# Leaving No Maker Behind: Cultures of Tile Vault Making for Situated Design

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**Abstract**

Although recent calls in digital fabrication acknowledge local construction methods, the "local" in this framework is either a passive recipient of technological tools or a passive source of inspiration. The difference between high- and low-tech is much more than switching from robots to hand-making, as the two domains represent equal (but almost contradictory) modes of imagination, planning and decision-making This paper aims to reflect on the possible contribution of architectural practice and technologies to support vernacular building crafts. It reflects on four experimental case studies of tile vaults made in collaboration between the master vault makers and an architect to push the technique towards new applications and approaches to resourceful construction. The paper shows that the link between architectural practice and local building crafts is a threefold dialogue. First, designers should engage with the complexity of craft by illustrating its processes, not products. Second, designers should work with local building crafts communities beyond formal institutional channels. Third, designers should include vernacular knowledge in the current research on manufacturing and prefabricating replicable low-carbon building components. These threefolds can be translated to methods to engage socially and environmentally with local materials and knowledge. "Leaving no maker behind" acknowledges the overlooked human dimension of local construction: working directly with makers.

**Keywords**

Building crafts · Tile vaulting · Vernacular architecture · Low-carbon construction · Experimental pavilions

## 1 Introduction: On Withoutcisim in Architectural Praxis

Construction is one of the most environmentally extractive activities. It accounts for 40% of global energy consumption, 38% of greenhouse gas emissions, and 40% of waste generation (UNEP 2021). The increasing requestioning of 'how we build resourcefully under climate emergency' has fuelled two strands of critique. The first seeks to introduce digital tools, smart applications and data-driven planning into design and construction (Agustí-Juan and Habert 2017; Beorkrem 2017). The second emphasises the role of vernacular knowledge, sometimes called 'indigenous', 'situated' or 'traditional', that relies on local materials and building skills (Sayigh 2019;

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Watson 2019). However, relatively little has been said about the relationship between the two.

This paper aims to reflect on the shared terrain between these two domains: the vernacular and the technological. We explore experimental and collaborative projects of tile vaults—a craft that incorporates design and engineering to make structural building elements (Collins 1968). The article starts by introducing tile vaulting as a vernacular technique that both outlived and co-lived with industrial construction for its efficiency and resourcefulness. These features are then examined in four case studies of collaboration between an architect and a vault master. After reflecting on these case studies, the article concludes with a methodological framework on ‘how to work with local crafts?’ through three sets of activities: (1) modelling existing processes of vernacular making, (2) collaborating with the crafts community within and outside formal and institutional structures and (3) working with artisans to develop replicable building components.

Since the establishment of architectural design as a modern profession, its relationship with other forms of making outside its recognised circles has been a space of tension and ambiguity. Between dismissing or patronising how non-architects build, studies of architectural theory and history understood architecture by the presence or absence of the centralised design agent—*with* or *without* architects (Rudofsky 1964). Under this self-centred framework, design studies coined multiple terms such as adhocism (Jencks and Silver 2013), design-in-use, unintentional or unselfconscious design (Alexander 1964) for describing the alteration or creation of the built environment beyond the formal architectural profession (Kuijer et al. 2017). This *withoutcisim* to define the vernacular and indigenous built environment represents a twofold problem in architecture praxis. The first is limiting design thinking to a ‘single mode of processes’, where steps and procedures of illustrating the building to its finest details precede its construction. The second is limiting design operations to a ‘single mode of agency’ where such illustrations are conditioned with verification procedures that are complexified and regulated through institutional channels. This twofold problem has led to limiting the creation of building components to a list of studied, tested and verified elements. It, therefore, pushed for an architecture that, due to its strict systematisation, excludes forms of building that are more open to adopting local conditions, materials and knowledge.

This is changing now. With the urgency to rethink how architecture can rethink its resources, emerging environmental approaches call for engaging with indigenous and vernacular architecture which are tied with the notion of local materials and techniques. However, with the excitement to link the high-tech and low-tech in construction cultures, there is a lot to examine on how such bridging culturally, socially and economically impacts both design and craft communities. Therefore, the question of ‘how can we **learn from** indigenous or local knowledge of making?’ is not enough because it treats such knowledge as static sources for a one-way understanding of learning. It limits the exchange to extrapolating modes from craft to architecture and deprives architects and local makers of a fruitful discussion on the future of both professions. The question, therefore, is how can we **work with** indigenous or local knowledge of making?

