The masonry of three-lobed churches

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Long Abstract

The paper deals with churches of orthodox rite wide-spread in the Carpathian-Danubian-Pontic area. The three-lobed shape lasts from the fourteen centuries when the old wooden churches were replaced by stone and brick masonry ones. Unfortunately, strong tectonic earthquakes, with deep focuses and long duration, frequently occurred in that area. Their main focus is located in the Carpathian curvature at depths of about 150 km. During history, many three-lobed churches were severely damaged or even destroyed by such earthquakes. The first attempts to enhance their seismic resilience, by a slight widening of the pronaos of each church, were made in Moldavia between the years 1490 and 1496. Then, in Wallachia, Prince Neagoe Basarab built up the Church of Argesh Monastery that was consecrated on August 15th, 1517. Due to its beauty, that church became famous. It was included in the Legend of Master Manole in connection with the myth of immolation. In that way, the Legend became like the first code of seismic protection of monumental churches. All subsequent churches which adopted the same dimensions for their three-lobed plan behaved safely under EQ actions. Particularly, the Patriarchal Church built in Bucharest in 1655 successfully faced much stronger EQs than those currently occurring in Argesh County (Fig.1).

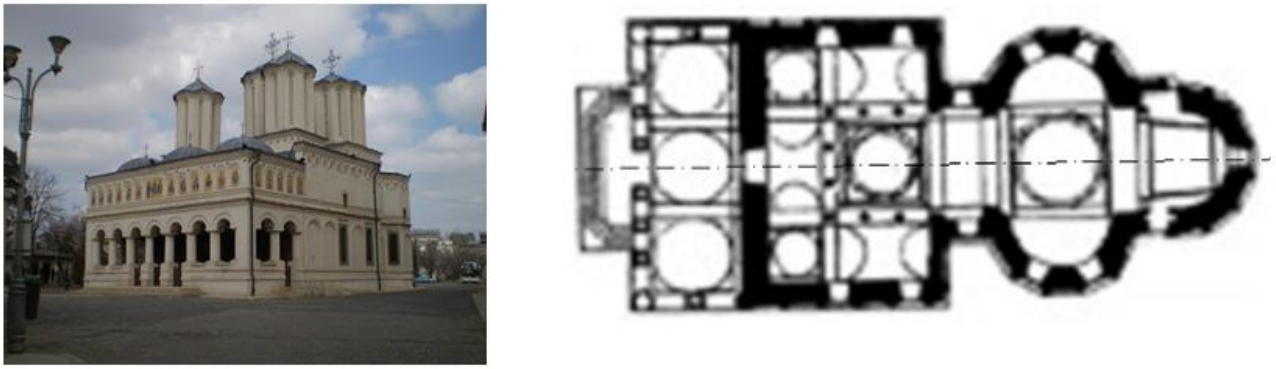

Fig. 1. Patriarchal Church in Bucharest - 1655, view and plan

During the strong earthquake that surprised Romania on the night of March 4th, 1977, many three-lobed churches in Bucharest and the countryside were severely damaged or even destroyed. By inspecting directly on their site, the dramatic consequences of that EQ many lessons of civil engi-

neering were learned. At the IABSE Symposium VENEZIA 1983, a paper was presented, summarising the concepts and methods of seismic protection available at that time (Sofronie, 1983, pp. 287-294). The common method of strengthening most of the damaged buildings at that time, churches including, was based on reinforced concrete. Fortunately, in a short time after that symposium, it was published a new copy of the Venice Charter 1964. The Charter did not agree to associate brick masonry with reinforced concrete because according to Aristoteles Fire and Water are two antagonistic Elements (Irimia and Sofronie, 2021). That moment was followed by many years devoted to further site investigations and laboratory tests to preserving the masonry of the three-lobed churches. This is why in the year 1995 in Bucharest the method of reinforcing brick masonry based on lime mortars with polymer grids was patented. This original method essentially differs from the former two existing methods, that of Joseph Monier in 1867 and Henri Vidal in 1962. The new method is based on the Theory of dislocations for which in 1962 Landau was awarded, Nobel. According to that method, the vertical joints between bricks were regarded as geometric faults or imperfections. (Irimia and Sofronie, 2021). The regular grids of polymer applied in the lime plaster on the masonry surface prevent the development of stress concentrations around them. In this way the integrity of supporting masonry is conserved. The method is reversible since after a while the grids can be replaced, and the protection of masonry enhanced. The durability of existing polymer grids depends on the producer but currently, it can reach 120 years. The patented method was first tested in local laboratories. Then, due to the interest in preserving the patrimonial buildings, the new method of reinforcing the masonry results received the support of UNESCO. All research program was carried out to successive static, pseudo-dynamic on 2D models on reaction walls and seismic on 3D models on shaking tables, all on the natural scales. That research was extended over about one decade, and in this way, the method of reinforcing the masonry was physically validated. The testing results were devoted to historic or original masonry with solid-backed bricks and lime mortars. Ceramic hollowed bricks based on cement mortars are not recommended and therefore were not further considered in research. Two results of the comparative tests carried out on the shaking table over historical and modern masonry are suggestively presented below in fig. 2. As long as the proposed reinforcement is strongly non-elastic the numerical analysis was adopted (Irimia, 2021).

