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REHABILITATION OF A PARTIALLY COLLAPSED MASONRY TRADITIONAL TOBACCO WAREHOUSE OF THE LATE 19TH CENTURY

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Abstract. *This study presents morphology, pathology, recording method, applied rehabilitation procedure and constructional problems of a four-storey masonry building in Alexandroupoli which today is partially collapsed. It was constructed before 1900 and enlarged in 1924 to be used as tobacco warehouse. From 1950s onwards, it has been neglected and because of the total lack of maintenance it has sustained structural and architectural deterioration; intervention works for its re-use as Municipal Library began in 2004. The first approved rehabilitation plan based on false strategy adopted the total removal of the interior structural members including wooden diaphragms, beams and columns and the construction of a new internal reinforced concrete frame structure. It proved to be catastrophic since in 2005 a sudden partial collapse of masonry and the roof was caused. The building has remained partially collapsed and difficult to approach due to the danger of a potential further collapsing. Recording of the present state has been based on photogrammetry. A proper intervention plan is applied. This work is a contribution in the field of structural rehabilitation of partially collapsed historic masonry buildings that constitute an extremely unsafe working environment.*

1 INTRODUCTION - ANAMNESIS

The building is located in the center of the city of Alexandroupolis which is a significant port at the most North-East side of Greece. In the late of the 19th century and the beginning of the next century still under the Turkish occupation an exponential growth of the city occurred as a result of the immigration of many catholic families from west Europe. Most of them were railway technicians and employees, consulate staff and merchants. Before 1900 this well established catholic community constructed the building under examination to be used as a school. It was one of the most well-constructed buildings of the city. It seems though that it was only a part of the structure as it looks today since the community was but 5000 people and a larger school building was really not realistic. In 1904 a major fire during a student exhibition destroyed part of the existing building along with its equipment and facilities. The fire damages in conjuncture with the eventual economical decay of the community had as a result the utter forlornness of the structure.

In the year 1924 under the Greek rule anymore the rapid economical growth of the area due to the intensive cultivation of fine local tobacco allowed the reconstruction and simultaneously the enlargement of the building to its final shape. It became one of the largest and most prestigious and well-constructed buildings of the whole area and its new usage was the base of the renowned "Companie general de Tabac" (General Tobacco Company).

After the reconstruction and enlargement of the building size in the year 1924 the structure has taken its final L-shaped plan, as shown in Figure 1. The length of the building is 26.75 m, while its width is 12.30 m and 10.30 m at the northern and the southern side, respectively. The total height of the structure is 12.45 m. The building consists of four storeys; a basement, a ground floor, an upper floor and an attic under a gabled roof (Figure 2).

In World War II the building was used as prison by the Bulgarian army of occupation. After the war and until early 1950s the building was used as a shelter for the accommodation of the refugees. Henceforth the building remained completely forlorn and derelict. As a result of the long period of neglect and lack of maintenance the building had sustained damages to a considerable extent.

