The dynamic behaviour of the roof interventions in the Basilica San Francesco in Assisi

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Extended Abstract

The Basilica of San Francesco in Assisi, Italy is one of the most famous Basilicas in the world and in 1997 it was struck by a sequence of earthquakes. Two of the vaults of the Basilica of San Francesco in Assisi collapsed as a result of the earthquakes with 5.6 and 5.8 magnitudes. The construction of the building began only two years after St. Francis of Assisi's death in 1226 and was completed in 1253. The structure had endured stronger earthquakes for centuries before these events, and there are likely many reasons for the 1997 collapse, such as damages cumulated from previous earthquakes or the retrofitting made to the structure over its lifetime. A full description and history of the different retrofit interventions of the Basilica are presented. In particular, the Basilica's roof has been subjected to three major restorations in its life. As an original contribution of this study, the structural systems of each roof were presented and cross-referenced with the seismic history of regional earthquakes that have hit the Basilica over the years to show the historic seismic performance of the Basilica with each roof. From this cross referencing, it is curious that only 50 years after a roof intervention, the Basilica incurred more damage from the 1997 Umbria-Marche earthquake than it had in almost 750 years of strong seismic activity. For this reason, an analytical model has been used to study the dynamic behavior of the Basilica over the centuries and determine if the roof installed during the 1958 intervention played a role in the 1997 vault collapses. The analytical model consists of a shear beam on an elastic supports and solved for the fundamental period of the structure while varying certain parameters. The results of the modal analysis shows that although the XV century roof intervention changed the mass and the stiffness of the roof, both parameters were changed by the same amount and thus, the period of the structure was not significantly affected. As a result the Basilica maintained similar seismic performances and it was able to withstand over 700 years of seismic events with minor damages. Conversely, the second roof intervention performed in 1958 changed the mass by a factor of 1.5 and the stiffness of the roof by a factor of 12.9 in comparison to the first roof system. This difference caused a change of the fundamental period of the structure and the global dynamic behaviour of the structure which explains why the 1997 Umbria-Marche earthquake showed a sharp change in the dynamic performance of the Basilica. The numerical results of the simplified analyses presented, related to the 1958 intervention, has shown that the redistribution of the seismic loads towards the façade and the transept without verifying if the structural member

Fig. 1- Basilica of San Francesco in Assisi.

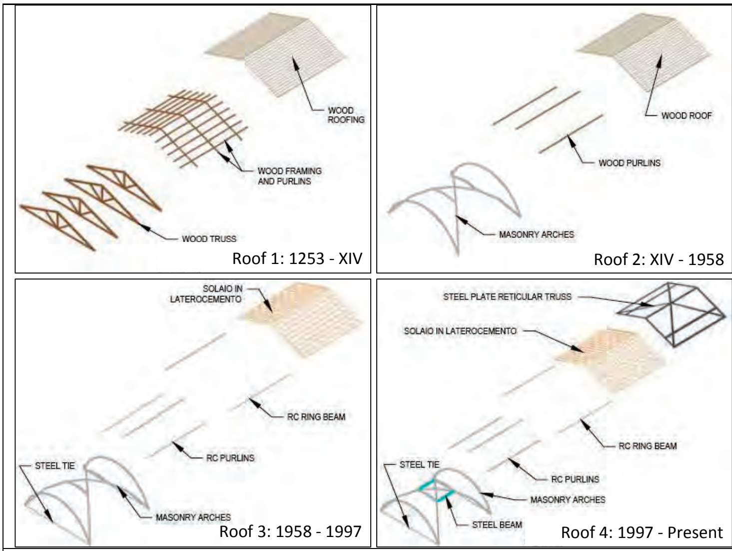

Fig. 2- Scheme of the roof types.

underneath (i.e. the rigid support) had enough residual capacity to withstand the additional seismic loads, the stiffness asymmetries of the nave (i.e. the missing tendons at the transept and at the façade and the missing flying buttress at the bell tower) leaded to the collapse of the two Gothic vaults during 1997 earthquake. After the roof inspection of the Basilica by the authors in 2013, these vulnerabilities are still there even after the recent retrofit intervention by Prof. Croci. The findings of this study are meant to educate engineers and decision makers to preserve the historical monuments of our country avoiding similar retrofit interventions in the future without performing opportune checks.

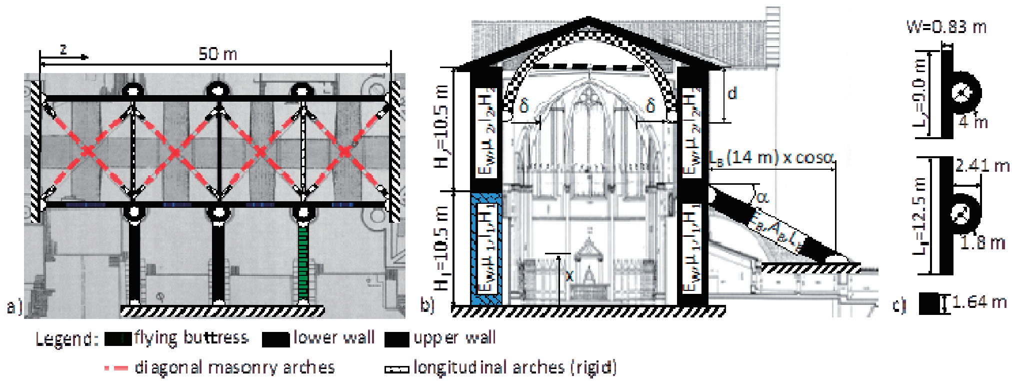

Fig. 3- Schematic view of: a) analytical model, b) nave section model, and c) element sections.

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2. References

[1] Cimellaro, G. P., Reinhorn, A. M., and De Stefano, A. 2011. "Introspection on improper seismic retrofit of Basilica Santa Maria di Collemaggio after 2009 Italian earthquake." *Earthquake Engineering and Engineering Vibration*, 10(1): 153-161.