THE RESTORATION OF THE LITHOGLYPTIC BELL TOWER OF THE CHURCH OF EVAGGELISMOS OF THEOTOKOS AT GDOHIA, IERAPETRA, IN CRETE

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ABSTRACT

The lithoglyptic bell tower of the Church of Evaggelismos of Theotokos at Gdohia, Ierapetra, in Crete, is one of the most representative ones of the 19th century bell towers of Crete. It is made of ashlar stone course of limestone, bound with lime mortar. The joints are reinforced with iron fasteners and melted sulfur, instead of lead. This constructive defect, in combination with the environmental parameters, caused the oxidation of the iron-made joints, the expansion of the corrosion products and the subsequent mechanical damages of the stone courses. Unsuccessful restoration treatments of the past, during 1970s, made use of Portland cement and brass pins, and further contributed to the deterioration of the tower’s condition, with the action of salts of sulphuric sodium.

During autumn 2009, after the completion of the research study, the new restoration and anastelosis campaign took place. The stone fragments of the Bell tower were dismantled and were treated separately. They were then rejoined, with the use of lime mortar and titanium alloy fasteners and glass thread. The restoration worked lasted until the end of spring 2010.

This article will present the actual deterioration mechanisms and the methods employed for the restoration of the monument.

Figure 1: The lithoglyptic bell tower of the Church of Evaggelismos of Theotokos at Gdohia, Ierapetra, in Crete.
INTRODUCTION

The Church of Evaggelismos of Theotokos, is located at the entrance of the village Gdohia, in Ierapetra, Crete and at a small distance from the road that joins Ierapetra with Vianos. The bell tower is positioned above the south central entrance of the church. It is trifid and it is made of rectangular micritic limestone. The pilasters have cross sectional dimensions 59x 50cm and 151cm height. They are decorated with a fillet and a frame above which stand the arches.

The span of the two lower arches measure 70cm. The surfaces above the pilasters have relief decoration with cherubs. The frieze stands at a distance of 252cm from the base of the bell tower and it is decorated with grapevive, similar to the ornamentation of chancel screens found in Byzantine churches. The arch stones are exerted slightly above, and have relief decoration with graven sun and cherubs.

The upper arch lies above the frieze, with a span of 50cm and cross sectional dimensions of 45x45cm and 163cm high.

DETERIORATION FACTORS

Biological factors of deterioration

The biological factors of decay include algae, lichens, fungi, bacterials and other organisms of animal or vegetal origin.

In the case of the bell tower of Gdohia, the biological growth has been detected at the areas of the fillets and the architrave. The degree of deterioration caused by the biological growth is not very high and it can be treated without difficulty.

Chemical factors of deterioration

The basic factor of physicochemical decay of stone materials, apart from the stone itself is the action of water.

Water penetrates through stone material by the action of rain, capillary action, or by the condensation of water vapor by the atmosphere.

The porosity of the stone (pore diameter, distribution and capillary volume) plays an important role on the absorption of water at a first stage and then on the circulation of water in the interior of the stone.

Rain water contains carbon dioxide from the atmosphere and contributes to the dissolution of calcite. By this action calcium carbonate is converted to acidic bicarbonate. Due to the high constant value of Henry’s law (about CO₂), and in combination with the partial pressure, the solubility of carbon dioxide changes greatly and its content in rain water may vary between 50-285mg/Lt.

The two-way chemical reaction \( \text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{Ca}_2(\text{HCO}_3)_2 \), together with the selective material deduction and its re-deposition to different areas of the surface causes further damage to the stone material.
After the evaporation of water from the surface of the stone and the recrystallization of calcium carbonate, the final form alternates from aragonite to calcite. Depending on the thermodynamic phenomena and the various ion content of the solution, a phenomenon called “sugar effect” occurs.

The main weathering effect due to the action of water is the circulation of soluble salts in the stone material. The crystallization of salt, either on the surface or in the interior of the stone, apart from the micro-mechanical action by the pressure at the walls of the pores, various types of deterioration occurs, that are related to the nature of the salts.

Chloride salts penetrate in the crystal net of the stone and due to this action, part of the material is converted to powder.

Sulphuric salt, which derives from the material used in previous interventions, is converted to tenandrite and decandrite, resulting in an astonishingly high volume increase (10 atoms of water in its molecule results in 308% of its volume). Due to the volume increase severe mechanical stresses occur to the stone material.

Microclimate conditions (wind-rain-humidity) play important role to the salt action, because each salt type crystallizes at different and absolute temperature.

The electrochemical corrosion of the metallic fasteners is related to the thermodynamic law that determines the tendency of phenomena of lower energy (F), free enthalpy (G), chemical potential (μ) and higher entropy (S), \( \Delta F < 0, \Delta G < 0, \Delta S < 0 \), thus the materials’ reversion to their initial state, or the formation of chemical compounds of lower energy.

