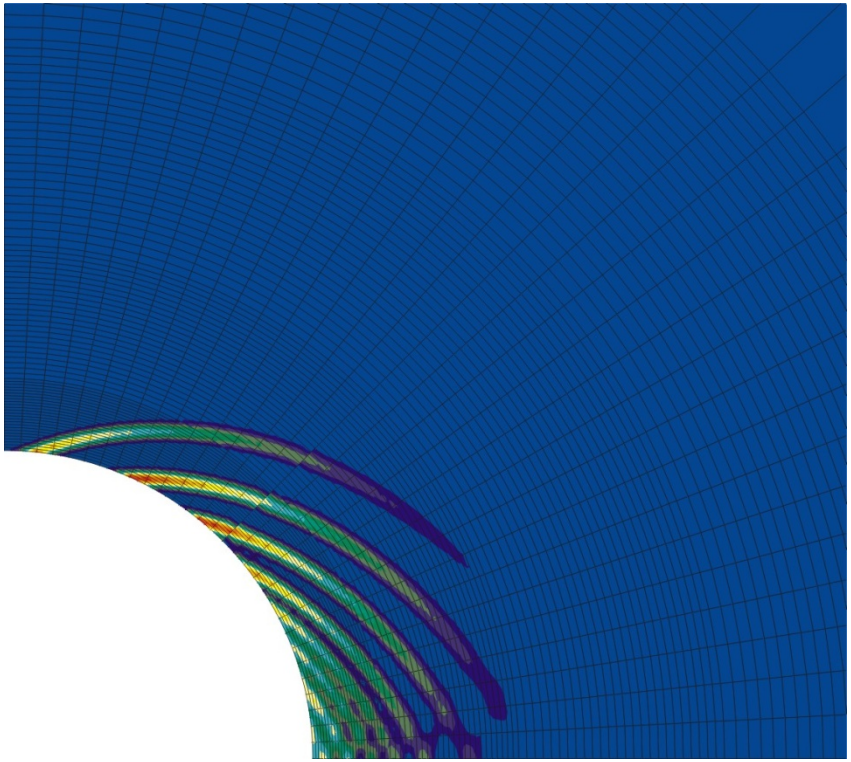
Soil mechanics, geotechnical applications

Moisture transport, thermal problems, …

Multi-physical coupled problems

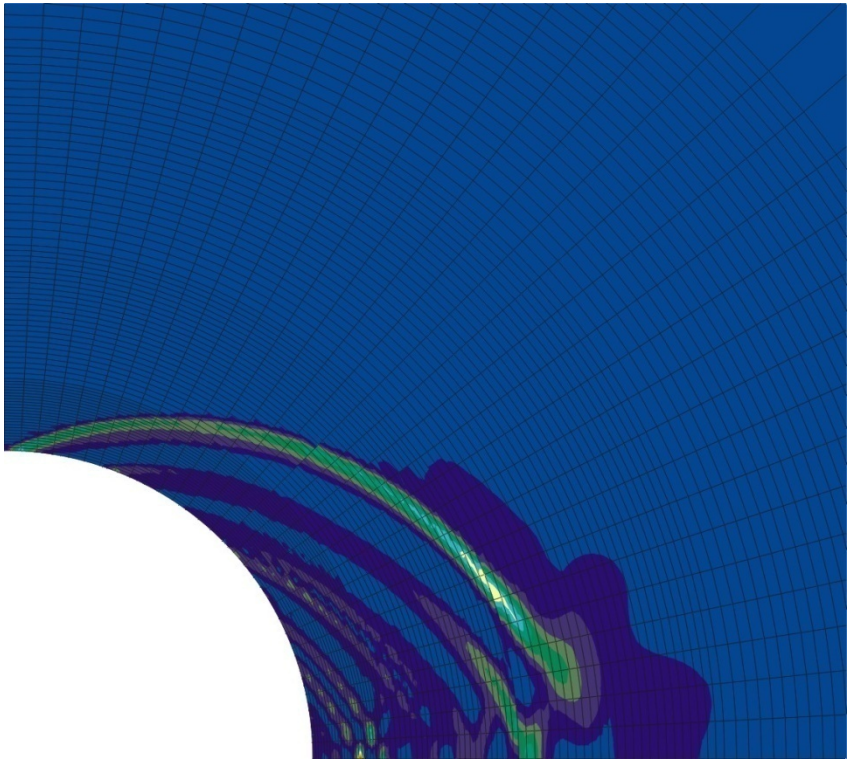
In this course: **Civil engineering problems**

