Analysis and assessment of Swedish vaulted masonry structures using funicular methods

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ABSTRACT

There is a need for practicing structural engineers working with historic masonry structures to have access to further developed methods to analyse and assess the structural behaviour of masonry vaults. The aim of this study is partly to investigate and evaluate methods to analyse vaulted masonry structures and to some extent further develop suitable methods. The methods used are based on funicular analysis since they are considered suitable [1, 2, 3]. A secondary aim is to use the studied methods the analyse and assess the structural behaviour of three Swedish church buildings with vaulted structures.

The methods that have been used and evaluated are Parametric graphic statics of thrust line analysis [4] and Thrust network analysis (TNA) [5]. To investigate and evaluate the applicability of the methods in actual practiced engineering projects three Swedish churches of different type and with vaulted structures have been analysed. The churches are Gökhem church, a small parish church built in the 12th century and the cathedral of Lund also built in the 12th century, both originally in Romanesque style but with later alterations. The third church is St Johannes church in Stockholm built in neogothic style in the late 19th century.

The result give an understanding of their structural behaviour and clearly shows how different variables such as the weight and shape of vaults, the angle that the line of thrust meets the walls and the height that the line of thrust meets the wall strongly effect the magnitude of the thrusting force. Other results from the case studies show the significance of load from the roof structure (both vertical and horizontal), the structural behaviour of flying buttresses and the impact of structural changes such as removal of earlier buttresses and pinnacles.

The project and the case studies show the strength in using methods based on funicular analysis to assess and evaluate structural behaviour of historic vaulted masonry structures. The result also show that the methods provide a pedagogical description of the structural behaviour of masonry vaults and the conditions that effect the load carrying capacity.

The methods to perform Parametric thrust line analysis have been used over a longer period for analysing and assessing structural behaviour by the authors but have been further developed in this project. The methods and software to carry our Thrust line analysis [6] needs to be further developed than those that have been available in this project. TNA have a great potential to become a very effective method to perform advanced 3d-analysis of masonry vaults but needs development in order to perform “closest-fit solutions” to map the thrust network to the actual shape of the existing vaults. Such methods are under development [7, 8].

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