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Extradosed vaults in the Monastery of El Escorial: The domes at the church towers

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The analysis of ashlars vaults at the monastery of El Escorial shows that a great effort was done in research and development since the beginning of the construction work, in what finally became a definitive contribution to the introduction of the formal Renaissance repertoire in the Spanish architecture. Complex constructive tasks were carried out, i.e. the realization of low profile and planar vaults,[1] and extradosed domes. Before the monastery was built, the examples of extradosed vaults, i.e. the type of vault in which the internal shape, materials and quartering are recognisable in the exterior, were very scarce, and even more of those built on tambours (Bustamante and Marías, 1982, 8, 103). Juan Bautista de Toledo, the first architect of the monastery, who had worked with Michelangelo in Saint Peter's, died twelve years before construction work on the dome started, so his followers had to carry out tasks in which they had little previous experience. In the building we are studying, several extradosed vaults on tambours can be found: the dome of the church and those of its towers (figure 1).

The study of an extradosed vault is especially interesting as it gives the added possibility of analysing the external face as well: a precise survey in which there is a direct relationship between intrados and extrados permits the geometry of the whole section of the vault to be studied, and an analysis of the quartering to be made, proposing a hypotheses on the constructive configuration. The aim of this work is to approach the domes of the towers of the church at the monastery in El Escorial to know something else about how they are, how they were built and why certain decisions were made. On the other hand, the content of this paper is part of a doctoral thesis on the vaults of this building.[2]

Figure 1
Dome and church towers at the monastery of El Escorial

THE TOWERS AND THE DOME: THE SAME IDEA

The analysis of the church towers is fundamental in the study of the vaults of the monastery, as they are part of a whole together with the main dome: on the one hand, though in a very different scale —the internal diameters are 6.68 m and 18.94 m

respectively— the same constructive and formal problems are posed and solved. In both cases, they are stone extradosed vaults on cylindrical tambour with spherical surfaces in the extrados and intrados, finished in a lantern.

On the other hand, the three domes were built almost at the same time. The conditions and budget to carry out the works of the main dome are written by Juan de Minjares, clerk of the work of the church, on November the 12th 1579. Five days, on November the 17th this party is contracted; the works of the bells towers are contracted on the same day, being Juan de Minjares also in charge of the writing of the conditions, what he did the day before (Bustamante, 1994, 494–497). Francisco del Río and Diego de Cisniega, who later were responsible for the space under the choir place, were in charge of the southern tower and Juan de la Puente and Lope de Arredondo of the northern one.

On January 1580 two wooden cranes are finished and placed to work in the carpentry of church towers (Bustamante, 1994, 498). On July, the eight initial cranes for the dome are also placed and the towers ones are elevated 40 feet (Bustamante, 1994, 498). The works in the southern tower go faster than those of its twin (Bustamante, 1994, 501).

On September 1581, the centrings of the three domes are placed (Bustamante, 1994, 501). Both towers are finished by December 1581: on the 22nd the works are measured and described (Bustamante, 1994, 503).

The works in the dome go slower, but by March 1582 they must be near the end as the carpenter is told to dismantle the cranes of the dome, the centring of the large *half-orange* and the lantern scaffolds. José de Sigüenza points out that on June the 23rd 1582, the fabric body of the church was finished and the cross was placed on top of the dome (Sigüenza, 1602, 147).

Existing graphic documentation

The existing graphic documentation of the church towers is wide and very worthy, despite the fact that no section drawing has been found, what is basic for the realization of this work, nor of the vaults quartering.

Among this documentation, following a chronological order, there is an elevation of the towers in the well known C section, supposed to be by Juan Bautista de Toledo, which shows an state of the idea very far away from the final result. The drawings by Juan de Herrera of 1579 include several floor plans and a complete elevation in which outstands the treatment of the extrados of the dome and the lantern proportion, to which the size of the external sphere should be also added. In the drawings by Herrera for the *Estampas* printed by Perret, the dome still appears with projections in the extrados, as probably they would have liked to build; however, in the budget conditions by Juan de Minjares, no reference to that projections appears, though there is neither any reference to the interior ones, which in fact were built (Bustamante, 1994, 496).

