Analysis and building process of hidden wooden frameworks in 17th century Spanish treatises

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Although the Treatise called «Breve compendio de la carpintería y tratado de lo blanco, con algunas cosas tocantes a la Iometria y puntas del compás» [Brief course in fine woodwork, including issues concerning Geometry and compasses] by Rodrigo Álvarez has not been dated accurately, it probably appeared some time after the publication of the Treatises (first and second books) written by Fray Lorenzo de San Nicolás, called «Arte y uso de Architectura» [The Art and Use of Architecture] in 1639 and 1664.

This research work focuses on the analysis of the wooden structures described in both treatises, which are built to cover large areas and designed to remain hidden after the construction is finished.

By using this method, great differences in the way to approach the inside and the outside of the building may be achieved, and regardless of the type of supportive structures, new architectural solutions may appear, such as false vaults made of light materials and spires, which, in both cases, are supported by hidden wooden frameworks. Thus, apart from the fact that they are made of wood, the formal aspect acquires a special significance when defining such elements.

False vault of light materials

It is one that, without a constructive function, is fictitiously made of wood and covered by plaster. (J. M. Paniagua)

Rib-spread skeleton of a building, where a light lathing or raddle is fixed, which generally acts as support for a plaster decking. (E. Nuere)

Spire

Pyramid-shaped member, which may sometimes be conical or bulbous in form, that finishes as a very sharp arrow and culminates a tower. It may have a stone structure, but it is usually made of lead or slate-plated wood. (J. M. Paniagua)

Framework with a regular polygonal base that finishes off a tower. Cupola framework with lantern, the intrados or soffit of which is generally covered following the technique used for creating false vaults, employing light materials, such as wood. (E. Nuere)

In the latter definition, the two types of architectural solutions, known as spires, are distinguished:

— That which is used to cover and crown a tower, a solution that was imported from Burgundy and was introduced in Spain in the 16th century.
— The model that resolves the problem of an important cupola with a lantern, the inside finishing of which is similar to that of the false vault with a light lathing or raddle, which generally acts as support for a plaster decking.

The fact of being apparently subordinated to ornamental motifs is the reason why these structures have not been thoroughly studied, despite of their
significance. There are two other features that have certainly influenced this fact: they are difficult to access and due to the fact that they are hidden, sometimes they have lacked the proper maintenance, and in many cases, specially from the 19th century onwards, when the need to renovate such structures arose, wooden frameworks were simply substituted by metallic structures. The result is that the original structure no longer exists.

It is important to consider whether the structure is an imported model, or a part of the tradition of the fine woodwork carpenters.

In this paper, I analyze several of the chapters that deal with the wooden structures at hand and which are defined in some of the Spanish treatises of the 17th century. The Treatise written by Fray Lorenzo de San Nicolás describes two kinds of spires, and that written by Rodrigo Alvarez focuses only on the model based on a cupola with lantern. A subsequent treatise by Juan Garcia Berruguilla (1747) also deals with a model that is based on a cupola with lantern.

In order to gain a deeper knowledge on this field, I think it is absolutely necessary to study on location some of the structures that were built at the same time in which the Treatises were published. By doing this, I have been able to experience by myself how difficult it is to access buildings, both physically and otherwise, in which those structures were used, and the large number of them that were substituted by their metallic versions.

THE TREATISE BY FRAY LORENZO DE SAN NICOLÁS

The treatise written by Fray Lorenzo de San Nicolás was published in two volumes. The first one appeared in 1639 and the second one in 1664. The first volume has eighty-three chapters and the second volume is composed of seventy-one chapters. Both volumes cover a wide range of issues. The first volume—from chapter 46 to chapter 49—deals with woodwork; the same topic may be found in the second volume in chapters 50 and 51. I now proceed to mention the chapters in which woodwork is the main subject.

First volume

Chapter 46. On seasons in which to cut wood and the appropriate way to do so.

Chapter 47. On the way to trace frameworks and the different ways to do so.

Chapter 48. On framework cuts, bases and strengthening.

