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Transmitting Culture through Building Systems: The Case of the Tile Vault

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Abstract: Until now, the technology behind building systems has largely been neglected, and an exploration of the cultural transmission of these systems has been undervalued as a way of understanding changes in the symbolic worldview of society. This article analyses the developmental transitions in a specific building system, specifically the tile vault, as a case study that illustrates the changing values of a construction process as it has evolved, together with an understanding of the philosophy that has accompanied those changes over time. An ethnohistorical and ethnographic method has been used, enabling a longitudinal and rich analysis through time that illustrates the indissolubility of the technical issues from the prevailing social institutions of each era. These are based on a careful reading of changing conditions (environmental, social, and cultural), and of the progressive participatory appropriation which takes place through cooperative, synergistic working.

Keywords: tile vault; Catalonia; anthropology of building systems; Guastavino; cultural transmission

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Citation: Alcindor, M.; Jackson, D. Transmitting Culture through Building Systems: The Case of the Tile Vault. *Buildings* **2023**, *13*, 873. https://doi.org/10.3390/buildings13040873

Academic Editor: Davide Settembre-Blundo

Received: 14 February 2023
Revised: 19 March 2023
Accepted: 22 March 2023
Published: 27 March 2023

1. Introduction

Humans are the only animals capable of influencing their own evolution, because each day we add new nonhereditary heritage to our genetic inheritance, one capable of retroacting on the latter [1] (p. 69). Conversely, an animal's individual accumulated experience is lost for its species as a whole. With each birth, everything must begin anew. So, excepting species drift and genetic mutation, stable societies of the animal kingdom remain invariant. By contrast, humans are the only animals that can conserve traces of their ancestors' knowledge and experience, and be modified by it in turn. They invent themselves insofar as they store memory. So, heredity belongs to all living beings; inheritance belongs only to humanity [1] (p. 67). The human activity that leaves one of the most obvious traces, and that in some way unites us as a community is, without a doubt, architecture, and more specifically, architectural heritage.

Each community has principles that generate a multitude of practices. At the same time, the development of a human being (as an intentional, creative agent) takes place within a total field of organic/biological, sociocultural, psychological, and historical–political relationships, transformations which describe a dynamic process throughout their lifespan [2]. The construction of different building systems, within the context of processes and social/cultural structures in different physical environments, is shaped by cultural differences in human enculturation, through socialization, and intergenerational sharing of culturally worked content [3–5]. Therefore, traditional construction processes used in the creation of buildings over time offers a valuable basis for exploring the complex interplay between the material and the societal, and in particular, how cultural transmission works with regard to changing environments.

These changes commonly emerge from the actions of people engaging with their environments, as a part of the activities either directed or pursued by each of the participants [6]. At the same time, the conditions found in a specific environment can influence ways of

understanding and interpreting the world. For example, training in an occupation (or even socialising) represent exercises in the reasoning processes encountered when attempting to incorporate new solutions for tackling difficulties, and which end up becoming established positions in the legitimized discourse [7].

This article intends, through the study of a distinct construction process found in different contexts, to establish the relationship between the material and the social, by focusing exclusively on the traditional building system of the tile vault. Each change in a building system process allows for an understanding of the changes in the dominant values of the philosophy informing and guiding each process. This study focusses on traditional construction in order to uncover the mediated relationship between judgement, motivations, and actions over a large period of time (c.f. [8]).

The occidental cosmovision is deeply rooted in a rationalist tradition, based on a separation of the tangible and intangible, which frames and orientates conventional/particular ways of thinking and enquiry. From that awareness, it is important to be aware that other opportunities for reflection exist, and are still waiting to be explored. With this as a starting point, there are dimensions to construction processes which can only be appreciated or deeply understood through a holistic analysis, and in particular an analysis of embedded symbolic aspects and perspectives.

This symbolic perspective in analysis offers a way of understanding building systems and their life stories, economies and their networks of trust and obligation, and the co-production of people with their environments [9].

The objective of this paper is to elaborate on the symbolic knowledge associated with building systems within architecture, and to make explicit the embedded knowledge which is passed down through cultures, but which is rarely analysed. The intention is to offer a new approach to the ways in which we interpret construction techniques used in architecture. As Gaston Bachelard stated, the substance of specific materials is as much a matter of matter, as it is of individual and cultural memory. Accordingly, inventive engagements with building systems emerge out of a circular process in which specific individual and group associations with them are shaped by experience, memory, and cultural imaginaries through time and use (cited in [10]).

2. Theoretical Framework

The theoretical framework of this paper is based on reflections made by Jules Régis Debray [1] about cultural transmission. This author emphasizes the indissolution of matters considered material, such as building systems, and the immaterial, which has too often been neglected in the field of architecture. Although Debray has not specifically identified cultural transmission as a philosophical category, he has related symbolic achievements with those at the technical level [1] (p. 78), which provides an important foundational reference for the analysis used in this paper.

The difference between the human and the animal, is that the human race would have no intellectual and spiritual history if it had not first learned how to transform matter into artifacts [1] (p. 72). The human miracle consists of an ability to make materials which have meaning. This is the real achievement, when compared to animals that are surrounded only by things. In the human species, the artifact, such as a building system, is the mediation between the human and the material [11]. This is evident in architectural activity, and even more obvious when it is about heritage that represents a way of doing things in a specific period and context. Culture and technology evolve together, and are mutually dependent. In fact, heritage protection is founded on this basis.