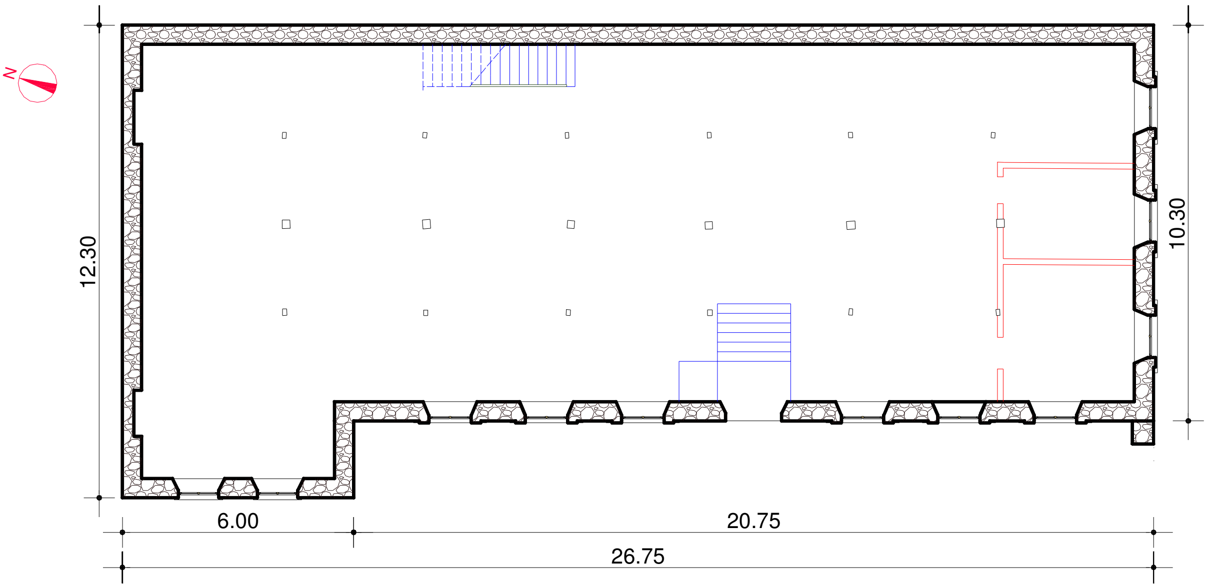

Figure 1: Plan view with the external dimensions of the ground floor of the building.