Tunnelling



F. Collin, ULg

Deviatoric deformations

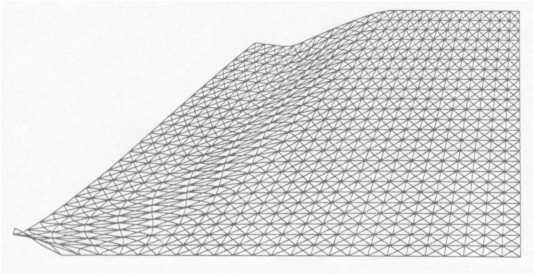


Deviatoric deformation gradients

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

Slope stability

Ouro Preto, 2012

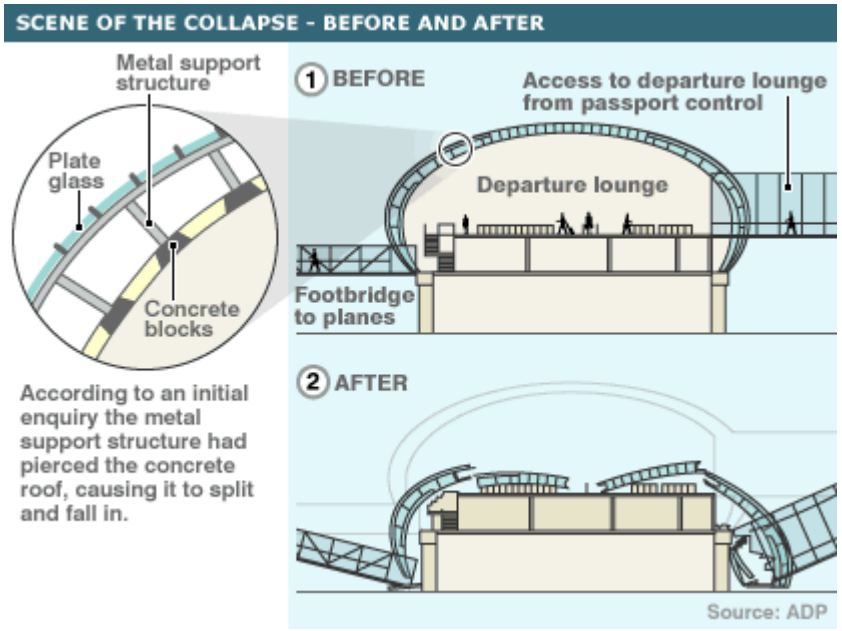


Ph.D. Jerzy Pamin (TUDelft, 1994)

[unknown source]

Punching failure

Charles de Gaulle Airport T2E
Cost ~ 750 M€, collapse 2004

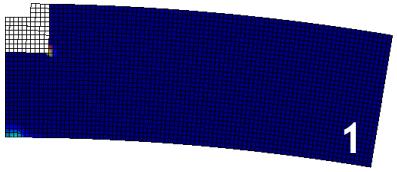


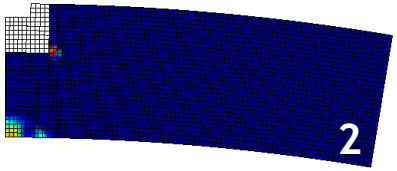
[http://newsimg.bbc.co.uk/media/images/40353000/gif/_40353045_paris_airport_new_inf416.gif]

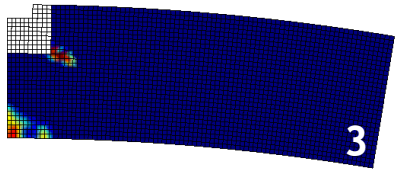
[http://en.wikipedia.org/wiki/File:Paris_Charles_De_Gaulle_Airport_Terminal_E_a.JPG]

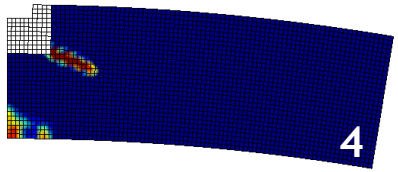
[http://english.peopledaily.com.cn/200405/24/images/0524.paris2.jpg]

