LUSAS

Engineering analysis and design software

Software Information

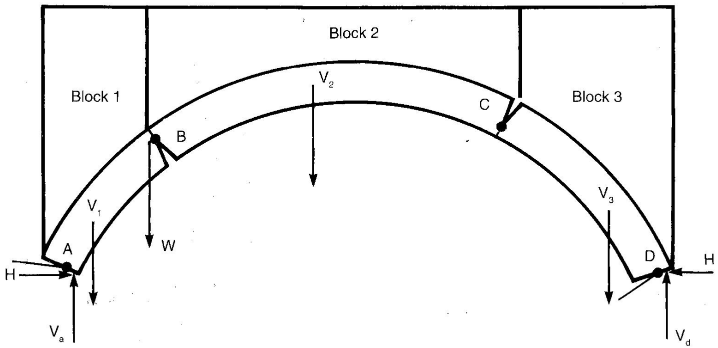
Masonry arch modelling with LUSAS

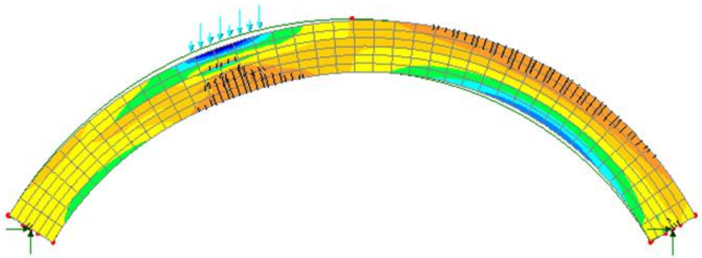
Account Manager Name

Job Title, LUSAS

Analysis of masonry arches

- Introduction
- Simple methods
  - MEXE
  - Mechanism method
- FE analysis
  - Cracking & crushing
  - Ring separation (delamination)
  - Soil/ structure interaction
- Other masonry structures

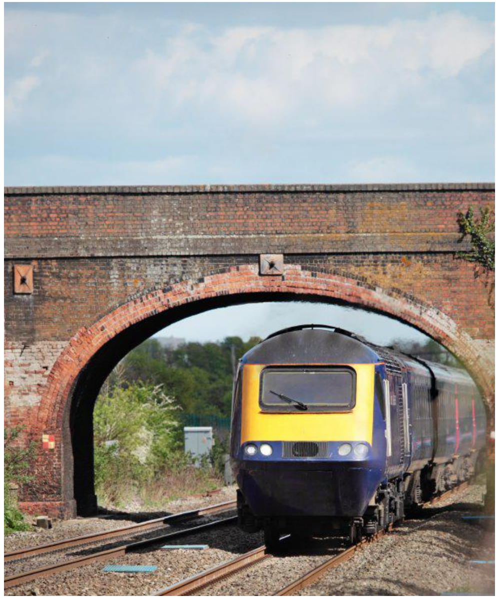




End presentation

Introduction

- Arch bridges - long history and very durable
- Still significant in the transport network
- Still being constructed
- China: 18 No. >100m span (since 1950)
- Analysis is potentially complicated
- Use LUSAS for simple or in-depth analysis



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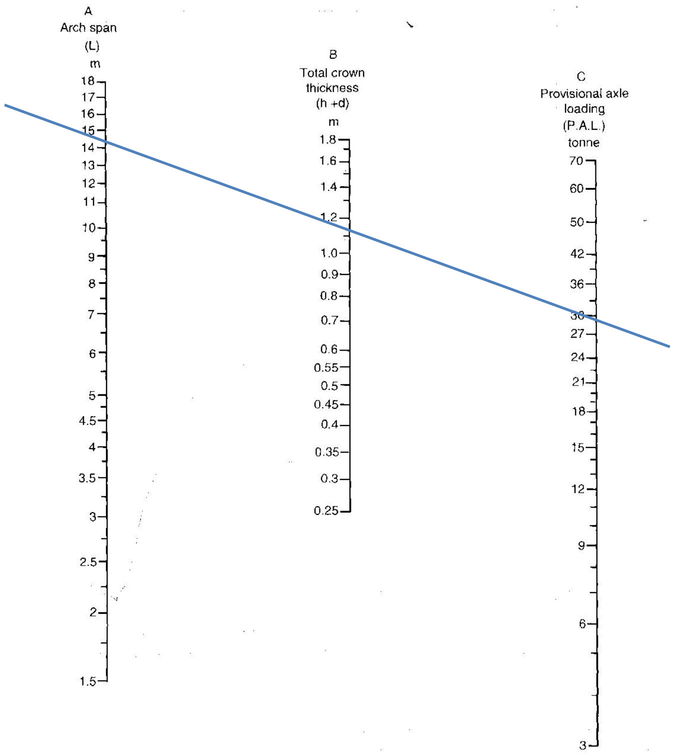
MEXE (Empirical) (1/2)

Factors for

- Span to rise
- Profile
- Materials (barrel & fill)
- Joints (width, depth, mortar)
- Condition