## 2 Methodology: Building in Conversation

Tile vaulting, also called Catalan, Timbrel and Guastavino vaulting, is a Mediterranean technique of laminated vaults (Fig. 1). This method uses lightweight terracotta tiles and fast-setting mortar such as plaster of Paris or rapid cement (Collins 1968; Huerta 2003). After finishing one layer of tiles with the fast-setting mortar, it serves as the formwork for subsequent layers, infill or lime concrete, or ribs that converts the thin shells into floor systems for multistorey building (Ochsendorf 2014).

Tile vaulting is associated with resourceful building techniques. First, by being a vault, it relies on geometry, not materials, to gain its

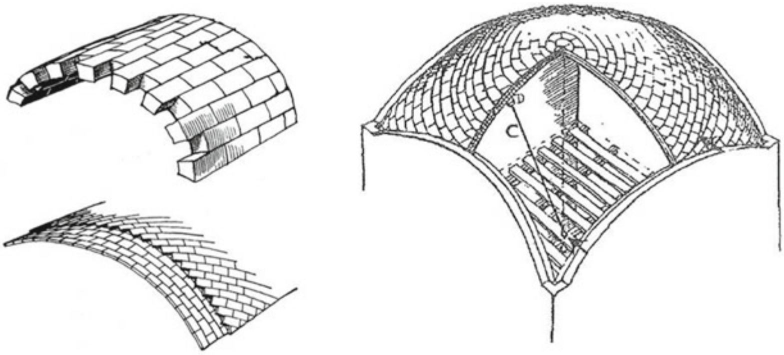


**Fig. 1** Three types of vaults—clockwise, from top left: conventional stone, tiled dome and tiled vault. Luis Moya Blanco 1947

strength. This method leads to minimum use of steel and concrete, especially when constructing floor systems in multistorey buildings where a concrete slab has the highest carbon footprint among other building elements (Jayasinghe et al. 2022). Second, tile vaulting uses minimum formwork and relies on a builder's skill guided with light structures known as guidework. As an architectural element, it interlaces many aspects. It strongly connects with tacit knowledge, inherited from being a craft first and foremost, and structural design governed by rules of gravity. Approaching tile vaulting for contemporary application engages with both craft and structural design (Davis and Block 2012; Ramage et al. 2019; López et al. 2019).

The traditional knowledge of tile vaults could survive standardised construction. With the wide use of standardised reinforced concrete construction, formal architectural practice pronounced tile vaulting nearly dead in the 1950s (Truñoi Rusiñol et al. 2004, p. 4). However, this vernacular technique was kept alive thanks to the masters who specialised in building vaulted stairs (Al Asali 2016). Because they are faster to build than reinforced concrete stairs, vaulted stairs were, and are still, favoured in Spain in multistorey housing buildings.

Tile vaulted stairs have never been studied within building regulations. It is approved by empirical load testing after it is built. Further, while architects draw stairs in their layouts, their drawings are more figurative and approximative for building masters to rearrange the design on site before construction. It can be stated then that what was lost was not tile vaulting technique but its relationship with structural and architectural design. To restore this relationship with the recent attention to this resourceful technique, the role of these tile stairs master builders was crucial in training others to build tile vaults, contributing to new vaulted projects, and building several expressive structures in architectural exhibitions.

A snippet of these roles will be shown in the following four collaborative projects of tile vaulting. We will examine how to work with local craft by reflecting on design-build examples and architectural projects developed as part of a 5-year collaboration between an architect researcher and a master builder of tile vaulting. The experiments have been developed through small-scale commissions or self-funded initiatives. Each experiment had to respond to specific questions about the role of structural craft in contemporary construction, which includes vault prefabrication, developing tools for in situ form-finding, co-designing of shells and using accessible modelling technologies with vaulting craft. The analysis forms the experiment was based on notes, records of discussions and noting the development of the designed element in the experiment. Co-making as a methodological approach proved very useful in researching architecture and building crafts. Given the limited scale and scope of the experiment, they do not necessarily represent the complexity and intricacy usually found in the practice of architecture. However, learnings from them can be extrapolated into actionable strategies that can hopefully be explored in future research.

