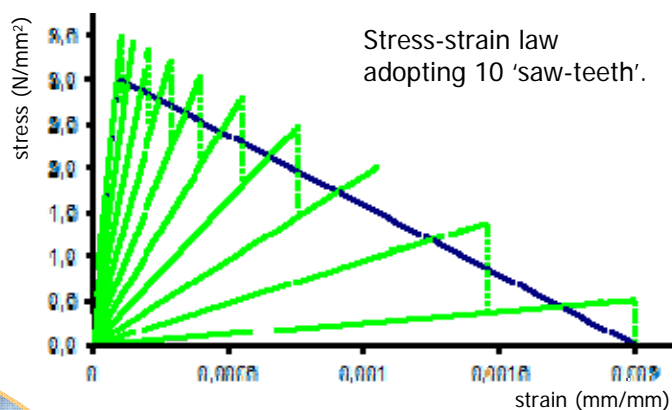


# Capturing complex non-linear structural response through a series of linear analyses

## Subject

Differential settlements of the soil due to underground construction may lead to damage of (historical) buildings in urban areas. To properly assess the effects of underground construction on the surrounding structures there is a need for accurate and robust crack prediction models at building level.



## Goal

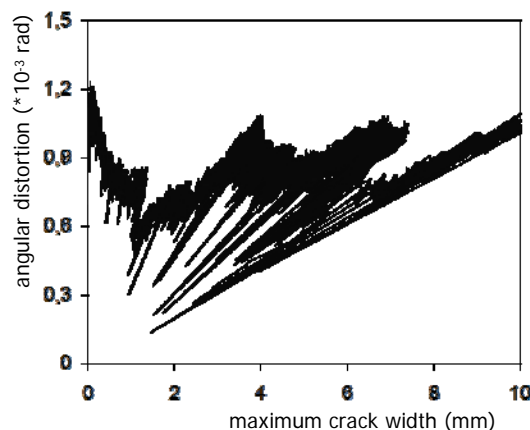
Many nonlinear finite element codes have been based on some incremental-iterative scheme. Despite their popularity, convergence problems may become an important issue, in particular when fracture of brittle structures is involved. To overcome these problems, an alternative solution procedure based on the Sequentially Linear Analysis (SLA) scheme is being developed and implemented in DIANA.

## Current research topics

Current research focuses on:

- Non-proportional loading: first apply one load, then apply another load on top of the first load.
- Implementation of line-interface elements to facilitate discrete cracking.

Structural response of a masonry façade subjected to imposed displacements.



## Capturing complex nonlinear structural response through a series of linear analyses

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### Subject

Underground construction in urban areas may result in damage to existing buildings and architectural heritage due to differential settlements. Particularly in case of soft soil conditions and unreinforced masonry facades this is a relevant and challenging issue. To deal with this problem properly, there is a need for accurate and robust crack prediction models at building level.

### Goals

Since fracture of brittle structures subjected to ground settlements is a highly discontinuous process, standard incremental-iterative methods often fail to provide a properly converged solution. To overcome these problems, an alternative solution procedure based on a Sequentially Linear Analysis (SLA) scheme is being developed and implemented in DIANA. The key idea is that cracking and softening of unreinforced concrete and masonry are captured via a number of positive secant stiffnesses, which improves robustness.

On top of that, numerical support is provided to the companion project 'Computational modelling of building damage due to tunnelling'. In that project the numerical models result in updated engineering design rules for building response to settlement.

### Research Question

How can we develop an analysis scheme which is suitable for accurate and robust predictions of crack patterns and crack widths at building level?

### Strategy

First, an application is written in DIANA which is capable of performing basic SLA (isotropic damage models and proportional loading). Next, this application is extended to include more sophisticated constitutive models, such as orthotropic crack models, and non-proportional loading. Depending on obtained analysis results other features may be included as well.

### Expected Results

- A 'saw-tooth' softening model that gives robust and reliable predictions of crack patterns and crack widths in masonry and concrete structures.
- Improvement of the numerical stability for brittle fracture analyses of buildings subjected to ground movements.
- Improvement of the computational performance of SLA: a more efficient way to sequentially solve the systems of equations involved.

### Preferred Partners Applications / Sponsors

This project is attached to COB-project F530 'Monitoring North-South Line', in order to inter-address the engineering and scientific challenges: applied and fundamental research. Funding is provided by Delft Cluster and COB.

### Prime Publication / Prototyping

Graaf, A. V. van de, M. A. N. Hendriks, J. G. Rots (2009). "Sequentially linear analysis for modelling tunnelling-induced surface structure damage". EURO:TUN 2009, Computational Methods in Tunneling, eds. G. Meschke et al., Aedificatio Publishers, Vol. 2, pp. 977-984.

### Research Period

2008 – 2011