Structural solutions in wood in order to recovery historical monuments from Ouro Preto - Brazil

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ABSTRACT: In this paper, the necessary procedures to the realisation of design of the wood structure of the roof to the work of recovery of the Chapel of Nossa Senhora das Dores in Ouro Preto-MG-Brazil have been described. To this work inspections in loco are used, important files placed in the IPHAN (Instituto do Patrimônio Histórico e Artístico Nacional), documents that contain architectonics and photographically surveys like research sources. The present Brazilian Standard to the Structures on Wood (NBR 7190/97) was researched. Computational resources have been used to calculations of the structure. One electronic register table is created in order to verify structurally according to the active loads, what contributed very much to the analyse of the proposed models, allowing one refined analyse of the whole interactive process with the designs with fastness, feasibility of input of data, and a good visualisation. Nowadays, the tasks of the recovery have already been in development.

1 INTRODUCTION

1.1 Background

Based on given data from existent documents into the files from IPHAN, in Rio de Janeiro-Brazil, the Fraternity of Nossa Senhora das Dores and Calvário, religious institution that is responsible by the construction of this Chapel was originated in 1768 by Portuguese persons who lived in Vila Rica (Ouro Preto at the present times) and who were pieces from the Fraternity Dolorosa de Braga.

At April 06th 1770, in Cathedral of Antônio Dias, had gotten by the first time the ceremony of imposition of the scapulars and crown of Dores to the members from that Fraternity. The first provider from the Fraternity was Mr. Manuel Luiz Saldanha.

The funds that had permitted the construction of the chapel, finished in 1780, arrived at January 31st, 1775. The terrain where it was designed, place where after there was an old cemetery, was gotten through one agreement with the Fraternity of Santíssimo Sacramento de Antônio Dias. There aren't registers about data from the history about its construction; however, it is known that from 1845 until 1850, it suffered an intervention to a process of enlargement, advancing until the present frontispiece. The cemetery at the left from the chapel was built in 1914/1915 and the soliciting of the overturn was carried out in the decade of 1990. The building had suffered, during all its history, four interventions which were realised in 1845/1850 (enlargement), 1954, 1964/1965, and 1982/1983.

1.2 Archictectonical Features

The Chapel of Nossa Senhora das Dores, of which owner is the Archdiocese from Mariana-MG-Brazil, is placed in Ouro Preto-MG, namely in the Largo de Nossa Senhora das Dores. The chapel was recorded by IPHAN at September 08th 1939 (Process of record IPHAN Nº 75-T, Inscription Nº 254, Book of Beautiful Arts, f.44).

The Chapel has had a constructed area of $600m^2$, being used at the present times to religious cults and meetings. It is characterised because it has rectangular way, growing in two levels and having, setting in the first ground the atrium, the church nave, the main altar, side runways, and the sacristy; in the second ground it sets the choir, the tribunes, and the consistory. The body of the church nave, more elevated, presents the roof in two waters and that one from the main altar in three ones, both finished with cornice in mass. The arrangement of the empty spaces which receives enclosure in stones, follow the following scheme: door in the axle and two windows profuse sidely in the level of the choir. The door has increased stick and it is topped by plastered decoration with the symbol of the patron. The profuse windows have sticks in complete arc and they are provided by glasses keeper on worked iron. A curved pediment finishes the composition, with pyramidal pinnacles at the ends, bell ringer in the middle and cross in the crowding.

The masonry is composed of stone, mud wall, adobe, stud and mud, and brick. The roof is composed of wood and the cover by tiles, mantle and water spot. The ground is composed of wood, cement and floor tiles. The padding is in on wood and the T-squares are on wood and glass.

The present state of the conservation of the Chapel is shown like regular one, although the precarious situation in which the roof and the cover are revealed. In determined points from the structure someone can observe the disconnection of masonry, studs, floors, and the deterioration of the components of the building in general.

2 METHODOLOGY

2.1 Technical Inspection and Formulation of the Problem

It was carried out a technical visit in order to make survey about the present conditions in which the roof from the chapel was.

The precarious state from the cover was noted and is shown broken and porous tiles, with excess of moss in its external face, the slipping and the lack of some pieces, what permitted the entry of rain waters.

The padding presents deformations, disconnections of small areas and degradation due to the attack of xylophagous insects. At the upper area from it, a large quantity of rubble is presented.

