The structural analysis and proposed consolidation methods for the Franciscan monastery in the Arad fortress

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ABSTRACT

This paper presents the effects of poor maintenance of the Franciscan monastery inside Arad fortress which is an historical heritage building. The structural resistance is severely affected and after a visit to the monastery cracks were observer in the walls, spandrel beams, arches and vaults. Also there were some unauthorized interventions done to the structure. A nonlinear analysis was also done for the structure and the analysis showed the structure will have structural failures after an earthquake. Some consolidation methods have been proposed for the foundations, walls, arches, vaults and towers. The consolidation of the structure should be done with reversible materials that do not affect the historical value of the historical heritage building.

Keywords: masonry, degradation, consolidation, monastery, heritage, restoration

I. INTRODUCTION

The fortress of Arad (Fig. 1) is an historical monument with national importance to Romania. The fortress is situated in the western part of Romania in Arad city, Arad County. It is a Vauban type fortification that has a star shape with six bastions. The walls are made out of masonry and filled with dirt, with the average thickness of three meters. The construction of this fortress was ordered by Maria Terezia of Austria in the year 1762 and are based on the plans of the austrian architect general Filip Ferdinand Harsch [1].

Inside the fortress there were built three structures: a building which housed the guard of the fortress, a building which housed the headquarters of the fortress and the Franciscan monastery. The fortress had to withstand a single siege during the revolution from 1848-1849 which lasted for 9 months. After that the fortress was used as a military prison, where a lot of revolutionary prisoners were held including the 13 generals that were executed in 1849. Without doubt the most famous prisoner held there was Gavrilo Princip, after the assassination that took place in Sarajevo in 1914. During the revolution in 1989, on the 21st of December the soldiers inside the fortress switched to the revolutionary's side Arad becoming a free city [1].

Fig. 1. Arad fortress [1]

The "Heritage restoration and regeneration" master at the faculty of Architecture and urbanism in Timisoara had the goal of reintegrating the fortress into the life of the city. Currently the fortress is occupied by the army but the army has an arrangement with the city hall to leave the fortress in a few years. One of the teams that worked on this project was charged with the restoration of the Franciscan monastery inside the fortress. A structural damage analysis was made for the Franciscan monastery (Fig. 2) and some consolidation methods were proposed for the degraded structure.

Fig. 2. Franciscan monastery in Arad fortress

II. THE ON SITE DEGRADATION ANALYSIS

The structure is made out of the monastery main structure plus two sanctums on the left and right side of the main structure. The resistance structure is made out of masonry walls and masonry arches and vaults. Because of the poor maintenance the structure has degraded in time.

What follows are some of the damage that was observed at our filed trip to the fortress.

The first thing that is obvious when you first see the structure is the infiltration of water and the exfoliating plaster of the building which occurs all around the building and is heavily affecting the structure.

Observations were made that at the corners of the building there were vertical cracks that were caused by the faulty foundation settlement of the structure (Fig. 3).

Cracks were also visible in the halls of the sanctum on the right, on the vaults and arches as seen in Fig. 4 and vertical cracks over the entrances of doors.

There were also vertical cracks found in the spandrel beams over the windows (Fig. 5).

The main structure of the church has structural degradation as well. The walls of the church have vertical cracks because of water infiltration in the foundation (Fig. 6).

Also some vaults in the church and some vaults in the sanctum are partially or completely collapsed (Fig. 7, Fig. 8) because the roof over the church and parts of the sanctum are completely gone and the water infiltrated these vaults.

Fig. 3. Vertical cracks at the corner of the building

Fig. 4. Cracks in the arches and vaults

Fig. 5. Cracks in the spandrel beams

Fig. 6. Cracks in the monastery walls

Fig. 7. Partially collapsed vault in the church

Fig. 8. Completely collapsed vault in the sanctum

There were also some unauthorized interventions done to the structure like holes done in walls for passing, some windows and walls were blocked with masonry and a masonry wall with RC frame was built in the church (Fig. 9).

Fig. 9. Unauthorized masonry wall with RC frame

A complete analysis of the structure was not possible because access was not possible to the sanctum left of the church, the roof or to the basement. Observations were made that the roof is missing over the church because of the collapse of the vaults, and from the outside that where the roof is missing vegetation has started to grow in those places (Fig. 10).