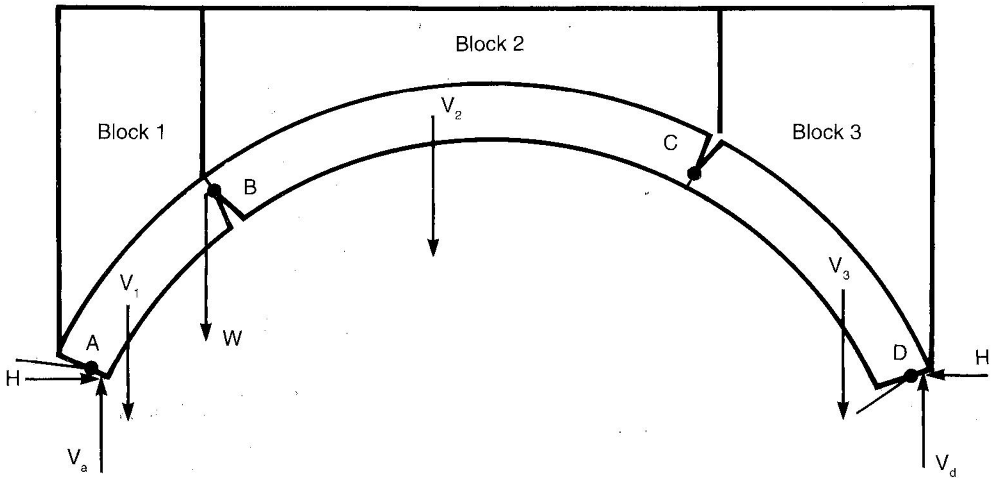


MEXE (Empirical) (2/2)

- Based on gross assumptions & limited tests
- Limited accuracy for
  - Small spans
  - Large depth of fill
  - Mis-shapen arches or gothic arches etc
- No account of ring separation
- No transverse effects or spandrel walls
- Not applicable to multiple spans or skews

Mechanism methods (1/4)

- Hinges form at intrados or extrados
- 4 hinges form a mechanism



Mechanism methods (2/4)

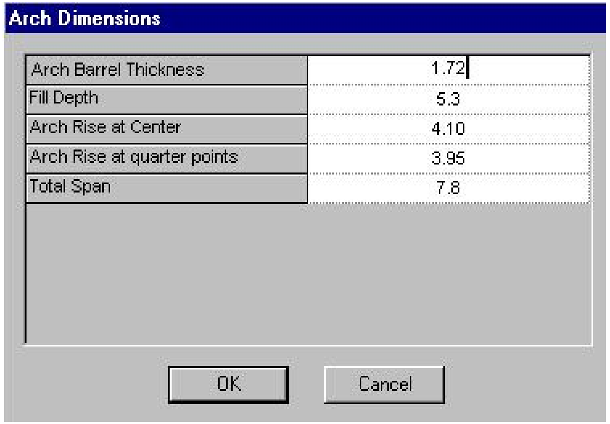
Pippard's assumptions:

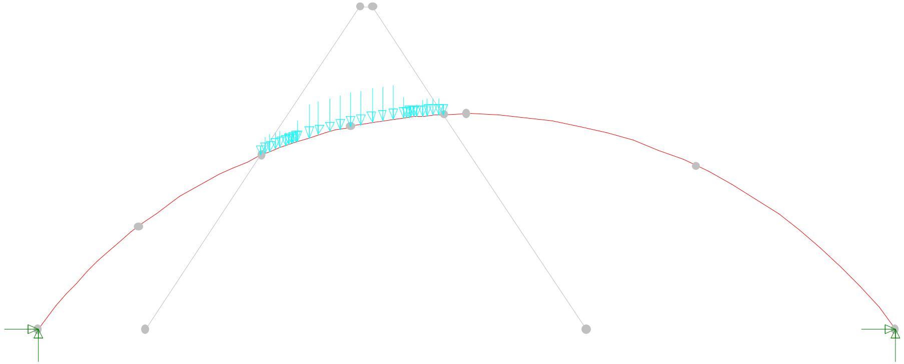
- No tension
- Infinite compressive strength
- Infinite elastic modulus
- No sliding between blocks
- No structural contribution from the fill

Upper bound theory ("unsafe method") – the lowest upper bound solution is sought

Mechanism methods (3/4)

- Plastic "hinge" analysis could be carried out in LUSAS
- Modelling could be automated using VBScripting





Mechanism method (4/4)

- LUSAS advantages:
  - No limit to shape of arch
  - Can carry out on 3D basis & skews
  - Can adjust support conditions
  - Can include backfill as load/ spring support
- The method does not address
  - ring separation
  - soil-structure interaction

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FE analysis

- Cracking & crushing in barrel
- Ring separation
- Soil/ structure interaction
- Geometric nonlinearity

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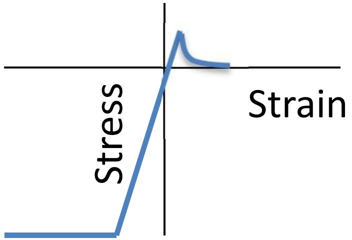
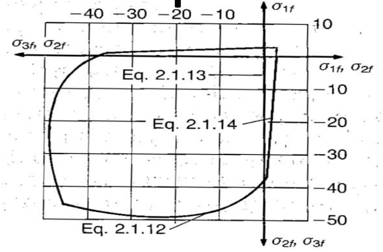
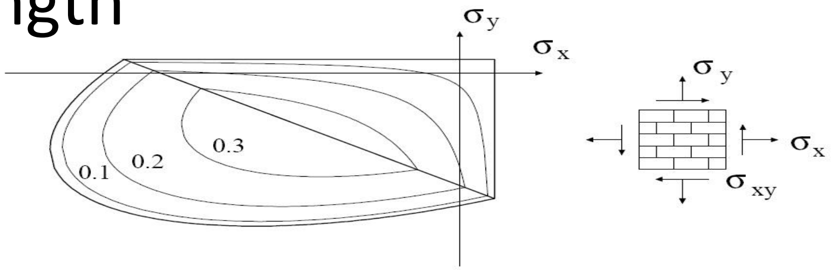
Concrete and masonry (1/3)

