# *Spanish wooden interlaced carpentry, the beginning of prefabrication in architecture*

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***ABSTRACT***
***One of the architectural peculiarities that identify the dissemination of Spanish inherited knowledge was interlaced carpentry, wrongly called 'mudéjar', which puts together the inheritance of Visogothic, European and Islamic culture. Interlaced carpentry, a development of Visogothic tradition, knew how to readapt the oriental sketches to make them into a resource that provided an exceptional precision to its carpentry works, something that was achieved by the use of a system of carpentry squares and managed completely without the use of the inaccurate measuring stick. The habit of using carpentry squares for the construction of frameworks promoted a spectacular development of a set of geometrical drawings that contributed to facilitating the prefabrication of frameworks, guaranteeing the accuracy of measures of the various components, which once finished could be mounted without any coupling default at the top of the building. In short, this interlaced carpentry which started in the 14th Century, was, perhaps, the first method of prefabrication in architecture.***

***INTRODUCTION***

*The mixture of cultures has always been enriching. The Iberian peninsula, in the medieval* finis terrae, *always attracted conquerors and merchants and, although it suffered the oppression of all those who went through it, it also knew how to assimilate everything positive that could be learnt from them. It even surpassed its masters going through the world in search of what it did not have, also taking its knowledge to the territories it thought to have conquered.*

*Interlaced carpentry has been a good example of this. For those who do not know what this is about, I will show a piece of this carpentry work, of which magnificent testimonies were left in many American territories. In this case, it is the ceiling of the church of the convent of San Francisco de Quito (Figure 1), although I could have chosen another from so many.*

*Until a few decades ago, nobody doubted that these pieces were the work of mudéjares, that is to say, Muslims submitted to Christians, and the most distinguished historians supposed that they had an Almohad origin, although some of them, specifically Leopoldo Torres Balbás, dared doubt it (Torres Balbás, 1955)[(1)]. Although at the beginning of my encounter with this carpentry I had no arguments to doubt what history affirmed, little by little I began to find evidence that did not agree with the official chronicle of our interlaced carpentry.*

*No matter how hard I searched in the Islamic world, I could not find carpentry works linked to what was produced in Spain and, if I found something, it came from the traditional Roman carpentry, based on the use of triangular knives, completely different from the one done traditionally in our peninsula, made of sets of rafters, more or less next to each other. As I have acquired a deep knowledge of our historical carpentry, I have been able to verify how it became a tradition of Celtic or Visogothic origin or from people from Northern Europe, which was the basis for the spectacular interlaced carpentry, whose way of designing in the peninsular Northeast, based on carpentry square sets, was totally unknown in the Islamic world.*

*As far as the authorship of some pieces whose artificers might have had a Muslim name, they could hardly be Mudejars, whose social status made it impossible to have the guarantors required in contracts made between promoter and carpenter. In any case, it could be Muladíes (Ferrera Cuesta, 2005), that is, Christian renegades, something that many nobles did in order to avoid payment of capitation tax, required from Christians or Jews who kept their religion. But mentioning this in Spain before our 1977 transition was politically incorrect and nobody thought of that possibility.*

*This does not prevent me from admitting that such carpentry is imbued of an undeniable Islamism, but, in spite of that, I neither believe that its main promoters were the Nazarene monarchs who remained on the peninsula, but the Christian Trastamara dynasty, whose* *taste for things Islamic remained, from the time when power was snatched from Pedro I el Cruel in the last quarter of the 14th Century (Valdeón Baruque, 2002), until the end of the 15th Century. Certainly, in a newly Christian Seville, it was Pedro who also transformed his royal alcázar with the help of Toledo artisans.*

***INTERLACED ROSETTES AS A MODULAR SYSTEM***

*However, it is not the history and origin of our carpentry that I want to refer to, but to what this trade meant regarding the introduction of prefabrication in architecture, something in which the discipline that established interlaced carpentry was very involved.*

*I have also mentioned the use of carpentry squares, heirs of what carpenters already used to determine the size of the pieces to assemble the roofs, in addition to the right cutting angles that those pieces needed at both ends, which allowed not to draw a plan, something still valid among North American carpenters (Wagner, 1987).*

*It is quite probable that before incorporating designs of Islamic origin to their ceilings, Toledo carpenters already used the simple eight-pointed star to decorate their ceilings, for which they would use a square with one right angle and two of 45º (still used nowadays) and another whose angles would be half of 45º and, logically, its supplementary of 67,5º (Figure 2). Someone used to drawing simple eight-pointed stars, when needed, would not hesitate to use the new carpentry square to turn that star into the new rosettes (star patterns) coming from the East.*

*Originally, only the eight-pointed star decorated the covering framework, which was formed by two simple wood bridgings that were used to fasten the rafters. But when the rosette imposed itself for the new possibilities of design it offered, in addition to the eight-pointed star, those of nine and ten began to be used and, each one, following an identical procedure, could generate another depending on which one could complete any plan in all its dimension without a solution of continuity.*

