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The *corde à treize nœuds* and the *quine des bâtisseurs*. The origins of two mythical tools

The *quine des bâtisseurs* is a measurement tool presenting five units, widely accepted by the general public as a genuine medieval tool, especially in France. However, it is a creation of Jean Bétous in the 1985 publication *Les cahiers de Boscodon*. Bétous, a golden ratio enthusiast searching for mystical proportions in religious architecture, suggested that most medieval religious buildings were built using five basic units based on the golden ratio. This idea is supported by no evidence, and is actually adapted from Le Corbusier's Modulor developed in the 1950s. Even the names of the units are problematical: three of the five units in the *quine* (*paume*, *palme*, *empan*) are just derivations or equivalents of the same name (*palma*). However, Bétous's idea had a quick success in the 1990s and is now referenced as a fact in many publications.

Another supposedly medieval tool is the *corde à treize nœuds* (13-knot rope). It is a rope divided in 12 spaces, for measuring out right angles by tracing the right triangle based on the Pythagorean triplet 3-4-5. There is no mention to be found in period sources, indeed the tool appears for the first time in 1900, in the book *Vorlesungen über Geschichte der Mathematik*, in which the German science historian Moritz Cantor theorised that the *harpedonaptai* (rope-stretchers in ancient Egypt) used a rope divided into 12 to construct right angles; however, many scholars have since invalidated his idea. Then, in 1933, the freemason symbolist Wladimir Nagrodski suggested that the *houppe dentelée*, a symbolic rope of heraldic origin, was actually a 12-knot rope in disguise – a medieval tool of Egyptian heritage, secretly transmitted to the freemasons through the ages. He provided no justification, especially since the link between freemasons and medieval builders is now debunked.

However, the theory was accepted, and in 1963, the architect Jean-Pierre Paquet suggested that medieval builders used a knotted rope, supposedly only based on observation; but the similarities with Cantor's rope are too many to be coincidental. Later the *corde à treize nœuds*, promoted

by architectural occultists and fiction writers, made its way among the public and today even some scholars still believe in its existence.

The enduring success of those two fictitious tools despite all the evidence can be explained by the appealing concepts they endorse and the lack of any publications debunking their existence. It is our hope that in the future, scholars will be more careful when dealing with the history of those pseudo-medieval tools.

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Pressure and privilege. An economic approach to the remuneration of ironworkers and their relations with building yards through the study of accounting records (mid-14th–early 16th century)

The great construction sites of the late Middle Ages provide a view of the work of some of the urban metalworkers. Accounting series such as those from Troyes, Rouen and Metz allow us to evaluate and characterise the workers' presence and activities over long periods, by examining the work and socio-economic situation of these craftsmen through their relationship with the building yard. The stability of the actors, the prices they charged and their evolution, the occasional or regular recourse to other professionals are all indicators of the relations between these powerful institutions (city, cathedral, etc.), and these men, who usually belong to the urban middle classes.

Because of the diversity of production, from the small lock to the imposing hundred-pound iron framework, these great building yards are ideal observatories to address the skills and infrastructure available

to these craftsmen, depending on their location: small workshops within the city or larger forges in more rural areas. The morphological and metallographic study of iron framing complements the written sources by giving access to information on the technical processes used by the blacksmiths, and the supplies according to the nature of the items.

In the absence of preserved sources, contracting terms are not known. Yet the long accounting series enable us to examine the practices with their continuities and interruptions. The permanence of metalworkers, often dealing with the same construction site, sometimes across several generations, is remarkable and all the more so as, in a given city, different commissioners seem to engage the services of different craftsmen. In the building industry, where much flexibility is observed, these privileged links between artisans and building sites revealing quasi-monopoly situations are complex, but each party nevertheless seems to have benefited from them.

From the point of view of the contracting authority, this permanence reveals that bonds of trust often seem to prevail, perhaps favoured by geographical proximity, facilitating exchanges, transport, and even control over the work of the blacksmith, and ultimately aiming to reduce the risk taken by the building site. However, by showing interruptions in pricing or collaboration, market capture is examined, as well as the economic pressure that the institution was likely to exert on these workers. The craftsmen's subordination to the yard is materialised through certain recurrent price changes or reductions imposed by the operator.

The value of obtaining orders from these construction sites was nevertheless obvious for these craftsmen, who gained a sometimes modest – but not negligible – complement to their other activities, likely to become long-term by giving them access to regular markets and, above all, the prospect of considerable remuneration, albeit more intermittent. Without really modifying the conditions of employment in the field of iron metallurgy, these construction sites thus constituted a valuable source of income for blacksmiths' workshops.