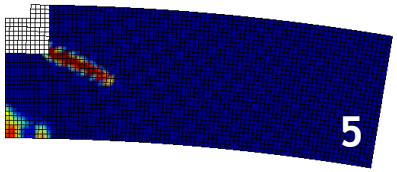
Punching of curved shell - modelling

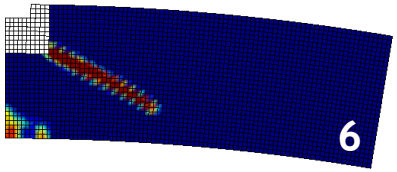


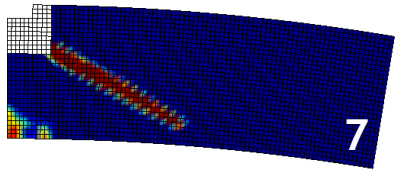


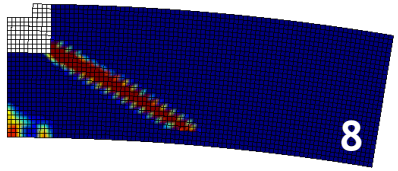


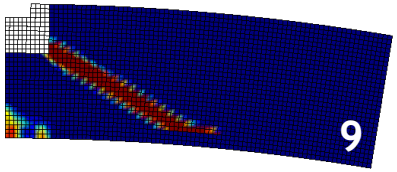


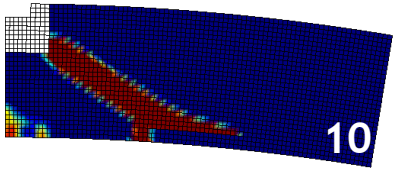




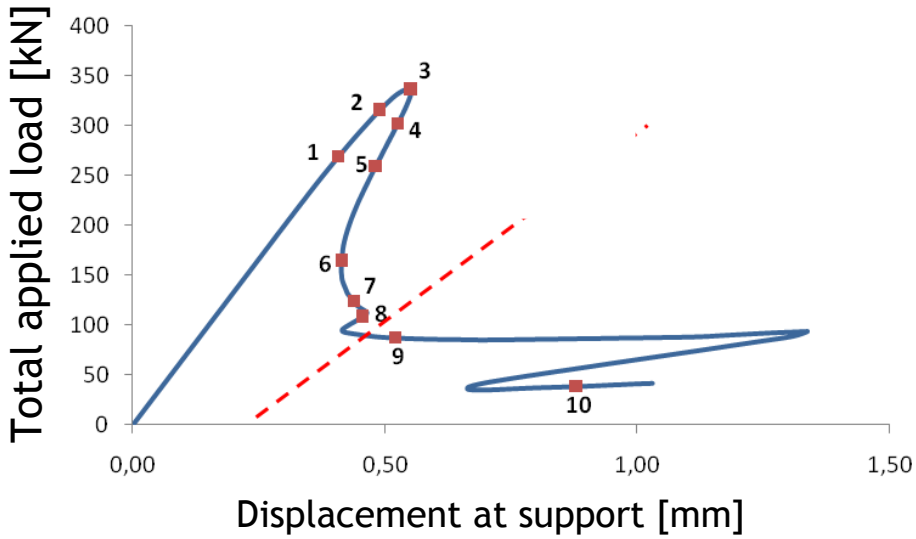




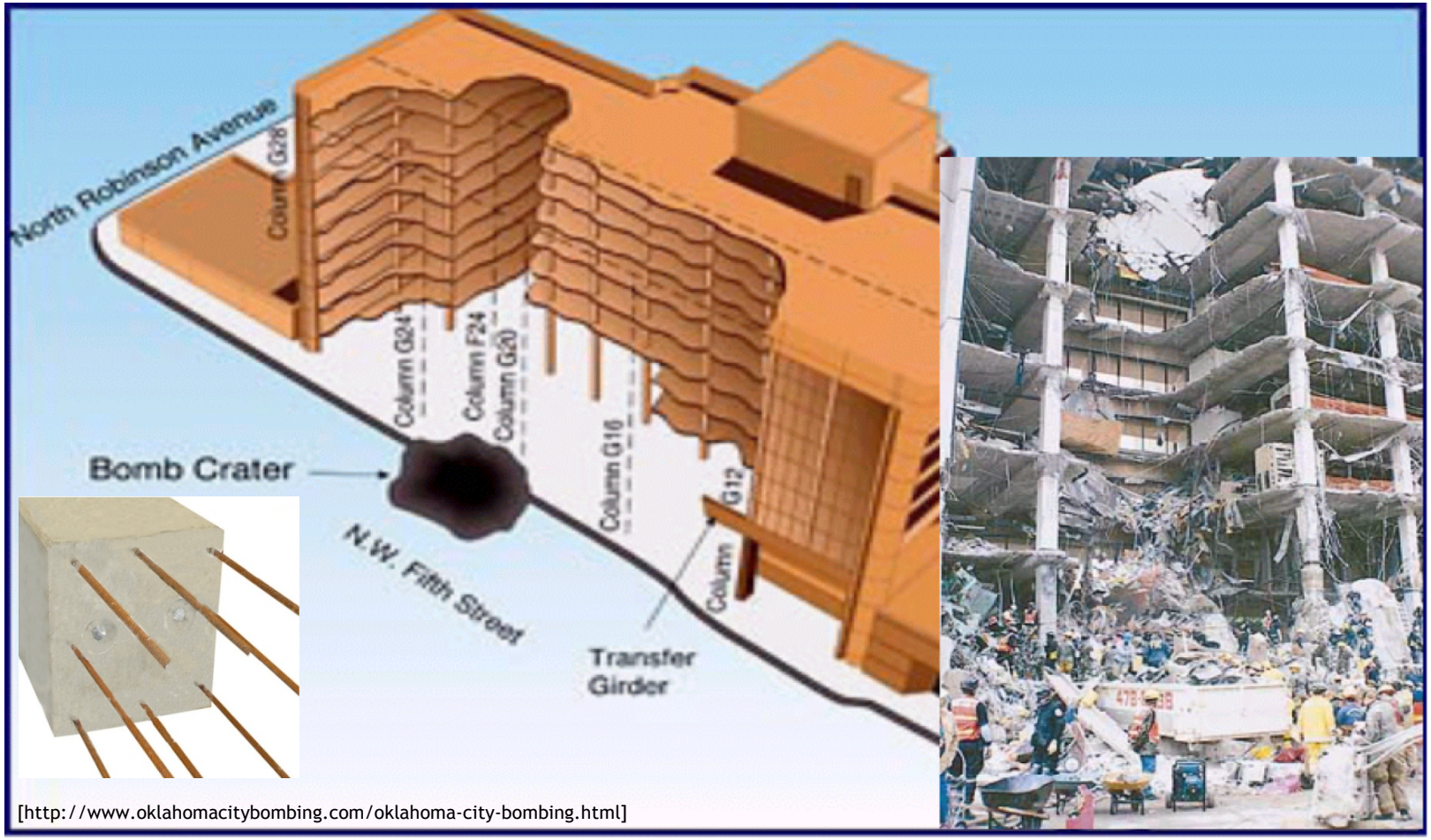




M. Syed Ali Azor, MFE grad. damage, 2008

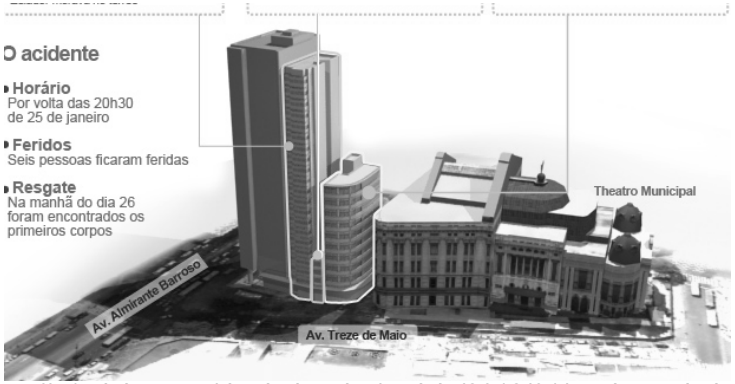


Structural failure (progressive collapse)