- Brittle fracture
- Low tensile strength,
  high compressive strength





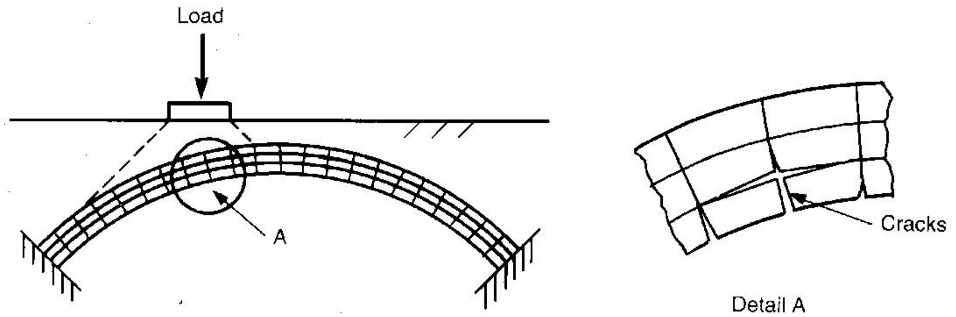
CEB-FIP failure envelope for concrete

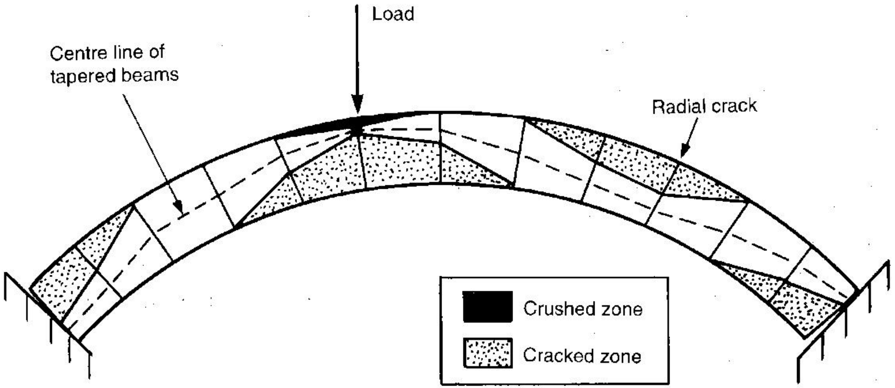


Rankine-Hill failure envelope for masonry

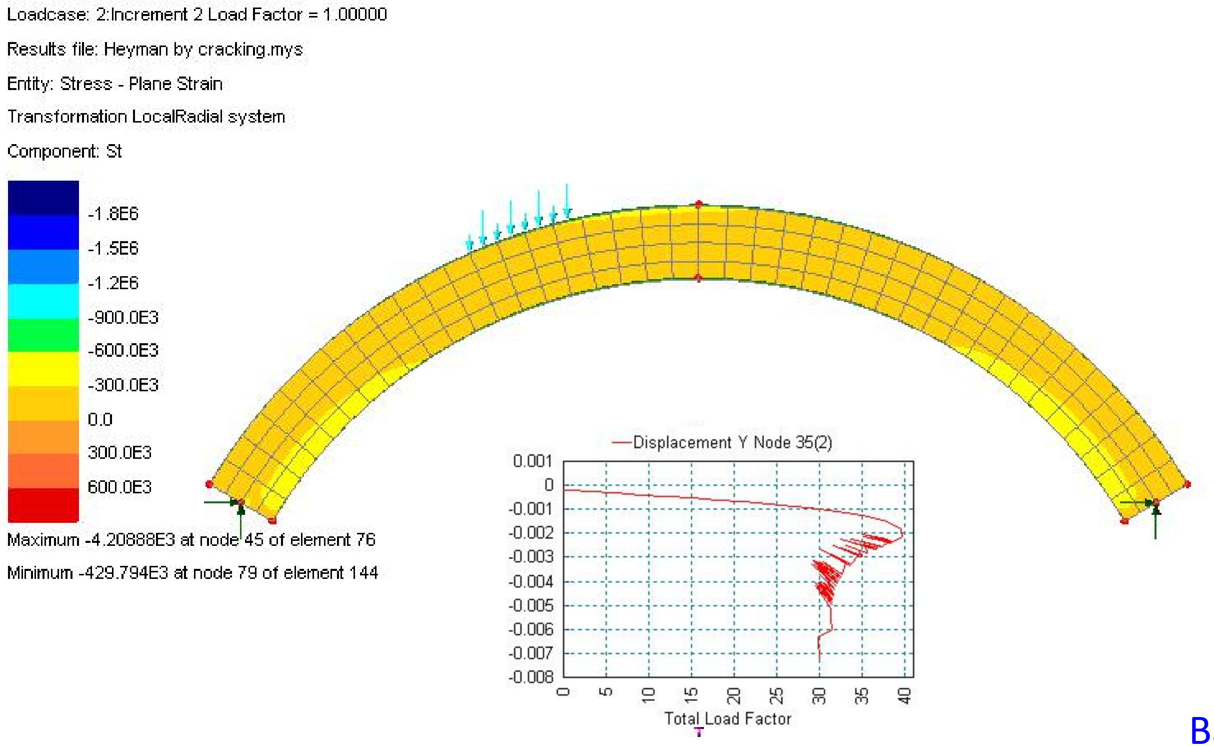
- Can use LUSAS advanced concrete material