Modern humans construct their environments at maximum anthropogenic levels. Never before have living beings constituted or shaped their environments in relation to themselves to such an extent, due to reflective recursion processes that are increasingly self-induced and complex. In fact, humans have become so techno-culturally overequipped because they are underequipped physio-anatomically and are inadequately specialized. The delayed biological maturation of Homo sapiens causes a considerable advance in com-

pensatory acculturation [1]. Human beings are not passive, but instead actively construct their environments as a generative field of actions and relationships [12], and it is in the mediation between actors and their objects (often produced through technologies) that our humanity is constituted [2,13,14].

In fact, the relative stagnation in the further evolution of our organic bodies has had, as its counterpart, an explosive and prolific extension of numerous artifacts of enablement and facilitation in the world external to the immediate human body [1], with architecture being one of the most important. The modification of the settings where relationships take place also has the effect of altering ideas. Buildings inevitably influence beliefs, behaviours, values, and the practices inherent in the fabric of the physical environment, functioning as complex objects of the extended mind [15].

As Debray [1] states, at the material-level form, transmitting is necessary to inform the tangible world by manufacturing consultable stores of externalized memory through available technologies, such as inscribing, conserving, inventorying, and distributing recorded traces of cultural expression. In architecture, these are usually conveyed through reliefs, engravings, paintings on façades, and/or other less obvious means such as the use of certain building systems. This has direct implications for one of the important ways in which people construct their individual identities, which emerges from a mixture and interaction between their place or places of residence, and their past histories. As Kirshenblatt-Gimblett states, 'heritage is continuously produced and reproduced by living persons, and their knowledge, practices, artifacts, social worlds, and life spaces' [16] (p. 73). Architectural heritage is an important way to create community and cultural continuity [17] due to the fact that heritage contributes to a sense of place by providing a rich network of references which help individuals to locate and place themselves [18].

In this process, meanings are created as the products of an endless cycle between humans and the environment [19]. A nodal point appears where organized matter and materialized organization interact [1] (p. 21), and architectural heritage becomes corporeally absorbed into our behaviour in the pre-reflexive and mechanically repetitive forms of cultural praxis. It is imposed on us in a materially objectivized form by our buildings and spaces, which have incorporated routinized networks, and compendia of meaningful signs and symbols. Both these gains—incorporated and objectified—are now virtually invisible to us [1]. Specifically, these are referred to as orientation schemata [20]. In other words, the cultural construction of space comprises not only organized space, but it also represents the spatial relationships between objects and their relative positions. Following this, the inclusion of subjects implies information about those occupying and using those spaces as well. It is not about simple associations. Instead, they consist of cultural schemata that are both structure and process—that is they combine the organization and relative disposition of the physical elements with the sequence, the approach, and the succession of elements or behaviours in relation to an end [20].

These schemata, in their material manifestation, transmute individual memory into social memory [1] (p. 69), and buildings, as material heritage, are the least uncertain means of conveying this inheritance across space and time. Buildings are not simply an addition or accessory. As Pallasmaa [21] states, architecture has become our second nature. Furthermore, inanimate matter is more reliable than organic matter, and buildings more certain than gardens, because the first last longer than the second [1]. The meaning, therefore, is not merely a subjective mental phenomenon, but is objective instead, in the sense that it involves activity [22]. In fact, any given culture is first of all a distinct technological culture, and a person of any specific period is related to their preferred toolkit of accoutrements for influencing people and decisions. So, it is important to analyse current and emerging trends, and use this knowledge to educate accordingly. Every major reshuffling of technologies means a corresponding change in saddle for the citizenry [1] (p. 23).

Through architecture, materialized organization (such as an institutions) can lay out communitarian arrangements, namely, all those diverse forms of group cohesion that bring together the human agents of a given transmission. In sum, the art of transmission through

architecture consists of adding a strategy to logistics, a praxis to a techne, or establishing an institutional home and engineering a lexicon of signs and symbols [1] (p. 13). Paradoxically, because heritage is a fetishized memory of material forms, its facticity causes us to overlook the origins of how and why it was built in the first place [1] (p. 14).

In the next section, an analysis of the evolution of the construction processes of the tile vault, together with its generational transmission process, will be undertaken in order to give substance to the issues discussed so far. The aim of this analysis is to illustrate the indissolubility of the technical issues from the social institutions of each era. Since construction techniques emerge from certain conditions, with differentiated access to resources throughout different periods, they demonstrate how those changes modify the techniques in order to maintain the visual lexicon of signs and symbols with which this system was identified. An outcome of this is that as institutions undergo cultural change, they provoke changes in the culture of architectural construction. By undertaking an analysis of the symbolic dimensions, a reconstruction of the totality of relationships between agents is sought, together with the changing forms of social life over time and their products, and the establishment of a framework that allows for us to understand the relationship between changes in a particular construction system, the tile vault. As those engaged in building and construction are also rooted in the traditions and heritage of the places they live, they are also influenced unconsciously by the wider cultural values of their communities, so the use of a reductionist analysis of materials, forms, and techniques misses the symbolic value and meanings those forms possess, and the influence of these on decision-making by those engaged in the building process [9].

3. Methodology

The research paradigm used has been interpretivist, conscious that the patterns (and associated data) sought and found in interpretations of social reality are not immutable, or 'laws' in the sense given to them by positivist sociology. As there is no separation between the observer and the reality being studied, knowledge is produced from understanding. In other words, the key points of this research consist of situating itself in the perspective of all the participants in the construction process, the importance of the context, and the holistic and processual evaluation of the object of study, renouncing the imposition of closed hypotheses from the outset [23] by pursuing an inductive path of investigation. Therefore, an in-depth analysis and study of the symbolic dimension has been favoured over simply parsing quantitative data, providing a new filter for understanding not only the technical approach used in the tile vault building system, but also the forces influencing construction technology more generally as well.