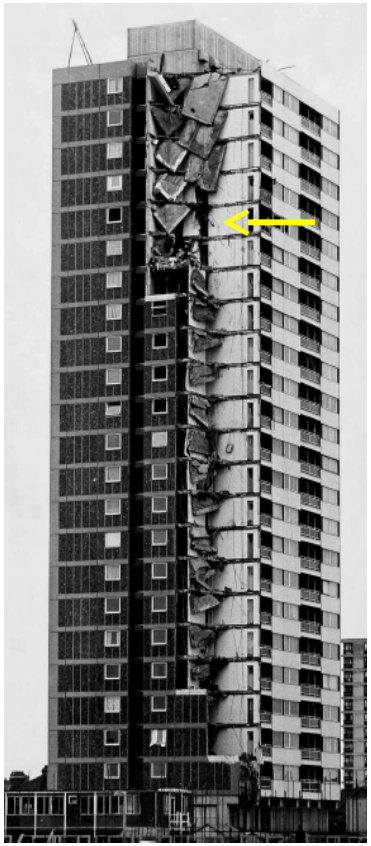


[http://www.oklahomacitybombing.com/oklahoma-city-bombing.html]

Progressive collapse



[http://g1.globo.com/rio-de-janeiro/noticia/2012/01/equipes-ainda-buscam-5-vitimas-de-desabamento-diz-defesa-civil-do-rj.html]



[Gas explosion, Ronan Point building, London, UK, 1968]

[WTC debris, Bankers Trust Building, New-York, 2001]

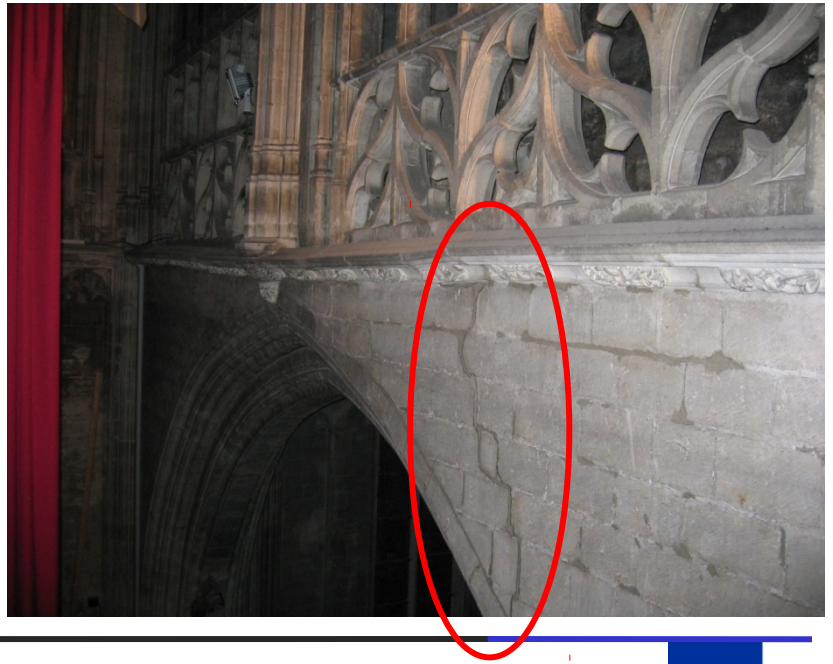
[The Real Class Building, Belém, Brazil, 2011]

Structural failure (geometrical effects)

[unknown source]

