

STRENGTHENING THE DAMAGED WOODEN COLUMNS AFTER INVESTIGATING OF SEVERAL INTERESTING APPROACHES FROM ABROAD

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ABSTRACT

The article describes an accident in colonnade of the 200 years old church, "Sv. Uspenie Bogorodichno" in Kyustendil. The article has investigated several interesting approaches to amplify damaged wooden columns in historical structures in China, Azarbaijan, Iran, Spain and USA. The decision was made to temporarily reinforce the whole structure of the church during its renovation and the method of strengthening the damaged wooden columns in the church was propose. The church was built in 1816, and is made of stone walls and a wooden roof structure. It is built according to the traditions of the Revival Age in Bulgaria and consists of walls with stone masonry, wooden floor constructions for emporium, wooden beams and columns. The outside walls are made of brick stone with a thickness of 60-70 cm. The building of the church is on one floor with height to the emporite-3.30m, height to the roof of the church with H-2.40m, with double sided roof, made with wooden constructions and roofing: boarding, waterproofing and tiles and three drum wooden dome. According to the plan, the church is a dyed single-pseudo-three-nave pseudo-basilica with a wooden roof structure and geometric plan dimensions: 23,60m x 14,40m. The building of the church is executed from the outside with powerful stone walls, the upper end of which reaches the level: 3,30m. In the interior of the church there are 12 main wooden columns in the longitudinal and transverse direction, which reach the level of the floor structure on the first floor of the church (the emporium). In the longitudinal direction, the columns are axially spaced through: 3,70 + 2,40 + 2,90 + 2,70 + 2,60 + 3,03m. In the transverse direction, the columns located on the axes of the building B and B are at a distance of one another axially through 6,230m.

Keywords: *wooden structures, damaged wooden columns, mechanical joints*

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1. INTRODUCTION

On the day of 16 June 2015, a partial temporary reinforcement of the church's support structure was carried out, covering certain areas under the longitudinal wooden beams above the wooden columns, with metal stands from the Hünebeck scaffold (Figs. 1a, b, c).



Fig. 1a, b, c. Replacing in certain places the longitudinal wooden beams located above the wooden columns with metal stands from the Hünebeck scaffolding on the A axis.

The observation carried out on the damaged and cracked cover on the columns and its detection in several places made it possible to describe the following facts. The wooden columns have a circular cross-section with a diameter of 46cm. Their support is done on stone base that protrude above the floor of marble slabs at a height of about 50cm. The revealed wooden columns show an interesting composite wooden-steel structure, made of timber, on which steel rings are attached (Fig.2a, b, c).

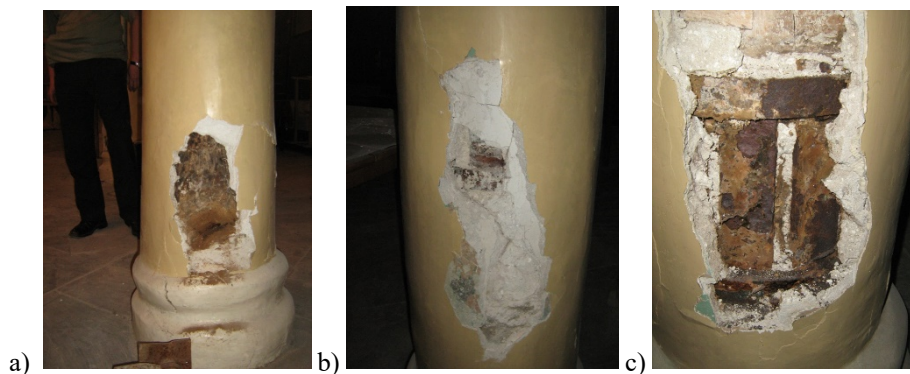


Fig. 2a, b, c. Cracked outer cover of the column in the church shot at 16.06.2015 at 18.30 hours. The ties are arranged side by side, on which about 40 cm are placed steel rings with a height of 40 mm and a thickness of 2.0 mm. The rings are attached to the wooden column with ordinary iron nails

2. BRIEF LITERATURE REVIEW - SURVEY OF EXAMPLES CONCERNING STRENGTHENING OF THE TIMBER PILLARS IN THE HISTORIC STRUCTURES

2.1. Investigation about the decay of the timber structure of an ancient wine cellar in la rioja (Spain) and sanitation proposal [1]

In 2011 the collapse of one of the timber pillars of the centuries-old warehouse of maceration that the firm "Bodegas Bilbaínas, S. A.", helds in the town of Haro (La Rioja), occurred[1]. Specifically, these primitives maceration and fermentation naves, which still keep the ancient wooden vats built in 1859 (Fig. 3, 4, 5).