Fig. 10. Vegetation taking over where the roof used to be

III. NUMERIC NONLINEAR INVESTIGATIONS

The nonlinear numeric investigation was done using the program TreMuri by S.T.A. DATA srl. [2] The program was used to build a 3D model (Fig. 11) of the structure and then compute a nonlinear push-over analysis on the structure.

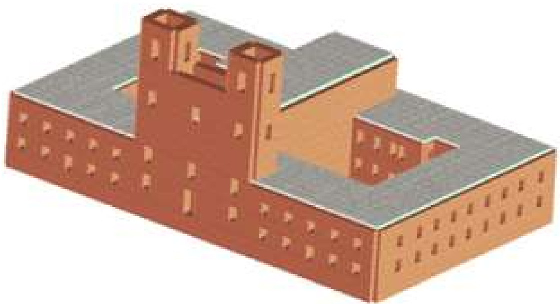

Fig. 11. 3D model of the structure [2]

The push-over analysis was made with the ground acceleration of the earthquake equal to 0.20g, which according to the Romanian earthquake code P100/2013 is the correct ground acceleration for that region of the country [3].
After running the analysis the most significant

analysis results gave Fig. 12 as the force-displacement curve for the structure.
After that the degradations of the structure after an earthquake with 0.20g ground acceleration were also possible to view. Fig. 13 represents the damage that the main façade can get after such an earthquake.

that the bearing surface of the building is larger. The underpinning is executed in several stages, on a section of maximum of one meter [4].
For the walls the coating of the walls with galvanized steel nets and pure hydraulic lime mortar (Fig. 15) was chosen. The masonry can be coated on both sides of the wall. The nets are bound

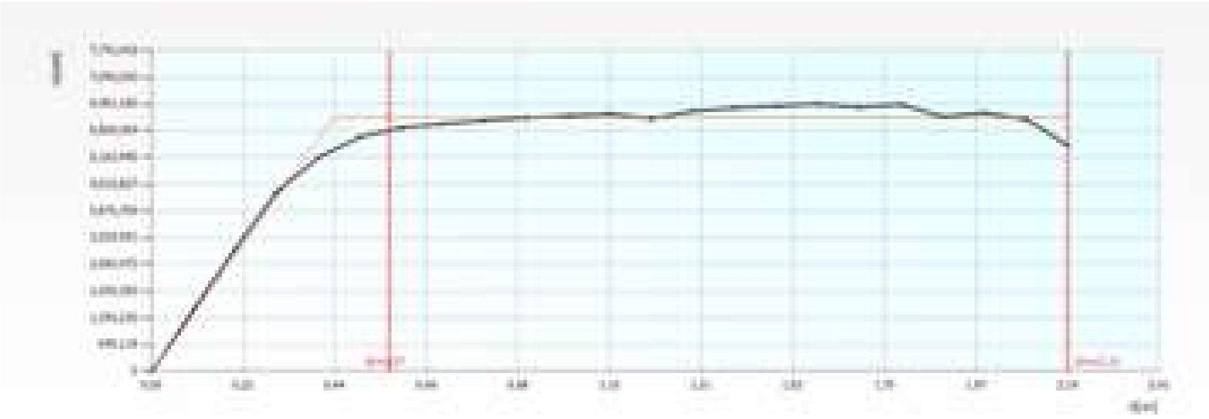

Fig. 12. Force-displacement curve [2]