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Metal framing for windows and glazing in the building envelope in Britain, c.1700–1950

The construction of metal windows of wrought iron, cast iron, brass, pewter and bronze alloys such as Eldorado metal, involved craft skills until the early 1800s. The use of machinery to create glazing bars of constant cross-section by rolling or drawing began in Britain in the 1780s and these processes competed with cast metal frames. The rolling of iron and steel sections became a fully industrial process in Britain only in the 1840s. The first great designer of glass houses, from around 1816, was the Scottish botanist and garden designer John Claudius Loudon who worked with ironmasters W. & D. Bailey to create many remarkable structures such as the Palm House at Bicton Park Gardens in south-west England in around 1816. From that time, throughout the 19th century, there were two main parallel strands of development – one was the development of windows for domestic, industrial and commercial buildings; the second was the construction of hothouses, glasshouses, greenhouses and conservatories, which became increasingly fashionable from the 1820s. Together these developing technologies facilitated the architectural use of large glazed roofs for covered passages and courtyards or atria, railway stations, museums and exhibition buildings.

The development of metal framing for windows and glazing from the early 1700s to the 1950s shows a transition from craft-based skills to industrialised production that is similar to that which occurred with other building elements, especially the load-bearing structure of buildings made of cast iron, wrought iron and, from the 1870s, steel.

During the last quarter of the 19th century hundreds of firms in Britain manufactured metal framing for windows and glazing using rolled-steel bars which were connected by brazing or using mechanical joints. By the early 20th century the number of firms had reduced considerably and soon only a few, highly industrialised producers were

active. In the first decade of the 20th century, Crittall led the way in industrialising the manufacture of window frames by rationalising the amount of steel profiles, introducing oxy-acetylene welding and using the Fenestra joint to create a much stronger product suitable for curtain walls. These processes maximised the benefits of standardisation while still offering architects and builders great choice in the shape, size and style of windows and glazing. Other firms soon followed Crittall's lead, notably Henry Hope & Sons, and by the end of the 1920s these two firms dominated the British window market; they finally merged in 1965.

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Administration or *asiento* in building works in Spanish Louisiana. A controversy between the Commander of Engineers and the Intendant (1800-1801)

Between 1763 and 1803, Spain governed Louisiana, and as in its other American possessions, tried to push ahead an ambitious programme of colonisation and fortification works. In this context, close to the final years of this period, in relation to military building repair and extensions in New Orleans, there arose a fascinating controversy that can now be analysed from the copious correspondence between the Commander of Engineers (Joaquín de la Torre) and the Intendant (Ramón López y Angulo), in 1800 and 1801. For 13 months, in 32 letters written on 86 pages, several topics were discussed, such as better mechanisms for

executing the fortification works -by direct administration or contract-, with many references to treatises, experiences and technical details, all amid power struggles; but without reaching an agreement. This article offers a brief but substantial evaluation of good and bad practices in building works, mechanisms and customs in contracting, methods of price estimation, and criteria for defining the *asientos* -even as a kind of service for the King, with defined time limit-, in Florida and places along the Gulf of Mexico and the Mississippi river (Natchez, San Marcos de Apalache, Pensacola, Placaminas, San Fernando de Barrancas, Baliza, Nueva Madrid, San Luis de los Illinueses), as part of the history of construction that has received little attention: repair, extension and maintenance works. The controversy between the engineer Joaquín de la Torre and the Intendant Ramón López y Angulo, exemplifies how the rules of art -defended by the Military Engineers' Corps- faced the pragmatism and strength of the commercial networks of the British in Florida, the French already established and recruited by Spaniards, and North Americans expanding along the Mississippi river. In the framework of discussion about the Fiscal-Military State and the Contractor State, selected trajectories of these and other individuals still reveal the value of researching the activities of builders, on the territorial margins of Imperial and National States. And, in particular, they allow us to delve further into the explanatory power of the history of construction.

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Public works, central state and local authorities. A programme for port construction sites in the early years of Italian unity

With unification and despite the financial cost of a wartime economy, the new Italian state embarked on an expeditious policy of port works. Via the study of the various levels of authority, from the nationwide policy to the woes of the Neapolitan public market, this paper aims to question the underlying elements and efficiency of such a programme.

In the first years of unity, government investment was more substantial in the ports of Genoa and Livorno than in the south, which tended to deepen already noteworthy inequalities. Moreover, the application of Piedmont-Sardinian tariffs to the entire kingdom, as well as the proactive state attitude regarding developments also worsened social inequalities, as the costs of construction were borne by general tax revenues or loans, i.e. by private speculation on the public debt.