Chapter 49. On the way in which to cover frameworks.

Second volume

Chapter fifty. On two kinds of modern frameworks, which are very much decorated on the outside.

Chapter fifty-one. On another way of covering large or small Chapels with wood.

I refer to chapter 48 in the first volume, and chapter 51 in the second volume.

CHAPTER 48

On framework cuts, bases and strengthening.

Figure 1

In this chapter, Fray Lorenzo de San Nicolás starts by describing three different types of frameworks.

Figure 1

Types of frameworks defined by Fray Lorenzo de San Nicolás.
— First, the armadura a la molinera, commonly known as single gable. He lists examples where the rafters protrude, thus forming an eave, and examples where the rafters reach the walls without protruding, and the different cuts that apply in each case (oblique cut or reduction of thickness).

— Framework formed by rafters and courses. There is a description of the cuts to be made, their names and proportions. As a reinforcement for the framework, the author speaks of a piece of timber that he calls brace, which may be defined as a horizontal beam, and includes the proportions, since it is explained that they shall be placed on the third portion of the rafters. The location of the rafters is also explained, as well as the part of the wood that allows a better performance, and the importance of an adequate execution. The reader is advised not to use valleys, whenever possible.

— Armadura de tijera, in which the rafters cross like scissors. The ends project over the joint on the upper portion, and are joined at the bottom by reducing thickness with an oblique cut. In book 4, chapter 2 of the Treatise by Vitruvius there is a reference to this type of framework, under the title On Column Ornaments, where it is explained how Architects imitated ancient wooden temples to erect stone and marble ones.

Figure 2
Anchoring of wooden frameworks on stone or brick constructions, as defined by Fray Lorenzo de San Nicolas

The chapter then continues with the explanation of the anchoring of wooden frameworks on the brick or stone constructions, by putting first some short and thick pieces of timber or horizontal beams, measuring two thirds of the width of the bearing wall, at a moderate distance from each other, of the same thickness as the wooden base. The evened bases are anchored on these horizontal beams to the inside of the wall. It also explains how to join the pieces of the base when necessary, and that this should be done on the horizontal beams. The ties rest at different lengths at the bases of both sides, according to each case. It may be necessary to include oblique timbers in the incoming angles as well as the diagonal timbers, the framework is then ready to receive the pair of rafters or tijeras. It is said that the way to join the rafter to the buttress should be through an oblique cut. The author leaves the calculation of the size of all elements to the savoir-faire of the Master.

Apart from the oblique timbers in the incoming angles and the diagonal timbers, the crossed ties are also anchored on the spire, so that they form a square in the middle, where the main support, where the spire is strengthened, is anchored.

Strong winds are a great danger to spires. Therefore, certain proportions should be kept according to the width of the tower supporting the spire and the height. Fray Lorenzo highlights the need to include sloping pieces (hips, toral rafters, pieces that go from the base to the hip, and rafters) in an orderly manner, and in
large numbers, which are to hold the vertical supports that will stick out on the upper part, allowing carpenters and architects to decide on the way to distribute them. The author also refers the reader to the measures that appear in the scale. The description and study of the decisions to be taken when building the spire is less complete and methodic than the aforementioned topics. Figure 3 and Figure 4.

CHAPTER FIFTY-ONE

On another way of covering large or small Chapels with wood. Figure 5.

This chapter starts by explaining the advisability of covering Chapels with the cupola framework, that is, with a tower of a squared or octagonal base that finishes in a spire, or steeple, that is made of wood. The choice of wood over other materials is due to the reduction in cost, but it remains a secure and strong structure. It then lists some of the works carried out following such pattern: the first one by Father Francisco Bautista in Madrid, three works carried out by Fray Lorenzo, two in Madrid and one in Talavera, and one carried out by Fray Pedro de San Nicolás in Salamanca.

There is a description of the plan, which is circular inside, and chamfered on the outside, without ties.

