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Restoration of a historical building for Cyprus Technical Chamber

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ABSTRACT: An abandoned building in the old town of Nicosia, built in 1828, was chosen by the Council of the Technical Chamber of Cyprus to host their offices. Our design team won the first price of the architectural competition in 1998. The task was to restore a half ruined building, restore its bearing capacity for the usual loads and strengthen it for earthquake loading, trying at the same time to minimize interventions so that historical identity and traditional character is not lost. Study and works were monitored by Nicosia Municipality, the Preservation Department, and the Antiquities Department and by the Chamber's monitoring committee. Study started 1998, works commenced in 1999 and by 2001 Cyprus Technical Chamber moved to the new offices. The building is approximately 600 sq.m, and is made of stone built walls and adobe walls, wooden floors and roofs. Small additions were built for connecting the two parts and the two levels of the building. These were made of light steel frames, wood and glass. This presentation concerns the structural design and supervision of the project.

1 INTRODUCTION

The old town of Nicosia and mainly areas near the buffer zone were abandoned after the war of 1974. Abandoned buildings were rented by carpenters, steelworkers, car mechanics and electricians etc, who established their workshops in these properties paying a very low rent. All these buildings were built using traditional material and techniques. They were the heart of the old Nicosia and since 1974 this part of the heart stopped beating. New users never cared about these buildings, other than to do their work and for decades no maintenance works were carried out. Damages or partial collapses were patched up using improper materials and sloppy work. After these works could not anymore preserve the building, the workshop was moving out leaving the building in a ruinous condition. When authorities realized what was happening, they started giving motives for the workshops to go to organized industrial areas, they started to provide benefits for owners interested to restore and rehabilitate their properties, they expropriated buildings repaired them and are renting them to young couples and additionally with the help of UNDP/UNOPS, projects for the restoration of important parts of this area of the city, on both north and south side, were and are being carried out.

Following the effort for reactivating life in the old town, the Scientific – Technical Camber of Cyprus decided to restore an abandoned building and move its offices in the "within the walls" part of Nicosia and especially near the buffer zone.

The building was delivered to the Chamber by the Ministry of Interior. The Antiquities Department, the Preservation Department and the Municipality gave their consent. Our design team won the architectural competition and took over the design and supervision of the project.

Study works commenced and ended in 1998–99

Works commenced in 1999 and ended in 2000–01 restoring a 600 sq.m building with an 800 sq.m yard.

The budget was 800.000 Euro.

2 REGULATIONS & STUDY PHASES

2.1 *Regulations*

Cyprus regulations for the restoration of traditional buildings refer only to the architectural study and for a monument to the involvement of an archaeologist from the Antiquities Department for monitoring purposes. There is nothing about the structural study, or the involvement of a structural engineer. But at some point someone has to take the responsibility for the safety of the building, so authorities started to ask for a structural study to give building permits. Anyhow design for earthquake was never included in the mandatory list. The case presented here is probably the first public traditional building and monument,

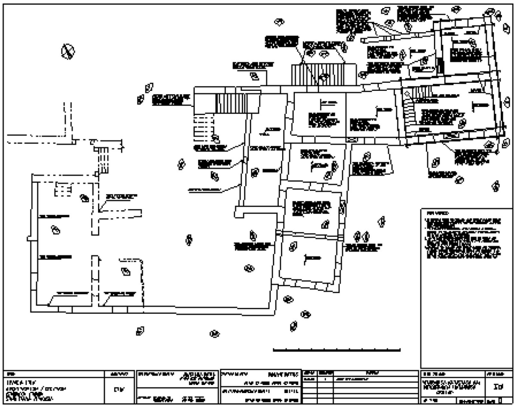

Figure 1. Existing layout of ground floor.