Historical structures: local cracking

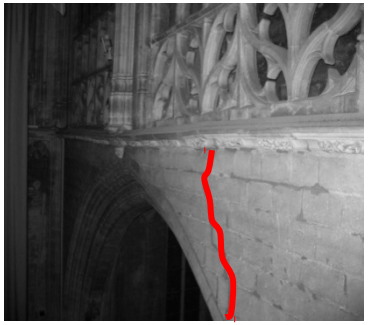
M. Provost

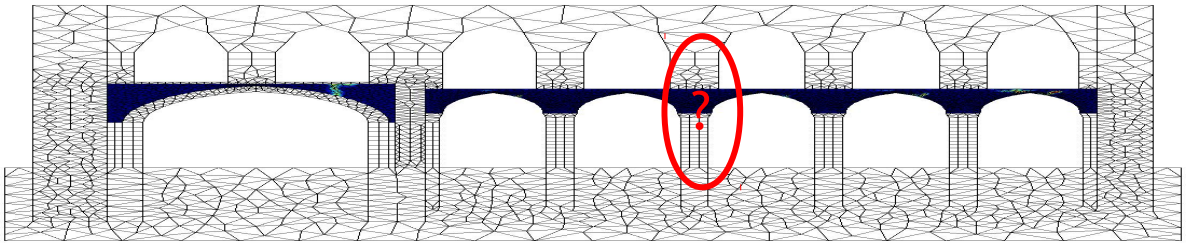


Historical structures: local cracking

M. Provost

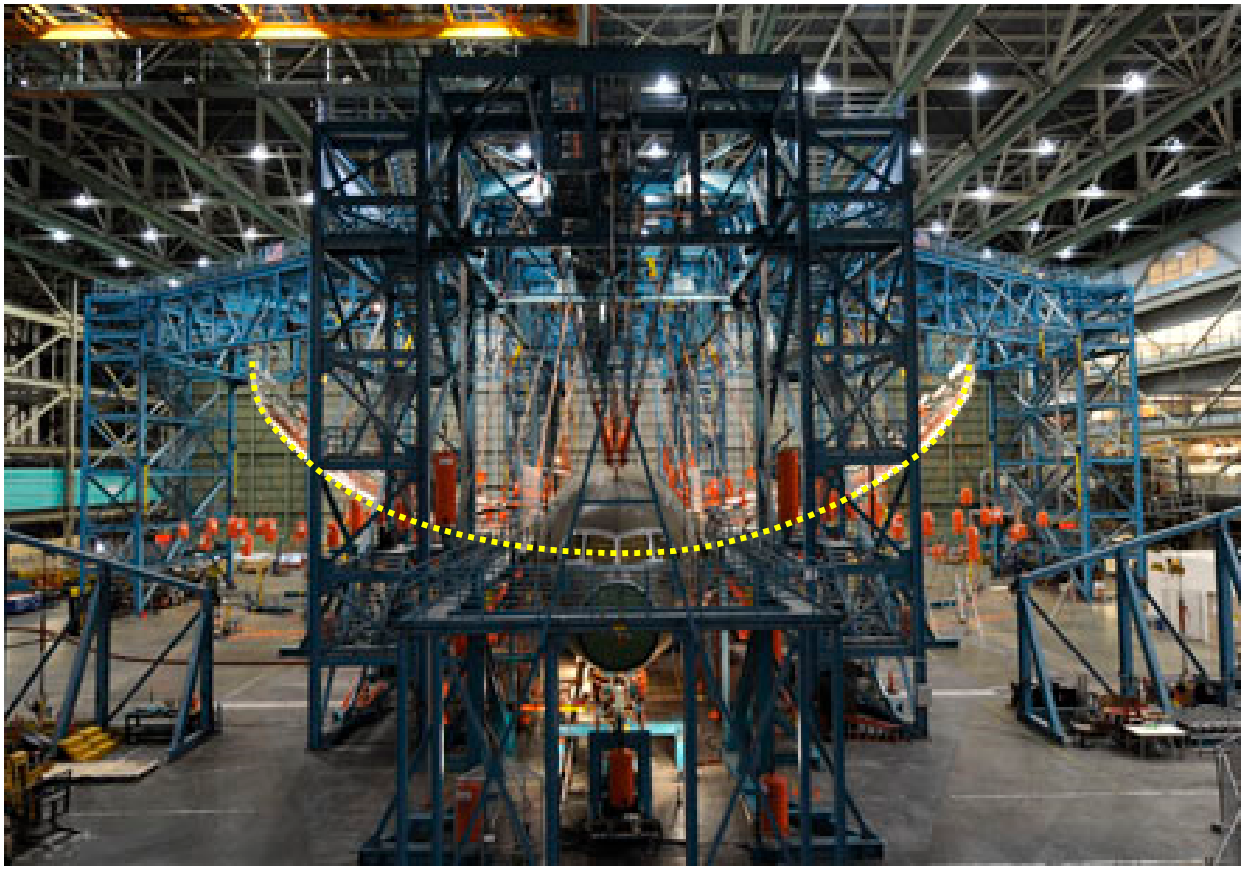
Computational results vs. observations





Structural failure

Boeing 787



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

Mechanical Engineering - Tribology

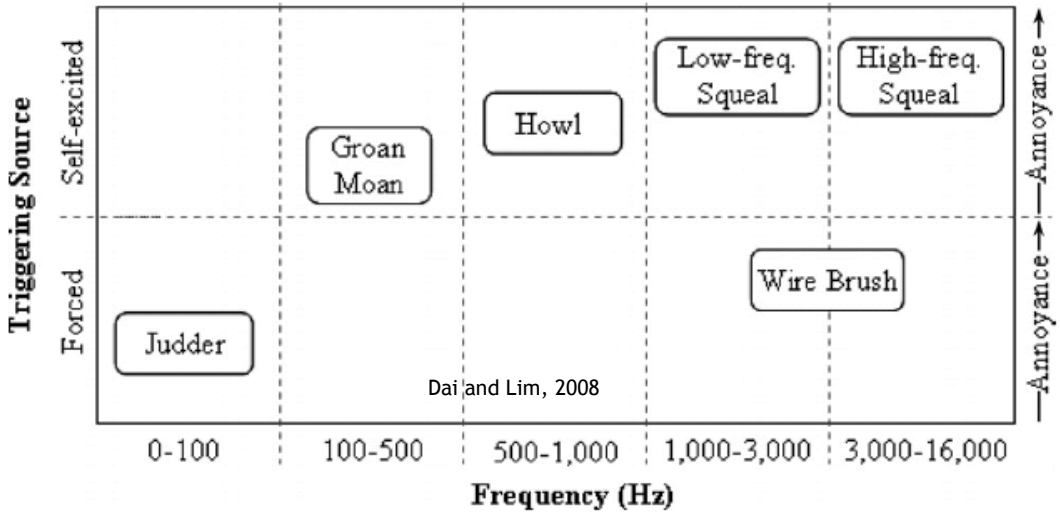


Fig. 1. Brake noise classification based on the frequency range of occurrence and excitation source.