## 3 Results: Four Case Studies of Tile Vault Experiments

### 3.1 Fabricarte: Altering Sequences for Shells Manufacturing

In 2018, we were invited to design a pavilion for a project during the annual Expo of Spanish Ceramics (Cevisama), coordinated by the Instituto de Tecnologia Ceramica (ITC) and curated by the Asociación Española de Fabricantes de Azulejos y Pavimentos Cerámicos (ASCER). We proposed to make a walk-through pavilion that celebrates the craft of structural tile vaulting in Spain, inspired by late-gothic vaulting in Valencia's 13-fifteenth centuries. The pavilion FabricArte's is based on a groin vault composition resulting in a shell that changes from flat systems of shallow slabs to a full-height expressive vault (Fig. 2).

Expo regulations permit 2 weeks for transportation of materials, onsite construction, and preparation for the exhibition. This period did not allow for the designed 7.5 m walk-through structure to be built. The challenge prompted a new experiment in tile vaulting, in which vaults were constructed in a workshop, sliced, transferred to the site, and reassembled for the exhibition. Repetition and modularity were central to the design, where two moulds only of quarters of the vaults can generate the entire pavilion. The slices in each quarter were made to avoid linear horizontal cuts and maintain interlocking joints between the pieces (Fig. 3). The calculations of the cuts were studied based on the height and weight of parts to keep the manufacturing process manageable without machinery, each piece was calculated to be held by two workers on the ground (maximum of 120 kg) or one person on a scaffold (maximum of 50 kg). The structural analysis of the vault was made using graphic

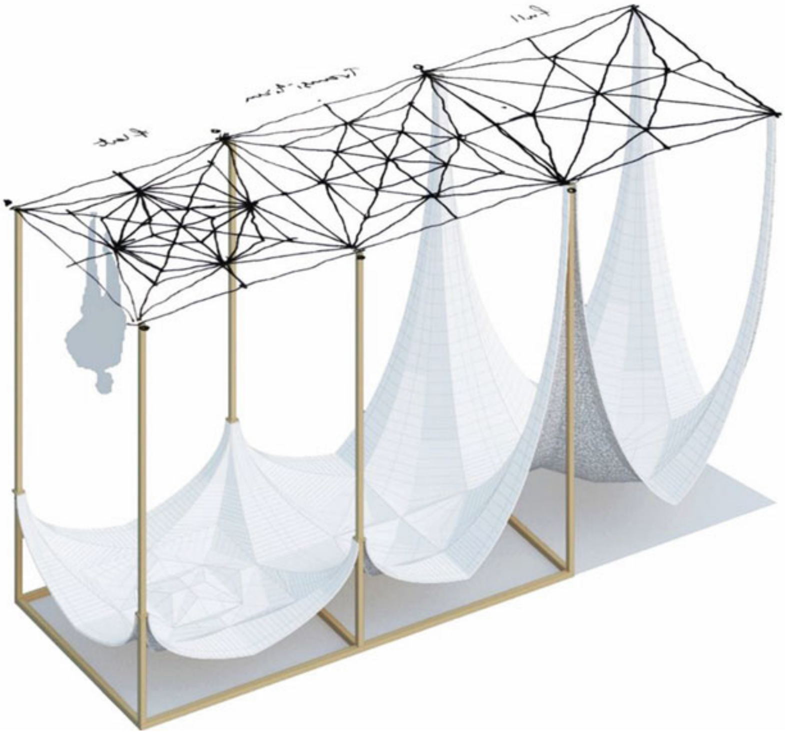
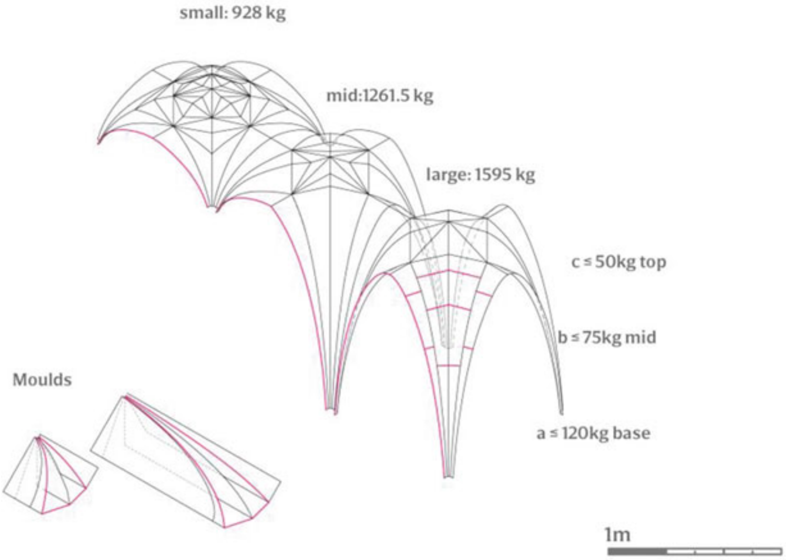