Cracking and crushing (2/3)





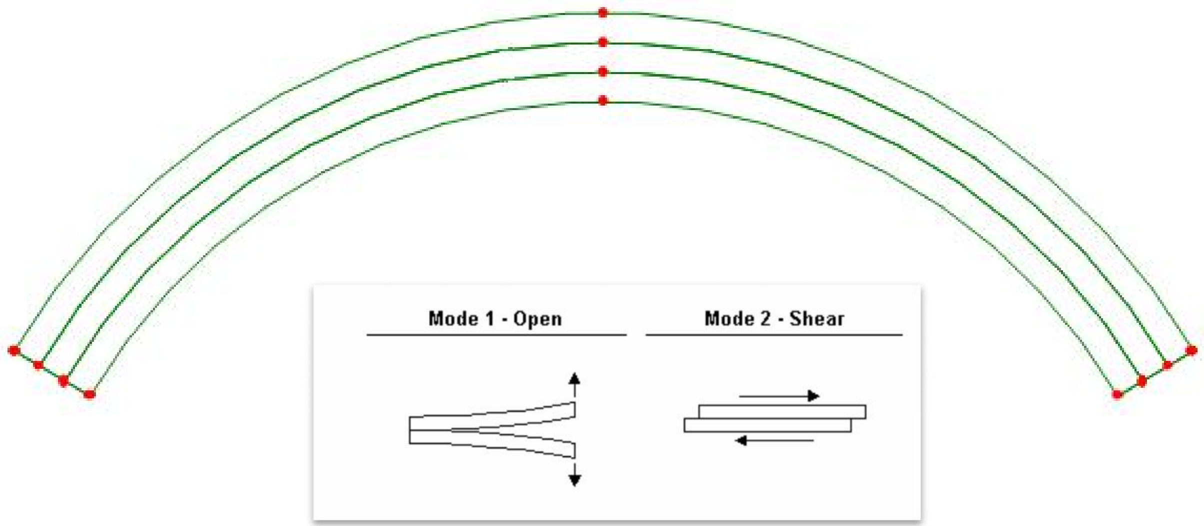
Cracking and crushing (3/3)



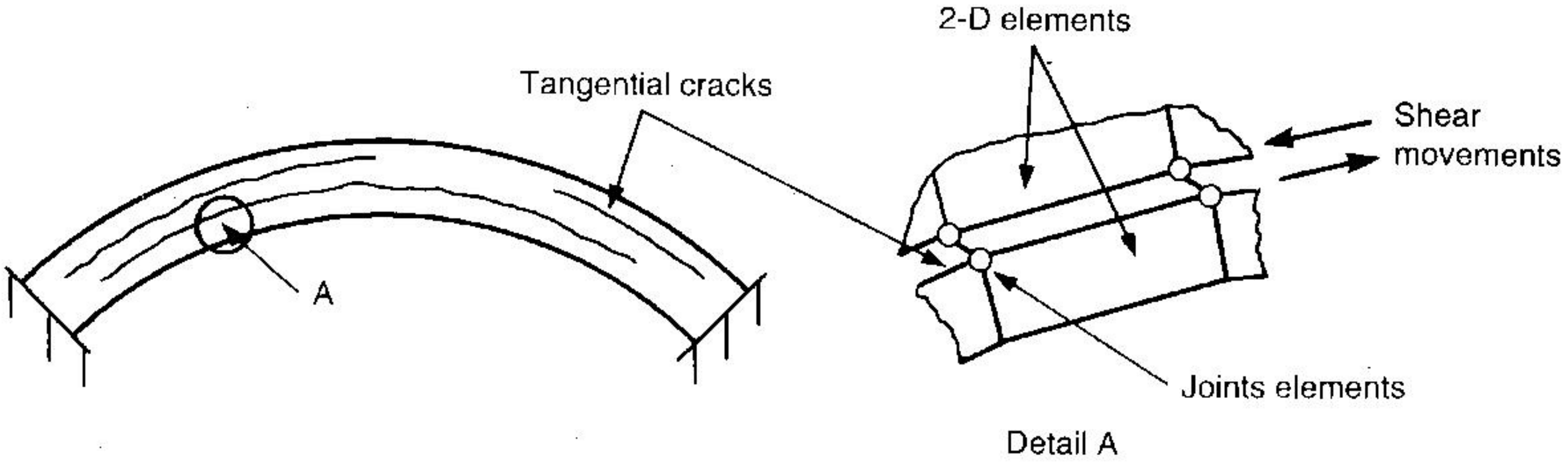
[Back to FE analysis]