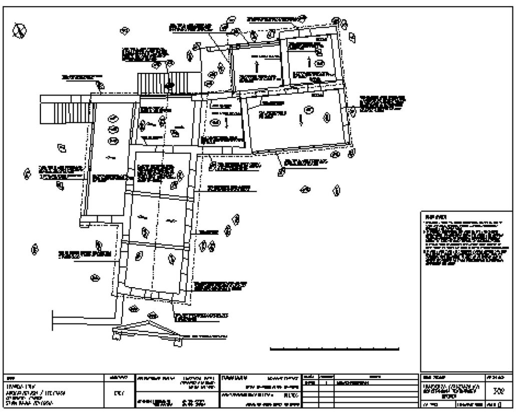

Figure 2. Existing layout of first floor.

designed for earthquake in Cyprus and concerns the structural study and supervision of this project.

Design data, including requirements for safety against earthquakes, were thoroughly discussed and agreed with the employer and the monitoring committee.

2.2 *Study phases*

Study was carried out in the following phases:

a) Measured drawings, architectural and structural, were issued. Structural drawings (Figures 1 & 2) recorded the existing bearing system and provided details of existing structural elements. The structural survey included recording of damages in structural elements and materials, detection of damaging mechanisms and a detailed photographic documentation.
b) Investigation of existing materials was carried out. Samples were taken, cores from stones, mud bricks, pieces from mortars and wooden elements and they were tested.
c) Preliminary structural study. Based on the architectural proposal, the existing condition of the building and especially the level of damage of its bearing system, the available materials and their mechanical properties derived from the tests, a proposal for the structural interventions was submitted.
d) After the approval of the preliminary, calculations were carried out to verify the proposed interventions and define the required sizes and sections. Calculation results were put into drawings, details, descriptions and specifications and they were submitted for approval by the authorities and the employer.
e) After approval was granted, tender documents were issued, the tendering procedure was carried out and the successful bidder was hired for the works.
f) The work finally closed with the execution of restoration works, supervised by our team.

3 THE EXISTING BUILDING

3.1 *The layout of the building*

The building consists of two parts, the Main and the Secondary building.

The Main consists of two orthogonal shape parts built together forming the shape of a Γ. The ground floor was built using ruble stone built walls in distances of 4.00 to 5.00 m. Four arches were used to bridge large spans with heavy loads on top. The ceiling over the ground floor was supported by round section wooden beams. The second floor was built using a few ruble stone built walls, a lot of adobe walls, 2 stone built arches and a few wooden walls. Adobe walls were built using sun dried mud bricks. Wooden framing and stone built infill was used for the wooden walls. Wooden beams were used for lintels.

The Secondary was a single orthogonal building. Ruble stone built walls were used to support the ground floor and adobe walls for the second floor. The ceiling over the ground floor was supported using orthogonal wooden beams. For the roof both round and orthogonal section beams were used.

There was no foundation for the walls. Each stone built wall was extending about one meter into the soil without any thickening. Under the stone built wall, in some areas, around 50 cm of week lime-concrete was provided.

For communication between ground and first floor two stone built staircases were built externally. At a later stage an interior concrete one was built.

The area between main and secondary building was most probably covered, since remains of stone columns and arches were found. Since no other evidence of

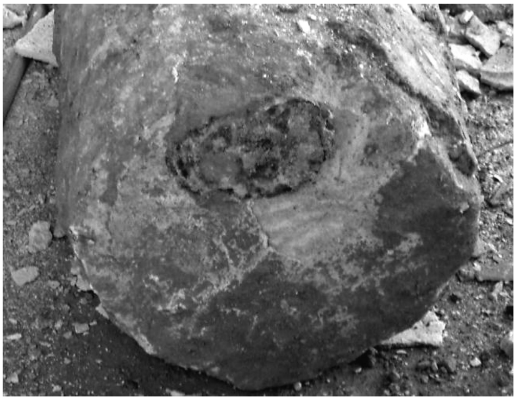

Figure 3. A drum of a stone column with the trace of a donkey shoe used to fix drums.

such a structure could be found, authorities approved building a modern steel ground floor building between the two parts, instead of a stone built one using arches.