The nature of this study does not attempt to be conclusive. Instead, it seeks to explore and discuss ideas for progressing the academic study of systemic cultural transmission, and the need to study building systems from a social perspective. For this reason, the anthropology of building systems has been the focus, and an interpretivist paradigm appropriate to the nature of the subject has been used, coupled with a qualitative methodology. Identifying shifting conditions through different periods has required an exploration of the relationships between communities, building systems, and social change. This is most accurately achieved (according to [24]) by means of the ethnographic and ethnohistorical methods, because they help to identify complex transformations and changes occurring collectively with regard to human–environmental engagement, and to identity. Specifically, the search for these findings was made using a comparative analysis of tile vault construction processes in order to highlight and demonstrate the "embedding" of constructive action in networks of interpersonal connections and, in particular, cultural conditions [7]. Through the use of ethnography, it attempts to address the complexities involved by studying relationships between micro-level behaviours and macro-level phenomena.

The ethnographic field research draws data from a variety of sources. These include 65 semi-structured interviews which were conducted with relevant agents in the context of refurbishment and restoration, specifically with 21 builders, 28 architects, and 16 materials

distributors, bricklayers/masons, and other building professionals in Catalonia (Table 1). The criterion used for conducting the interviews was the 'saturation of the sample', with interviews conducted until the answers became repetitive. This was accompanied by a survey of the available literature, through the collection and study of books featuring the different processes of tile vault construction.

Table 1. Profile of the participants.

Participant IDs	Gender	Profession	Participant IDs	Gender	Profession
01-J. Batet	Male	Architect	33-J. Miàs	Male	Builder
02-O. Roselló	Male	Architect	34-R. Artal	Male	Architect
03-J. Casademont	Male	Builder	35-J. Fabrellas	Male	Architect
04-A. Ylla	Male	Architect	36-A. Batllori	Male	Architect
05-J. Guardia	Male	Builder	37-J. Soler	Male	Builder
06-D. Rusca	Male	Architect	38-E. Ribot	Male	Developer
07-J. L. Frigola	Male	Architect	39-M. Pagès	Male	Architect
08-J. Fornaguera	Male	Builder	40-J. Batlló	Male	Builder
09-J. Vidal	Male	Architect	41-S. Trias	Female	Architect
10-A. Reca	Male	Builder	42-J. Orpina	Male	Builder
11-S. Figuerola	Male	Architect	43-S. Falgàs	Male	Council architect
12-F. Batlle	Male	Architect	44-M. Oliveras	Male	Timber distributor Stone dealer
13-S. López	Male	Builder	45-L. Balliu	Male	Historian
14-J. Fusté	Male	Builder	46-J. Llinàs	Male	Geologist
15-I. Masia	Male	Architect	47-J. Ferrer	Male	Architect
16-J. Alsina	Male	Architect	48-J. Fuses	Male	Lime producer
17-F. Prats	Male	Architect	49-J. L. Zorilla	Male	Mason
18-A. Enea	Male	Builder	50-A. Vila	Male	Owner factory
19-P. de Prada	Male	Architect	51-Name Unknown	Male	Carpenter
20-F. Baltasar	Male	Builder	52-M. Quintana	Male	Architect
21-J.M. Ramos	Male	Architect	53-G. Barbeta	Male	Material vendor
22-A. Herrera	Male	Builder	54-J. Hugas	Male	Material vendor
23-E. Luque	Female	Architect	55-F. Ruiz	Male	Mining engineer
24-F. Jordi	Male	Builder	56-J. Comalada	Male	Architect
25-L. Hontangas	Male	Architect	57-A. Chust	Female	Builder
26-J. Ferrer	Male	Builder	58-J. Figueres	Male	Builder
27-F. Bonastre	Male	Architect	59-M. Saló	Male	Builder
28-C. Plana	Male	Architect	60-J. Arnau	Male	Builder
29-L. Auquer	Male	Architect	61-J. Massot	Male	Builder
30-C. Maragall	Female	Architect	62-E. Ribot	Male	Arch. Professor
31-D. Lizarritiburry	Male	Designer	63-J. R. Rosell	Male	Insurance technician
32-F. del Pozo	Male	Architect	64-J. Arjona	Male	Carpenter
			65-E. Minguillon	Male	

Another essential part of this study included the in situ observation of current projects (some completed, and others underway), which provided another mode of documentary analysis (with a relevant architectonic element) in which the object of analysis was the building itself. A total of 44 construction sites were visited in this research (Table 2).

Finally, the extensive experience of the lead author is also relevant, having worked as an architect who has participated in the management of 25 restoration and refurbishment projects. This professional experience has provided her with an intimate knowledge of how agents work, such as local developers and builders, while enabling a deeper investigation of the complexity of the construction solutions commonly used in refurbishment, and the use of traditional techniques.

This provides the foundation for the 'participant observation', which is the main anthropological technique used in this study, and provides empirical material aimed at recording social practices, which can then be subjected to analysis [25].

The complementary nature of the various research techniques used must also be stressed. The search for connections between the architects' designs, the words of the various agents, and the reality that can be seen in the finished works (and in particular, the ensemble of constructive processes that explains those connections) has been of central importance.

Table 2. Construction site cases.

