Simplified modelling of cracks

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Introduction

Research topics

- Structural analyses on patrimonial buildings by using ABAQUS.
- Those buildings often suffer from pathologies:
  - Soil instabilities (settlements, etc.)
  - Structural elements failure (cracks)
- The structures are highly redundant and it is interesting to have an overview of the stress redistribution due to the introduction of cracks.

- That’s why a simplified tool for automatically introducing discrete cracking phenomena in the models was developed (coupling MatLab/ABAQUS).
- This tool is intended for engineering offices and is therefore simplified in order to be more easily and efficiently used.
Introduction

Discrete cracking

- The introduction of a discrete crack consists in creating a crack as a geometrical discontinuity.

- In opposition to a smeared cracking phenomenon for which the crack is simulated through a local modification of the material mechanical properties (reduction of the Young modulus).
We essentially studied masonry buildings and we have made some approximations about the material: elastic, isotropic material with a tensile strength $\sigma_{\text{max}}$ and an infinite compression strength.

A Rankine criterion is used for determining the location of the failure of the material. This criterion compares the maximal principal stress (SP3) in the model to the tensile strength of the material $\sigma_{\text{max}}$. The vector representing the maximal principal stress gives us the orientation of the crack plane.
Coupling
MatLab/ABAQUS

Discrete cracking

- As we are dependant on the morphology of the mesh, a fictitious crack plane is chosen as close as possible to the real one.
- If $SP3 \geq \sigma_{max}$, then introduction of a crack.
- When there is no more stresses higher than the tensile strength, the program stops.
**INTRODUCTION**
- RESEARCH TOPICS
- DISCRETE CRACKING

**COUPLING MatLab/ABAQUS**
- DUPLICATION OF THE NODE
- CASE STUDIES
- 3D BEAMS
- MAGDALENE CHURCH
- OUR-LADY CATHEDRAL
- POSSIBLE IMPROVEMENTS

**Computing the first model without cracks**

**Storage of the stresses, nodes, elements,...**

**Detection of the node with the highest maximal principal stress**

**SP3 > \( \sigma_{\text{max}} \)?**

**Yes**

**Storage of the coordinates of the node with the highest stress**

**Storage of the node composing the elements containing the previous node**

**Computation of the vector representing the maximal principal stress**

**Choice of the fictitious crack plane closest to the previously determined one**

**Duplication of the node in order to create the crack**

**Re writing of the input file**

**MatLab launches ABAQUS for computing the cracked model**

**No**

**No (more) cracks detected**
### INTRODUCTION

- Research Topics
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**COUPLING MatLab/ABAQUS**

- Duplication of the node

### CASE STUDIES

- 3D Beams
- Magdalene Church
- Our-Lady Cathedral

### POSSIBLE IMPROVEMENTS

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**Coupling MatLab/ABAQUS**

**Duplication of the node**

- **Initial node**
- **Initial elements**
- **“Face” upon which the maximal principal stress is applied**
- **Fictitious crack plane chosen**
- **Fictitious crack plane rejected**
- **New node and elements of the cracked model**

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POSSIBLE IMPROVEMENTS
Coupling MatLab/ABAQUS

Process

- The first (uncracked) model must be created under ABAQUS/CAE for introducing the geometry, the material, the loads, the boundary conditions and the mesh.
- MatLab is used for analysing the results provided by ABAQUS. It detects the location of the crack and models it by duplicating nodes.
- Then for managing the cracked models, MatLab launches automatically ABAQUS for calculating the stresses.
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POSSIBLE IMPROVEMENTS

Case Studies

3D Beams (only flexion)
Case Studies

3D Beams (Flexion and compression)

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Possible improvements

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Case Studies

Magdalene Church (Tournai, BE)
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POSSIBLE IMPROVEMENTS

Case Studies

Magdalene Church (Tournai, BE)

Highest Stresses

Cracks Introduced

MatLab/ABAQUS
Case Studies

Magdalene Church (Tournai, BE)

- Highest Stresses
- Cracks Introduced
- MatLab/ABAQUS

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Our-Lady Cathedral (Tournai, BE)

Cracks Introduced
Possible Improvements

- The tool developed here is a simple one which gives quite good qualitative results. It can, of course, be improved!
- With this tool, it is not possible to take into account the cracks due to shear stresses. This could be implemented in the MatLab routines.
- Another criterion (e.g. Mohr Coulomb) could be implemented for studying other materials.
- Cycle loads could be analysed if the contact between the faces of the cracks was introduced.
Thank you for your attention!