Maintaining large historic buildings with no cement

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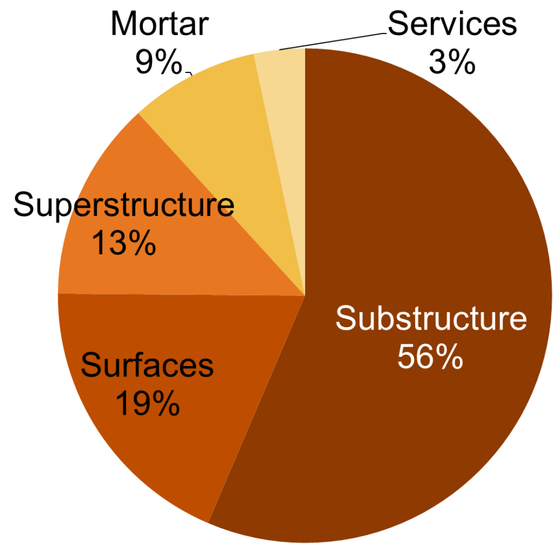
Background

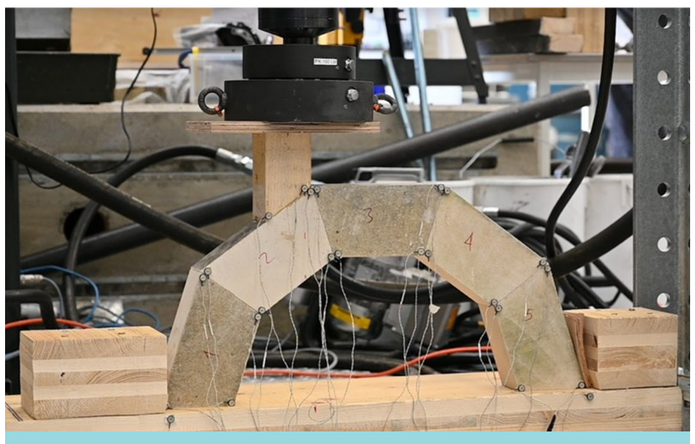
In 2020, the Church of England committed to achieve 'net zero' emissions by 2030 [1]. Over half of the emissions from Ordinary Portland cement and lime are process emissions, which cannot be easily mitigated without relying on dubious carbon offsetting schemes or carbon capture [2]. In the future predicted by *Absolute Zero* [3], how do we eliminate cement from cathedral maintenance?

Where is cement used in cathedrals?

Cement is used in cathedrals for maintenance and new build projects e.g. toilets or cafes. Cement use and its corresponding emissions were estimated from archived bills of quantities at Ely Cathedral [4], with results summarised in the following pie chart. Contrary to popular belief, **Ordinary Portland cement is used significantly more than lime in new build cathedral projects**, mainly in the form of concrete, and is responsible for 13 times more emissions than lime. **Alternatives exist to replace cement in substructures, surfaces and superstructures**, although not all are suitable for historic buildings and more developments are needed to eliminate cement from these areas altogether.

Embodied carbon from cement and lime by function





Dry stone arche before loading

Cork arch on the point of collapse

Can we build masonry without mortar?

In order to explore whether mortar can be eliminated rom masonry structures, three stone arches were built and tested to destruction. **Cork joints and dry stone masonry were compared with traditional lime mortar** in stone arches spanning 0.5m.

It was found that **masonry with lime mortar was slightly stiffer than dry stone, whilst cork was three times less stiff**. Strength could not be compared as the arches exceeded the expected failure load by two orders of magnitude and thus experienced localised material failure at the point of load application. The predicted failure load was based on a four-pinned mechanism forming due to joint opening [5]. It is thought that the abutments and load application restrained rotation, preventing the mechanism from forming. Crushing, cracking and sliding were also observed. **Whilst results were not conclusive, they suggest that masonry can be built without mortar.**

Conclusions

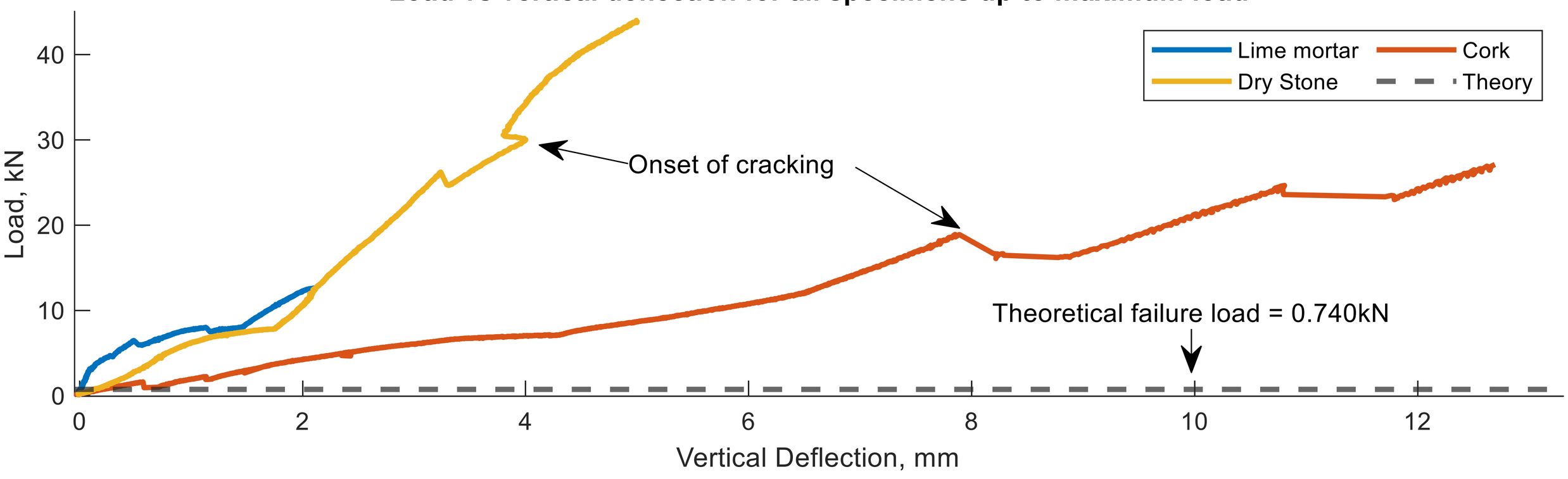
With more research into the behaviour of masonry without mortar and the development of a robust design method, **cement and lime can be removed from masonry construction**.

Shortcomings in stiffness of masonry without mortar could be overcome by looking at developments in seismic resistance of masonry such as dry steel connections.

The **transition to greener cathedrals will require collaboration** between academia, practising engineers, architects, craftspeople and Church officials to combine old techniques such as drystone masonry with new developments.

It is recommended that **future experimental work focuses on either specific phenomena or models of realistic structures**, as the experimental method used here limits the usefulness of the data.

Load vs vertical deflection for all specimens up to maximum load



The Institution of Structural Engineers

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