Case IDs	Municipality	Built-Up Area	Case IDs	Municipality	Built-up Area
1	Albons	46,070 m^2	23	Jafre	36,569 m^2
2	Albons	50,960 m^2	24	Palau-Sator	22,248 m^2
3	Bellcaire d'Empordà	28,180 m^2	25	Palau-Sator	36,495 m^2
4	Colomers	25,813 m^2	26	S. Feliu Boada	26,100 m^2
5	Corça	23,155 m^2	27	Parlavà	54,692 m^2
6	Corça	28,367 m^2	28	Parlavà	21,615 m^2
7	S. Sadurní l'Heura	23,625 m^2	29	La Pera	50,904 m^2
8	S. Sadurní l'Heura	49,515 m^2	30	La Pera	52,080 m^2
9	Cruïlles	31,619 m^2	31	Regencós	27,170 m^2
10	Cruïlles	48,336 m^2	32	Rupià	122,228 m^2
11	Monells	170,955 m^2	33	Rupià	41,600 m^2
12	Cruïlles	68,204 m^2	34	Rupià	33,770 m^2
13	Foixà	25,806 m^2	35	Serra de Daró	35,970 m^2
14	Foixà	30,510 m^2	36	Marenyà	32,785 m^2
15	Fontanilles	21,520 m^2	37	Torrent	37,800 m^2
16	Fontanilles	28,480 m^2	38	Ullà	21,239 m^2
17	Forallac	91,332 m^2	39	Ullà	42,700 m^2
18	Forallac	49,039 m^2	40	Ultramort	39,378 m^2
19	Vullpellac	45,000 m^2	41	Verges	26,495 m^2
20	Forallac	0	42	Verges	46,090 m^2
21	Forallac	40,350 m^2	43	Vilopriu	22,320 m^2
22	Garrigoles	42,550 m^2	44	Vall-Llobrega	67,907 m^2

4. Discussion

4.1. The Tile Vault in Roman Times

For understanding the emergence of the tile vault construction system, one must begin with the studies carried out by J.P. Adam. This author states that its origins were due to the constraints and opportunities found in the material environment, and that the technology used reflected a past where the horizontal transport of raw materials was not feasible on a large scale [26]. Traditional construction techniques emerge from an active and dialectic interrelation between ecological and cultural factors, and this building system is a historical one found across different regions of the Mediterranean.

Historically, one of the most important techniques used to cover large spaces has been the barrel vault. This consists of a sum of voussoir arches, which only support themselves once the placement of all the pieces has been completed. It is therefore necessary to use an auxiliary structure, a formwork (falsework), usually constructed of wood, to support the pieces in the construction phase until the arch is completed. This formwork must have the same curvature as the arch or barrel vault to be built. It must also be strong enough to support the weight of the voussoirs [27]. Over time, the more expensive, slower, and rigid formworks were replaced by integral formworks made of tile, until finally the use of simpler and cheaper Opus Caementicium (known as Roman concrete vaults), became widespread.

The formworks for these required sufficiently rigid surfaces able to support the weight of the liquid concrete until it set, and the vault became self-supporting. In addition, it was also necessary to ensure the subsequent removal of the formwork, i.e., to ensure that the formwork could be separated without causing significant damage to the vault.

At the beginning, these formworks were built with timber, supported by use of props, and separated by the length of the large ceramic slabs that defined the first leaf of the vault (0.60 × 0.60 m). On top of these ceramic slabs, a layer of mortar was placed, followed by a thinner sheet of ceramic tile bricks, on which a series of edge position bricks were also placed in order to guarantee the tying together of the tile vault and the final poured mass concrete layer. In those environments where it was not easy to obtain timber, the first two steps in the formation of the formwork were eliminated, and only the layer of thinner bricks was used [26] (Figure 1). This was the birth of the tile vault as an auxiliary structure, which would later emerge as a new building system.

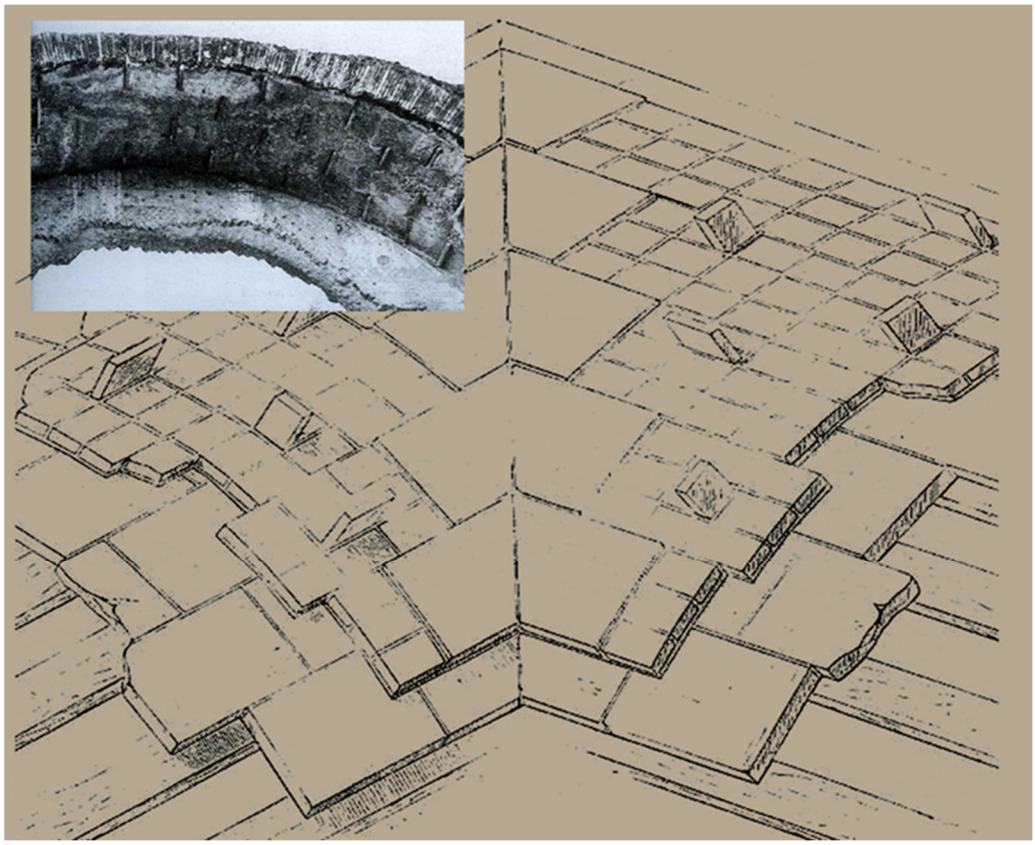

Figure 1. Illustration from Adam's book (2005). Framing scheme using bricks in a groin vault.