*The advantage of these designs is that they offer a control of measurements based on geometry, and their drawing guarantees the accuracy of the set, given that the design can only be made correctly (any mistake is automatically detected). This gave carpenters the confidence they needed to prefabricate their ceilings: the different components could be done on the ground and at the time of assembly, the coincidences between the prefabricated sets were guaranteed, being able to reject the inaccuracy of the measuring stick in use, whose smaller division was a finger.*

*Let´s imagine that we want to work with the eight and the sixteen point design shown on the left, or with the nine and twelve fold rosette of the centre (Figure 3). If we go to López de Arenas (1966), his manuscript provides the whole of the wood we need in each case, although the size he gives us refers to his own drawing to which he has added the streets that close both basic designs at their edges (Figures 4 and 5).*

*All the above starts from the assumption that the design is made so that the wood representing the design ribbons are separated between them by a distance which is twice its thickness (Fray Andrés de San Miguel, 1630). If the separation between them wanted to be wider, the alternative has a simple solution that allows respecting the divisions previously mentioned.*

*In fact, starting from a simple design, the simple indication that we can see repeated in various samples of the Seville manuscript, established the width of the timber to be used, on which the cuts required by the configuration of the lace are drawn directly. Thus, the set produced will finally measure what the dimensions of the room require, without risking error. However, in order to prevent the small imprecisions that a handcrafted work might have, the carpenter invented a resource that would give it a safety margin: the space between hip rafters (López de Arenas, 1966), which not only allowed finishing each roof plane (or roof side) independently, but once the framework was mounted* in situ, *the added pieces (that is to say, the pieces that give continuity to the hip jack rafters beyond the hips) allowed correcting possible imprecisions of continuity of the drawings between adjacent walls.*

*On the other hand, to carry out work of such precision at the top of precarious scaffolding was a practically impossible mission and, although it might seem that lace geometry could be the inspirer of prefabrication, I tend to believe that this was already done before the incorporation of the attractive Islamic decoration, since the system of carpentry squares used (those called 'carpenters steel square' or simply 'frameworks') allowed pre-cutting all the components on the ground, without fearing they would not fit when they were mounted later, and if this was already done, it was very easy to use similar carpentry squares to guarantee the incorporation of such complex designs to their frameworks.*

*The system of framework squares offered an additional advantage in interlaced carpentry, the fact that the number of framework roof planes multiplied itself, whether they were four, six, eight or the* *number the carpenter wished, allowing a simple control between the chosen geometric design and the inclination of the roof planes so that the design chosen was not interrupted at the joints. If we choose, for example, the equilateral triangular module, typical of rosettes of nine and twelve points, the same trapezoidal roof plane, formed by three basic triangles, will be suitable to cover a triangular, square or pentagonal floor, just by adapting the inclination of its roof planes.*

*If we wanted the design of the ceiling to be an hexagon, the roof plane used in these three examples would not longer work, because the roof planes would be on the same surface of the collar plane (the set of collar beams), without a possible inclination. For poligons of more sides on the collar plane, the angle of the roof planes would be too small to join it. However, carpenters knew how to overcome the limitations that strict geometry could pose. I have proposed what could be done if a powerful sponsor asked me to use that geometrical motif on an octagonal collar plane ceiling and I have imagined a possible solution whose angle at the border of the roof plane with the horizontal (formed by the bottom of the roof side and the hip) has to be more than 60º of the model used. If the rosette of a full arm had been removed, the remaining arm forces me to make a vertical cut of the roof plane, which would result in a prolongation of the walls and not a sloping ceiling. Then, if I want the drawing to have continuity between roof planes, I have to split the rosette by half an arm, a practice often used and although I do not think there is anything similar in our historical carpentry, I show it as an example of resources used by carpenters to skip the rules when the work required it.*

*If we wish to keep the twelve fold rosette at the joint of the roof planes with the framework, the first problem is that a regular rosette of 12 arms is not compatible with the octagon of the collar plane. But I will be able to fake it if I change the angle between its arms slightly, in such a way that the four that fit between the sides that meet at a corner of the octagon (three full and two halves), instead of its 120º, separate slightly between them in order to reach an angle of 135º, exactly 3.37º more between each arm.*

*As can be appreciated in the drawing (Figure 7), this geometric alteration is totally unnoticed by the spectator, above all taking into consideration that the rosette is shown fragmented into three pieces. Neither is it noticeable that the rosettes have lost one of their arms to be able to adapt themselves to the joint of the three roof planes. Another resource would have been to increase the lost arm at those corners, what would give an angle of 27º even closer than the original. On the other hand, it is easy to distract the attention on the irregularities made to follow the drawing at the collar plane, as in this case, introducing one or several stalactites of carved wood (*mocárabes*) into its design.*