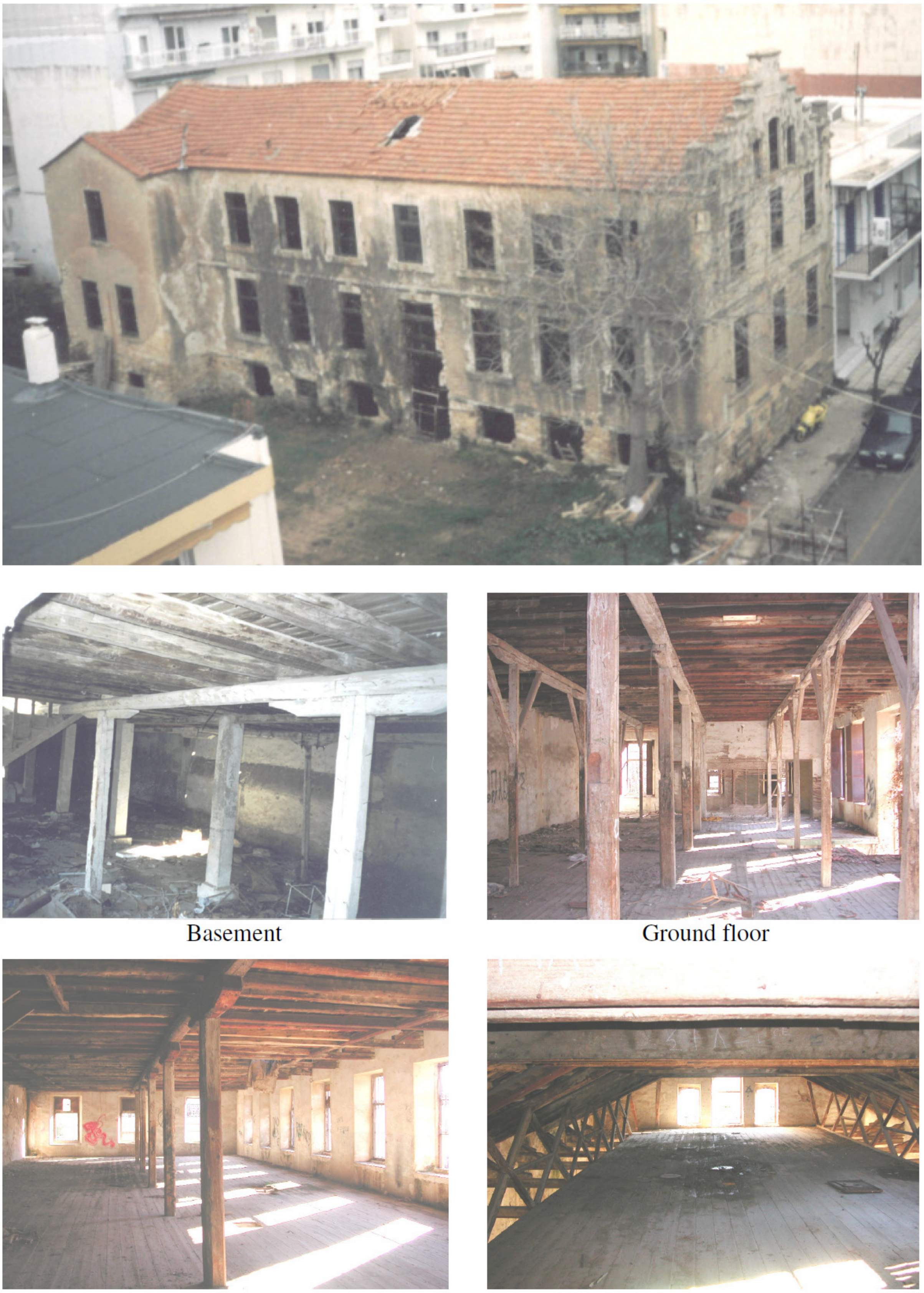

Figure 2: Outside south-western view and inside views of each floor of the tobacco warehouse (the photos were taken in 2003, before the intervention works of 2004-05).

2 STRUCTURAL CHARACTERISTICS

The building can be considered as a historic load-bearing masonry structure. It is an excellent sample of industrial architecture initially influenced by the urban architecture of the late 19th century. After the reconstruction and enlargement of the building in the year 1924 it was composed by the basement, ground floor, upper floor and an attic. The area of a typical floor is approximately 293 m^2 in a building plot of approximately 846 m^2. The building has a gabled roof composed by wooden trusses and terracotta tiles forming gables on the façades. The roof consists of 13 wooden trusses having a slope of 27°.

The basic building materials that prevail are stone and wood and secondly also used are cement and metal. Metal is used at the window recesses and in some cases as steel beams. Concrete is used for the middle row of columns in the basement only. The roof, the floor diaphragms, the beams and the columns except of the middle ones in the basement are made of wood.

The structural system consists of load-bearing masonry made of ashlars of regional granite connected with mud mortar. The hierarchical way of the construction of the perimetric wall at the floors in a way that the thickness of the masonry is being reduced as we reach the higher levels of the building is something worthy of remark. This reduction of thickness is attributed to the reduction of the loads. Thus the thickness of the masonry at the basement is almost 60 cm, at the ground floor it becomes 50 cm and finally at the floor and the attic it is only 45 cm. The masonry was lime - casted on inside and outside surfaces. The thickness of the foundation masonry is a little bigger than the thickness of the basement walls whereas the depth of the foundation level is approximately 1.50 m. The building as it is today neighbors with a multi-floor Reinforced Concrete (RC) residential structure at the east side.

3 FALSE REHABILITATION STRATEGY - BUILDING'S SITUATION

3.1 Rehabilitation plan

Recently, the building was bought by the municipality with the purpose of its future use as the Municipal Library. At that time despite the large extent of the damages due to the forlornness and the thieveries the building was a stable structure as it can be observed in the photographs of Figure 2. The wooden diaphragms of the basement, the ground floor, the first floor and the attic were intact and in a relatively good condition. These diaphragms and the roof connected the opposite perimetric masonry walls and maintained this way a stable equilibrium for the whole structure.

A reasonable rehabilitation strategy would provide for the repair and the total restoration of the existing structural members and materials and further where it was necessary for the possible reinforcement with materials friendly to the existing old materials if possible. Grout injections, deep repointing, jacketing and partial reconstruction are some well-known and widely-applied strengthening techniques for deficient or damaged masonry walls [1, 2]. A combination of these intervention methods on the same wall could be applied too. Furthermore the excessive use of cement or concrete in restoration works of historic buildings, and especially the construction of a whole new RC multi-storey frame that replaces all the existing old members is usually considered invasive for the preservation of the authenticity of historical heritage. Therefore, official authorities or bodies of experts involved in the conservation of cultural heritage usually prescribe the use of cement or concrete to be limited, whereas in some cases it is strictly prohibited (for example in classical and Byzantine monuments and antiquities). Besides, grout injections, deep repointing and partial reconstruction have proved quite successful restoration techniques for bearing masonry walls [3].