**Fig. 2** Fabricarte design and construction concept (inverted)

**Fig. 3** Construction and manufacturing strategy, calculating the weights of pieces. Mould design and assembly



statics with a particle-spring system for form-finding, verification and maximum loads (Fig. 4). The vault was made of three layers of tiles with a maximum thickness of 100 mm. While the first and last symmetrical vaults were calculated by graphic statics for parallel sections, the forces in the middle transitional vault were studied in both directions to ensure that the modular construction of the vault would not result in discrepancies between thrust lines and the geometry of the vault. Moulds were designed for modular quarters and cut using computer numerical control (CNC) for screw-less easy assembly and disassembly without drawings.

In a workshop, the moulds were assembled and one layer of tile vaults with plaster was built; only side arches had a second layer to add stability to the pieces during onsite assembly. After the completion of a quarter, it was sliced by radial saws using the suggestive pattern as a guide. The pieces were transported on a mid-sized truck, and the moulds supported the shells' reassembly. The building team completed all loading and unloading; the mould/formwork

**Fig. 4** Structural design and analysis using graphic statics

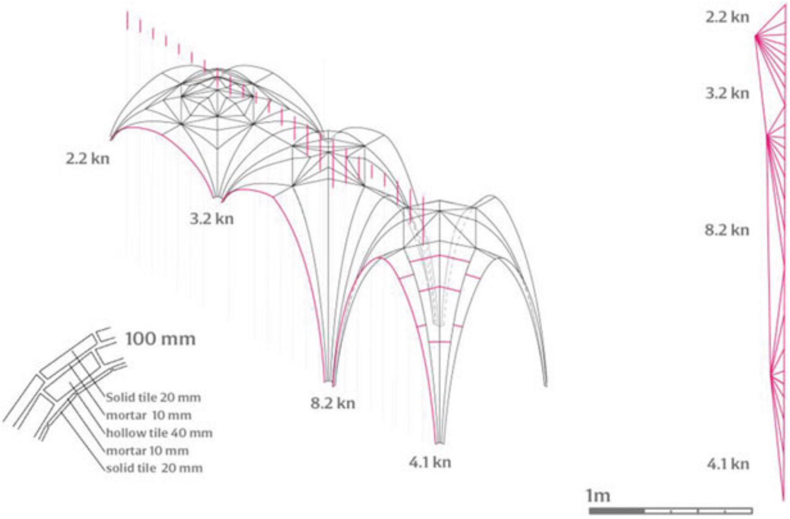


**Fig. 5** Construction process of fabricarte

installation took 1 day and the vault assembly took 5 days. The assembly of the shell was made with plaster glueing its parts again. The tiles were hollow and the plaster at the cut edge did not need to be thick, making only minimal changes in the original geometry. Strips of fibreglass textile with plaster were added under the primary diagonal edge connections (Fig. 5). Once the pieces were joined in the three vaults, two layers of tiles were added at the top and bottom of the vault. The lower layer was made with plaster, and the joints between the tiles were filled with cement mortar (Figs. 6 and 7). The pavilion's flooring reflected the cutting lines of the vaults as a diagram of the process of manufacturing.

