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THE STRUCTURAL REHABILITATION OF THE BASEMENT OF A BUILDING WITH BRICK MASONRY STRUCTURE

I. POP[1] N. COBÎRZAN[1]

Abstract: *The paper presents the structural rehabilitation solution that was applied to the basement of a masonry building, design at the beginning of 20th century. In the first phase of structural evaluation, was determined the causes of masonry decay based on visual and on site investigations. Secondly, was evaluated the building safety and proposed the strengthening solutions. The strengthening of the masonry columns was made with reinforced concrete jacketing and in the area where the vault collapsed were used a new structural system made of steel.*

Key words: *arches, masonry, strengthening, vaults.*

1. Introduction

A high number of existing buildings have structure made of masonry (walls, columns, vaults, arches, domes, etc.), where some local failures of structural elements occurred during service time which may put in danger the building stability and people's life.

The buildings incapacity to satisfy the structural performance exigencies imposed by norms in force has made necessary to approach some structural strengthening measures required in order to restore the buildings structure at least initial state or to confer a superior level of performance. This is the reason why the scientific researches conducted in this field were intensified worldwide in the last 20-30 years, especially in countries with seismic areas [1-9]. The researches has been more and more focused upon the assessment of the technical state of the buildings structures, on studying, developing and implementing new techniques and methods for strengthening and rehabilitation of structural elements and buildings as whole. For rehabilitation and strengthening interventions were used traditional techniques and conventional materials (reinforced concrete and steel) [1], [2], [4], [5], [6], [7], new materials and inovative technology (mortars or concrete with fibers, carbon strips, composite materials, etc.) [3], [8], [9] or seismic energy-dissipating systems [1], [2].

In general, the moral and physical decay of a building significantly affects its strength and serviceability by imparting an insufficient level of safety in relation to the minimum set of performance.

The causes that lead in time to the reduction of the load-bearing capacity of the structure are very complex, starting from the ageing of materials to external factors that

[1] Technical University of Cluj Napoca, 28 Memorandumului Street, 400114, Cluj Napoca, Romania.

act upon the buildings (humidity, thawing-freezing, settlements of foundations, chemical or seismic actions, etc.).

It is well known that moisture is one of the main causes of degradation of masonry buildings. Due to the fact that masonry is a non-homogeneous material made up of brick and mortar, the technical characteristics of all component materials play an essential role in durability of structural elements. Brick and lime mortar are water-sensitive porous materials; humidity generating and amplifying their deterioration processes during the entire service lifetime of the constructions.

Considering all these issues it is obviously that the structural rehabilitation of an existing building require for structural intervention different technical solutions, each case study being treated as unique and particular one.

In this respect, the paper present a case study consisting in the basement rehabilitation of an existing masonry building.

2. Description of the Building

The building belonging to the Municipal Theater from Turda city and subjected to the analysis was built between 1901 and 1904, having different destinations at the beginning, later becoming a theater, respectively the municipal theater of the city.

The partial building was built on an existing basement of another building, constructed in 19th century.

The height of the building is about 6.58 m (B+GF+attic), respectively 12.98 m (B+GF+2ndfloor+attic) (Fig. 1).

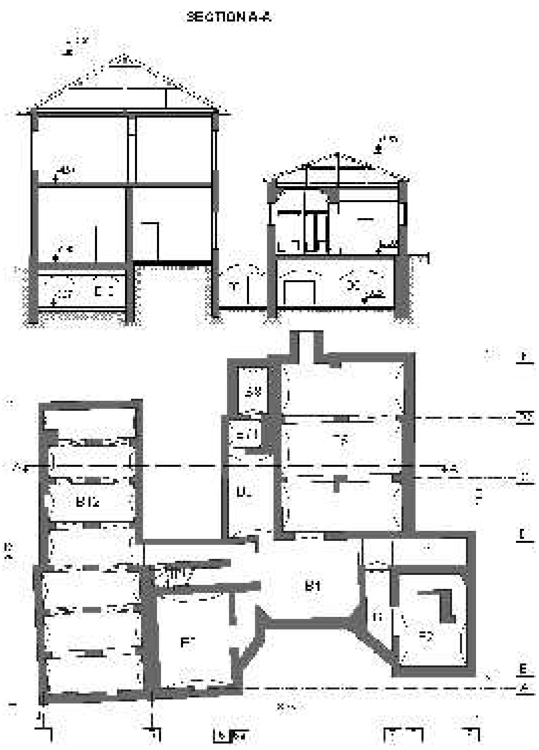

Fig. 1. *Basement floor plan and A-A Cross section*

The analyzed area of the building is between the axes 6,8-D,F and has a vertical structural system made of masonry loadbearing walls and columns.

The slab above the basement is made of a cylindrical masonry vaults intersected with masonry arches, and above the ground floor, the slab is made of wood.

As the ground floor is erected over the basement, the attic floor is supported on two columns in axes F and D1 (Fig. 2), starting from the foundations and passing through, up to the attic floor.

The foundations are from mixed masonry made of a combination of brick and stone.