There are also available a number of detailed drawings of the survey by José de Hermosilla, on 1759 (Marías, 2001): the towers appear in an elevation with great fidelity to the actually built, except for the height of the lantern and the finial which appear with some exaggeration. On the other hand, the survey and analysis carried out by Ortega are also available, whose consultation has been of great importance for the realization of this work. In his drawings the tower appears described in two plans and a complete elevation (Ortega, 1999).

Survey

The survey was done on the southern tower. The measurement of inaccessible areas was carried out with a laser survey station and those of the interior in the two levels of the lower body were done manually with tape and laser measure.[3] The work at the monastery with the laser station was partially done with Miguel Ángel Alonso Rodríguez.

The cloud of points located by the laser station determined all architectural shapes and joints of the vault quartering. It was necessary to take data from several station base points that were merged afterwards in the same coordinate system locating sharing points between at least two bases. The points were then processed and analysed in a single digital file, where all the drawings that are showed in this paper were done (figure 2).

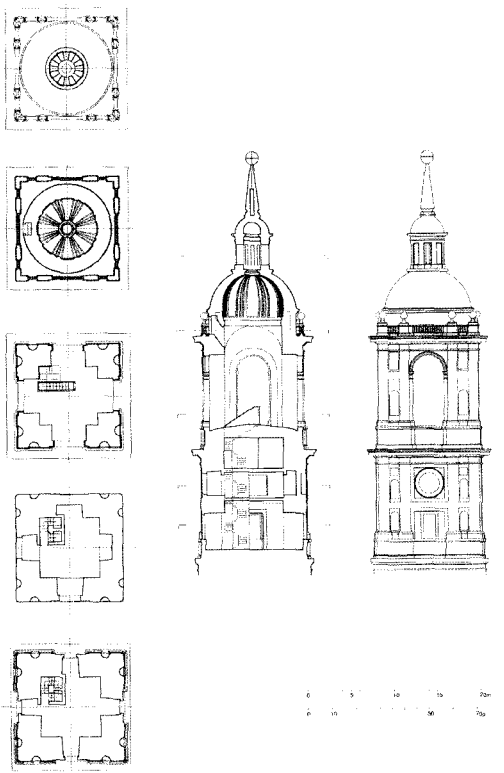

Figure 2
Plans and sections of the southern tower

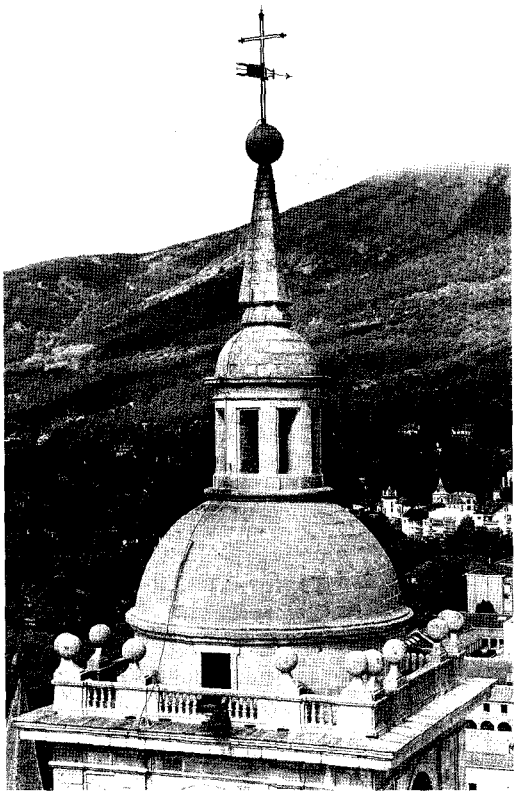

Figure 3
Southern church tower at the monastery of El Escorial

Geometric configuration and quartering

The top of the bells body in the church towers is formed by a hemi-spherical extradosed vault on cylindrical tambour laying on pendentives in the interior and finished in a lantern and finial (figure 3).

The intrados of the dome is formed by an elevated hemi-sphere 25 feet diameter with projections. In the external face another sphere with different centre with respect to the previous one and virtually tangent to the laying tambour forms the almost *half-orange* (figure 4). The main projections are sectors of a 24 feet diameter sphere and the secondary ones are sectors of a 24.5 feet one. These three spheres are not concentric: the height of the centre increases as the radius decreases. In this way the thickness of the projections reduces as it approaches the centre of the dome and equally the width decreases given the fact that they are radial sectors.