FabricArte examined the possibility of tile-vault manufacturing. It showed a system of pre-fabrication that does not rely on the high-precision fabrication of building components for rapid onsite construction. Instead, precision is inherent in the cutting of the shells. Tile vaulting remained the primary technique used in the building.

**Fig. 6** FabricArte exterior views

**Fig. 7** FabricArte interior view 1

## 3.2 Bending Parabolas

Inspired by the recent advances in the research on controlled bending, we wanted to explore bending-active structures for regenerative formwork or guidework for load-bearing shells (Tamke et al. 2013; Lienhard et al. 2013; Alexandrou and Phocas 2017). Traditionally, vernacular tile vaults' construction incorporates bent elements of reed or steel bars wedged between the vault's corners to mark the curvatures for sail or cross vaults. However, this method is only useable when the bending is minimal, where the parabolic, catenary and elastic curves are very similar. When bending with more acute angles, the elastic and parabolic curves begin to diverge significantly, and the bent steel bar is no longer valid as a reference for vaulting (Fig. 8). Our approach is to control the bending by changing the stiffness of the material along the strut by adding and subtracting material at a given location.

Two main equations were used to find the stiffness variation, the buckling equation and the parabola equation. The material variation can be solved and approximated when the two are equal at a given span-to-height ratio. The process resulted in a strip with a maximum thickness in its first and third quarters and a minimum thickness in the middle (Fig. 8).

$$y = a - bx^2 \tag{1}$$

$$R(x) = \frac{\left(1 + (2bx)^2\right)^{2/3}}{2b} \tag{2}$$

The tool in hand, now called the *bending parabola*, can be used to devise an elastic guidework for a parabolic arch as it closes and opens, resulting in a valid shape as guidework for vault builders (Fig. 9).

The structural and design property vaults become inherent in the tool. Both can be made without designing a geometry-specific structural analysis. Therefore, the strip offers the possibility for an autonomous in situ form-finding of structures that can be built with unskilled or novice labour (Fig. 10). Based on the bending parabola tool, we created three vaults using engineered bamboo strips with varied laminations. The method successfully described the geometry and served as a learning tool for the

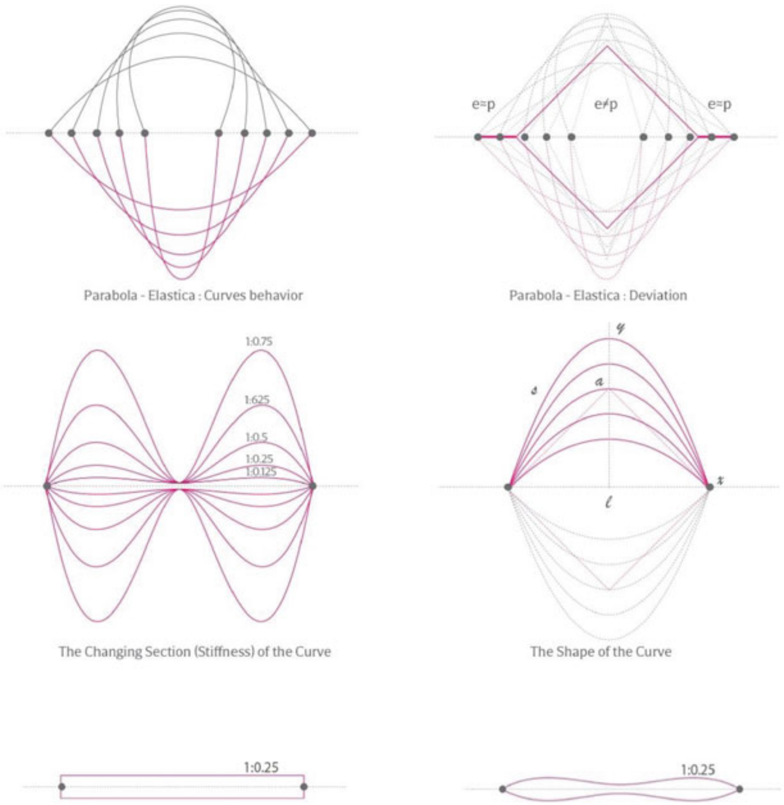


**Fig. 8** Top: Elastica and Parabola behaviours. Middle: Results from approximation by changing stiffness concerning the height of the parabolic arch. Down: The resulting average bending parabola tool (right) compared to a typical strip