4.2. The Traditional Tile Vault

From this point onwards, it becomes possible to analyse how subsequent changes in the building process also reflect cultural changes within institutions, which in turn provoke changes within the culture of architectural construction.

The traditional construction processes used until the beginning of the 20th century are documented not only in historical construction manuals, but also through oral history, as it was in this century that the main changes occurred. This enables the introduction and consideration of first-person recollections from the recent past as an invaluable source of information.

This particular building system covers spaces using materials with low resistance to tensile stresses (ceramic bricks and tiles), by means of a curved arrangement of unit pieces which allow for them to work in compression. It should not be forgotten that in pre-industrial times, the only existing material capable of responding to these tensile stresses was wood. Therefore, in those areas where wood was not an abundant or easily accessible resource, or of poor quality, the use and perpetuation of the tile vault was encouraged. Its use had great advantages since, if the builder was skilled, it did not require any type of formwork, and only in the most complex cases would a template or mobile formwork be

used. It was also light in relation to its load-bearing capacity, which avoided the need for excessively thick walls (to support the horizontal forces and tile arches to transmit), and was unlimited in its capacity to cover irregularly shaped spaces.

As a general rule, the tile vault was characterized by three defining features: construction without use of a supporting formwork, the use of gypsum paste as a binding material, and the use of brick. The execution of the first layer was the most delicate phase, as it required greater skill on the part of the builder due to the rapid setting of the gypsum used as a binding material. This rapid hardening of the gypsum paste, together with the light weight of the tiles used, was of vital importance, as it was these which made it possible to dispense with a supporting formwork. Once the first layer was finished, it was reinforced with successive layers of tile [28] (Figure 2).

Figure 2. Illustration of Truñó's book (2004). Traditional process of execution of a tile vault.

Over time, in certain areas (such as Catalonia), this construction system acquired an identity value, where the familiarity of the forms and images of this distinctive building system generates feelings of trust and 'ontological security', that is, they maintain confidence in the continuity of the past, present, and future, connecting that trust with routine social practices [6,15,29,30].

This system became widely used by different architects at the beginning of the 20th century, who appreciated both the structural virtues and its aesthetic qualities. This led to new variants of the traditional model, where the construction technique was consciously left exposed, with care taken over the placement of the visible pieces used in the final layer, rather than hiding this behind plaster or render. Later, an interest in tile vaults was again reignited during and after WWII [31–34], when the speed and economy of the system led to its renewed appreciation within the context of material shortages of iron, wood, and cement.

4.3. The Tile Vault from the End of the 19th Century, to the Beginning of the 20th Century

The case of the vaults of the Sant Pau Hospital: Domènech i Montaner, the architect, has bequeathed a noteworthy example of a variant of the traditional vaulted ceiling, which he used on the first floor of an administration building built around 1906–1907. His aim in using a traditional tile vault was to achieve significant aesthetic effects, so the exposed layer took on a role that went beyond the structural one. The vault section consisted of an exposed layer of 1.2 cm-thick glazed tiles, two layers of 1.5 cm brick, and a final layer of bricks of 3.5 cm. The first layer to be executed was one of the two layers of 1.5 cm, cemented with plaster in the traditional way, and the subsequent upper layers with an air lime mortar. The layer which remained visible from below, however, was executed later, with pieces

glued to the underside of the vault after it was finished, with tiles chosen and arranged for their aesthetic effect (Figure 3). In effect, this represented an important change and reversal in the construction process, with what had traditionally been the first layer being finished last, due exclusively to adaptation to changing aesthetic values, connected inextricably to social identities.