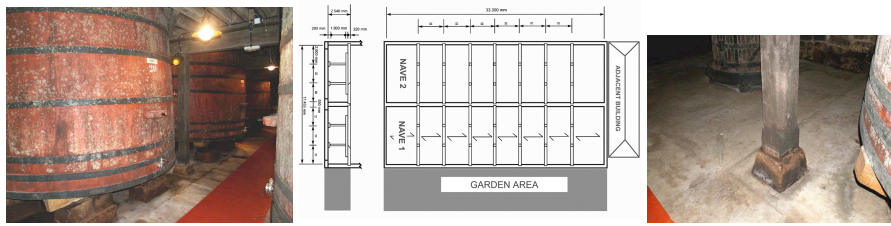


Fig.3,4,5.Vats and Cellar floor timber structure and cross section respectively

The pillars, spaced at regular distances of 2.90 m from each other and the side walls, with approximate section 220x220 mm and height 1.90 m, lead from stone bases of 200 mm on edge. Moreover, as discussed above, to a height of only 1.90 m, sections close to the 220x220 mm, the associated mechanical slenderness round the value of $\lambda = 32.90$, so it can be said that the security against buckling, for all the timber pillars in the same condition, is fully guaranteed.

2.2. Conservation and renovation of the timber constructions in the palace museum [2]

The Palace Museum, which was constructed in the 18th year (1420) of the reign of the Yingle emperor, is the largest and the most complete ancient palace complex existent in China as well as in the world. It has manifested traditional Chinese construction technology and revealed a remarkable achievement in art. By illustrating the main types of the ancient timber constructions and representing the construction features, the following text provides some useful references for the conservation and renovation of the northern palace-style buildings that were constructed during the Ming and Qing Dynasties[2]. As concerning the basic structural type of timber construction: Architectural types of the Palace Museum are varied, while the main type is bond to the shape of roof. On the basis of the building's sections, the Palace Museum buildings can be divided into four types: Diantang style, Tingtang style, Column-beam style and Composite style.

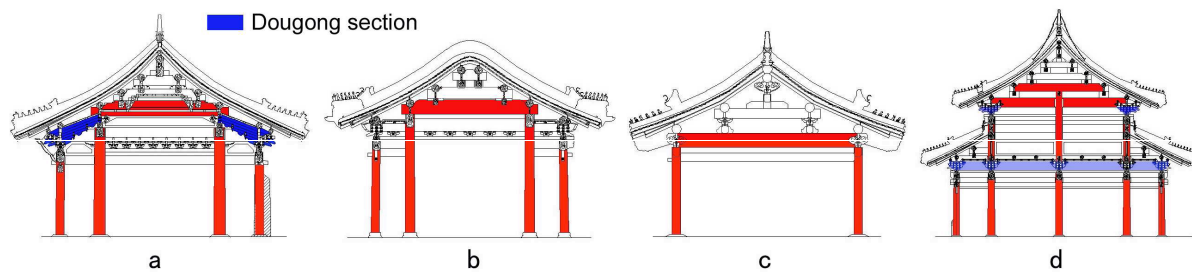


Fig.6a,b,c,d. Sections of four kinds of structural types

In the Palace Museum, all members of the timber structures are jointed by mortise and tenon (Fig.7a,b,c). Under external forces, the joints connected by timber members mobilize friction on the contact surfaces of the mortise and tenon. This friction guarantees the stability of the mortise and tenon joints.