### *THE LACE AND FRAMEWORK CARPENTRY SQUARES*

*It is not by chance that in order to design the lace peninsular carpenters used a set of carpentry squares similar to the one used to measure and cut the pieces of a framework. That system of squares, which continues to be used in North America with the so-called 'rafter square', allows the carpenter accurately to measure rafters, hips and hip jack rafters of a framework, as well as make the correct angles at the cuttings of its ends.*

*For a gable roof one carpentry square is enough, the one of the framework, but if the number of roof planes is increased, two more will be needed (Nuere, 2001): the hip rafter slope square for the joint piece of the different roof planes (the hip), and the hip rafter plane angle for the hip jack rafters, that is, the rafters cut at the leaning ends of the roof planes.*

*The main advantage offered by the carpentry squares regarding the interlaced design is, precisely, the relationship between them that our carpenters knew how to use in order to fix the inclination of the frameworks in relation to the chosen design. Today we decide previously the inclination we want to give to the roof planes of the ceiling without thinking of the form they will eventually have.*

*But this was not the only advantage: as the measurements of the various components were easily controlled thanks to the precision provided by the interlaced design, carpenters became confident to use prefabrication of rafter and collar frameworks. It is probable that at first they would do it by mounting complete stretches of the '*harneruelos*' (first name the collar plane had in Castilla), what would help the setting of the rafters by giving them support between the collars, but in order to do this, it was necessary to modify the usual assembly of these two pieces.*

*As this type of framework needs suspenders to secure the rafters support against the impact of the rafters, the suspenders can be the support of boards that provide a worktop, or support, by means of struts, a set of collars previously joined together, that would allow supporting the necks (the wood union) of the rafters at their ends and its bases at the rafter support.*

*We do not know whose idea this may have been, but someone must have thought, and imagine, that the set of collars would allow the easy installation of the rafters, so that the traditional assembly of two pieces could be modified, something that had already been done in the last quarter of the 13th Century in the ceiling of the cathedral of Teruel and the one of the Cuarto Real of Santo Domingo – one of the oldest frameworks done in Granada – and it continued to be done well into the 18th Century, when the then created Academia de Bellas Artes de San Fernando turned to classical constructions and the triangulated Roman knife began to be used systematically, as it was a more efficient solution to build carpentry roofs.*

*As I have just said, it is probable that the first set to be prefabricated was the collar plane, what would allow doing on it a finer decoration than the one possible* in situ*, and whose measurements would not, in principle, be critical, at least if what wanted to do was to install rafters one by one. And perhaps later, with the advantage of knowing how to control the relationship between the form of the roof plane and the slope of the framework, carpenters would be willing to prefabricate roof plane pieces, too.*

*The sets of rafters fastened together, like the ones I have found when restoring historical frameworks, confirm these assumptions. And in order to be even more certain that this assembly was plausible; I have used it in some restorations, confirming their effectiveness. It is true that in our days we have cranes not available before that allow us to lift heavy weights, but in the restoration of the church of Méntrida, in the province of Toledo, the crane we had to lift all the pieces previously finished could not reach the place due to the narrowness of the streets surrounding the church, and the pieces had to be lifted by hand by the same carpenters who had to assemble them, without a serious problem.*

*In the case of another church, the parish of Perales de Tajuña, in the Comunidad de Madrid, we could actually have the valuable help of a crane (Figure 11). Once all the framework components had been restored separatly, in sets easily manageable, the collar plane supported on a simple scaffold was installed. Once the groups of rafters were lifted, after supporting them on the rafters support, they were tilted to fit their shafts between the side tenons of the collars of the collar plane.*

### *CONCLUSION*

*It is quite probable that, during the period of Visogothic dominion in the Iberian peninsula, simple sets of carpentry squares were already being used for the construction of rafted frameworks, something that must also have been usual in Atlantic Europe, carpentry squares that not only allowed measuring and defining the cuts of framework components but were also used to cut joining angles of timber facing various angles.*

*At a certain moment, between the middle or the end of the 13th Century and the beginning of the 14th Century, a particular taste for a geometry of Islamic origin developed in the Hispanic-Muslim world, with designs of interlaced ribbons that combined with the interlace rooted in the ancient Celtic culture, which promoted the introduction of a new geometry siutable for decorating wooden ceilings. The recurrent interest shown for this type of work by the Trastamara dynasty, ruling from the last quarter of the 14th Century to the beginning of the 16th Century, consolidated this way of building frameworks. But, above all, the accurate control of the measurements of its frame planes, which guaranteed its geometric decoration, undoubtedly influenced the change of this carpentry into one of the first prefabrication practices used in the history of architecture.* m

NOTES

(1) "The founders of the Almoravid empire – nomads of the Sahara – as well as the Almohad – rough people of the Atlas mountain – lacked artistic tradition to modify or take the place of the existing one" (Torres Balbás, 1955, p. 10).

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