3.2 *Existing materials*

Stone built walls consist of two leafs and the hearting. Leafs were built using calcareous sand stone and clay, lime and in some cases even gypsum mortar. Irregular joints were created because rubble stone was used. Cement mortar was used for repairs at a later stage. Some of the stones were extending into the hearting to provide a connection between the two leafs. In very few cases a stone was bridging the two leafs extending from the exterior to the interior face. For the hearting gravel, stone fragments, broken ceramic tiles and a lot of clay mortar was used.

Samples were taken from the sand stone and tests gave a compressive strength between 7 and 14 N/mm^2. There was increased porosity and the absorption tests gave a result of approximately 10%.

Adobe walls were built using row – sun dried mud bricks. They were 5 to 7 cm thick. Samples were taken and tested. The analysis of the consisting materials gave 70 to 75% clay and silt. The rest was granular material, sand and fine gravel, and organic material, straw from wheat and barley. Flexural tests on some of the mud bricks gave for the strength a value of approximately 0.70 N/mm^2.

The traditional production of mud bricks involves mixing the soil with the straw and water and leaving it to mature, until straws release their resin. This is detected by the characteristic smell and by increasing the workability of the mixture. This way the resin acts as a plasticizer and curing agent and the straws function as a reinforcing mesh, bridging micro cracks that may develop during the drying period of the bricks.

Figure 4. Stone built wall and buttress. An adobe wall is built on top. An arched stair case is shown at the back.

Figure 5. Stone built walls. An adobe wall is shown at the back. A deteriorated wooden frame in front.

Existing wooden elements were coming from local pines and cypresses. They suffered heavy damages (infestation, loss of material, cracking, collapse) so there was no reason to examine any existing or residual strength.

Soil investigation should be carried out normally, but there were results from adjacent plots and from studies of the Geological Survey Department, so necessary information was already available.

3.3 *Damages*

The building was in a very bad condition. Significant deterioration of materials, detachment of adjacent walls, cracks, out of plane deformations, out of plumpness, collapse of the roof over some areas and in some cases of the ceiling over the ground floor were giving the image of a ruin. This was the condition of the building when it was delivered to our office for investigation and study. Complete collapse was avoided because a few years back Municipality installed a system of steel plates and rods. These were acting like stirrups do in a column holding the walls together.

Figure 6. Stone built wall on ground floor. Adobe wall built on first floor.

Figure 7. Loss of material and erosion of stone built and adobe walls.

Moisture was penetrating from the surrounding yards and from the interior of the building due to the collapse of roof and floors. Damp was rising from the walls coming to the surface. Cycles of temperature and moisture variations caused cycles of crystallization of soluble salts into pores of stones and mud bricks, resulting to loss of attachment between plaster and wall. Plasters lost support and started to deform,

Figure 8. Erosion of surface, birds nests.

crack and collapse exposing the wall to the environment. This mechanism caused deterioration of stone transforming the sand stone into just sand and disintegrated the clay mortar and the mud bricks transforming them into soil dust.

Exposing the wall to the environment caused additionally erosion of stone surfaces and mortars. Exposed adobe walls are very week to water erosion, so significant loss of material developed on these walls. Wet surfaces of adobe walls become soft and even birds are digging their nests on these walls.

Loss of material developed at the base of walls due to rising damp. A loss of 10–20 cm of thickness on a 50 cm thick wall and usually on one side, introduces significant eccentricities between external and internal forces, leading to deformations and cracking and overstresses the remaining section of the wall.

Wooden elements were also left for years without any protection and maintenance. Longitudinal cracks developed due to moisture and temperature cycles, reducing the available strength.