Instead, the approved rehabilitation plan for the re-use of the building under consideration as the Municipal Library included first the removal of the all the parts of the interior of the building and then the construction of a new, interior RC frame structure inside the existing masonry historic building. According to this plan in the first step all wooden diaphragms, the wooden beams and the wooden and concrete columns were to be removed. After that an entirely new interior structure was panned to be built. This interior structure consisted of new foundations, columns, beams and slabs, all made of RC, which were intended to serve the new purpose of the building and its bear increased loads.

Thus, in the year 2004 the intervention works for the rehabilitation of the building and the forthcoming re-use as the Municipal Library began. However, these works during the years 2004-05 proved to be inappropriate and catastrophic for the building because the removal of all the interior old structural members without the proper shoring of the perimetric walls and the roof had as a result the sudden partial collapse of the building; part of the eastern and northern wall along with part of the roof collapsed, as displayed in Figures 3a & b. After that incident the works stopped and the building has remained heavily damaged, partially-collapsed, unsafe and apparently unapproachable to anyone due to the immediate danger of further collapsing.

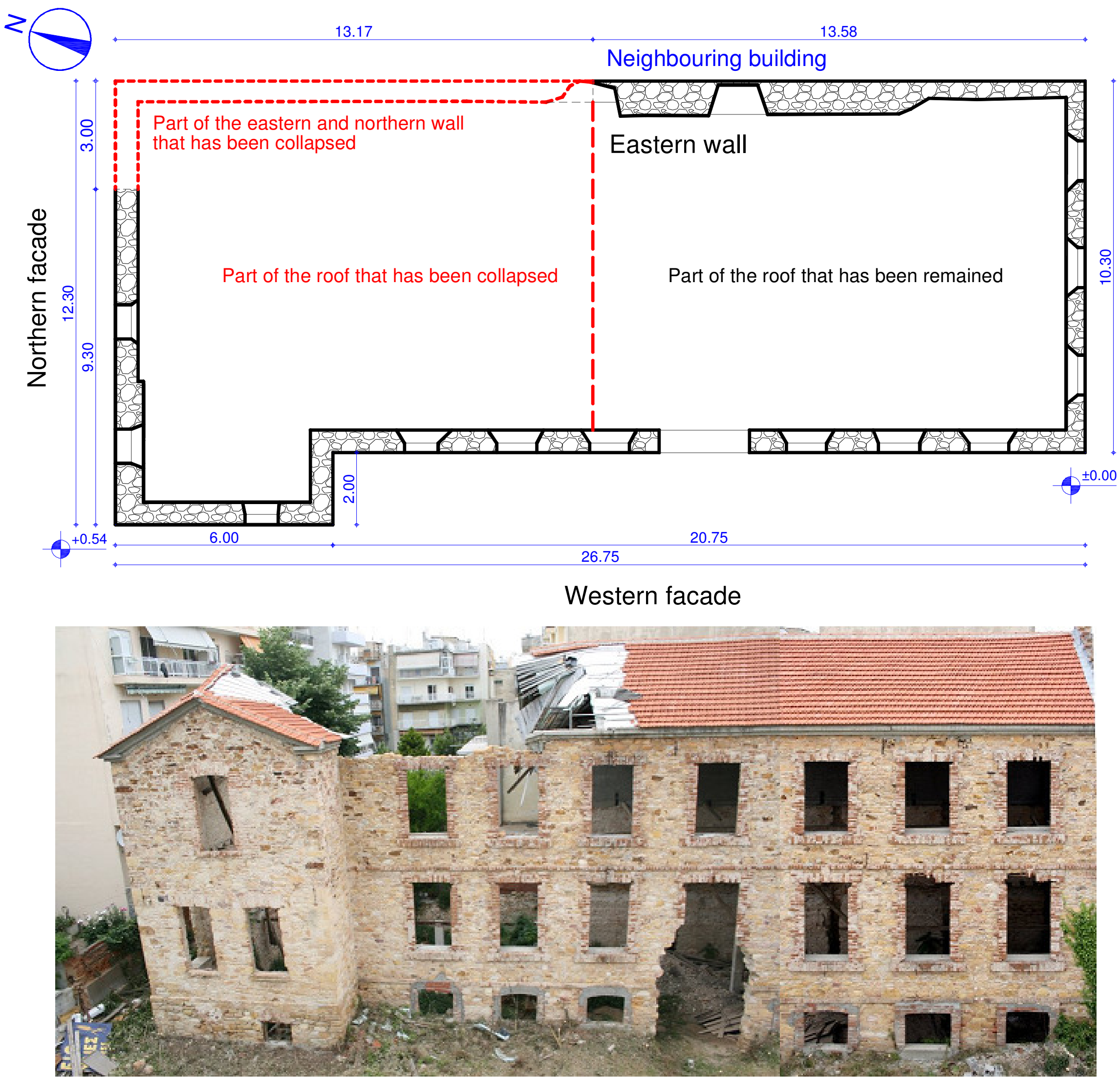

Figure 3: (a) Plan view and (b) external view (western façade) of the building after the partial-collapse of 2005.

3.2 Pathology

The building sustained severe damages due to (a) its age, the many years of non-use, the total lack of maintenance and the utter forlornness (b) the inappropriate and catastrophic rehabilitation plan which included the total removal of all the interior structural members: the wooden diaphragms, wooden beams and wooden and concrete columns; and (c) the partial-collapse of the eastern and northern wall along with part of the roof (in 2005), during the intervention works.