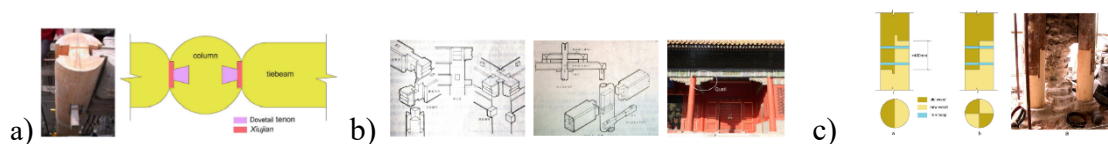


Fig. 7a,b,c. Dovetail tenon and Xiujuan, Conner tenon, Half tenon – Queti, Two kinds of Dunjie methods

As concerning the renovation of the timber constructions for timber structural constructions, daily maintenance and renovation are necessary. The common methods including mending, matching, reinforcing, replacing, etc. These methods are applied according to each particular situation. The following specific cases of the renovation and protection of ancient buildings in the Palace Museum will be discussed in detail. According to the result of on-the-spot investigation, many of the wooden columns are rotted only on their bases; and the upper parts are intact. In such circumstance, should preserve the upper part of the column and repair the bases partially, usually by using Veneering method or by Dunjie, thus replacing the column's base, according to the extent of its decay, thus restoring the columns' bearing capacity (Fig.7c).

2.3. Wood assessment and historical research on timber testing at fort Adams, Newport, Rhode Island in USA [3]

Fort Adams, located in Newport, Rhode Island, USA, designed by French military engineer Simon Bernard and American military engineer Joseph G. Totten, was constructed from 1824 - 1857. Construction was overseen by Totten from 1824 through 1838. Built of stone, brick, and timber, the fort served as a testing laboratory for determining the strength of various types of stone, mortar, and timber species. An investigation was undertaken to assess the current conditions of the timber and investigate the historical significance of the testing programs developed by Totten (Fig.8a,b,c,d).



Fig. 8a,b,c,d. Moisture stains and efflorescence on joists within a corner casemate and arch; deteriorated girder and brooming at the base of a column.

Visual inspection, used in combination with probing the wood with an awl, allows for the rapid identification of missing or broken elements as well as voids, incipient decay, and advanced decay present near the surface of the wood. Wood conditions found within the fort were divided into three classifications: good, fair, and poor. Good condition describes wood that may exhibit moisture staining and/or efflorescence but is not structurally impacted and has no evidence of insect damage or deterioration from wood decay fungi. Wood in fair condition may have minor insect damage and may also exhibit evidence of past moisture damage, including minor deterioration from wood decay fungi. Wood in poor condition may have severe visible insect damage and may also exhibit ongoing deterioration caused by wood decay fungi. In general, most of the structural members within the fort were found to be in fair to good condition along their lengths; areas of poor condition tend to be limited to the bearing areas. In a few instances, the structural members are in extremely poor condition and have failed due to deterioration caused by wood decay fungi (Fig. 8a,b,c). Some of the posts are “brooming” at the base due to a combination of high moisture content and deterioration by wood decay fungi (Fig. 8d).

2.4. Mosques with wooden construction – south of east Azerbaijan province, functions and methods of conserving [4]

Wooden mosques of the south region of Azerbaijan have specific characteristics and being built in different towns such as Maraghe, Bonab, Ajab- Shir, and Qoravan village[4]. Pillars and beams were made of poplar, species of willow, and aspen(Fig.9a,b,c). The main beams, pillars, sub beams, all, were made of wood and joints had special characteristics which add to the resistance of the building.

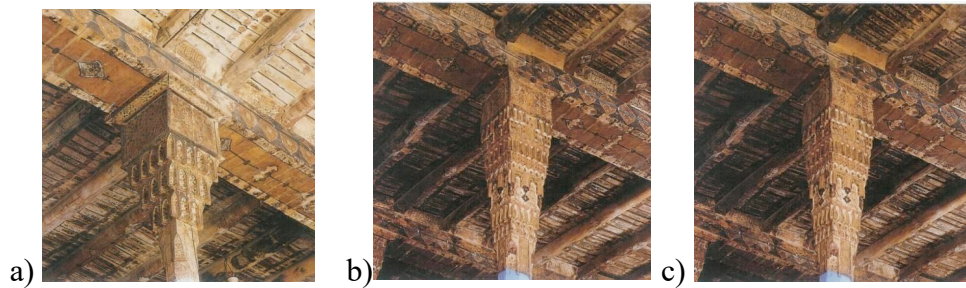


Fig.9a,b,c. Chamber(Shabestan) of Mehr- abad mosque; Sample of capitals in Mehr- abad mosque- Bonab