In the exterior sphere and tambour have the same diameter: 36 feet. The measures obtained for the thickness of the dome are clearly smaller than the ones reflected in the budget (Bustamante, 1994, 496). The hollow configuration of the finial is described in the expert valuation of the finished towers (Bustamante, 1994, 503).

The section of the dome of the tower has been compared to the one of the main dome. For that purpose, on the left side of the drawing showed in figure 5, the section of the dome of the tower (line) and the section of the main dome (shadowed) have been represented in different scales, to obtain the same center and radius of the external sphere. As can be seen, the section of the dome of the tower is

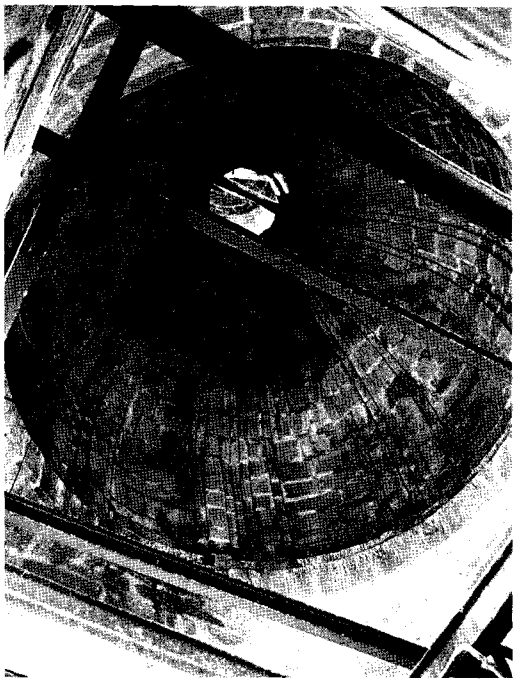

Figure 4
Intrados of the dome of the southern church tower

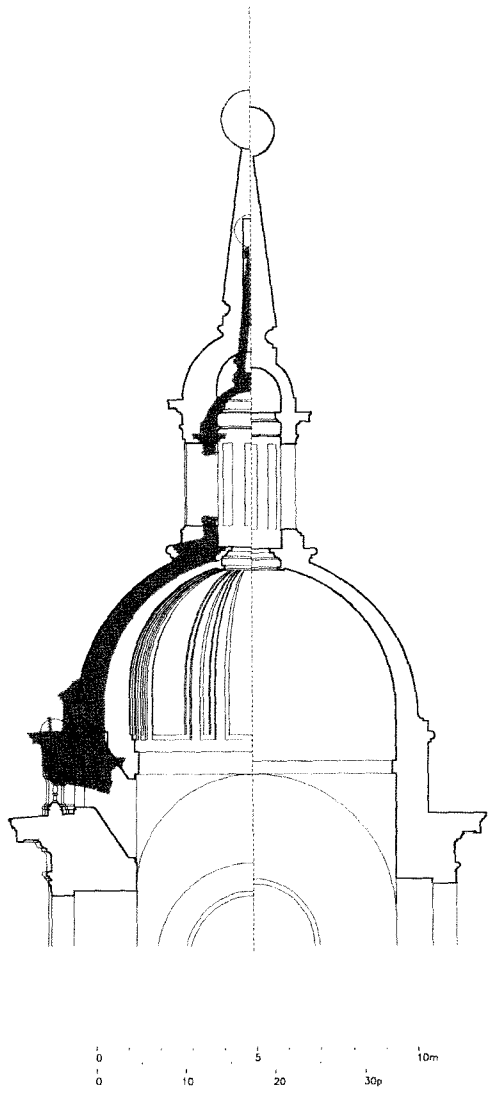

Figure 5
Analysis of the tower dome section

proportionally thicker. On the other hand, on the right side of the same drawing a proposal of what could have been Herrera's idea for the section at the moment in which he was drawing the plans and elevation of the tower (1579), is represented. For that purpose, the elevation profile has been copied and an intrados has been proposed with a diameter that is a figure that Herrera gives in the interior length of the square of the plan of the bell's body. The diameter would be 29 feet instead of the 24 actually built and could concluded that the dome that Herrera had in his head initially was much thinner, with a proportion similar to the main dome. On the other hand the relationship between the actual exterior diameters of the main dome and those of the towers is 2.27:1.