The net of the setting of the roof is shown in precarious situation, having all the elements deteriorated (laths, purlins, scantlings)

Some trusses are composed of three modules, being that every part from the central module is spread composing the sidely modules and these ones support themselves on the sidely walls. This scheme of modules forms a hypostatic system. (Figure 1). This referred system promotes an essential point of rupture on the connection nodes between the sidely and central modules. Other trusses have only one module being that the legs spread too and support directly on the wall plates. The extension of the legs are reinforced by juxtaposed pieces, which have still worked like support lines, too. This system is hypostatic one, too and because the reinforce pieces aren't sympathetic to the legs, suffers sidely displacements, what provokes deformations and breakdown on the structure. Together with the structural deficiencies, the action of the mosses and termites contributed very much to the reduction of the resistance of the pieces, especially of the legs of the trusses. Consequently, the trusses have presented irregular visual aspect, with pieces showing broken areas and, in any cases, disconnected.

It is perceived the preoccupation of practical order in relation to the compromising of the trusses staticism, what is verified throughout the adoption of small braces and against drawing in the major volume of them. These measures were adopted along the time purposing the reduction of the sidely displacement of the legs.

The present structure has shown a horizontal mudding, what holds the tapping. The scantlings hold themselves in auxiliary purlins that, in their side, hold themselves on the legs of the trusses.

2.2 Characterisation and Verifying of the Pieces from Structure.

The process of characterisation and study of the physical and mechanical properties from the kinds of wood that compose the real situation of the roof wasn't possible due to the advanced grade of degradation of all the structure. The knowledge of these properties of the wood only is possible with the removal of proof bodies to the realisation of the essays. This removal of samples would result the losing of pieces or reduction of the useful sections of some pieces, reducing more and more the quantity of utilisable pieces. Beyond, in interventions during the time in order to maintenance of the roof, there was the replacement of several pieces by wood of varied species, removing the characteristics, in this way in relation to the originality of the pieces. The process of characterisation purposed the utilisation of some pieces and the conservation of the originality of the building.

3 CALCULATION

3.1 Proposed Structural Model in a First Moment

The proposed structural model has purposed eliminate the problems of structural order detected on the existent model without damages of architectonic conception of the settling.

In this model of truss (figure 2), the reinforcement of the legs on the sidely modules and the auxiliary line of holding from the tapping were eliminated. Were adopted connections with the utilisation of metallic plates and bolts and one way to services of maintenance was added. The load of the tapping is redistributed throughout scantlings that hold themselves on three points of the truss. It was added a new purlin with the goal of reducing the deformation of the scantling and braces among the posts of the hoof truss from the sidely modules and the line becoming the purlin isostatic.

The wood to be used is the kind Paraju (Manilkara) and its physical and mechanical properties specified in the Standard 7190/97. The wood should receive a chemical treatment that purposes become immune all the pieces against the action of fungi and termites. The Standard ABNT 7190/97 suggests a treatment through of brushing of the wood using products based on creosote or pentachrorophenol.

The plates of connection will be made using structural and anticorrosive steel SAC 41. The bolts should be of the same kind of the steel from the metallic plates, avoiding the formation of galvanic piles on the contact plate/bolt.

3.2 Structural Model Proposed by IPHAN

After a clinical analyse of the existent trusses, was observed that they followed a determined technical standard. The consulters from IPHAN had resolved adopt the model of one of the trusses, possible the most ancient like standard, eliminating the braces, reinforcements and contra-drawings (figure 5).

Like the adopted model is hypostatic one, it was necessary to take one series of providences in order to the structure became stable. The first providence was the adoption of crowding beams with consoles on the external walls. These beams should be locked by drawing, forming a closed square. The shears hold themselves on the wall plates that, in their time, were locked by the consoles from the beams, being incapacitated of displacing in a horizontal way (Figure 6)

3.3 Structural Design

The considered loads to the calculation of the stresses on the truss are composed by the proper weight of the elements from the roof (tiles, lathes, scantlings, purlins, padding, studs, trusses and way to service) and accidental loads (wind and overload).

The accidental loads were gotten according to the prescription from the ABNT Standards NBR 6123 (Standard to Wind) and NBR 6120 (Overload).

The generated loading (figure 3) by the roof elements and accidental loads were taken by influence area.

The calculation of the stresses on the pieces of the truss is due to one combination of actions considering some basic hypothesis:

- The truss is plane and isostatic;
- The nodes are considered rotulated;
- All the loads are concentrated on the nodes;
- All the bars are straight
- The calculated truss belongs to the plane of the forces
- The stresses on the bars were calculated y the balance method of the nodes and after verified with the helping of the Software CIPECAD, simulating several situations.