The foundations of wooden mosques are located in the depth of 1.5 m and by the dimension of 1.70*1.50 cm. By using the stone and river stones, lime concrete, sand and probably the cement over which a podium of 1.5 meter in height has been built to prevent the cold and the humidity. The columns and the level ceiling of the mosques are all made of wood. The height and stem of trees, poplar (Tabrizi) and aspen trees used to cover the columns, ceiling, beams and the main beams. The main function of the wooden columns is structural and decorative. All the columns have three parts: column base, column body and capitals (Fig. 10a,b).

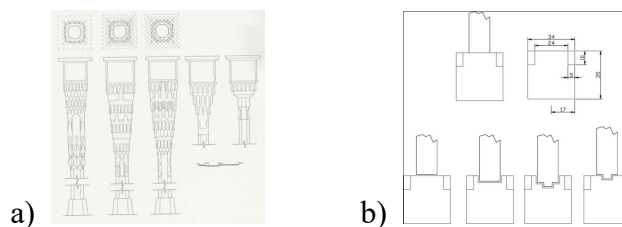


Fig. 10a,b. Capitals of Mehr- abad Mosque- Bonab; b) The method of arranging pillars on stone

The column bases are all made of stone and in different mosques have different forms and thickness. The diameter of the bases is usually a little more than the body. The form and shape of the column bases are circle, square, and hexagon, but the bases are generally square on the floor and the upper part is hexagon. The bases have been located on foundations that their dimension is about 1.5*1.5 m and the estimated depth is 80-90 cm. The end part of the column body is located on the mortise of the stone base which is different in the mosques. The last part could be located inside a special pad. The caps are important in dividing and transferring the pressure to the body, bases, and building. The caps are totally wooden and as it was mentioned, their connections are mortise and tenon. The pad of the columns which is connected to the column and the main beam are in different types which according to their function only one of them could be used. In some mosques the heights of the caps do not exceed one or two meter. The column caps with rectangle section or square with decorative arches are decorated in the form of a horn of the goat.

2.5. Development of an in situ repair strategy for the timber roof of the breeding barn at shelburne farms

Shelburne Farms, originally the agricultural estate of William Seward and Lila Vanderbilt Webb, is a 566-hectare National Historic Landmark District located on the eastern edge of Lake Champlain just south of Burlington, Vermont. Shelburne Farms quickly became one of the most ambitious model farm operations in the U.S.A(Fig.11a). New column bases were placed on limestone plinths and white oak shims, elevating them above a concrete floor installed in the mid-20th century. The roof system over the riding ring consists of a series of composite principal trusses of iron and timber, supporting a deck of timber purlins and common rafters.



Fig.11a,b,c,d. The Breeding Barn at Shelburne Farms

Trusses are supported on timber columns around the perimeter of the riding ring and bear most of the roof weight (Fig.11b). Strengthening of the wooden columns was done by cutting of the decayed part and substitute by with new wooden part (Fig.11c,d). Columns were repaired by scarfing in new timber to replace decayed portions, using a nosed scarf form found elsewhere in the barn. New column bases were placed on limestone plinths and white oak shims, elevating them above a concrete floor installed in the mid-20th century. In four cases, column splices were made at the aisle level, requiring renewal of girt joinery and replacement of the girts on either side.

CONCLUSION

The proposal for a design-construction solution for the rehabilitation of wooden columns in the naos of the church “Sv. Uspenie Bogorodicno”, taking into account the high pressures in them, the disturbance of the wood structure at the lower end and the unfavorable humidity and temperature conditions for many years of work will be done in several options according to the above mentioned examples. The ways are varied and they are coordinated with the competent authorities of the Institute of Cultural Monuments in Sofia. For our cases, however, the most commonly applied solutions are the dentures of columns with wooden dentures which reach 1-2 m height. However, before replacing the edges of columns with healthy wooden parts of the same type of wood, it is necessary to identify the causes of their rot. The explanation is that it is necessary to isolate these agents in the future leading to the decay of the wooden structure of the columns.

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