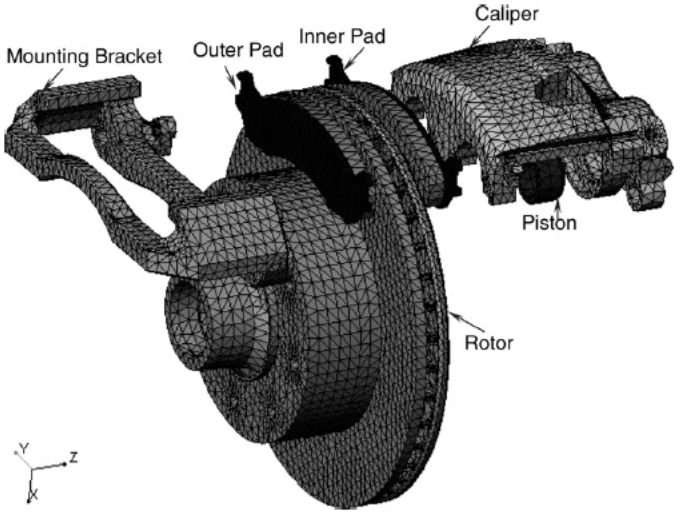
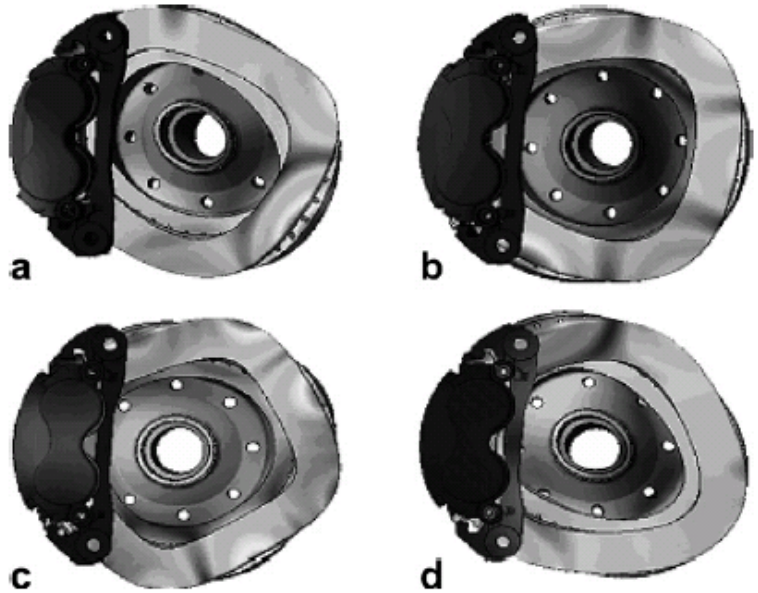
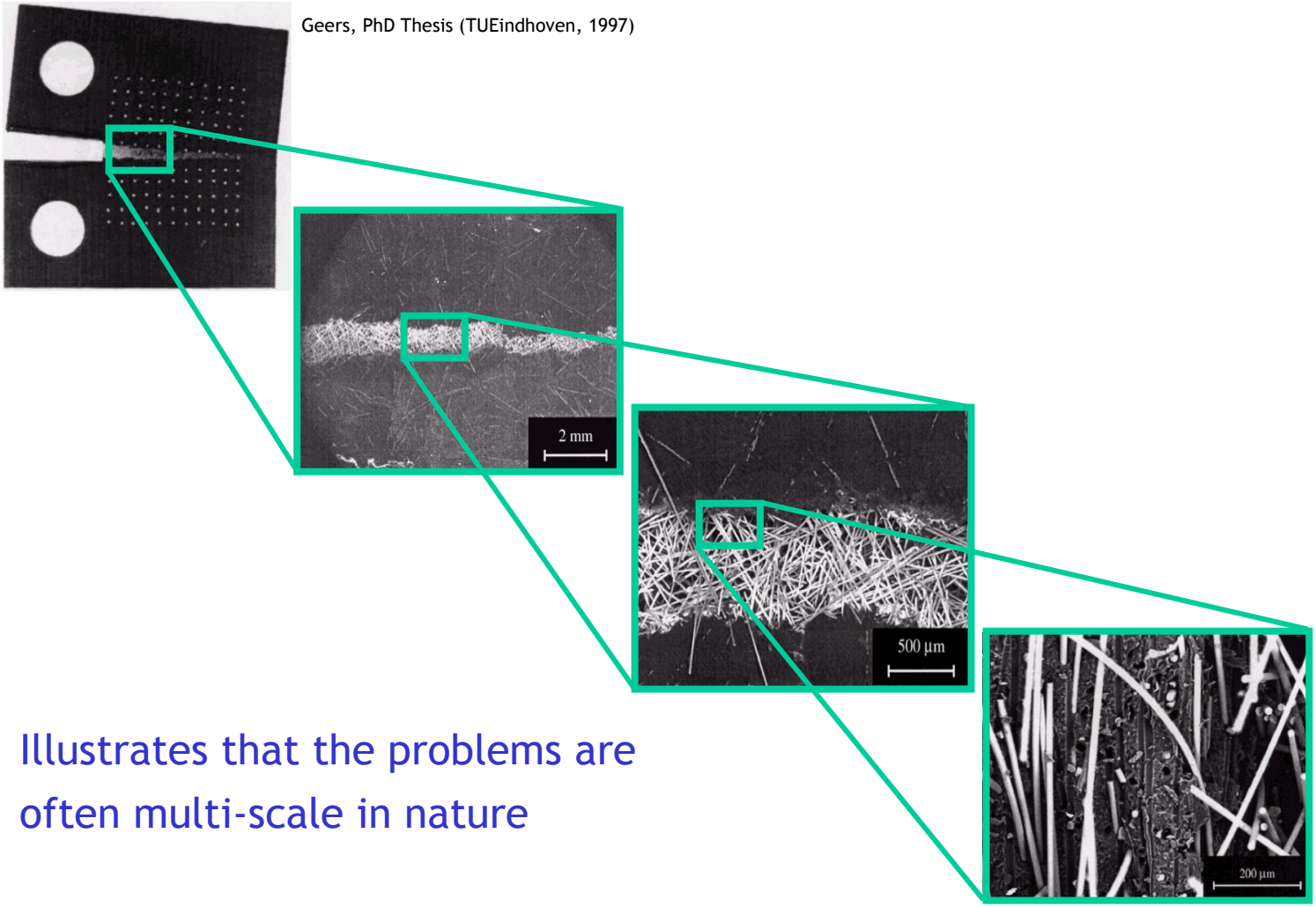


Fig. 4. An exploded view of the proposed FE model of a light truck brake assembly.



