Imperial College London

3D Modelling of Masonry Arch Bridges

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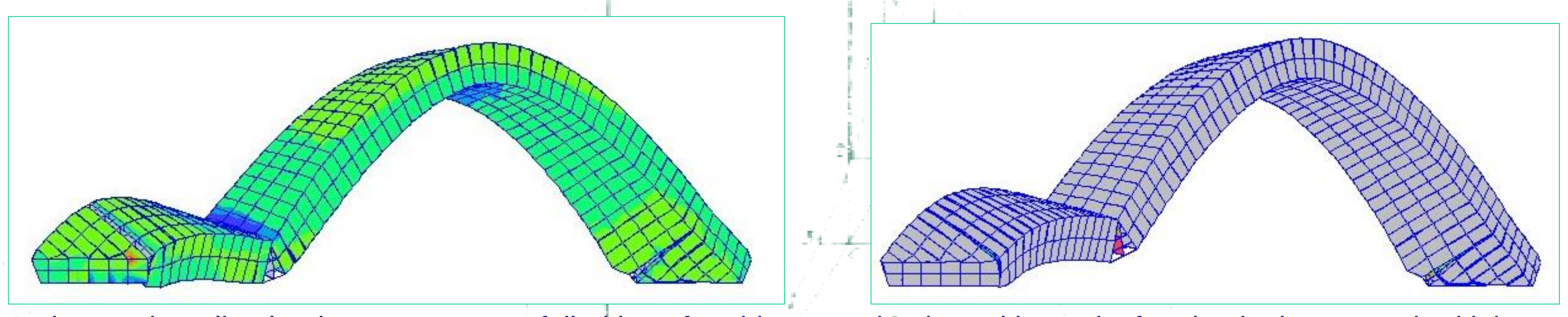
PROJECT AIM

In the UK alone there are over 70,000 masonry skew bridges which are vital to the transport network[1]. Many of these are over 100 years old and are reaching a critical level of disrepair and so there is a real danger of collapse under the current loading.

This project aims to develop an accurate finite element model, taking into account the real complex geometry of the skew arch, to facilitate the assessment and repair of these historic structures



Arches under a line load at quarter span failed by a four hinge mechanism with cracks forming in the mortar bed joints

MESOSCALE MODEL

Realistic geometry was integrated with a mesoscale description of masonry as developed at Imperial College[2]. This utilises very stiff solid elements, each representing half a brick, connected by non-linear interfaces which represent the mortar joints and crack planes through the centre of each brick.

Under load these interfaces deform to realistically model the rotation and translation of individual bricks as the mortar cracks and the structure fails.

GEOMETRY

Current FEA for skew bridges is done using simplified unrealistic geometry where the joints are parallel to the piers whereas in reality they are built in a helicoidal method where the bricks form a spiral around the centre of the arch.

Using rules set out in the 19th century used to build the arches that exist today, the actual geometry for these bridges was automated to find coordinates of the nodes at the corner of each brick.

METHODOLOGY

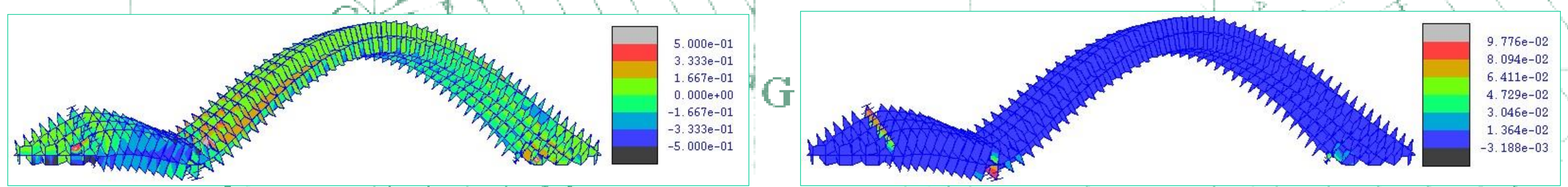
Once the coordinates of the bricks have been defined the interfaces and connectivity can also be found and identified as either a mortar joint, whether it is a bed joint or head joint, or the centre of a brick.