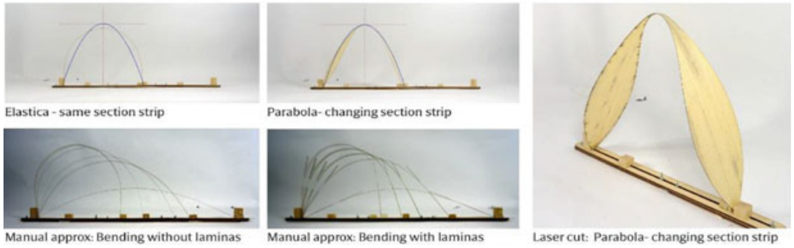


**Fig. 9** Physical testing of bending parabola. Top left and right: Using laser cutting. Down left: Adding laminas of rectangular strips

builder to build an unconventional vault (Fig. 10).

However, this project was more intriguing because it moved into new design territories. The focus on the tools pushed for a departure from bending linear elements to combine networks of bending-active systems with flexible formwork for concrete slabs or lightweight flat-packed structures. In this system, the changing stiffness of each component in the structure not only drives the bending but also allows for a sagging effect of the flexible formwork to make the stiffening ribs. Following the pattern of the internal stresses inside a sail vault, the voids were reconfigured to align to the force's direction and enhanced by changing the number of layers of

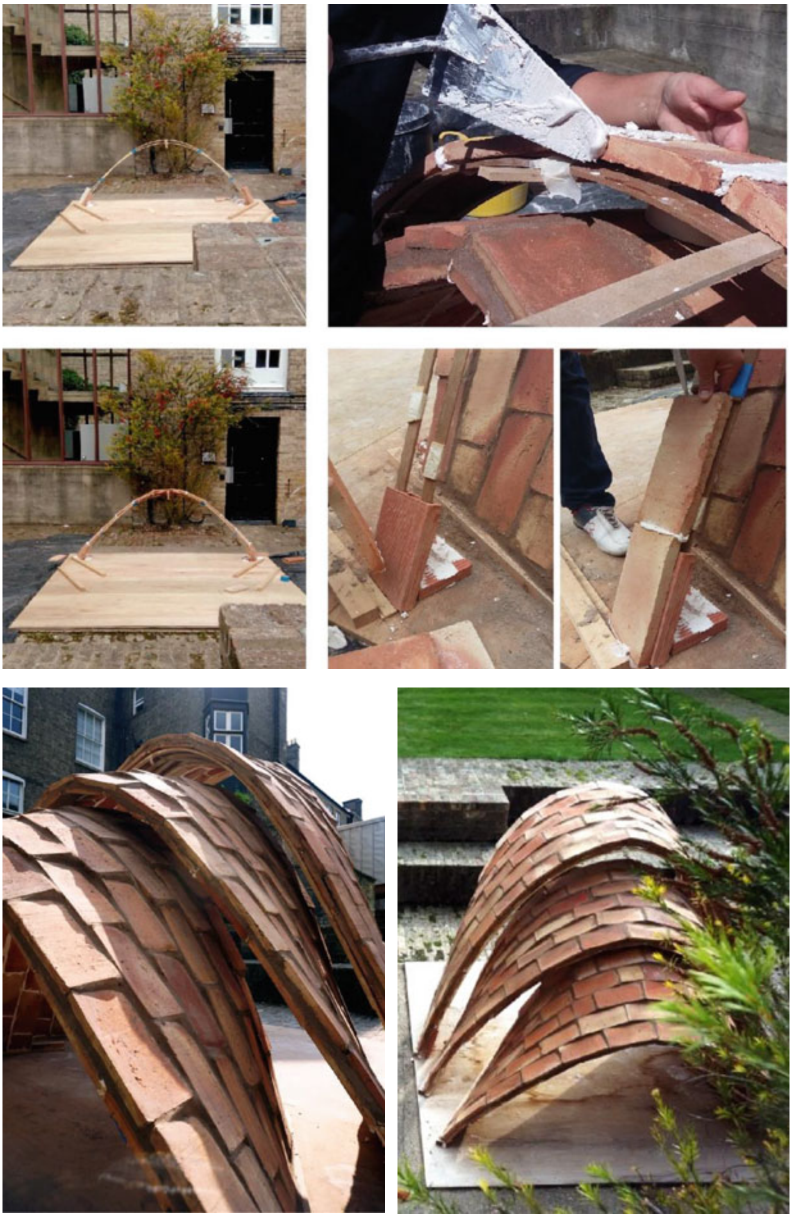
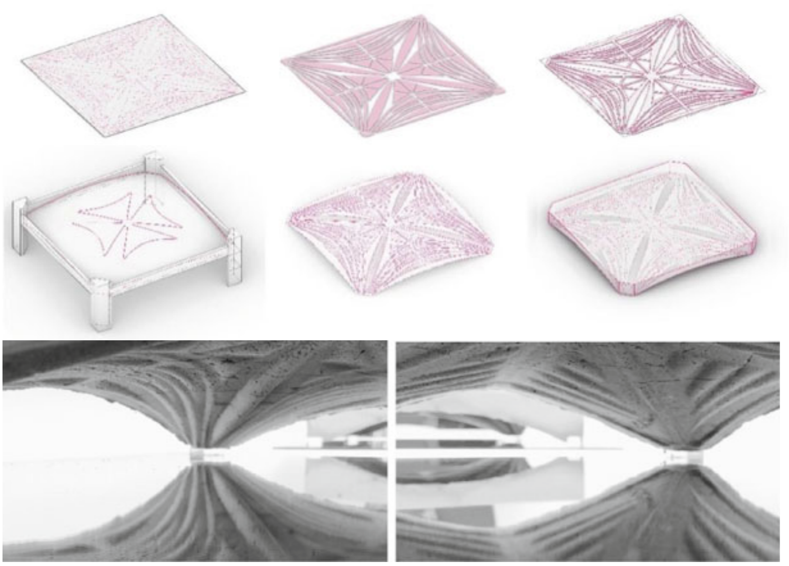