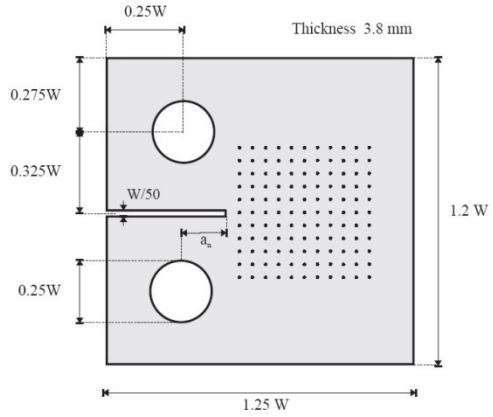
TGV speed record 574.8 km/h, 2007

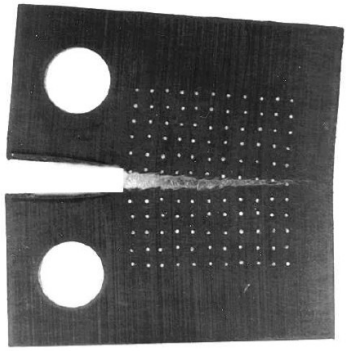
Composite failure (short fibers reinforced polypropylene)

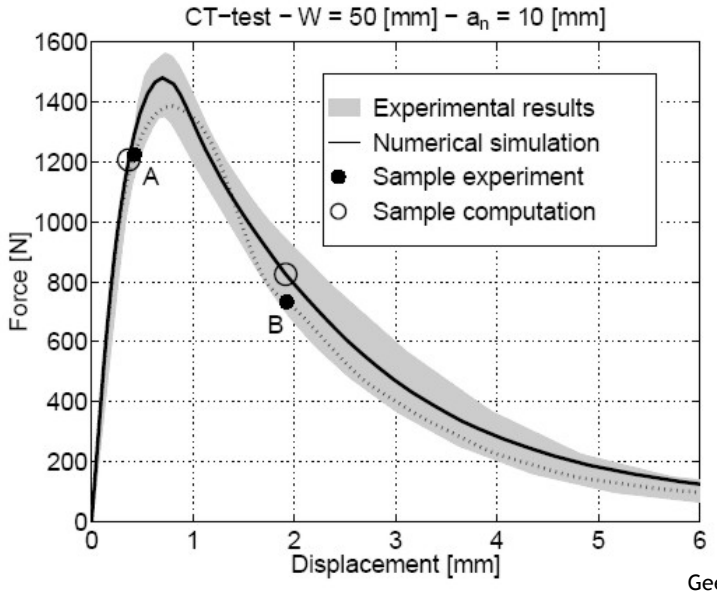


Illustrates that the problems are often multi-scale in nature

Composite failure - modelling





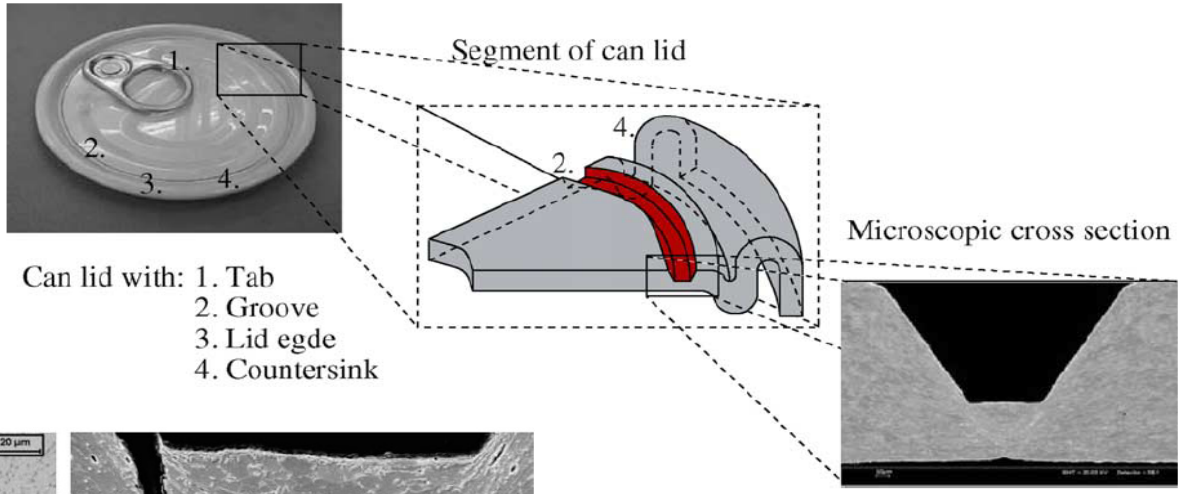


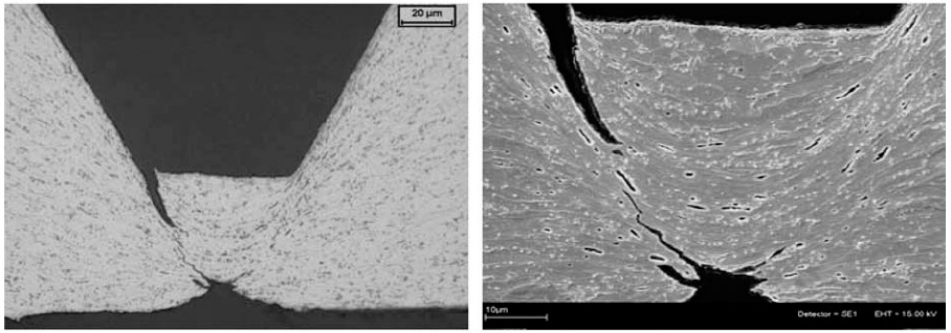
Geers, PhD Thesis (TUEindhoven, 1997)

Fiberglass pole

[http://global.fncstatic.com/static/managed/img/fn-latino/sports/borges%20cuba%20olympics.jpg]