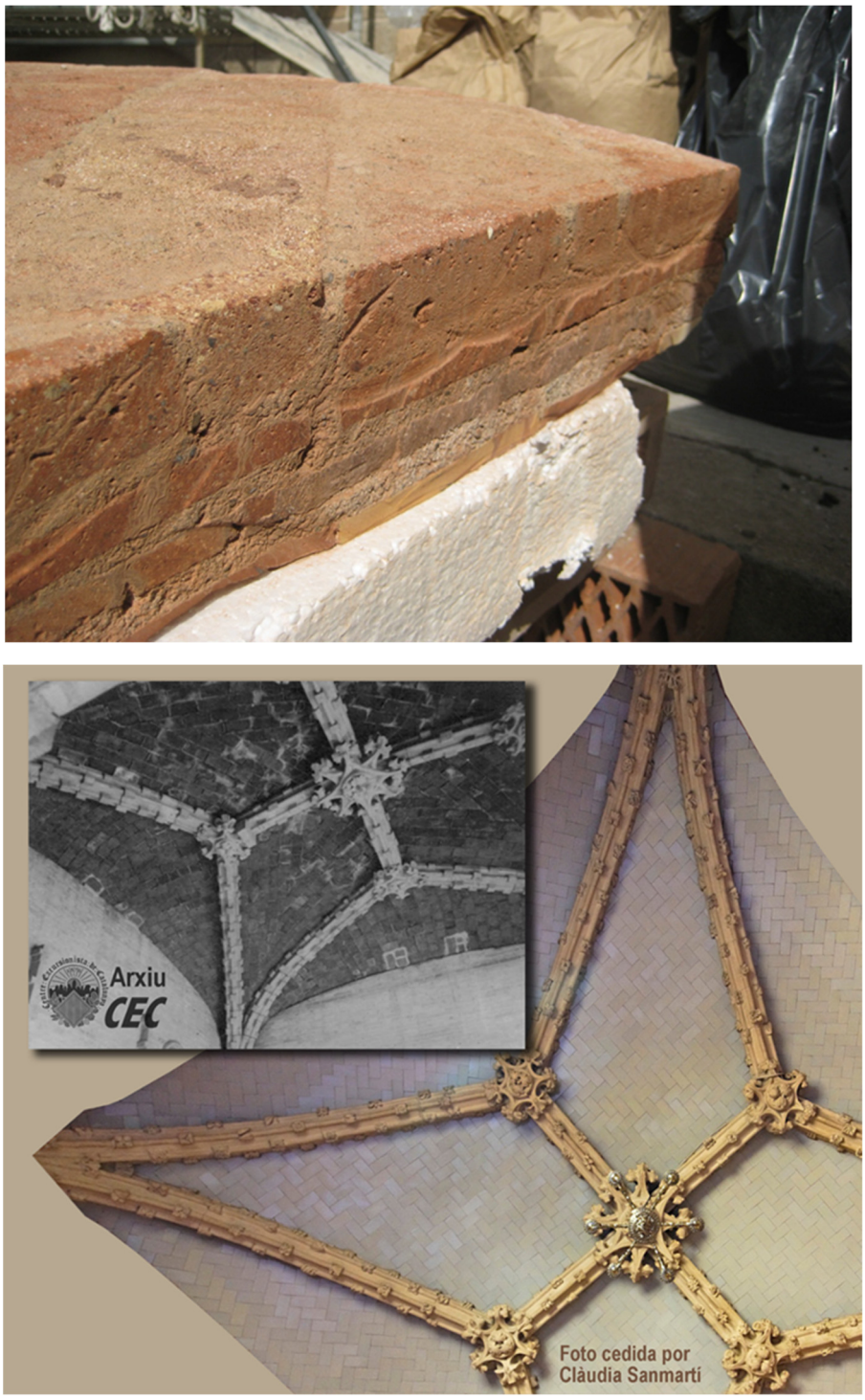

Figure 3. Illustrating the construction layers of the entrance vault of Sant Pau Hospital in Barcelona (**above**) and the finished tile vault (**below**). c. Cláudia Sanmartí.

Guastavino's vaults: Other unique examples from outside the Mediterranean region are the vaults built by the architect Rafael Guastavino in the USA [35]. This building

system was able to compete economically with other construction methods of the period, anticipating and fulfilling the needs of architects in the USA at that time. Guastavino successfully demonstrated the advantages of this system, which included fire resistance, soundproofing, hygienic finishes, speed of execution, and decorative effects, all of which lent themselves to the requirements of the American society at that time [36] (Figure 4).

The vaults built by Guastavino's company adopted the same approach as those of the Hospital de Sant Pau, in that the ceramic layer that was seen from the inside was designed and constructed for aesthetic purposes. The process of execution was also the same; however, the second layers of tile and brick were bound with Portland cement mortar instead, which reduced the risks of the hygroscopicity of the plaster and ensured the stability of the system. The lower, visible (aesthetic) layer was completed last, glued and embellished from below (also with Portland cement mortar [36]), with an appreciation and enhancement of the visible joints also becoming a feature for careful consideration. As in the previous case, these modifications to the construction processes were not motivated by purely technological reasons, but by aesthetic considerations, and by the identity value and meanings which tile vaults had come to represent.

This building system took on force beyond the fundamental matrix of economic, institutional, and technological advantages, because it managed to adapt to the prevailing systems of governance tied to capitalism (which had become hegemonic by the end of the 19th century), and its production of symbolic goods. These provide clear ethnographic vignettes of how cultural transmission through architecture consists of adding a strategy to logistics, and by establishing an engineered lexicon of signs and symbols.

4.4. The Tile Vault in Late Modernity

Nowadays, the variables that led to opting for a certain way of solving construction needs have changed, and what in the middle of the 20th century was an advantage that consolidated and perpetuated a certain system is no longer effective. The changes appear in two ways—on the one hand, as the economy operates at much larger scales, access to materials is no longer a limitation. On the other, the cultural environment in which these vaults were built has also changed enormously. Construction processes and systems are no longer reliant on the old order of a traditional society based on the know-how and experience of individual workers, but instead upon administrative regulations, business, and technical convenience. *'Poques companies (asseguradores) accepten aquests tipus d'intervencions perquè... no volen, saben que tenen un altre mercat més segur i es desvien cap a aquest (altre).' 'Les asseguradores no volen tenir riscos, han de ser mínims'.* (ID 64)

'Few business companies accept these kinds of interventions because... they don't want to, they know they have another safer market and they're moving to this (other one).' 'Insurers do not want risks, these must be minimalised'. (ID 64)

New processes have been established cotemporally, however:

A. Vaults built without formwork (in the traditional way), but instead of using a traditional gypsum paste; the bonding material used for this layer has been replaced with quick-setting cement. This avoids the risks associated with the hygroscopicity of plaster, where a significant increase in humidity can create an increase in volume and a loss of strength, leading to destabilization and possible collapse. This risk disappears with the use of quick-setting cement, even if the atmosphere is humid. The use of gypsum plaster also requires more experienced workers as it must be carried out quickly to avoid wasting material, and becomes unusable in a very short space of time. Again, the use of quick-setting cement avoids these issues, even if the execution time takes a little longer.