The effects of varying the skew angle from 30° to 60 ° as well as size and span:height ratio were investigated.

Various loading configurations were applied to the model such as line loading in different orientations and positions as well as patch loading

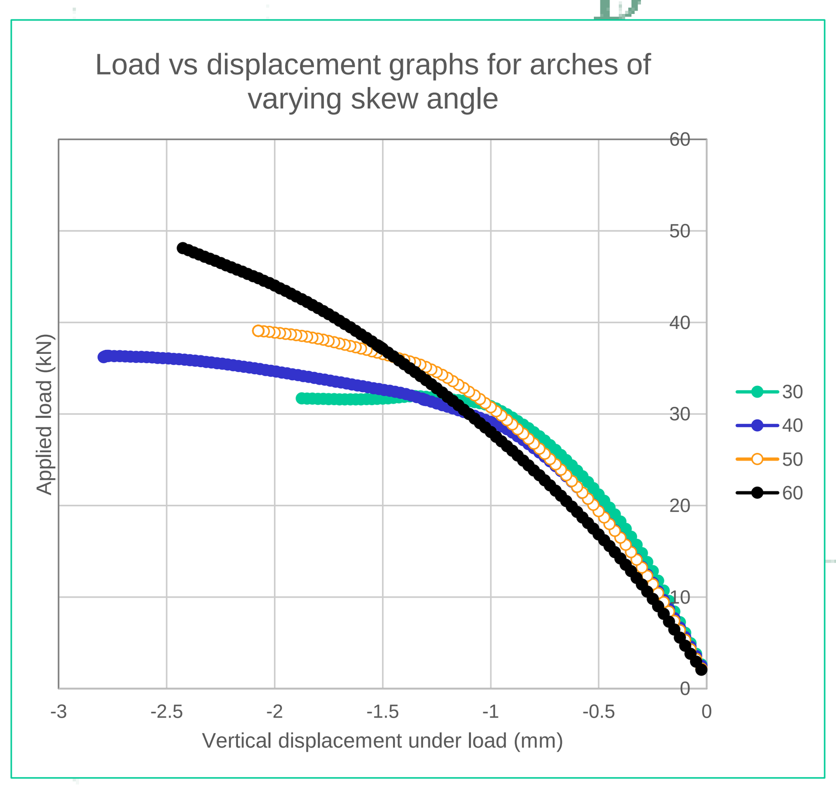
Having defined the elements as well as the loading and restraint conditions the simulation was run using the general nonlinear structural analysis software ADAPTIC[4], also developed at Imperial College.

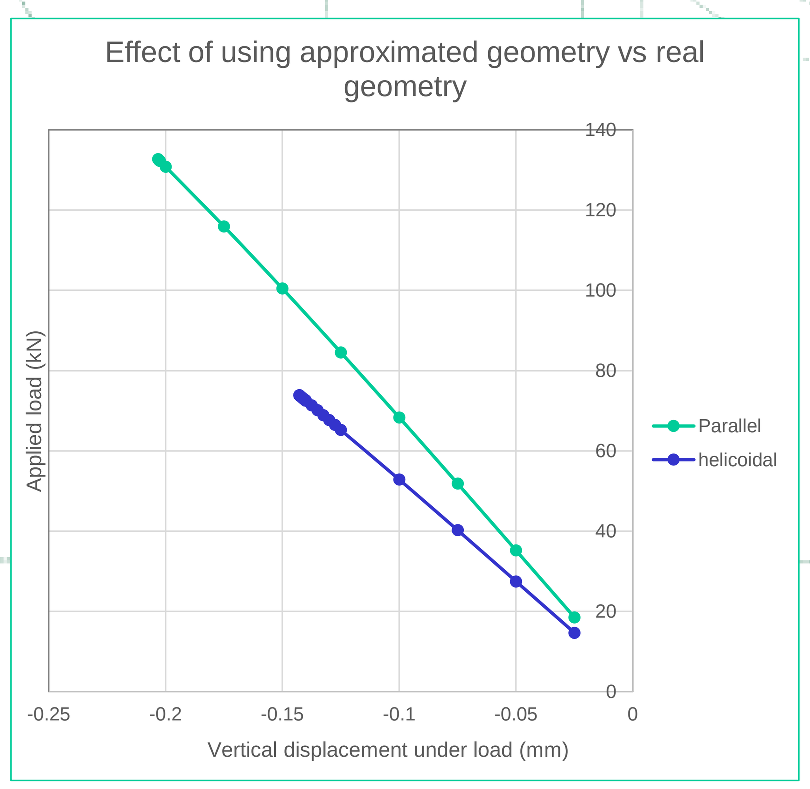
Both the failure method, as well as the ultimate load carried by each arch, were examined.