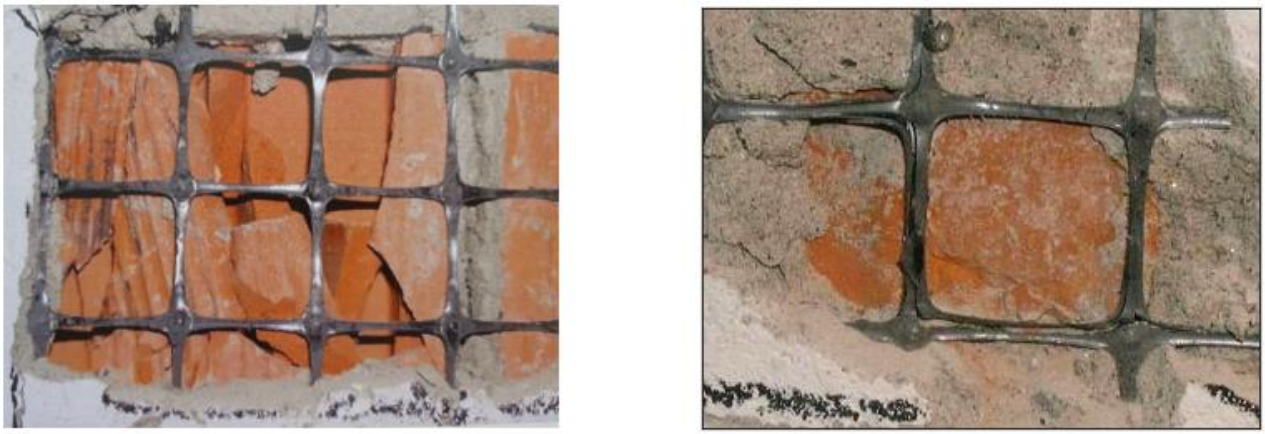

Fig.2 Left, the damage of hollow bricks only, and right - the damage of polymer reinforcement only

Due to advanced methods of analysis, numerical modeling has been developed for historical and modern masonry panels but also tests performed in the European Union laboratories. The numerical analysis was carried out. for each panel in three cases: plain masonry and the reinforced one with

biaxial and triaxle grids. The results obtained for the internal energy are presented below in fig. 3. Numerical values confirm that triaxial grids are more efficient than biaxial grids.

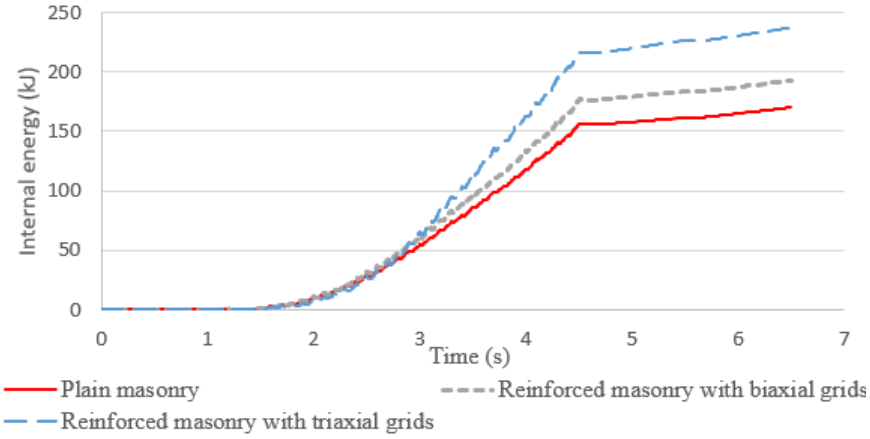

Fig. 3 − Internal energy for the panel with openings

The paper was devoted to the three-lobed churches because they are part of Romanian National Heritage. Original masonry is based on lime mortars and according to the Chart of Venice 1964 is the only true masonry. Due to the lime mortar, the adaptation phenomenon appears in the historical masonry, through which each brick receives six micro degrees of freedom. Modern masonry based on cement mortars was called in the paper with the acronym *mascret.* It is wet, brittle, and due to the content of SiO_2 unhealthy (Sofronie, 2021).

Only the original masonry is reinforced with polymer grids. This new construction material is dry, ductile, and healthy. It is devoted equally to external and internal walls. The synthetic reinforcement is according to ICOMOS-Iscarsah Recommendations since 2001 in Paris, reversible. That means after a while the synthetic reinforcement can be replaced with a new one.

Author Contributions

Software: Mihai Irimia

Supervision: Ramiro Sofronie

Validation: Ramiro Sofronie

Visualization: Mihai Irimia

Writing – original draft: Mihai Irimia and Ramiro Sofronie

Writing – review & editing: Ramiro Sofronie

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