Ring separation (1/5)

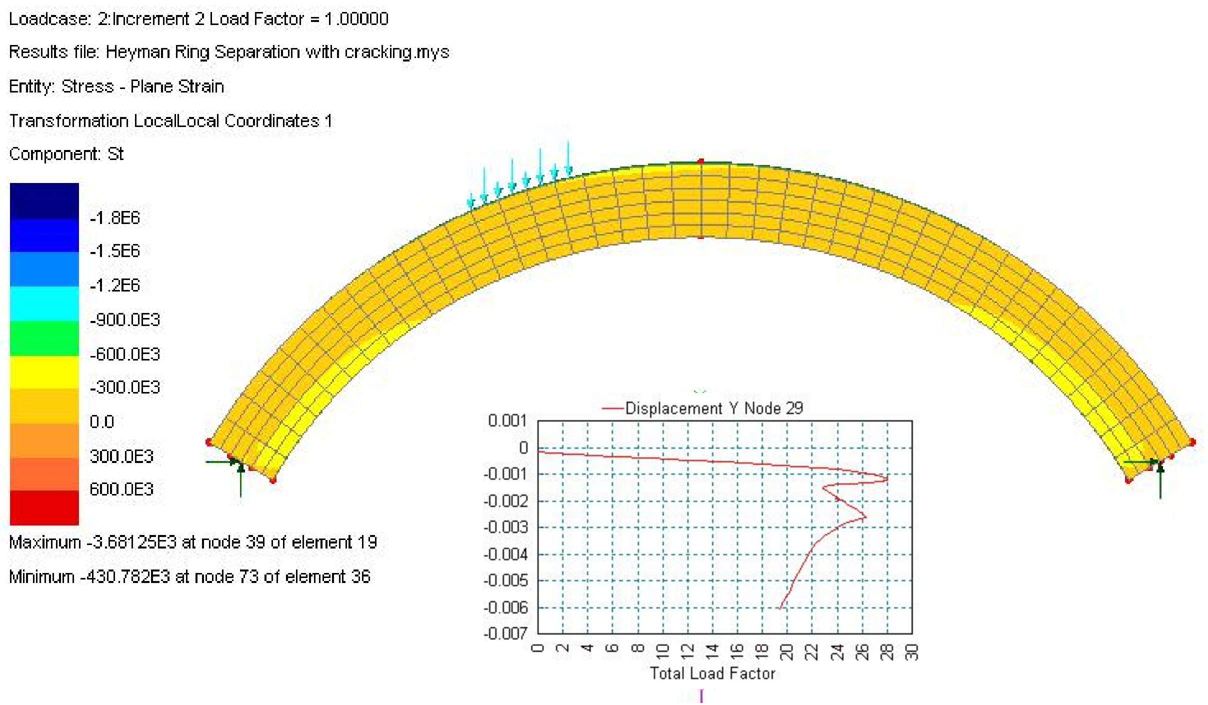
- Using cracking & crushing material
- Introduce interface elements. 2D or 3D



Ring separation (2/5)



Ring separation (3/5)

