

# Importance of Wood and Iron Tension Members on Seismic Performance of Historic Masonry Buildings: Three Case Studies from Turkey

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## ABSTRACT

Wood and/or iron tension members in the form of either ties (both wood and iron) in historic masonry arches or externally applied tension rings (iron) of masonry domes have been used in historic buildings especially in the areas that are vulnerable to severe earthquake excitations. These members have their unique details to masonry units to function as a tension member, limiting excessive deformations and internal forces in main masonry load carrying elements. Earthquake reconnaissance investigations revealed that masonry arches and domes with tension members showed satisfactory behaviour under earthquake loading. However, due to some reasons like time dependent material flaws (e.g. corrosion), damaged members (fractured or buckled ties), sectional losses etc., tension members lose their functions and need to be repaired or replaced by appropriate members. In some cases, further measures may also be required if the safety of building against gravity and seismic effects is not sufficient. These ways of interventions are considered herein with the help of three real life restoration projects as case studies in Turkey. The first building (Fig. 1) is a 16<sup>th</sup> century mosque having structural cracks on its 25m-diameter brick dome. Combined steel and CFRP sheets as tension members at several dome levels are proposed as a seismic retrofit measure. Time history FEM analyses are conducted using SAP2000. The maximum normal and shear stresses are computed and compared before and after the retrofitting of the dome. Significant improvement is obtained in response, leading to maximum 60% reduction in stresses. The second case study (Fig. 2) is a stone masonry vault having damaged wooden ties. This building was also analysed with and without the wooden ties. Similarly, numerical results show that stresses as well as deformations can be reduced up to 50% by replacing the ties with the new wooden ties. The third one (Fig. 3) is a 508-year-old tomb, having a nearly collapsed brick masonry dome. The dome of this building was completed with bricks having similar properties to the original brick. At the support level of the dome, externally applied steel rings were used as tension members to limit stresses and deformations. Similar amounts of reductions in stresses are obtained. All of the selected retrofit strategies were approved by architectural historians with pleasure since the structural intervention was at minimum level and the buildings were near their original form and factor of safety. Restoration works have been completed for the mosque and the tomb, while restoration of the masonry vault is still in progress. This study also shows that both traditional and contemporary retrofit strategies can be used in the same project when required.

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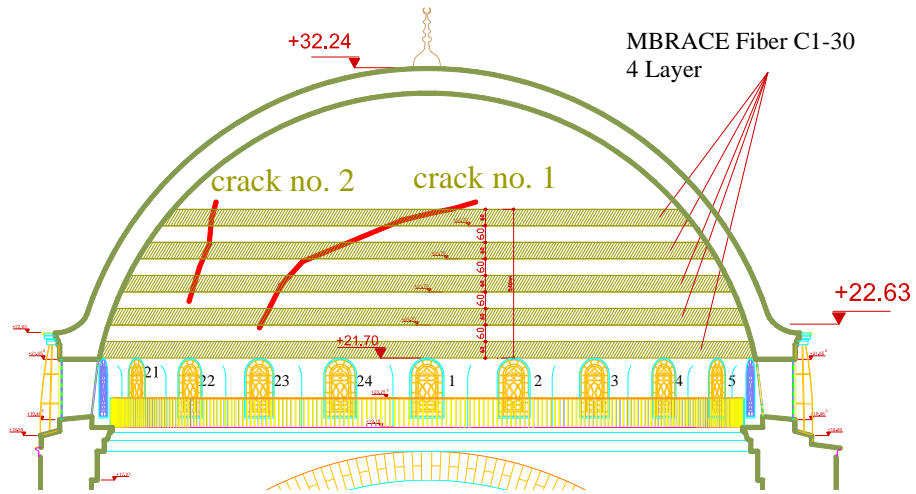


Fig. 1. Application of CFRP Sheet Layers on the Inner Surface of the Main Dome (Case Study-1)

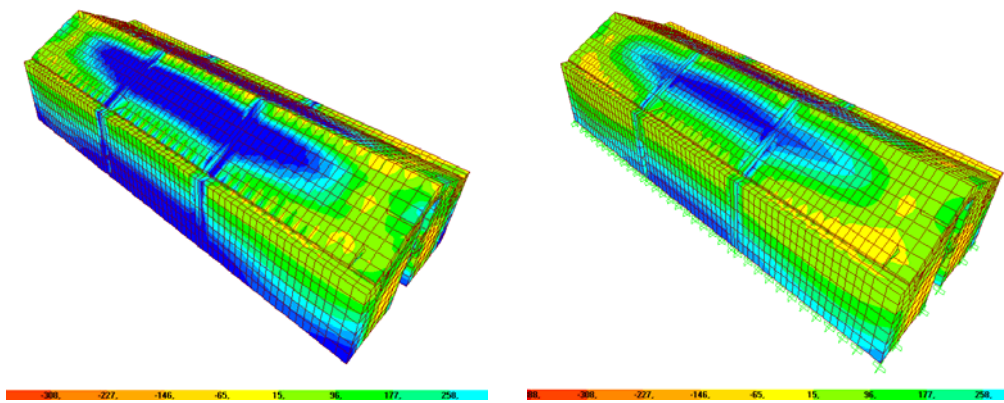


Fig. 2. Stress Distribution in Masonry Vault (a) Before Retrofit (b) After Retrofit (Case Study-2)

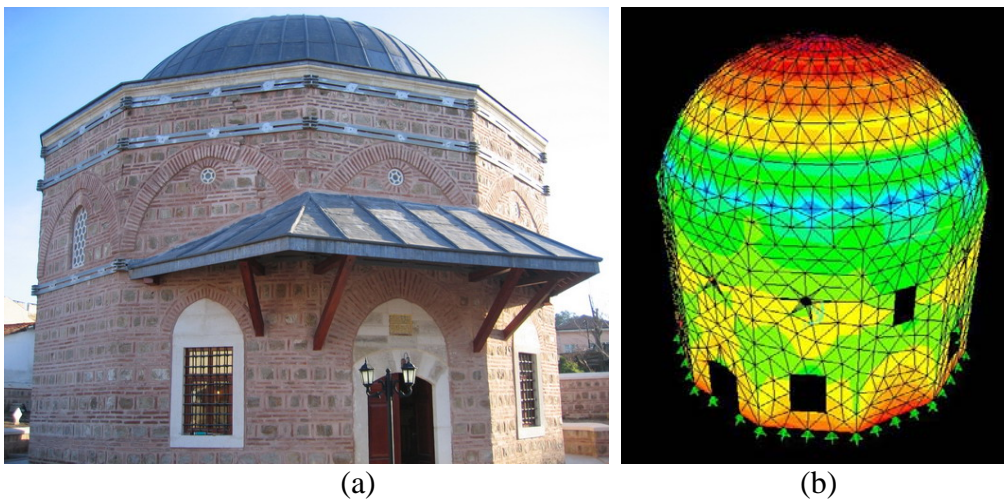


Fig. 3: (a) The Tomb After Reconstruction of Dome and Steel Rings  
(b) Principal Stress Patterns after Retrofitting (Case Study-3)