According to the approved restoration plan of 2004-05 almost all the wooden floors and columns of the building were removed (see also Figure 4a) without shoring the walls or any other safety measures, although it is well known that floors of multi-storey bearing masonry buildings are very important structural components since they form horizontal diaphragms that connect and restrain the perimetric masonry walls of the building. After the partial collapsing the few remained columns can hardly bear any loads and even more some remained parts of wooden columns are literally hanging from the roof making the working environment quite risky and dangerous.

After the collapse the building consisted of the perimetric masonry walls (except for parts of the eastern and northern walls that have fallen), two columns per floor and part of the roof. The masonry walls sustained ageing, damages and cracks. The main entrance at the west façade has become a very dangerous point for anyone who wants to enter the building due to its inappropriate widening of the opening during the intervention works (Figure 4b). Further, the eaves of the walls (the ridge was made of concrete) sustained serious damages and cracks, whereas at some parts they have been destroyed by the fallen parts of the roof. Figures 5a & b shows the partially-collapsed masonry walls (northern and eastern walls). The masonry wall that sustained the greater damage is the eastern one. Further there are three vertical and one horizontal deep grooves on the internal side of the eastern wall (Figure 5c).

According to the plan of the recent interventions those grooves were meant to be the positions of the RC columns (vertical grooves) and beam (horizontal groove) of the new internal RC structure. In order to gain space, the new RC columns and beams at the eastern side of the inner structure were designed to be placed inside the existing masonry walls. For this reason the cutting and creation of vertical and horizontal grooves in the masonry of the existing eastern wall was planned. However, this intervention proved to be quite inappropriate, very dangerous and in effect catastrophic for the stability of the existing masonry walls and the old structure as a whole.

Figure 4: (a) Inside and (b) outside views of the building after the partial-collapse of 2005.