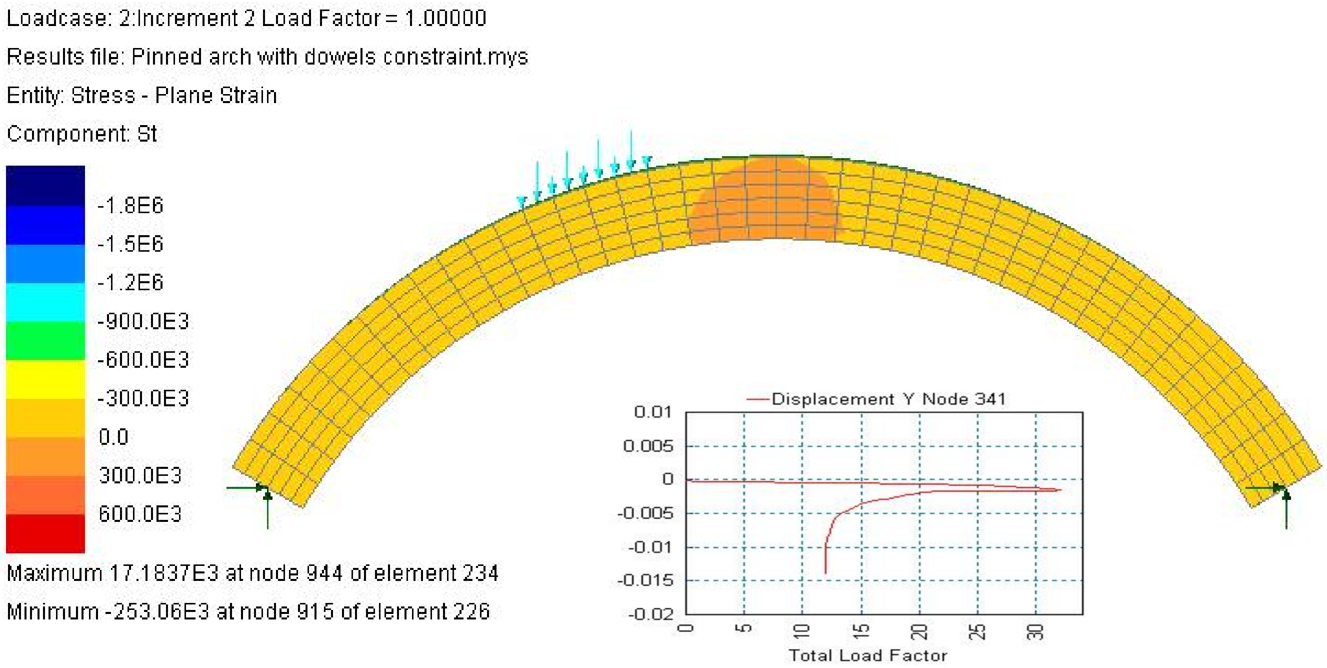


Ring separation/repairs (4/5)

- Can model defects and/ or repairs e.g. Dowels using joints or constraint equations

Dowels

Ring separation/repairs (5/5)



Back to FE analysis

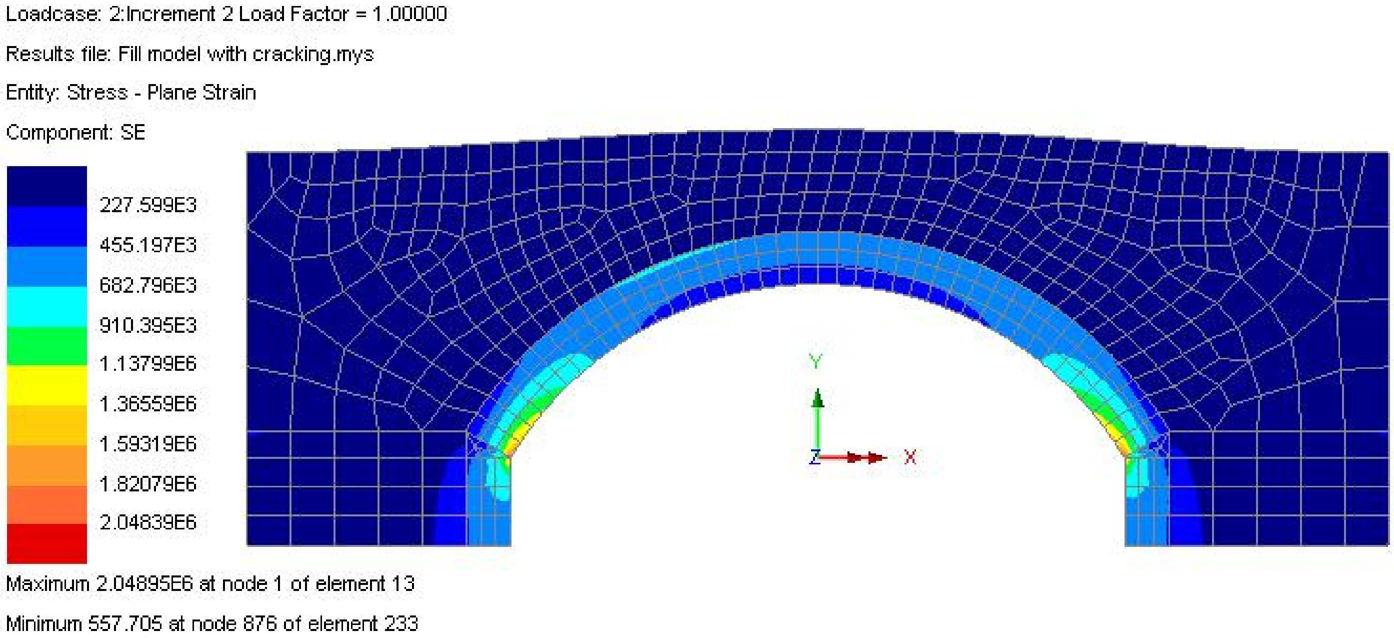
Defects and repairs

- Can model in 3D
- Good for skews

Soil-structure interaction (1/2)

- Include backfill and surrounding structure
- Soil material models including Mohr-Coulomb

Soil-structure interaction (2/2)



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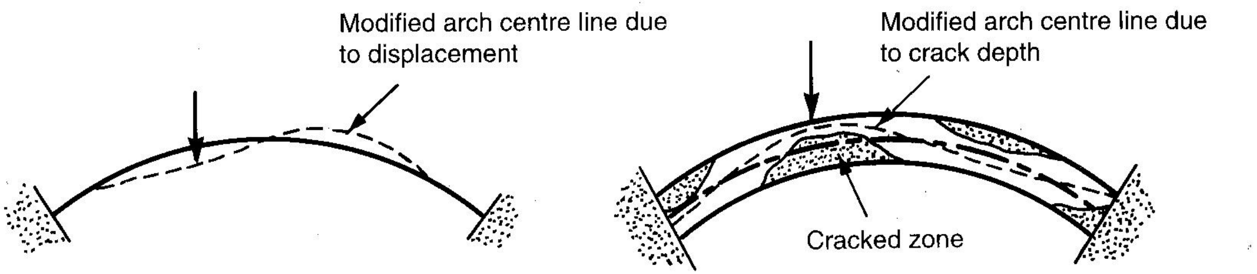
Geometric nonlinearity (1/1)