Can lid opening





Boers et al., 2005

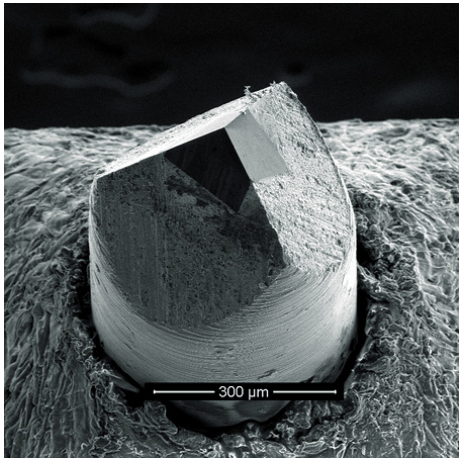
→ Pre-damaging required to allow 'easy' opening

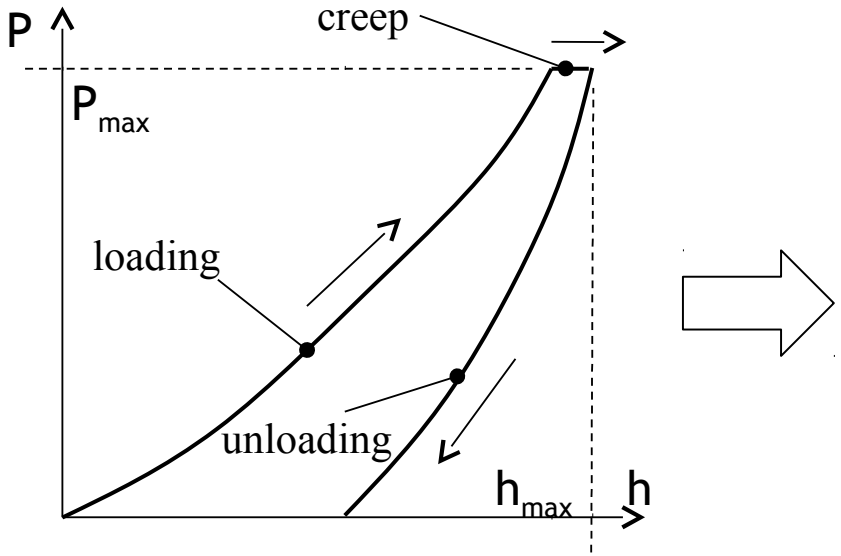
→ However the sealing should not be compromised

→ Computations can help optimising the process

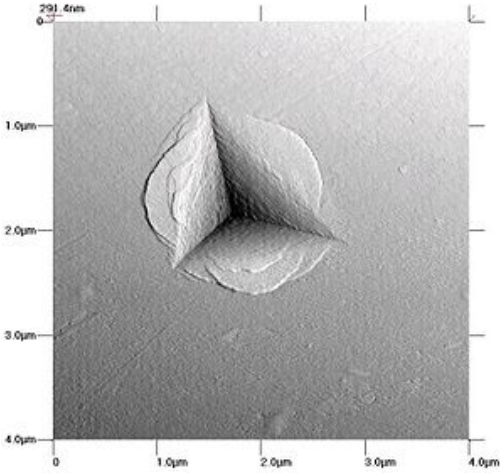
Materials characterization

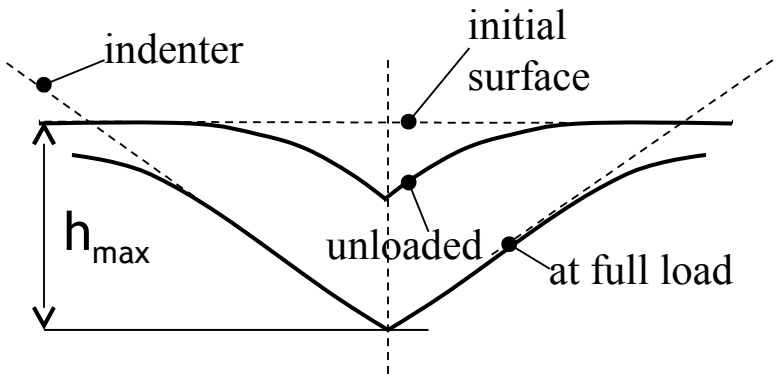
Nanoindentation





Elastic modulus, Plastic parameters





Course objectives

Computational tools are required

→ Analytical approaches not always available

→ In this case, efficiency of simulations is required

But they 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

→ Develop a critical mind to computational results

→ Understanding the limit of applicability of the proposed methods

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

Course organization

	Monday	Tuesday	Wednesday	Thursday	Friday
Lecture	Introduction Newton-Raphson	Linear bar FE	Geometrically nonlinear bar FE	Geometrically nonlinear bar FE	
Labwork	Newton-Raphson	Linear bar FE	NL bar FE	NL bar FE	Applications

- Evaluation based on homework and discussion on the applications

Remarks

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

O.C. **Zienkiewicz** and R.L. Taylor, The Finite Element Method. Volume 1: The Basis. Butterworth-Heinemann, Linacre House, Jordan Hill, Oxford OX2 8DP, 225 Wildwood Avenue, Woburn, MA 01801-2041, England, 2000.
O.C. **Zienkiewicz** and R.L. Taylor, The Finite Element Method. Volume 2: Solid Mechanics. Butterworth-Heinemann, Linacre House, Jordan Hill, Oxford OX2 8DP, 225 Wildwood Avenue, Woburn, MA 01801-2041, England, 2000.
M. A. **Crisfield**, Non-linear Finite Element Analysis of Solids and Structures VOLUME 1: ESSENTIALS. John Wiley & Sons Ltd. Bafins Lane, Chichester West Sussex PO19 IUD, England, 1991.