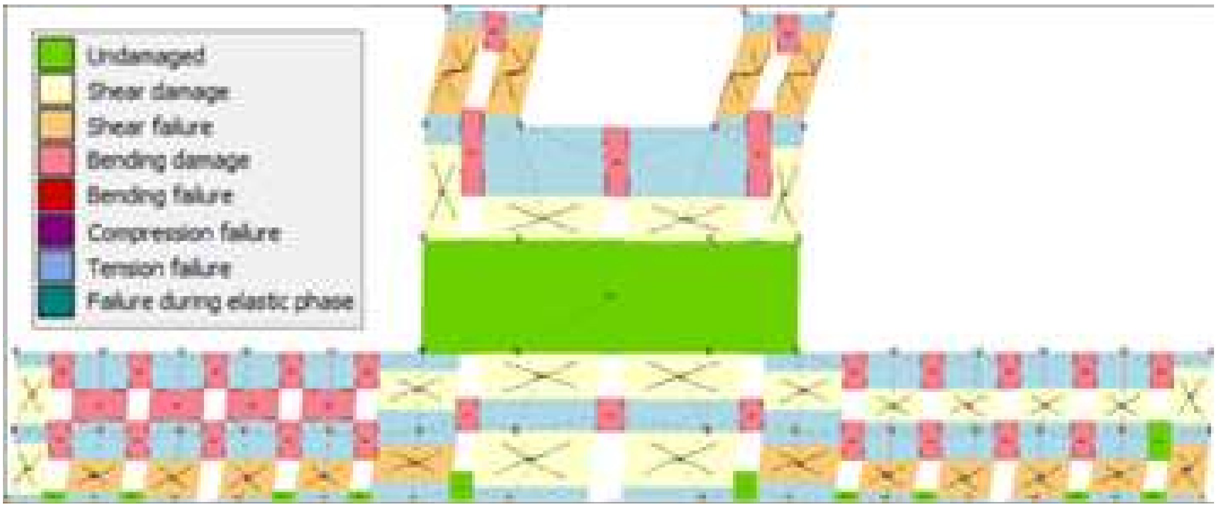

Fig. 13. Degradations of the main façade [2]

After viewing the analysis results a deduction was made that the structure would sustain high damage after an earthquake with 0.20g ground acceleration.

IV. PROPOSED CONSOLIDATION METHODS

For the consolidation of the foundation of the building the underpinning of the foundation (Fig. 14) and a perimeter beam that are both made out of reinforced concrete was chosen so

together with steel connectors which are introduced through holes made in the wall from both sides [4].
For the door and window openings the consolidation with steel profiles (Fig. 16) was chosen. The intervention is done by eliminating a few rows of masonry from the superior side of the opening and from the lateral sides of approximately 70 centimeters thickness and introducing in the thickness of the wall the steel profiles double T and constraining them with metal rods [4].

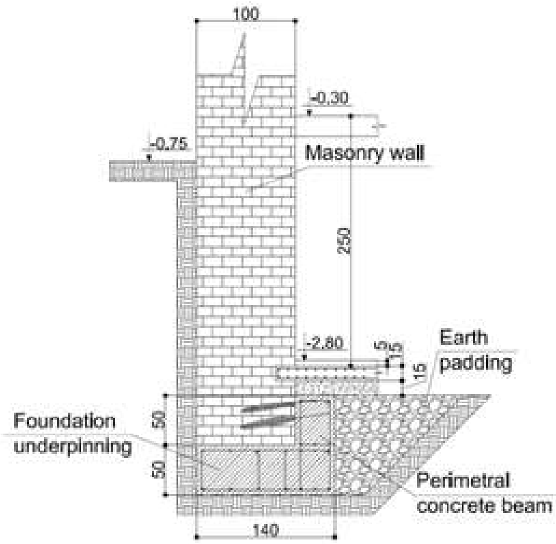

Fig. 14. Underpinning of the foundation [4]

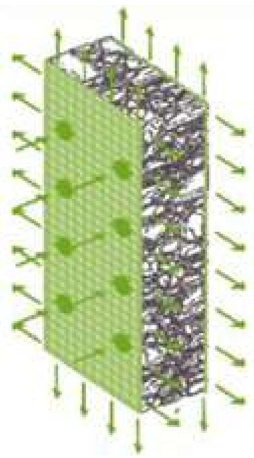

Fig. 15. Coating of the wall with galvanized steel nets and pure hydraulic lime mortar [4]

Fig. 16. Consolidation with steel profiles of openings [4]

The consolidation method for the arches is using a steel beam that has the role of taking part of the load from the arch therefore the arch will heave lower loads (Fig. 17) [4].