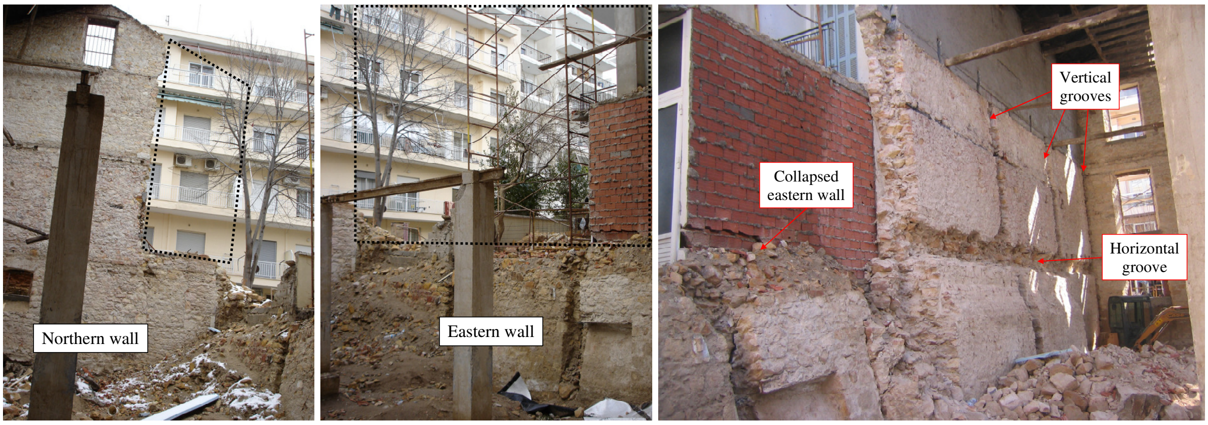

Figure 5: Inner views of the (a) northern and (b) eastern masonry walls of the building after the partial-collapse of 2005. (c) Eastern masonry has three vertical grooves and one horizontal groove on the internal part of the wall.

4 RECORDING USING PHOTOGRAMMETRY

Due to the dangerous conditions of the heavily damaged and partially-collapsed masonry building, the geometrical details of the structure could not be recorded using common procedures and a rather special refined survey was required. For this reason, photogrammetric image processing is used in order to create the orthoimages of the façades, as background information to digitize details of the building in a CAD environment with accuracy 1 cm [4]. Details of the recording procedure along with rectified images - mosaics of the building and a spherical 3D panorama of the inner of the building are given in Refs [5, 6].

5 REHABILITATION PROCEDURE

After the partial collapse of the building a different methodology has been adopted for the rehabilitation and reconstruction of the partially-collapsed historic masonry building in order it to be reused as the Municipal Library. This new approach is based on the cautiousness and the safety of the structure and the working personnel [7] and yet it is also constrained by the initial concept of the approved plan for a new internal RC structure. The presented rehabilitation procedure includes the following steps:

- Temporary support of the façades using external, non-permanent steel towers.
- Strengthening of the severely damaged eastern masonry wall using cast-in-place concrete or shotcrete and steel reinforcement in order to fill the dangerous vertical and horizontal grooves of the masonry and to form a permanent RC beams-columns supporting system.
- Construction of a new, interior RC frame structure inside the existing masonry that will bear the increased design loads of the new usage as the Municipal Library. This frame will also be the permanent support of the north, south and west façades. For this purpose efficient connection between the RC structure and the masonry walls will be applied. The construction of the new RC frame is unavoidable part of the approved initial rehabilitation plan of the building which has not been changed despite the partial collapsing of the old building.
- Restoration of the damaged masonry walls and removal of the temporary supporting system of the steel towers is the last step.

5.1 Temporary support of the remained walls

Supporting and securing the façades of the building is of great importance for the stability of the whole structure and the creation of a safe working environment. For this purpose, special non-permanent structural system has been used. The aim is to prevent potential horizontal displacements that would induce further damages or further collapsing of the entire building.

The geometry of the building, the condition of the damaged masonry walls, the urban character of the project, the free space inside the building plot, the neighboring buildings, the foundation soil and the seismicity of the region were the parameters that have defined the supporting system of the façades. Thus, vertical steel towers placed outside of the building comprise the temporary supporting system of the masonry walls, as shown in Figure 6. These towers will be removed when the rehabilitation procedure will be completed. It is mentioned that before the installation of these supports, it is necessary all the openings (windows and entrance) of the building to be properly stabilized. This can be achieved by mounting wooden frames and beams inside these openings (see also Figures 6 and 7).