The purlins are responsible by the transmission of the loads from the cover to the truss; in this case, applying the loads to the nodes, as well as the crosspieces of holding of the tapping have the same function in relation to the generated loads by the tapping.

The pieces of the structure of the roof are verified in relation to the active strains (compression, traction, simple flexure, and flexure-compression and oblique flexure), obeying the criteria established by NBR 7190/97.

The lathes were verified in relation to the oblique flexure, the scantlings in relation to the simple and composed flexure, the purlins in relation to the oblique flexure, and the pieces from the truss in relation to traction/compression.

The verifying of the structural elements was carried out using one record card of electronic calculations, developed by Microsoft Excel, working indirectly like a software.

The design of the connection plates were realised according to the prescriptions from NBR 8800/86. The number of bolts of connection was gotten with the helping of the card of checking.

The adoption of connections by metallic plates (figure 4), is justified by technical questions such as the reduction of the useful section of the piece, that would occur if connections by groove, feasibility and fastness of execution, and better technical performance were used.

3.4 Constructive phases

The process of disassembling and assembling of the present structure of the chapel will be made following one programmed sequence according the following sequence.

The preliminary phase is characterised by the removal and/or protection of all the existent historical patrimony such as images and objects. The preparative to the beginning of the work will be made in this phase, too (Place to the Building management, materials deposit, tools, sanitaries, etc.).

The provisory cover will be made with the purpose of protecting the Chapel and holding the good running of the work in the season of rains.

The removal of the cover should be carried out taking a special care with the sidely walls once that, according to what was observed in inspection, there is a possibility of collapse of these ones, provoked by the alleviation of tensions due to the removal of cover.

The new trusses will be settled in the ground and lifted until theirs definitive position, being necessary that someone notes the points of lifting on the truss, avoiding, in this way, the disconnection of bars and connections.

The banding of the walls will be realised with the purpose of becoming equal the surface of holding of the wall plates and contra-walls, in this way spreading, equally, the load of the shears about the walls.

4 RESULTS

In relation to the structural model proposed initially, its development proportionate one more efficient structure under the technical point of view. There was one better spreading of loads of the roof on the truss in a way that eliminates the excessive reinforcements on the legs, guaranteeing a limit of safety both this element and the remaining of the structure into the Standards from NBR 7190/97.

In relation to the structural model proposed by IPHAN, its design resulted in a less efficient structure in relation to the first proposed one. The generated load by the roof was spread in a way that doesn't create excessive stress over the portico and consequently on the sidely external walls.

The calculations of the active stresses on the elements both the structures in truss and of the portico structure, with the utilisation the record cards of electronic calculations, optimised the design of the pieces to the standards measures found in the market.

5 CONCLUSIONS

The project was developed into one technical reality considered by the architectonic features presented by the edification. The existent structural model was kept, with slight adaptations and the project was elaborated into the established time.

This is a pioneer work in Brazil in terms of using of a method of limit states (NBR 7190/97) to the structural project in systems on woods in the restoration area of historical monuments.

The utilisation of the electronic card record proportionate a great agility of the calculations to the verifying of the elements of cover, beyond of guaranteeing reliable results and the possibility of verifying several situations f loading with great velocity of calculation.

To the structural model initially proposed, it is verified that the connections made through metallic plates proportionate a great and practical advantage once it doesn't need specialised hand labour to its adaptation, against the connection made by groove. Other important point of such connections is that the piece doesn't suffer reduction of the useful area from the transversal section.

On the other hand, in the structural model proposed by IPHAN, the connections are made through groove, what implies in specialised hand labour and reduction of useful area of the piece. This structural model of truss, working like portico, generated simplifications that reduced the consumption of wood in a great volume.