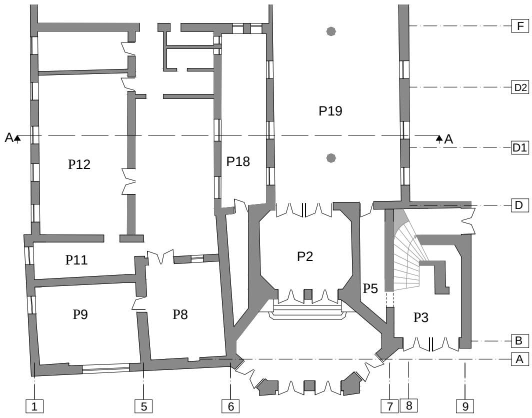

Fig. 2. *Ground floor plan*

3. The Causes of Structural Damage

Observations in situ showed that the structural damage stops at the level of the basement, mainly caused by the action of the rainwater and from the damaged pipes.

At the basement level, occurred a total collapse of the masonry vaults in the room 5, 5a, of arches from axis D2 and column from axis D2 (Fig.1).

The damage of the bricks especially in the columns from axis D2 (Fig. 1) and its associated foundation, led to a poor balance and consequently to the collapse. The column collapse, led to a local collapse of corresponding arch and adjacent vaults (Fig. 3), without breaking down the equalizer layer under the ground floor.

Fig. 3. *Collapse of the vault*

From on-site investigations it was found that the columns' foundations were approximately 20-30 cm deep in the ground. Degradations were also found in the columns placed in the D1 axis (Fig.1).

4. Intervention Measures

Taking into account the advanced state of masonry degradation with a real danger of slab over the basement to collapse, with a possible entrainment of the entire area of the construction, was imposed as first restriction to stop the circulation in the basement level.

For the rehabilitation of the affected area, the seismic risk assessment of the building was first provided [10-11] and after that a study was made to replace the traditional structure with a modern one in the collapsed area and to retrofit the existing structure in the less affected area.

For structural rehabilitation of basement, the following aspects were taken into consideration [12] and applied:

- ensuring a load capacity at least equal to the initial load or even increasing it;
- the elimination of moisture from water infiltration, which was the main cause of structural degradation, affecting to a large extent the resistance of masonry;
- the intervention measures should be based on a technology that will not induce vibrations into the building, vibrations that could accentuate the unstable equilibrium of the construction that could lead to its collapse;
- workers can achieve full safety intervention.

In order to assure the safety work conditions in the first phase of interventions, the water from the basement has been evacuated by lowering its level and maintaining the level below the basement floor, and in the second phase a passageway were build (Fig. 4) to protect the workers during the execution phase.

Fig. 4. *Scaffolding erected to support the reinforced equaliser layer form ground floor level*

Since the column from D1 axis had major deformations, were retrofited by reinforced concrete jacketing starting from the foundation level. Subsequently, the foundations were strengthened from lateral side, respecting four stages of realization.

After the reinforcement of the columns and foundations was finnished, the arch was reinforced and shotcrete layer was applied (Figs. 5-6)

Fig. 5. *Arch reinforcement*

Fig. 6. *Strengthening of arches and columns*

The collapsed area was retrofitted by using new structure made of steel to substitute the collapsed structure. The columns of the new steel structure were provided with their own foundations (Fig. 7).

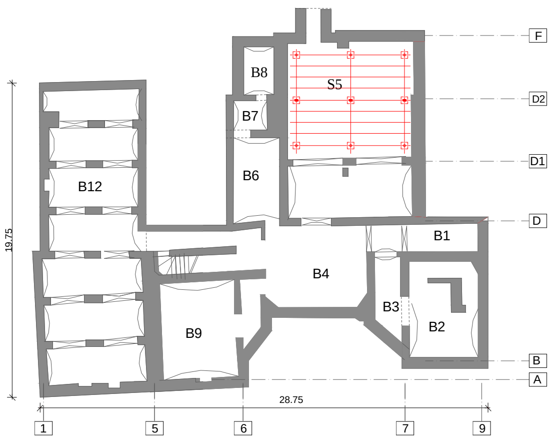

Fig. 7. *The rehabilitation solution provided in areas with problems*

The details of realization of the new structure, are presented in Figure 8 [12], and aspects during the execution in Figure 9.

