# A new numerical limit analysis-based strategy to retrofit masonry curved structures with FRCM systems

**R. Fugger[1]*, R. Maia Avelino[2], A. Iannuzzo[2], P. Block[2] and G. de Felice[1]**

[1] Roma Tre University, Department of Engineering, Via Vito Volterra 62, 00146 Rome, Italy,
rebecca.fugger@uniroma3.it, gianmarco.defelice@uniroma3.it
https://www.romatrestrutture.eu/

[2] ETH Zurich, Institute of Technology in Architecture, Block Research Group Stefano-Franscini-Platz 1, HIB E 45, 8093 Zürich, Switzerland,
maia@arch.ethz.ch, iannuzzo@arch.ethz.ch, block@arch.ethz.ch
https://www.block.arch.ethz.ch/

**Key Words:** *Retrofitting, FRCM, Thrust Network Analysis, curved structures.*

In most historic masonry structures, curved geometries, such as arches or vaults, are key structural components to the overall building stability. Therefore, assessing their safety level with respect to changes in the boundary conditions (increasead loads or settlements) is crucial. If the safety level of the structure needs to be enhanced, a strategy to intervene and retrofit structural members is represented by the use Fabric Reinforced Cementitious Matrix (FRCM) systems [1]. These types of externally bonded composite materials, made of high strength textiles embedded in inorganic matrices, are proven to be a particularly advantageous strengthening solution for curved masonry structures. Even though limit analysis approaches such as Thrust Network Analysis (TNA) have been widely used to assess the structural stability, their use in a retrofitting framework is seldom explored. This paper proposes an automated procedure to design the FRCM reinforcement required in masonry structures based on an initial TNA assessment analysis. To perform these analyses, the non-linear programming algorithm proposed in [2] is modified to compute the minimal reinforcement required for stability. These quantities are then used to design the FRCM reinforcement according to existing regulations [3]. Finally, the load bearing capacity of the reinforced structure can be re-evaluated for different load cases ensuring that the structure is safe. The effectiveness of the proposed approach is demonstrated on arched structures and compared to well-known literature cases.

## REFERENCES

[1] G. de Felice, T. D'Antino, S. De Santis, P. Meriggi, F. Roscini, Lessons Learned on the Tensile and Bond Behavior of Fabric Reinforced Cementitious Matrix (FRCM) Composites, *Front. Built Environ*. 6:5, 2020.

[2] R. Maia Avelino, A. Iannuzzo, T. Van Mele, P. Block, Assessing the safety of vaulted structures using thrust network analysis, *Computers and Structures*, Vol. **257**, 2021

[3] American Concrete Institute (ACI) 549, Guide to design and construction of externally bonded fabric-reinforced cementitious matrix (FRCM) systems for repair and strengthening concrete and masonry structures, *Farmington Hills, MI, US*, ACI 549.6 R-20, 2020.