Hypotheses on constructive configuration

A simple visual inspection of the exterior quartering of the dome of the towers reveals, following Enrique Rabasa (2000, 162–167), the existence of a course significantly higher than the rest: his reasoning about a change in the beds disposition in that course, which would be radial instead of horizontal, has guided the direction of this and other works.

The dome is formed by an ashlars double sided structure in its lower part; the internal and external

radial joints between voussoirs in the same course do not coincide in any point, not even taking into account small deviation in carving or posing. From the high course previously mentioned the coincidence in the radial joints is complete what leads us to think that there is a single sided structure. This proposal coincides with the way in which the dome was budgeted (Bustamante, 1994, 496). The proposal of beds configuration in the area of the vault in which there is a single-sided structure is immediate just joining, in the section drawing, the points which define each external course with its corresponding internal one (figure 6). The prolongation of this lines coincides very accurately with the center of the internal sphere. On the other hand the slope in the beds of the projections confirms this posing.

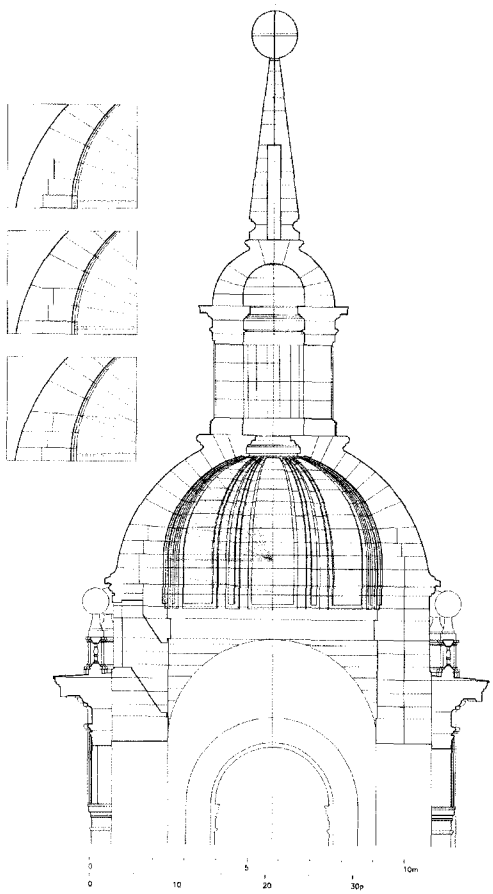

Figure 6
Hypotheses on constructive configuration

The first six courses, counting from the dome's internal elevation, are organized in horizontal beds; the seventh one would be the high course whose over-bed would be a little bit sloped, but not in a radial way and it would also be the piece of change, with more height in the extrados to avoid to finish too narrow in the intrados. In the drawings of figure 4, on the left side, three hypotheses, which could be valid for the support of the high course, are posed. In the immediately previous course, the inclination of the bed and the over-bed in the projections is different than that marked by the voussoirs of the plain areas, in a radial organization following the centre of the sphere of the main projections. Thus, in that course , the beds have an inclination that changes when *leaning* over the projections.

The described configuration poses that the dome was started to build by horizontal beds, with no need of centrings, for the successive projecting of the pieces. From a certain point, and now with centring, the construction was completed with radial beds after organizing a higher transitional course between the two constructive systems.

The confirmation of this constructive disposition in the dome of the tower could permit to propose a new reasoning line for the quartering of the main dome (Alonso and López, 2002, 303–308): the inclination of the beds in the lower part of the projections does not imply that all the voussoirs of the same course have to follow the same pattern, especially where the external side is organised in horizontal beds and a centring would be needed for the interior (figure 7). On the other hand, the analysis of the high course in this dome poses new questions: as it is still formed by a double sided vault, it would permit to organize two normal size courses in the external side, instead of just one. Perhaps it could be possible to pose that these large pieces work like belts, in an area in which the push has very little vertical component and the existence of a horizontal bed could make the voussoirs to slip.