ANNEXES

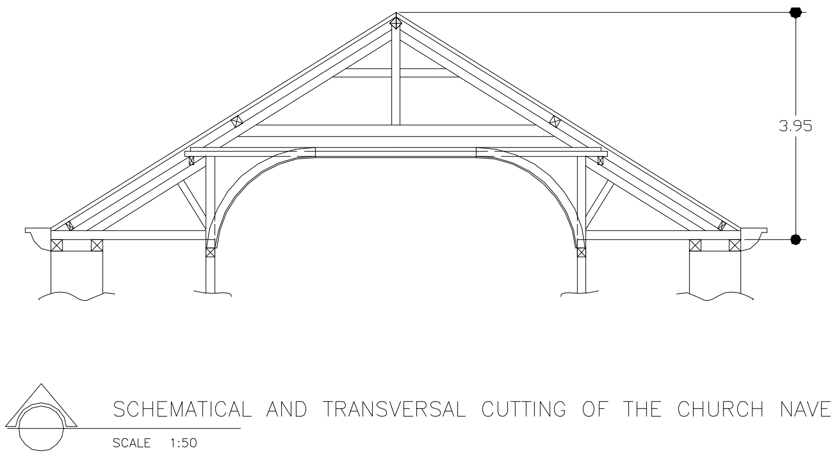

Figure 1 – Existent Structural Model

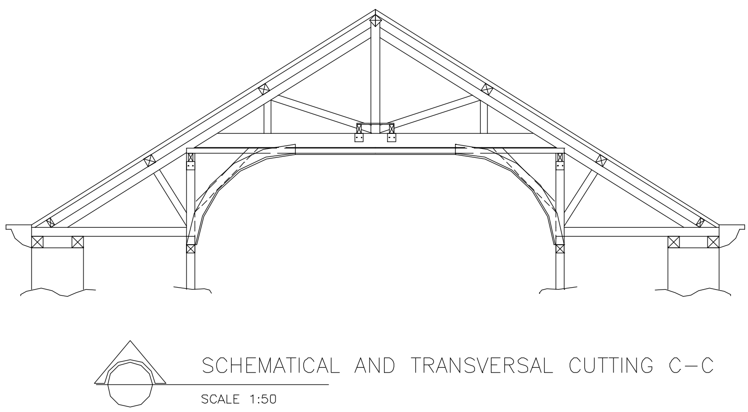

Figure 2 – Proposed Structural Model

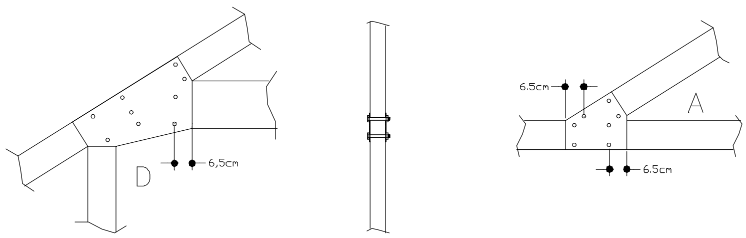

Figure 3 – Connections in Pieces from the Truss.

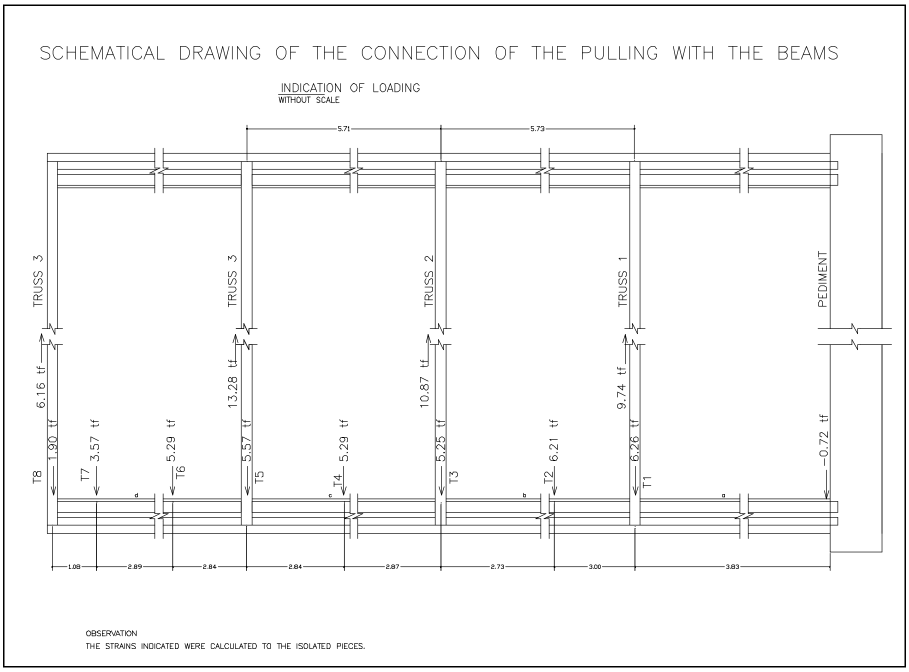

Figure 4 - Connections in Pieces from the Truss.