It explains the way to place the evened horizontal
Analysis and building process of hidden wooden frameworks

The hips, toral rafters and the pieces that go from the base to the hip are anchored, and when the text says *deshiladas por los cantos*, I understand that they are not joined, because the pieces of timber that join the roof rafter and the ties are going to be used to bring them together. The thickness of the hips is determined by the span that is to be covered, as well as that of the toral rafters and large pieces that run from the base to the hip, each of them being placed at each side of the hip. The remaining pieces from the base to the hip may have a smaller size, as described in the text.

The remaining upper chamfer is executed, and the roof angles and rafters are treated so that the width of the lantern is proportional to the total width to be covered. Bearing in mind the resistance of the structure (the size of the centering and the pieces of timber that join the roof rafters and the ties depends on the tracing), when tracing the proportions for the construction of the spire, the author states that in order to trace the rafters it is essential to have made a detailed real-sized drawing of the centering beforehand, as well as the *copada* of Point Y. The drawing is then drafted beginning at the central point; a minimum measurement for the centering is set, and the piece of timber that joins the rafter to the ties is thus fastened with wooden pegs both in the upper and lower parts of the centering, rafters, roof angles and the pieces that run from the base to the hip, with well adjusted and fixed chiseled joints. The result is a strong, firm structure with tied rafters.

The placement of the strengthening chamfer is the most important step. The text says that the eight chamfers receive the eight *toral* rafters, and that this strengthening chamfer is over two thirds of the *toral* rafter.

According to the drawing of the upper part on the right, marked with letter P., and in the empty space (T), there is a single *toral* rafter per breadth (in the axis). This is the only possibility for the *toral* rafters to fit into the T. This is not seen on the outside, since the finishing of all pieces is unified in form by timbers of different sizes that join the rafter and the tie. Eight braces are placed in such a way that they do not hinder the function of the real-size drawing of half the cupola. Above the strengthening chamfer, eight vertical joists are placed, the height of which corresponds to that of the lantern. The proportions of the lantern are discussed in the chapter so that it fits beams into the wall; on them, the evened buttresses are placed in a chamfered square into the wall, and they are fitted together through indentations made half way through each beam so that the heads are left sticking out, as may be seen in the accompanying drawing. He recommends that these buttresses be thick, giving measurements according to the space to be covered; thus, for thirty feet, we should never place a buttress, the thickness of which is less than half a yard and a third, approximately, and it should always be resting on a board. Joints are achieved by nailing, in the first place, the beams with two pegs, and iron squares above; at least two thirds at each side should be well nailed. This is also reinforced with masonry and carpentry work. When doing this, we should be careful not to allow the lime to touch the wood.
within the whole structure, and these vertical supports are received in the chamfer (R).

The construction of the *cupulilla* (little cupola above the lantern), the spire and the horizontal bar of the Cross, which is fixed to the ties, is also described.

However, there is no explanation as to the function of the buttresses (Z) according to the structure of the lantern, but it relates it to decorative motifs. In a less structured way, the chapter explains the reader how to build some decorative motifs with iron squares, from large ornamental convex moldings to the eight vertical supports, and in the chamfers on which the moldings are fixed.

Fray Lorenzo explains several decorative motifs as well as inside and outside finishes, and how he is carrying out some in some of the works in which he is involved at the time of writing, explaining several of the steps he is taking. The chapter finishes by giving some advices to the Masters and apprentices.

Lastly, there are some graphics containing a vertical section of the chapel with a cupola framework with lantern and five horizontal sections, four of which correspond to the four structural chamfers which are necessary to assemble the decking (chamfer of the buttresses, the chamfer where the rafters of the cupola framework are fixed with an oblique cut, the strengthening chamfer and the chamfer of the upper part of the lantern and the base of the *cupulilla*. The fifth one corresponds to a lantern section cut, where we can see some flying buttresses and the windows of the lantern.

All drawings are inside a vertical rectangle, where a graphic scale is also included at the bottom right.

**The Treatise by Rodrigo Álvarez**

The manuscript, which apparently was not intended for printing, but for work and study, is composed of a dedication and three books.

The first book has 24 chapters and deals with the Architecture, materials, geometry, water and the means to guide it.