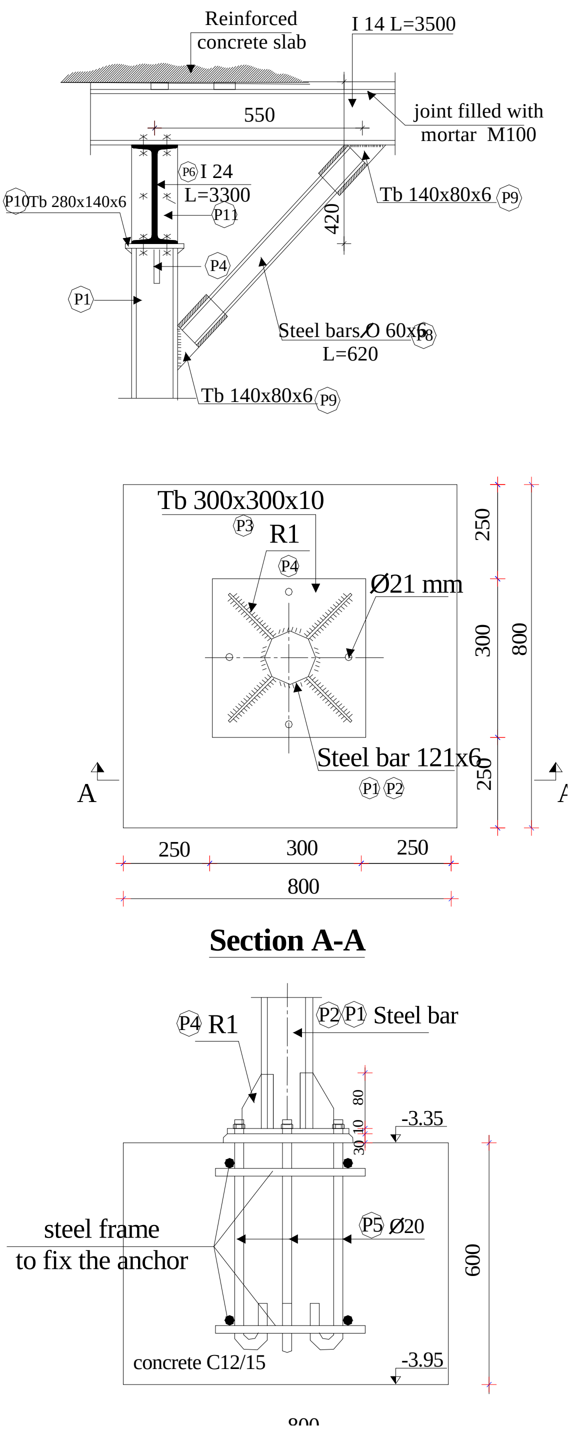

Fig. 8. *Elements of new structure*

Fig. 9. *Vault reinforcement details*

Details during and after the rehabilitation works were completed, are shown in Figure 10.

a) 

b) 

Fig. 10. *Aspects during the execution works: vaults overconcreting (a), after the rehabilitation (b)*

Conclusions

After approximatively 10 years after the structural interventions were completed, the behavior of the building as a whole and of the intervening area was seen, and was observed that there are no signs of inappropriate behavior of the building, consequently it can be said that the solutions applied were correctly designed and realized.

References

1. Curtean, M. N. (Roman-Pintican).: *Reabilitarea structurilor din zidărie utilizând diferite sisteme de reabilitare (Rehabilitation of masonry structures using different rehabilitation systems)*, PhD thesis, Faculty of Civil Engineering, Technical University of Cluj Napoca, 2014.
2. Hrenean, D. (Sucala).: *Reabilitarea seismica a cladirilor din zidarie prin izolarea seismica a bazei*, *(Seismic rehabilitation of masonry buildings using base isolation)*, PhD thesis, Faculty of Civil Engineering, Technical University of Cluj Napoca, 2014.
3. Indirli, M., Castellano, M., Clemente, P., Martelli. A: *Demo application of shape memory alloy devices: the rehabilitation of S. Georgio Church Bell Tower*, Proceedings of SPIE 2001;4330:262–72.
4. Forouzandeh, A. and Malekshahi, S.: *The Evaluation of Structural Strengthening of Historic Building on the Basis of Architectural and Restoration Consideration*, J. Civil Eng. Architect. Res, Vol. 1, No. 3, pp. 157-178, 2014.
5. Lourenco, P.B.: *Assessment, diagnosis and strengthening of Outeiro Church, Portugal*, Construction and Building Materials 19, 634–645, 2005.
6. Niculita, M., Groll, L.: *Consolidarea cladirilor din patrimoniu(Consolidation of patrimony buildings)*, Editura Societatii Academice Matei-Teiu Botez", Iasi, 2007.
7. Pop I., Cobîrzan N.: The Structural Rehabilitation of a Masonry Building, The Bulletin of the Polytechnic Institute of Jassy, Construction. Architecture Section, ISSN: 1224-3884, e-ISSN: 2068-4762, Tomme: LIX (LXIII), Fascicle: 4, pp. 99-106, 2013.
8. Taranu N., Oprisan G., Budescu M., Taranu G., Bejan L.: Improving structural response of masonry vaults strengthened with polymeric textile composite strips, Latest Trends on Engineering Mechanics, Structures, Engineering Geology, ISSN: 1792-4294, ISBN: 978-960-474-203-5,pp. 186-191, 2010.
9. Witzany J., Cejka T., Zigler R.: Problems of Masonry Strengthening with Carbon- and Glass Fibre Fabric, Procedia Engineering 14, 2086–2093, 2011.
10. P100-92, Ordinul MLPAT 71/n/1996 Prevederi referitoare la elaborarea expertizelor tehnice privind nivelul de asigurare a constructiilor existente.
11. Indicativ CR6-2006. *Cod de proiectare pentru structuri din zidărie(Design code for masonry structures)*.
12. Ioan Pop – *Expertiza tehnica pentru imobil Turda(Technical expertise for building Turda)*, Republicii Street, 2007.