	2D (Plane strain)	3D continuum
Concrete model 94	Yes	Yes
Mohr Coulomb etc	Yes	Yes
Compatible Joints	Yes	Yes
Geometric NL	Yes	Yes

On to summary

Benefits of using LUSAS

- LUSAS analysis includes:
  - State of the art crushing/ cracking material
  - Ring separation using slidelines or joints
  - NL soil materials for fill
  - Soil/ structure interface
  - Geometric nonlinearity
  - Complete flexibility of geometry, materials, support conditions e.g. to include haunches/ spandrels etc.
  - Full 3D modelling (if required)
  - Ability to model defects and repairs

Independent validation cases

Finite-element analysis of masonry arch bridges

K. H. Ng, BEng, C. A. Fairfield, BEng, PhD, MIHT, MInstNDT, and A. Sibbald, BSc, MSc, PhD, CEng, MICE, FInstNDT

Proc. Instn Civ. Engrs Structs & Bldgs, 1999, **134**, May, 119 – 127

Paper 11789

Written discussion closes 27 August 1999

■ **This paper describes a method of assessing the load-carrying capacity of masonry arch bridges using the general-purpose finite-element (FE) package LUSAS. Good agreement was found, in terms of collapse loads and load–deflection characteristics, between the FE analysis adopted here and the experimental data. Three bridges were assessed: Bridgemill (actual collapse load 361 kN/m, FE collapse load 362 kN/m), Strathmashie (actual collapse load 228 kN/m, FE collapse load 226 kN/m) and Barlae (actual collapse load 296 kN/m, FE collapse load 302 kN/m). These values were based on cases where the material properties were well documented, which will not always be the case for other less well-researched arches, and therefore a**

the arch bridge stock to allow increases in the maximum allowable gross vehicle weight (GVW) from 38 t to 40 t (certain bridges may have to be assessed for 44 t GVW) and in the maximum axle weight from 10 t to 11·5 t. Full-scale tests suggest that the MEXE method gives conservative results, with the consequence of heavy goods vehicles taking longer trips than would otherwise be required. This shifts traffic to bridges rated for the higher axle limits, thus speeding their deterioration. The actual safety factor on an arch bridge is very hard to find accurately by any of the current assessment methods; hence the current interest in arch analyses.

3. In this study a two-dimensional analysis was performed using LUSAS, a commercially available finite-element (FE) package.[3] Three

K. H. Ng, Postgraduate student, Department

Proceedings of the Institution of Civil Engineers, Structures & Buildings Issue 134

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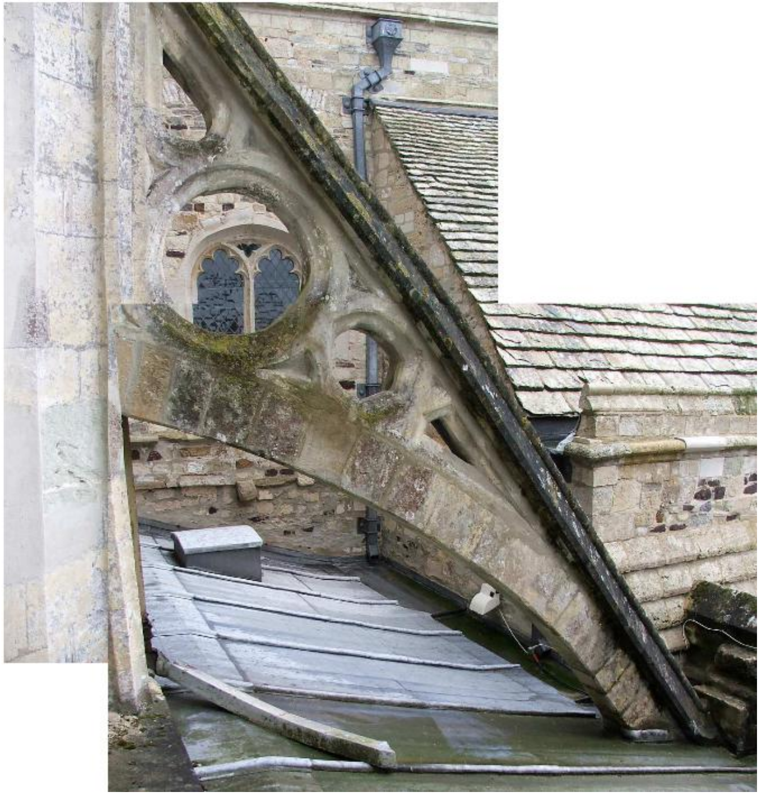
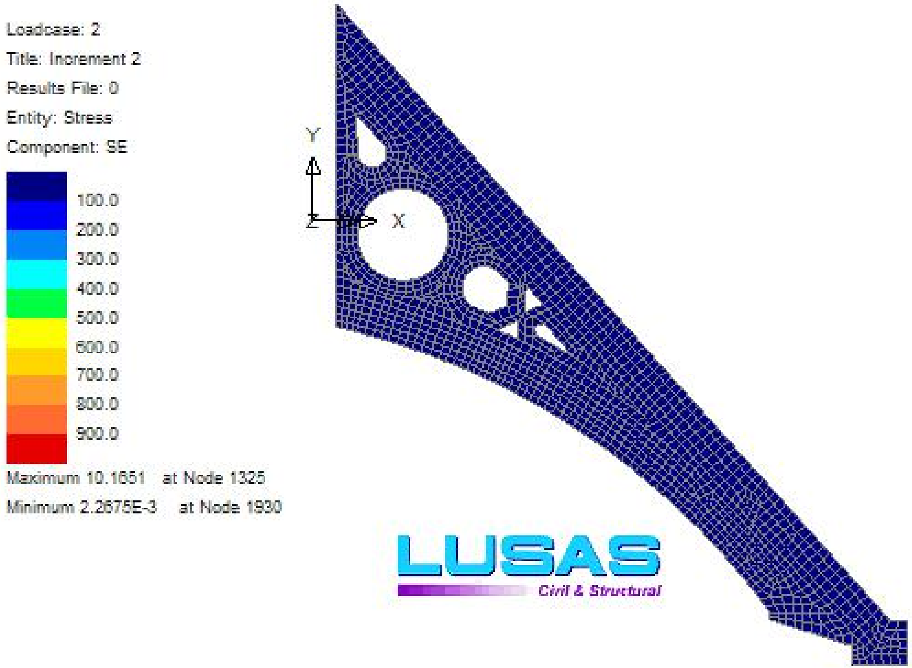
Other masonry structures (1/4)