Figure 6: Outside view of the external non-permanent steel towers for the temporary support of the façades.

Figure 7: Inside view of the temporary supporting system of the substantially damaged eastern masonry wall.

5.2 Support and strengthening of the eastern masonry

One of the challenges of the rehabilitation design plan is how to face the problem of the supporting and strengthening of the heavily damaged and unsecure eastern masonry, since at this side of the building there is an adjacent multi-storey apartment building and there is no space for the installation of an exterior steel tower. Part of this masonry wall has collapsed and furthermore some very deep and dangerous vertical and horizontal grooves have been formed on this stone wall during the works of 2005. These grooves have been cut for the construction of the RC columns and beam of the new internal frame structure that was the next step of the rehabilitation plan.

However, the depth of the grooves is approximately half of the total width of the wall and the capacity and stability of this stone masonry is considerably decreased. Further, the wall at the upper floor and the attic has been reconstructed during the recent interventions using low capacity cinder blocks. Furthermore the removal of the three horizontal wooden floors of the building has made the 11 m height wall extremely unsafe and totally unpredictable in any new intervention.

The problem can be approached with the use of cast-in-place concrete or shotcrete with dry-mix process that can fill the vertical and horizontal grooves, forming a RC beams-columns supporting system of the masonry [8-12]. These new RC members will also be part of the new internal RC structure. Geometrical outline figures of the RC internal frame of the eastern masonry wall are presented in Figure 8. The RC members can be designed according to the specifications of Eurocode 2 and 8 [13-16].

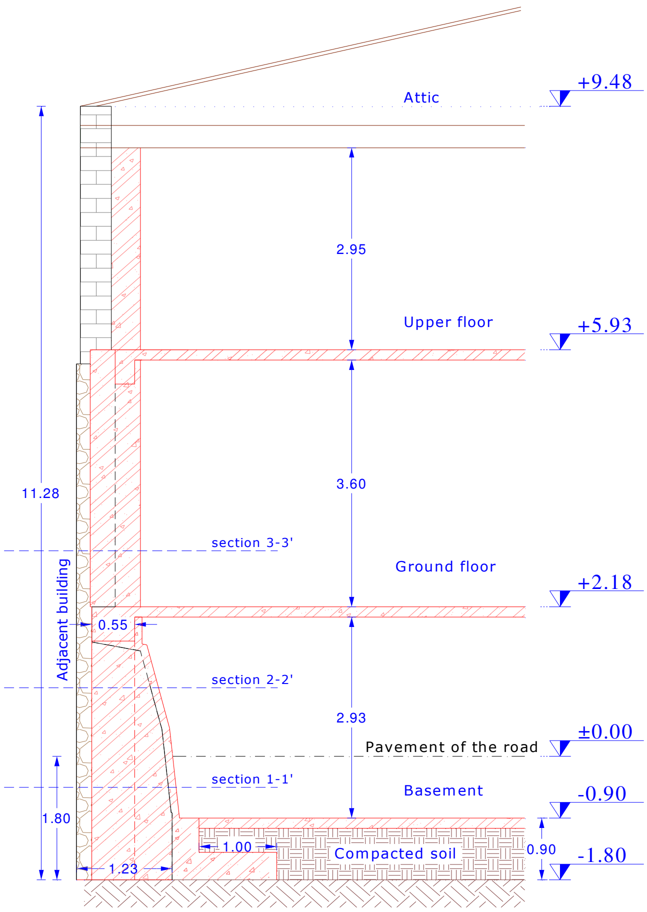

Figure 8: Geometrical outline figure of potential internal reinforced concrete frame inside the grooves of the eastern masonry wall.