The second book starts in chapter 25 (there are two chapters numbered 38) and ends in chapter 50 and it deals with the building and formal characteristics of frameworks. It includes a description of the *carpintería de lazo* and a model of the spire of the cupola framework with lantern.

The third book, which includes chapter 52 (chapter 51 is missing) up to chapter 61, deals with several topics, including treatises on caliber, clocks, and a list of towns, villages and places.

I refer to chapter 50 in the second book.

**Chapter 50**

**The way to carry out a Framework for a Woodwork Cupola. Figure 6**

To begin with, Rodrigo Álvarez tells the reader of some of the spire works in which he has been involved in Madrid and Salamanca.

![Figure 6](image-url)
He then explains the way to place the evened horizontal beams at a distance not exceeding, approximately, one yard into the wall; on them, the evened buttresses are placed in a chamfered square into the wall, and they are fitted together through indentations made half way through each beam so that the heads are left sticking out. The author remarks that these shall measure half a yard, approximately, and the thickness shall be one third; they should be resting on a board, with large well-nailed cogotes, and with these nails bent at the bottom, and over them, the iron squares should be placed, at least two thirds being well-nailed on both sides. It is then reinforced with masonry and carpentry work. When doing this, we should be careful not to allow the lime to touch the wood.

The roof angles and the toral rafters are fixed by oblique cuts at the upper part to another chamfered beam. Afterwards, the roof angles and rafters are treated so that the width of the lantern is proportional to the total width to be covered. Bearing in mind the resistance of the structure (the size of the centering and the pieces of timber that join the roof rafter and the ties depends on the tracing), when tracing the proportions of the spire, the author says that in order to trace the rafters it is essential to have made a detailed real-sized drawing of the centering beforehand, as well as the copada of Point C. Then, the drawing is drafted beginning at the central point; a minimum measurement for the centering is set, and the pieces of timber that join the roof rafters and the ties are thus fastened with wooden pegs both on the upper and lower parts of the centering, rafters, roof angles and the pieces that run from the base to the hip, with well adjusted and fixed chiseled joints. The result is a strong, firm structure with tied rafters.

The placement of the strengthening chamfer is the most important step. The text says that the eight chamfers that receive the eight toral rafters, are on each side of the toral rafter, and that this strengthening chamfer is over two thirds of the toral rafter.

Eight braces are placed in such a way that they do not hinder the function of the detailed real-sized drawing of half the cupola. Above the strengthening chamfer, eight vertical joists are placed, according to the height of the lantern. The proportions of the lantern are discussed in the chapter so that it fits within the whole structure, and these vertical supports are received in the chamfer N.

The construction of the cupulilla, the spire and the horizontal bar of the Cross, which is fixed to the ties, is also described.

Lastly, there are some graphics displaying a single figure that represents a vertical section of the spire of the cupola framework with lantern, which is folded in the manuscript, since it is bigger in size (279x197). The drawing, which is colored, contains the wooden pieces, with capital letters assigned randomly to specific pieces or to areas of the figure. The letters correspond to those referred to in the written text.

There is a scale at the bottom of the drawing.

**COMPARATIVE ANALYSIS OF THE CHAPTERS DESCRIBED AND EXTRACTED FROM THE TREATISES BY FRAY LORENZO DE SAN NICOLÁS AND RODRIGO ÁLVAREZ**

Chapter 48 of the first book in the Treatise by Fray Lorenzo de San Nicolás may not be compared to the Treatise written by Rodrigo Álvarez, since it does not focus on the same type of spires.

We may draw a comparison about the way to solve the building of a cupola with lantern, through the spire explained in chapter 51 in the second book of the Treatise by Fray Lorenzo de San Nicolás and in chapter 50 in the Treatise written by Rodrigo Álvarez.

Chapter fifty-one. Deals with another method of covering large or small Chapels using wood.

Chapter 50. On the way to carry out this Framework for this Woodwork Cupola.

The titles of both chapters are different, because Fray Lorenzo deals with the covering and building of spires in a much broader sense, and he even considers decorative motifs.