Plastic work for the compressive (left) and tensile (right) failure mode can be plotted in the interfaces to highlight the cracking mode

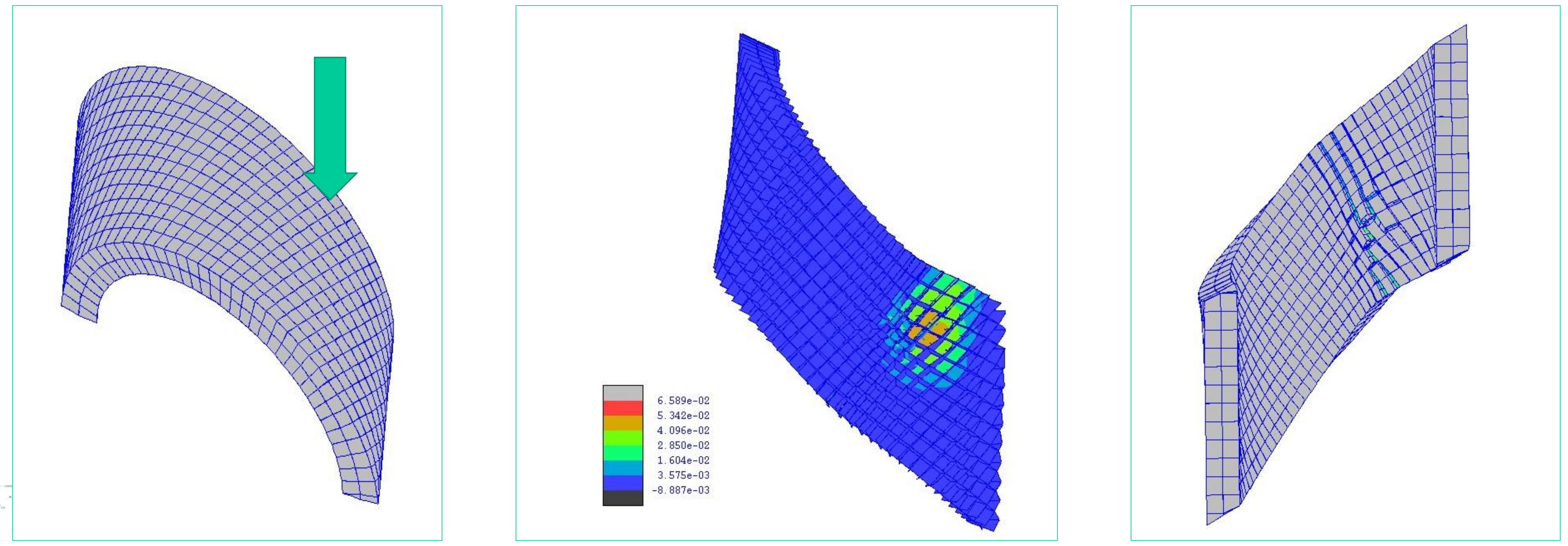
RESULTS OF MODEL





The simulations showed:

- An increase in strength with increased skew angle
- An increase in strength for shallower arches
- That loading at 3 quarter span gives weakest response
- Interesting 3D effects under eccentric patch load
- A significant difference between response of this model and previously attempted models in the literature with unrealistic geometry



Wider bridge under an eccentric patch load displays interesting 3D crack patterns as well as some ring separation,

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[3] Izzuddin, B.A. 1991. *Nonlinear dynamic analysis of framed structures*. Ph.D. thesis, Department of Civil and Environmental Engineering, Imperial College

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