Additionally insects created a lot of holes and channels causing additional loss of material and strength. The most significant case was the condition of the three main trusses over the meeting room. The trusses were formed using beams of sections 20×20 cm. No significant damage was detected at the beginning, but when they were lowered to the ground for inspection and maintenance, it was realized that areas embedded in wall's thickness and faces of the beams on the ridge were full of holes. Trusses were scanned using ultrasound equipment and the result was that sections around connection areas were significantly affected. It was decided to replace them with new ones and preserve the existing ones for repair in the future. (Figure 9)

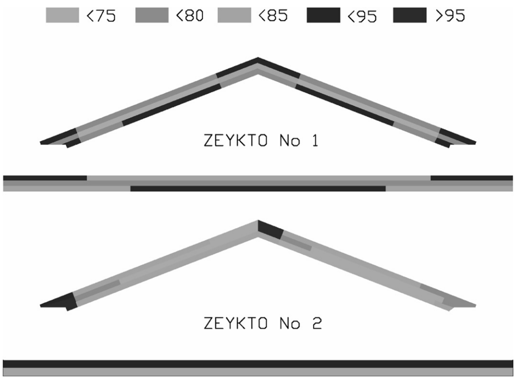

Figure 9. Ultrasound test on wooden trusses.

4 ANALYSIS

Two models were produced for analysis, one for the existing building and one considering that the building has been restored. The first model includes the whole of the building, even the parts that had collapsed. It also takes into account reduced mechanical properties, the detachment cracks between adjacent walls that were detected and the eccentricities introduced by damages on the base of the walls. The second model included the whole of the building including the new parts provided. It also takes into account enhanced mechanical properties, since the building has been repaired, reduced eccentricities and the new additional elements that were provided for strengthening.

Simple bar elements were used for modeling the wooden elements of floors and roofs. Hybrid plate – shell finite elements were used for modeling the walls. In the second model same finite elements were used to model the wooden diaphragm that was installed on the ceiling over the ground floor and the roof.

Analysis included dead and live loads and seismic loading according to Cyprus Regulations. Spectral analysis was used, applying bed rock acceleration of 0.10 g, magnification factor of 2.50, ductility 1.50 and the period after which the spectrum declines was set to 0.40 sec. A large number of eigenvectors had to be used in order to have over 90% mass participation.

Analysis of the first model gave high compressive and tensile stresses on walls. This was expected, because cracks and inadequate connection of wooden elements and walls leads to loss of support for the walls. Additionally eccentricities introduce additional stresses. Analysis of the second model gave acceptable compressive and quite low tensile stresses. It was then decided that interventions will include repair and upgrading of the existing walls, installation the wooden diaphragms with proper connection to the walls and wooden ring beams on top of walls. The new wooden elements properly connected to the walls improved significantly building's behavior to seismic actions (at analysis level) and upgrading of the walls could establish the required level of safety. Figures 10 & 11 indicate stress contours produced for walls scaled down. Analytical printouts of stresses were produced and submitted to authorities to verify and justify the proposed interventions.

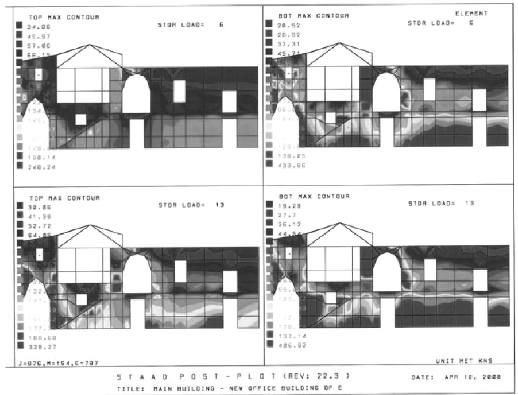

Figure 10. Stress contours on the north wall.

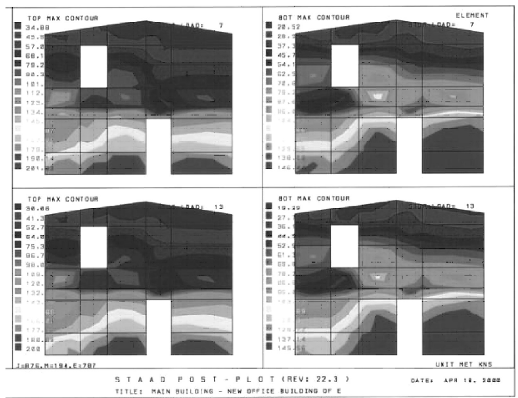

Figure 11. Stress contours on the east wall.