5.3 The new internal RC structure - Connection with the masonry walls

According to the approved rehabilitation plan a new interior RC frame structure inside the existing masonry historic building is planned to be constructed. This internal structure will also serve as a permanent support of all the masonries of the façades. Apparently, the temporary steel towers will be removed after the completion of the construction of the internal RC structure and after the full connection between the internal new frame and the old perimetric masonry walls has been achieved. The efficiency of this connection is of vital importance for the safety of the walls and the integrity of the rehabilitated building.

The cast in-situ RC slabs of the new interior structure will have significant importance for the stability and seismic capacity of the restored building, since they will form horizontal diaphragms that connect the perimetric masonry walls and distribute the seismic forces induced by the mass of the walls into the internal structural system [17, 18]. Simultaneously with the construction of the slabs, perimetric bond-beams are planned to cast inside the stone walls. The positions of the perimetric bond-beams are the existent holes inside the masonry walls that have been formed during the recent interventions when the wooden floors of the building were inappropriately removed.

Especially for the eastern masonry wall the proposed RC columns-beams supporting system which is part of the interior RC structure will also permanently support the masonry wall and connect it with the new frame structure.

5.4 Restoration of the damages on the masonry walls

After the construction of the new interior RC frame structure that will permanently support the cracked masonry walls of the building the next step is to repair the damages and the cracks on these masonries. The following restoration methods are planned to be used, depending on the features of the damages.

First, cement grouting [19, 20] is suitable to restore cracking of the basement and ground floor masonry walls with width greater than 45 cm and crack width less than 10 mm. According to this technique, cracks are filled with injected cementitious grout that is composed of cement, natural or artificial pozzolanes and admixtures for the cement dry contraction and to liquefy the grout. The grout is injected into the cracks with a pressure less than 0.1 MPa in order to avoid any additional damages to the wall.

Secondly, deep repointing [3] is suitable for the masonry walls whose old and low-strength mortar needs to be replaced with a stronger one. The joint-gaps between the stones of the masonry walls and the cracks have to be deeply filled using a thin trowel and a mortar with a very particular composition. The mortar contains terra theraic (earth of Thera): hydraulic lime: sand, with proportions 0.417: 1: 3.333. This new mortar is considered quite compatible with the existing mortar, but it has higher strength and improved durability capacities. Moreover, the hydraulic lime conduces to the mortar mixture, as it regards the pasting. Cement-based mortar should be avoided in these cases because it exhibits high compressive strength compared to the traditional-made, existing one.

Further, the deteriorated architectural features of the building also have to be restored according to their original shape and with respect to the historic value of the building. These features include the destroyed main entrance, the damaged frames of the windows and the damaged decorative cornices that rim the perimeter of the building and distinguish the floors of the warehouse from the external. The bricks and the stones that are missing have to be replaced with new ones having the same shape with the original ones. For this purpose mortar with terra theraic as described above is also suitable for this usage in order the building to obtain its original form and shape.

6 CONCLUSIONS

Inappropriate rehabilitation strategy and intervention plan in historic masonry buildings could be catastrophic both for the architectural cultural value of the structure and for the structure safety and integrity. Cautiousness and structural safety are fundamental issues in the field of rehabilitation of historical heritage. The masonry building under examination had suffered indelible damage due to failure of recently-applied interventions. These works caused the partial collapse of the masonry walls and created a quite unsafe working environment. The constructional characteristics the damages and the pathology in general of the historic building under examination have been recorded using photogrammetry and have been detailed in this paper.

The choice of a proper and feasible restoration process for a partially collapsed historic masonry structure that constitutes a dangerous and risky working environment is a difficult task. The presented rehabilitation methodology aims to successfully support, strengthen and restore the existing building, minimizing the risks of further collapse and personal injury. This procedure in general could include (a) a specially developed securing and temporary supporting system for the façades using external steel towers; (b) a permanent RC beam-column internal frame for the strengthening of the heavily damaged eastern masonry wall that will bear the increased design loads and serve as a permanent support for the façades; it is noted that the construction of a new interior RC frame structure inside the existing masonry building is the main concept of the approved rehabilitation plan and (c) the repair of the masonry cracks and the restoration of the architectural features of the building.

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