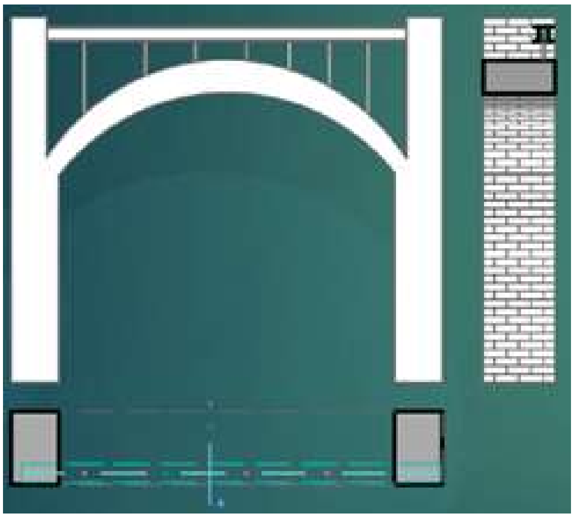

Fig. 17. Consolidation with beams of arches [4]

The same method as for the arches was picked for the vaults of the church but instead of a single steel beam there will be a network of steel beams that change how the loads affect the vault (Fig. 18) [4].

Fig. 18. Consolidation with beams of vaults [4]

The vaults over the sanctums shall be consolidated with composite FRP materials that will help strengthen the structure (Fig. 19).

Fig. 19. Consolidation FRP of vaults [4]

The towers of the church shall be consolidated by using a steel structure that is made of steel beams and steel pullers (Fig.20, 21) on the inside and on the outside of the building strengthening the resistance of the building. The walls of the towers shall be coated with steel nets and hydraulic lime mortar just like for the walls.

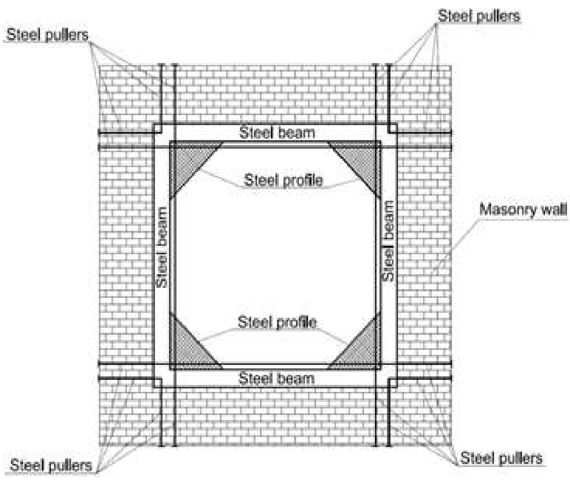

Fig. 20. Consolidation of towers on the inside with steel structure [4]

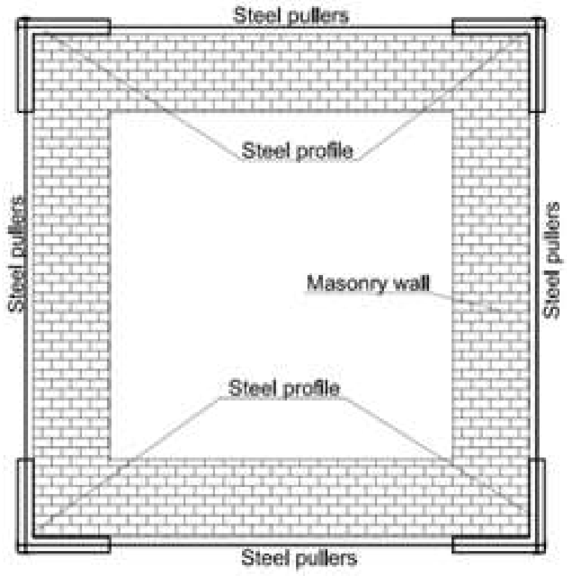

Fig. 21. Consolidation on the outside with steel structure [4]

V. CONCLUSIONS

The Franciscan monastery in the Arad fortress is an important historical monument that has been kept in poor maintenance. Because of this poor maintenance the structural integrity of the building has been severely degraded. Some of the most important degradations are the infiltration of water at the foundations, vertical cracks through the walls, cracks through the vaults and arches, collapsed and partially collapsed vaults and unauthorized structural modifications. Also the nonlinear numeric investigation of the structure shows that it could have severe implications for the structural integrity. Therefore the resistance structure of the monastery building should be consolidated with the methods that were enumerated above in such a way that the structure still withholds its historical value.

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