5 STRUCTURAL INTERVENTIONS

The interventions applied were briefly:

1) Provide temporary supports, prop up dangerous parts, remove all debris, and remove all plaster to expose walls for inspection. This were mandatory procedures and works, in order to establish safety and health on site and to be able to provide further specific instructions according to the type of damages that was revealed on walls.

2) Photographing of all wall panels from both sides and in detail was then carried out. These were used to indicate instructions for repairs directly on them. Repair of joints, bridging of cracks, replacing damaged stones and mud bricks, changing the location of stones to break continuity of vertical joints providing key stones etc. were marked one by one on the photographs using code numbers and marking of areas. This way a sort of wall repairing shop drawings were provided to the contractor. These were supplemented with analytical descriptions and specifications for each and every code number, for the work to be carried out and the material to be used.
3) All joints between stones were cleared to the depth of 7 cm and repaired using hydraulic lime mortar. Were vertical joints were continuous over more than two layers, changing of places of the existing stones was carried out, to break this continuity. Similar changing of stones together with placement of new stones (of same material and mechanical properties) was used to bridge cracks and to connect adjacent walls that have been detached. Stones that showed impregnation with oils (due to the former use of a workshop) were completely replaced. During this repairing procedure holes were drilled, 25 cm deep and plastic tubes were inserted to be used later for grouting. The area around these holes was sealed using the same lime mortar and after it hardened with an additional layer of gypsum locally.
4) Excavation was carried out on both sides of walls, in separated phases, to avoid exposing a wall on both sides at the same time. Excavations removed damped soil and insect nests and at the same time exposed the base of walls for repair. These repairs were included in the procedure abovementioned. Before backfilling, a drainage system along the exterior perimeter of the building was installed leading the water to the existing absorption pits that were extending to the existing ground water table, at the depth of approximately 9 meters.
5) After repairing the bases of walls from the inside, the existing soil surface was sprayed with insecticide, and covered with a granular sub base 15 cm thick 95%compacted and then a concrete slab on grade to lay the services and finishes.
6) Props and temporary supports of no use, since walls have been repaired, were removed. Pockets for the new beams were opened on walls and existing pockets were carefully cleaned. Additional pockets were provided on the top of the walls, to put wooden poles connecting the ring beam to the walls. The new ring beam consists of two wooden beams connected to the poles using stainless steel bolts. Hydraulic lime mortar was used for filling the vertical pockets and building the horizontal ones after the installation of the wooden elements. Faces of wooden elements that were coming in touch with mortars were treated with bituminous layers additionally to the conservation treatments.

Figure 12. wooden ring beam.

Figure 13. Steel connectors.

7) New roof beams were connected to the ring beam. Wooden boards 20 mm thick were used on both roof and ceiling over ground floor, so that beams together with boards provide the week diaphragm that was considered in the design. On roof level beams were directly connected to the walls through the ring beam. On ceiling over ground floor, special steel connectors were used. (Figures 12 & 13).
8) All lintels and sills have been replaced using new material of same origin and shape with the existing ones. Additionally stones of arched that deformed were brought to their right place and the ones cracked were replaced. Connecting the cracked parts of a stone together using injections was not successful due to the high porosity of the material.

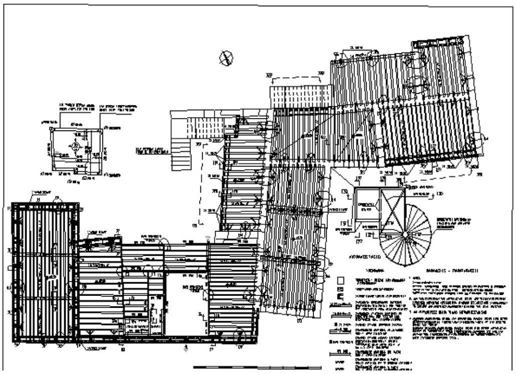

Figure 14. Final layout – ceiling over ground floor.