- Plate and shell models
- Orthotropic materials (linear and NL)
- Contact slidelines

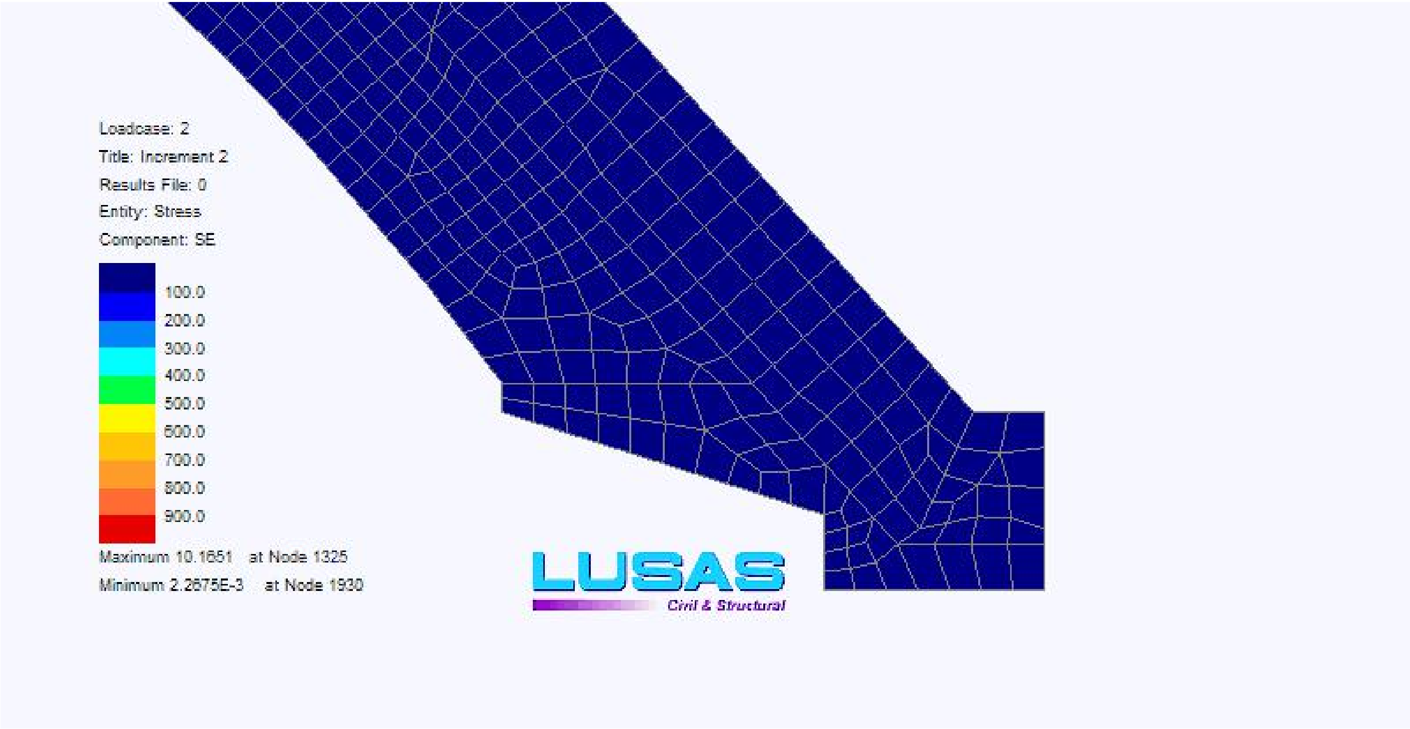
Other masonry structures (2/4)



Other masonry structures (3/4)



Other masonry structures (4/4)



Why use LUSAS for Masonry structures?

- Flexible: simple or advanced approaches
- 2D or 3D, applicable to any shape
- State-of-the-art cracking and crushing
- Delamination interfaces and slidelines
- Soil-structure interaction
- Orthotropic materials

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Bridge engineering

Composites engineering

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