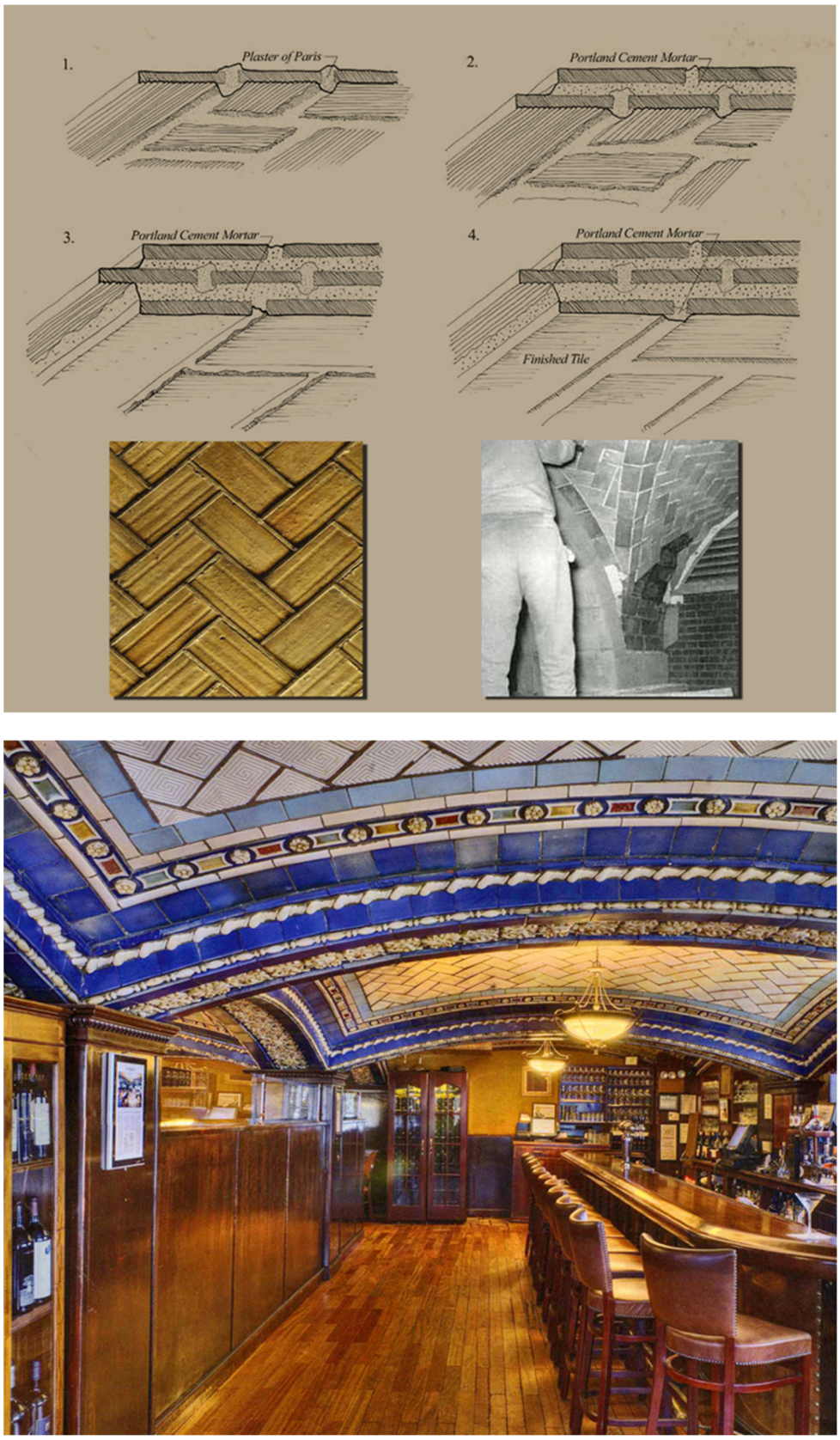

Figure 4. Illustrations from 'Guastavino vaulting: the art of structural tile' by Ochsendorf (2010), illustrating the Guastavino process of constructing a tile vault (**above**) and the finished tile vault (**below**).

When the first layer has been made, instead of adding a second layer of thin brick or tile, a reinforced compression layer is created using poured concrete. It is this layer which performs a structural function, rendering the initial layer structurally obsolete, retained instead for aesthetic purposes, or as a surface to which decorative tiles can be added from below using a cement glue.

'Abans ho feien tot manual, ara ja no es fa així . . . , fent la primera capa amb rajoles de 50 × 20 i després es forra per sota amb un ciment cola especial que la poses bé i ja se t'aguanta i . . . et queden molt maques aquestes voltes!' (ID 60)

In the past they did everything manually, now they don't do it like this . . . , making the first layer with 50 × 20 tiles and then coating underneath with a special cement that you apply and which adheres straight away . . . these vaults look very nice!' (ID 60)

In this variation in the traditional construction process, the first layer loses its original structural function, and instead becomes a simple formwork, but one which cannot be reused. This adaptation allows for us to perceive the bureaucratization of society, where the success of a construction system is no longer reliant on the acquired skills of craftspeople and builders, and is instead shifted to systems and builders without these skills—changes initialized by a society which is itself characterized by techno-economic globalization processes, since culture and technology evolve together as a generative field of relationships and actions. Precepts of the maximized efficiency of modernity have given way to standardized methods of construction, where there is no place for traditional building systems [37].