While the government first tried to legislate on a case-by-case basis regarding the funding arrangements for each construction site, it soon considered extending to the whole country the method of classification of ports that was applied in the Kingdom of Piedmont-Sardinia. This determined the level of state investment by the degree of importance of the ports. However, at any level, the central authorities had a say, which is not necessarily evidence of efficiency in the execution of the programme. Unreasoned ambition and hastiness do not go well together, especially since they can attract public works contractors who are more willing to renegotiate the conditions of public contracts to the detriment of compliance with official regulations.

The centralised state expressed itself through the development of projects and the control of the technostructure, and it was not exempt from certain controversies with local dignitaries. The Neapolitan case is an emblematic example. To what had once been a capital city, the State promised a prosperous economic future with port works that had not been carried out under the Bourbons, and that would happen in an attempt to legitimise effort. However, representatives of the southern left, such as De Sanctis and Settembrini, were outraged at the lack of consultation, which might lead to a poorly developed project and a waste of public funds. Yet articles published in their newspaper *L'Italia* were

perhaps too devoted to political arguments. Indeed, in the same year, despite the early investments, site problems arose during the preparatory works and led to the failure of initial promises.

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Experimental models in civil engineering. History, significance, perspectives

Reduced-scale models have been used for centuries by engineers when they are faced by new, unprecedented construction challenges that are beyond contemporary experience and for which there is often no adequate engineering theory available. Given the impracticality of carrying out full-scale tests on large works of engineering, experiments on small models often provided engineers with the only means by which they could develop their understanding of the engineering behaviours involved. Together with current experience, design rules and engineering science, the results of tests on reduced-scale models could be used to raise the engineers' confidence in a proposed design to a level that would allow construction to start. In particular, models have often been used to support the process of innovation in construction engineering.

This paper begins with a historical review of the use of models as design tools in civil and building engineering from ancient times to the 20th century and presents a categorisation of such models according to their function.

The authors then argue that the use of models in engineering design is of similar importance to the use of theory in engineering design and, therefore, that the historical development of models should be studied alongside the history of engineering theory. In particular, research should be undertaken to discover and record the use of models throughout history, and to identify engineering models that have survived to the present day. Such a study will provide the necessary knowledge to inform the conservation of the models and, if possible, ensure they can be put on display to advertise and celebrate their importance in construction and engineering history.

The paper concludes with a discussion of how the role played by models in engineering design can be studied, and how the part they have played in engineering progress can be better understood and more fully recognised. This would include archival researches in the various types of institution where model testing was undertaken, as well as searching museums and elsewhere for more examples of engineers' models that have survived.

A current research programme is studying some surviving measurement models, both to understand better their role in engineering design and to investigate and evaluate ways in which they may be conserved and their importance conveyed to future generations of engineers and historians, both by scholarship and their display in appropriate museums.

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The description of the construction site of the wooden dome of the Halle au Blé "à la Philibert De l'Orme" by the architect Jacques Molinos (1782-1783)

The Bibliothèque Historique de la Ville de Paris possesses an exceptional document: the detailed chronological description of the construction of the wooden dome of the Halle au Blé in Paris, built according to the method of Philibert de L'Orme, from July 1782 to January 1783. The dome is well known to architectural and construction historians. It covered the huge courtyard of the Halle au Blé built some twenty years earlier by the architect Nicolas Le Camus de Mézières (1721-1789). As soon as it was completed, the structure was considered to be a work of great "boldness" for its extraordinary dimensions, close to those of the largest domes built in Europe (120 *pieds* and 4 *pouces*, i.e. about 39 metres diameter) as well as for its construction method using planks "à la Philibert De l'Orme". Around 1780, the architects Jacques Guillaume Legrand (1743-1831) and Jacques Molinos (1753-1807) had proposed to apply to the roofing of the courtyard the process described by the Renaissance architect in his *Nouvelles inventions pour bien bastir et a petits frais* (1561). For the execution of this structure, they called upon the master joiner André Jacob Roubo (1739-1791) known at this time for his treatise on joinery published in the *Description des arts et métiers* collection.

The "Note" written by the architect Molinos is not exactly a construction site journal. To shed light on this document, the present paper recalls the political context of the construction. It examines the reasons that led the architect to write the text and the nature of the knowledge transfer between artisans and architects documented by this narrative. It ends by commenting on some tricky operations that are not described by Philibert de L'Orme and about which historians often lack information: the drawing of the *épures* (full-scale drawings traced on the spot), the lifting of the scaffolding and the erection of the lifting machines. The detailed chronology of the operations reveals a division

between design and execution that is less clear-cut than is usually thought. Solutions were found during the construction phase to solve problems that had not been anticipated. These solutions found by the contractors and sometimes the workers make the structure a collective work that it is difficult to attribute to a single designer.

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