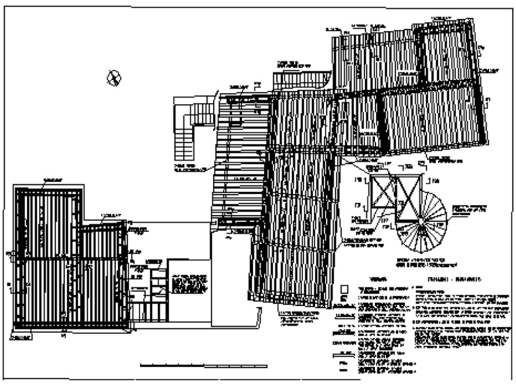

Figure 15. Final layout – roof over first floor.

Figure 16. Steel connectors.

Figure 17. Grouting equipment.

Figure 18. North wall before repair.

Figure 19. North wall today.

9) A net of grouting points on both sides of every wall, staggered from face to face and at distances between them around 50 cm and not more than 70 cm. was installed. After all wall repairs had finished and all wooden elements had been installed, grouting was carried out to enhance binding between the two leafs of the wall and fill any interior gaps or cracks. The procedure

Figure 20. Repair of existing wooden wall.

Figure 21. West wall being repaired.

Figure 22. West wall today.

includes injection of water in a wall the first day and the grouting the next day. Hydraulic lime mortar with fine aggregates was used. Approximately 2 litres per grouting point was used.

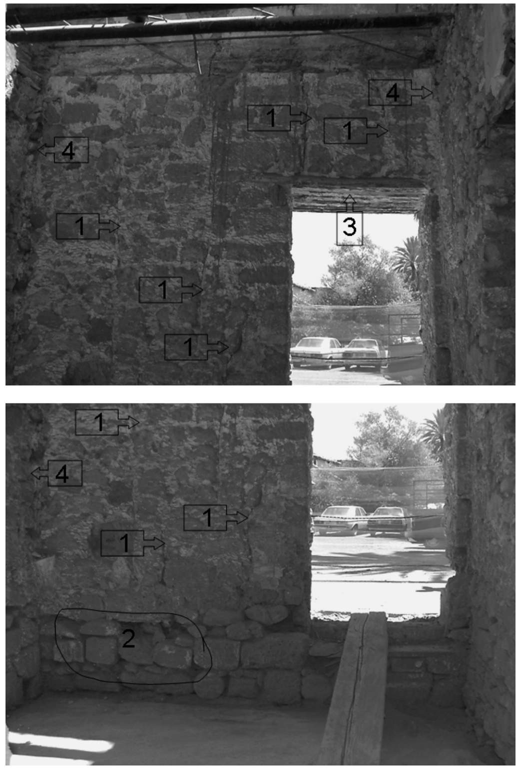

Figure 23. Instructions on photographs.

Figure 24. Installation of a steel truss to connect diaphragms on different levels.

10) The hydraulic lime mortar used for the repair of walls was prepared and mixed on site. For grouting two ready made products were used. Both used hydraulic lime. The first one had fine aggregates while the second had very fine aggregates. The second one was used for grouting walls that

showed almost no penetration of the first grouting. Maximum pressure used was 0.10 N/mm^2.

6 CONCLUDING REMARKS

A building almost 200 years old and in ruinous condition was restored and for 6 years now hosts the offices of the Technical Chamber of Cyprus, providing everything that today's technology can provide for a new office.

This was achieved by using simple techniques and traditional materials. Stones, mud bricks, lime mortars, wooden beams and boards and steel plates, properly used applying traditional techniques were able to bring the building to an acceptable level of safety, including its resistance to seismic conditions.