The aim of this work was to know something else about the domes of the church towers at the monastery in El Escorial. A proposal on how the towers are has been made; a number of hypotheses on its constructive configuration, where no verification is possible, has been established, and finally many

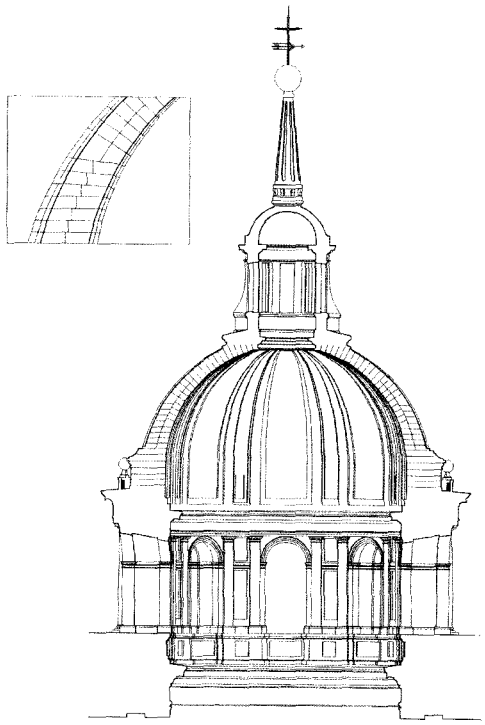

Figure 7
Church dome at the monastery of El Escorial. Survey by Miguel Alonso Rodríguez in cooperation with Ana López Mozo; in the box, her alternative proposal for the constructive configuration of the dome

question marks on the history of this elements and the events that took place around them have been opened: Why the dome changed so much from Herrera's drawings? Was its thickness increased for

the change in the lantern proportion or is there any other reason? Why the dome was budgeted without projections, Herrera draws it with external ones and finally it is built with internal projections which can be seen only from the interior of the bell's body? The domes of the towers could have been somehow models of the main dome in a ? scale: really new formal and constructive configurations which were going to be used very rapidly in the main dome, were tested there.

Notes

1. The analysis of these two planar vaults has been approached in a different paper for this congress, titled «Planar vaults at the Monastery in El Escorial».
2. *The vaults of the Monastery in El Escorial,* carried on by the author of this paper guided by Enrique Rabasa Díaz, professor at the Madrid School of Architecture.

Part of the content of this paper was presented at the symposium *The monastery of El Escorial and architecture,* which took place at El Escorial on September 2002. Another paper on the same subject was presented by Miguel Ángel Alonso Rodríguez, titled «About the towers domes at the Basilica of the Monastery of El Escorial».

3. The realization of this surveying has been possible due to the availability of the measurements instruments of the Department of Graphical Architectural Ideation of the Madrid School of Architecture, specially the laser surveying station, and also due to the kindness of the National Heritage Office at El Escorial, permitting all the visits needed to complete the fieldwork.

Reference list

Alonso Rodríguez, M. and López Mozo, A. 2002. «Survey of the church dome in the monastery of El Escorial», in *Papers of the IX International Congress on Architectural Graphical Ideation.* La Coruña: University of La Coruña.

Bustamante García, A. 1994. *La octava Maravilla del Mundo.* Madrid: ed. Alpuerto.

Bustamante García, A. and Marías, F. 1982. «La catedral de Granada y la introducción en España de la cúpula del Renacimiento», in *Boletín del Instituto «Camón Aznar».*

Marías, F. 2001. «El Escorial entre dos Academias: Juicios y Dibujos», in *Reales Sitios* 149. Madrid: National Heritage

Ortega Vidal, J. 1999. *El Escorial; dibujo y lenguaje clásico.* Madrid: Sociedad Estatal para la Conmemoración de los Centenarios de Felipe II y Carlos V.

Rabasa Díaz, E. 2000. *Forma y construcción en piedra. De la cantería medieval a la estereotomía del siglo XIX.* Madrid: ed. Akal.

Sigüenza, Fray José de. 1602. *La Fundación del Monasterio de El Escorial,* Madrid, ed. Aguilar, 1988.