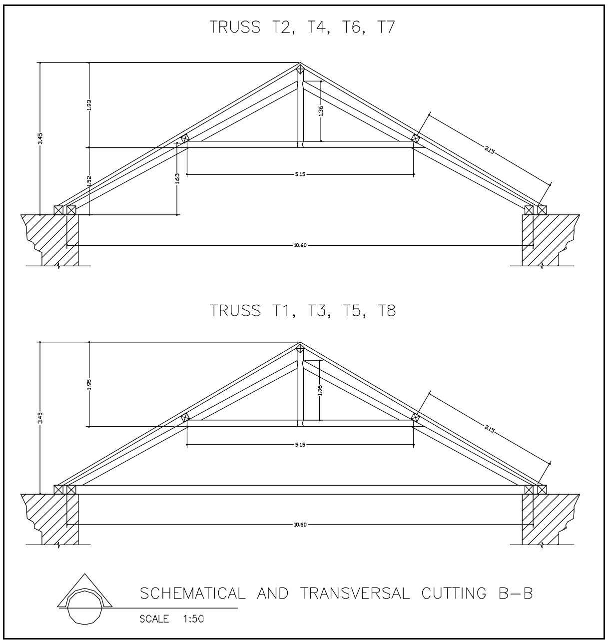

Figure 5 – Structural Model Proposed by IPHAN.

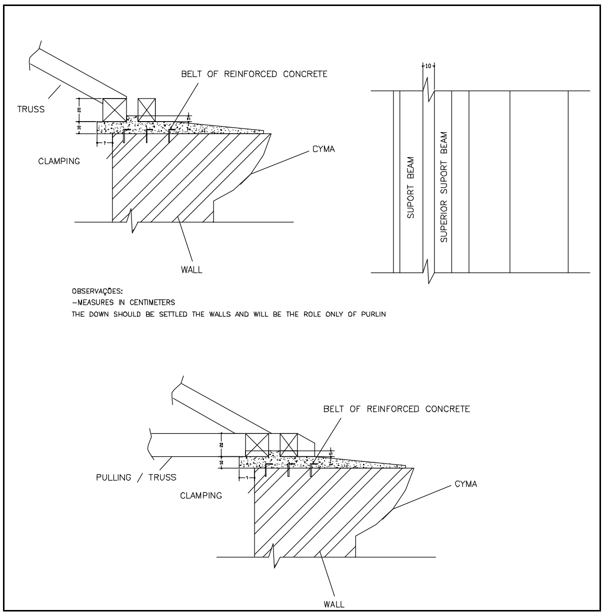

Figure 6 – Detail Showing the contact between the truss and the wall plate.

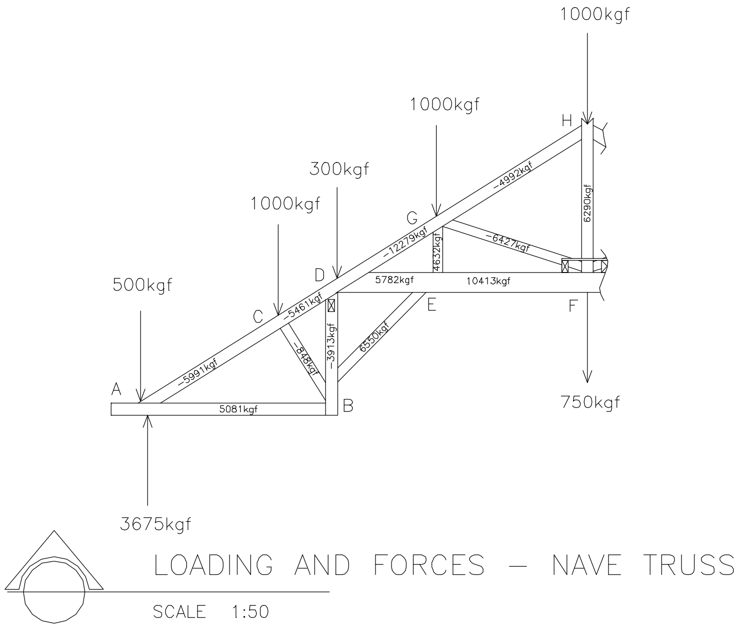

Figure 7 – Loading.

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