B. Another of the variations has been the reintroduction of wooden formworks. In the past, the necessary building materials were a scarce resource, and therefore, the tendency was to optimize them, which required the learning of techniques that dispensed with the need for auxiliary structures. Nowadays, this has changed, and an increase in the materials used is less significant. This is emphasized by the loss of mastery in the execution of the traditional construction techniques, which means that to build the same style of vault, mobile or stationary/fixed wooden formworks are being used once again (Figure 5). These allow for the vault to be easily assembled, and thus control the stereotomy of the layer which will be seen from below. This represents a slow but continuous process of substituting traditional masons who use highly skilled artisanal methods, for less skilled or specialised modern masons who are adept at using industrial building techniques, who can adapt and change their occupation in increasingly flexible labour markets [38]. Rationality systems that have governed society since the mid-20th century continually attempt to gain control over uncertainties, especially those created by the people who deal with or who use those systems [39].

In this case, the loss of craft is evident, as the transmission of the execution of these techniques is disappearing from the "discourse", in the same way as if adult cyclists began using training wheels again.

'Eran trabajadores extranjeros que no dominaban la técnica, pero el coste del material auxiliar no supuso un impedimento para compensar la falta de conocimiento' (ID 02)

'They were foreign workers who did not master the technique, but the cost of auxiliary equipment was not an impediment to compensate for the lack of knowledge.' (ID 02)

C. Other ways of proceeding are mixed solutions to those mentioned so far. The soffit layer (which provides the viewable surface) is laid out using the desired stereotomy. Subsequently, a layer of mortar made using Portland cement is applied, followed by another layer of ceramic tiles or bricks, and so on successively, taking care to overlap the pieces to ensure that joints do not line up between one layer and the next. When the entire space has been covered, the formwork is removed, and the layer which is intended to be visible is completed from underneath the vault (Figure 6).

Figure 5. Contemporary process of execution of a tile vault.

Figure 6. Contemporary process of execution of a tile vault. c. Gabriel Barbeta.

In this method of execution, the lightness of the tile and brick is no longer fundamental, as the aim is not to ensure the rapid stability of the vault, since it is supported on the formwork until the binding mortar is working and set. This illustrates how the internalisation of the use of expert systems is produced through a slow and accretive process, which not only gradually changes the ways in which structural materials are used, but also the traditional or local knowledge associated with vernacular building practices [38].

Neoliberalism is a key-concept to help understand these changes, providing useful insights into the current era. The structuring and shaping of the field of possible action of subjects through a heterogeneous array of regulatory practices and instruction ultimately ends with modifying the capacity of "autonomous" individuals [40]. For example, the construction of tile vaults in Catalonia using traditional techniques is no longer possible, not because of a lack of skills and knowledge amongst builders, or a lack of desire from clients and architects, but because it is very difficult to be insured for these techniques. An insurance company´s lack of knowledge and aversion to risk becomes a barrier which tradition cannot overcome, and so a living tradition dies in a region where it is still culturally valued, replaced with a facsimile instead.

5. Final Considerations

This research represents a preliminary phase of quantitative research without external validity, since, given the complicated nature of many of the situations that take place in this field, it serves to decipher which aspects and variables should be studied in greater depth in subsequent quantitative studies.

Through the types of relationships established in the various construction systems, and thanks to an unusual degree of solidarity between practitioners at different levels of ability and knowledge, the analyses of the processes involved in tile vaults also allow for the values of each period studied to be identified and captured.

At the same time, it reveals how cultural transmission adapts to—and is reshaped by—the dynamics of the processes involved. These include, for example, the development of activities and working practices, as well as the formation (and transformation) of sociotechnical arrangements.

These are based on a careful reading of changing conditions (environmental, social, and cultural), and of the progressive participatory appropriation which takes place through synergistic, cooperative working [7]. The intention of this paper has been to address the anthropology of building systems and processes which are 'embedded' in networks of interpersonal and cultural connections [7]. Namely, it has attempted to highlight that behind the evolution of the tile vault, there exists a cultural context which values the historic forms produced, while at the same time making it difficult or impossible to maintain the traditional construction techniques used to create them.

Beginning from origins based on a structural capacity to efficiently cover spaces using materials with a low resistance to tensile stresses, an appreciation of the system evolved which also valued its aesthetic qualities. This led directly to changes in construction processes and finishes, and the cultural meanings associated with tile vaults. These processes (and the cultural environments in which they were produced) were then further transformed by the neoliberal values which emerged in the 20th century. The load-bearing capacity of the construction system became a secondary consideration, replaced instead with a desire to produce forms evocative of social identity in the most efficient and simplest ways possible. Thus, the necessary skills of the builder were diminished, and the modes of vernacular construction systems were diluted or erased entirely, as neoliberal practices penetrated even to the heart of the most local level [40].

Building systems can also act as vehicles for the dreams, styles, values, and the self-image of a period, since as Bruno Latour [41] and others [42] have shown, there is no discrete technological object purely and totally inhuman, or reducible to a purely instrumental neutrality. Until now, however, the social analysis of technology behind building systems has largely been neglected, and the cultural transmission of these systems has been largely ignored. This should be redressed, as these can provide a valuable way to help understand changes in the worldview of society and offer new areas and ways of exploring how cultural transmission works in regard to changing environments.

Author Contributions: Conceptualization, M.A.; methodology, M.A.; analysis, M.A. and D.J.; investigation, M.A.; writing—original draft preparation, M.A. and D.J.; writing—review and editing, D.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: No new data were created.

Conflicts of Interest: The authors declare no conflict of interest.

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