R. Álvarez explains more concisely the way to build the framework for a certain Woodwork Cupola.

Regardless of the works to which both authors refer as carried out by them, or which are in the process of being carried out, and which, evidently do not coincide, the rest of the written information is very similar in both books, the treatise by Fray Lorenzo de San Nicolás being more complete, methodical and detailed than Rodrigo Álvarez’s. The text by Rodrigo Álvarez seems to have been copied from the former, obliterating some parts of the text and simplifying some of the descriptions:
In the treatise by Fray Lorenzo the sizes of the pieces are referenced proportionally to the lights to be covered; in the treatise by R. Álvarez minimum measures are given.

When describing the way to operate with the rafters between the first and second chamfer, the explanation of the members to be placed is simplified.

The whole explanation of the different aesthetic finishes and the decorative motifs, both on the outside (including the flying buttresses) and the inside, is only included in the text written by Fray Nicolás. Likewise, the explanation on how to build certain decorative motifs with iron squares, which go from the large ornamental convex moldings to the eight vertical supports, and in the chamfers on which the moldings are fixed, only appears in Fray Nicolás’ text.

Lastly, the advice to Masters and apprentices, and the description of some operations appear only in the treatise by Fray Lorenzo.

Graphics are different in both texts. The vertical section in the treatise by R. Álvarez is more elaborated than that in Fray Lorenzo’s, although the latter shows five additional horizontal sections, among which the one concerning the strengthening chamfer is especially helpful to understand what is written for building purposes.

The wooden pieces are thicker in the treatise by R. Álvarez.

Regardless of the differences in the way in which the information is displayed, there is a significant difference in the contents of both treatises. Figure 7.

The relationship among the upper chamfer where the rafters of the cupola are fixed through an oblique cuts and the eight vertical supports of the lantern.

Figure 7
Comparison of the vertical section of the cupola framework with lantern by Fray Lorenzo de San Nicolas and that by Rodrigo Álvarez. Link among the strengthening chamfer, the chamfer where the rafters of the cupola framework are fixed through oblique cuts and the eight vertical supports of the lantern.
cut, the strengthening chamfer and the eight vertical supports that make up the lantern, is different in both treatises. In this case, R. Álvarez represents such pieces and the way they are joined and in which they relate to each other more correctly.

None of the treatises explains where the eight vertical supports rest on the strengthening chamfer nor what is the relationship between these vertical supports and the upper chamfer where the rafters of the cupola are fixed through an oblique cut. This also affects the placement of the eight braces that do not hinder the function of the detailed real-sized drawing of half the cupola.

CONCLUSIONS

The spire used as decking and crowning element of a tower

Although there are several formal solutions to this type of spire, there is always a square or chamfered square, generally with a sharp pointed decking, which is finished in a cross, a weather vane or a ball, at the lower slope in the central portion.

The solution is defined by the proportionality of the width of the tower and the height. The higher the main support of the central portion of the spire, the more slenderness that is achieved, and the more resistance to the wind.

When building the spire, there are two framework mechanisms to counteract the strength of the wind.

— Abundance of wood. The weight is concentrated at the bottom of the main support and resistance of the main support itself.

The main support of the central portion, which is slightly higher and has a squared or chamfered plan, should rest at the bottom. The crossed ties form a square where the main support rests. By resting in the central areas of the void space, this member acts both as beam and tie, since the size of the tie should be out of proportion because it receives the weight of the whole support. On the other hand, the abundance of wood at the bottom of the structure also helps the building to counteract the strength of the wind.

The main support, which is composed of large vertical pieces, rests on the square formed in the inferior horizontal plan, where the spire is strengthened, as the treatise says. The way to carry out this joint is very important and it is not contained within the text.

Apart from the buttress on the wall, concentric buttresses in the inferior horizontal plan are needed.

— Less distance in relation to the main support acts as overhang against the wind.

Although the height of the main support is considerable, it can be less exposed to the horizontal force of the wind by shortening the distance of the overhang by using lower slopes that come from the concentric buttresses, including the external one, and underpin the vertical members that form the main support.