Iron, when exposed to the environment is corroded and has the tendency to come back to its initial form, \( 2Fe + 1,5O_2 \rightarrow Fe_2O_3 \) while at the same time dissipation of heat occurs.

For the above reason, since antiquity, iron is cased in lead when it is used for the construction of monuments. In the case of the bell tower of Gdohia, instead of lead, sulphur was used. As a result, with the effect of the environmental conditions through the course of time the corrosion products of iron had eventually covered part of the stone surface of the bell tower.

The presence of cement, used for the preparation of mortar, and the contiguity of the sea, contributed further more to the present condition of the bell tower.

**Mechanical stresses**

The volume increase of the metallic fasteners due to corrosion has caused the displacement of several stones courses. Furthermore, cement has been used for the normalization of the surface of the stones.
RESTORATION

For the restoration of the ell tower the following were carried out:

1. Disinfection
2. Facing of the stone courses
3. Dismantling of the stone courses
4. Removal of the corroded metallic fasteners
5. Cleaning of stone
6. Desalination
7. Consolidation
8. Reassembling of the stone courses – restoration

Disinfection was carried out by means of a solution of chloride isothiozolinon, due to the successful results that have been reported previously. At the final stage, a solution of quaternary ammonium (Desogene) was used. The residues of algae were removed by mechanical means.

Prior to any mechanical intervention, the stones were faced using Japanese paper and acrylic solution. At some areas, where the stone was considered to be in a bad state of conservation, the facing was reinforced using cotton gauze. During the dismantling of the stones, a set out made of wooden pieces and steel facilitated the safe removal of the stone fragments (two fragments at a time) while holding in place the remaining ones. Thereafter, the corroded metallic fastener was cut out using special apparatus and the stone fragment was removed from the set out, in order to get further treatment.

For the cleaning of the stones, several methods were used, using adequate materials and tools, taking into consideration the safety of the monument as well as following health and safety laws. The following were carried out:

a) Selective use of micro-sand blast was applied at areas where there were hard crusts of calcium carbonate. Controlled air pressure was applied (2-2.5 atm. Max.) and the spray nozzle diameter ranged from 0.6-1.1mm. Aluminum oxide was used as sand blast material.
b) Mechanical cleaning was carried out using scalpels No5, No4 and No3 and blades No10-22. Small brushes gave satisfactory results for the removal of hard crusts. Also, electric dental engine and micro drills were used selectively.

Deposits of dirt, oils, wax, pitch and iron corrosion products were removed using chemical reagents.

The removal of the corroded iron fasteners and dowels, together with their corrosion products, was carried out by mechanical means, with parallel use of electric drill and micro drill, with the adequate use of curettes, gouges and burins. Also, thioglycolic acid solution (5%) was used, with subsequent neutralization by means of dense ammonia with paste of carboxy-methyl cellulose.

In order to reinforce the physical and mechanical properties of the stone, at areas where loss of cohesion had taken place, consolidation treatment was carried out. The choice of methods and materials was made according to the following parameters:

A. Reversibility
B. Aesthetics
C. Persiration
D. Degree of penetration of the consolidant into the stone material

Between the two main categories of materials, the organic and the inorganic ones, the latter was chosen, due to the homogeneity with the original materials. Colloid solution of calcium hydroxide was applied on the areas high degree of wear. The method of impregnation was used by means of drainage tubes and probes made of latex. Immersion was used as well on small stone parts and fragment prior to the rejoining of the broken pieces.

During the reassembling of the stone courses, the pegs and fasteners used were made of titanium, in the form of bars and pins, of adequate diameters, together with bars of glass thread and epoxy resin. The later were then covered with lime mortar.

The joints were filled with lime mortar, ground stone and the addition of siliceous material.

The restoration work was carried out by a team of skilled restorers and technicians.

*Figure 2a:* During the restoration works (anterior aspect)
Figure 2b: During the restoration works (posterior aspect)

Figure 3: Detail of the relief at the doorway of the bell tower
Figure 4a: Details of previous construction using sulphur (construction failure)

Figure 4b: Details of previous construction using sulphur (construction failure)
Figure 4c: Details of previous construction using sulphur (construction failure)

Figure 5a: Details of construction failures
Figure 5b: Details of construction failures

Figure 6a: Sodium sulfate efflorescences on the iron oxides
Figure 6b: Sodium sulfate efflorescences on the iron oxides

Figure 7a: Details of cracked stones before restoration
Figure 7b: Details of cracked stones before restoration

Figure 7c: Details of cracked stones before restoration
Figure 8a,b: Details of the stone courses after desalination and conservation

Figure 9: View of the bell tower a) before and b) after the restoration works