This model of spire is a very solid structure, and its appearance and construction is far away from the traditional manner in which the fine woodwork masters worked within the Spanish peninsula.

Since it is an imported model, in order to get to know its precedents and any written text concerning its construction, we should study same in its places of origin, both by seeing built samples of them and their description in any treatises that may exist on the subject.

During the reign of Phillip II, several models of spire were used in the renovations and new constructions carried out within the Royal Palaces. The golden tower of the Alcázar of Madrid, which was finished in 1569, was an imposing view in the skyline of the capital city and the use of this kind of structures was thus extended. Figure 8.

Spire of cupola framework with lantern.

The vocabulary used in carpintería de armar which is employed in both volumes by Fray Lorenzo when explaining how to build those structures is similar to that used by Rodrigo Álvarez in the second book, which includes chapter 25 up to chapter 50, where, apart from the Framework of this Woodwork Cupola, the author displays a whole construction system using wood which was preserved thanks to the oral transmission of the labor techniques. (The Spanish carpintería de armar).
I would like to draw attention to the similarities and differences of the cupola framework with lantern with the wood construction system, which is peculiar of the Spanish carpintería de armar. In our case, the buttress is directly placed on the horizontal beam, whereas in earlier construction practices, a base was placed on the horizontal beam and on the base, the cant strip and the tie, subsequently fastening the buttress to the tie through indentations made halfway through the width of each piece. Figure 9.

In chapter 50 of the treatise by Fray Lorenzo we find the description of a chamfered structure with ties. The bases rest on the horizontal beams, and the ties are fastened to them through indentations made halfway through the width of each piece; to anchor the buttresses to the ties, it is explained how to place some short and thick pieces of timber on the base and on another horizontal beam that is as thick as the ties. This is then anchored at the angles where the base is and from these short pieces of timber or diagonal timbers, a metallic piece is placed, which fastens everything and thus constitutes a safe junction.

When no more ties can be placed in the framework, the buttresses are directly placed on the horizontal beams. A chamfered square is formed with the buttresses, which fits through indentations made with large cogotes nailed both on the upper and lower parts. On the junctions, iron squares are placed with the base of the chamfer and each branch at least two thirds long. It is then reinforced with masonry and carpentry work.

Figure 9
Chamfered structure with ties, as defined by Fray Lorenzo de San Nicolas
Despite the strength required to carry out all these operations in the buttresses, the structure may not be achieved without the strengthening chamfer, which is built at a height equivalent to two thirds of the rafter (plain surface among horizontal beams in rafter and horizontal beam decking), similarly to the process pertaining to the placement of ties on the chamfered structure described in chapter 50 of the treatise by Fray Lorenzo. Figure 10.

The link among the upper chamfer where the rafters of the cupola are fixed through oblique cuts, the strengthening chamfer and the eight vertical supports that form the lantern, is described differently in both treatises.

None of the treatises explains where the eight vertical supports rest on the strengthening chamfer nor what the link is between such vertical supports and the upper chamfer where the rafters of the cupola are fixed through oblique cuts. This also influences the placement of the eight braces in order not to hinder the function of the detailed real-sized drawing of half the cupola.

It does not seem advisable to cut the vertical supports that form the lantern at the height of the upper chamfer where the rafters of the cupola are fixed through oblique cuts. At this height, it seems more reasonable to have some kind of joint among all the members.

All the treatises from the 17th century that have been studied have a similar approach, although there are some obvious differences.

Juan García Berruguilla, in *Tratado Quinto. En que se trata de varios modos de Armaduras,* [Fifth Treaty. On different Frameworks] shows an example of a spire of cupola framework with lantern, and 16 trusses, a solution that is in no way similar to the approach of the treaties dealt with in this paper. Figure 11.

**REFERENCE LIST**

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Figure 11
Cupola frameworks with lantern, as defined in the treatises by Fray Lorenzo de San Nicolas, Rodrigo Álvarez and Juan García Berruguilla.

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