**Fig. 10** In situ, vaults prototype by bamboo strips as guidework 2016

textile to control the sagging depth (Fig. 11). Two 1/100 prototypes were made with wood plate and spandex and showed a possibility for developing this approach towards making concrete floor system from flatpack formwork. Because it is a pattern, the system can be translated into an object by various techniques, ranging from advanced computer-aided fabrication to a saw in the hands of a skilled carpenter. It can be reused or left as a stay-in-place formwork; be an offsite manufacturing industry or made on the move (Fig. 11).

While the core of this project was about tile vaulting, the technique itself was secondary, and the focus shifted to a study on describing the load-bearing shell by bending. Hence, what was examined was the tool to build and not the building. This project aimed to make a

**Fig. 11** Floor system from flatpack sheets from drawing to casting



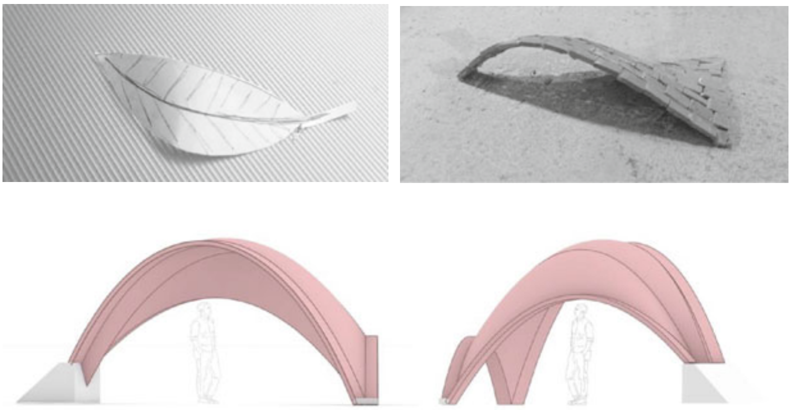
‘generative’ guidework whose inherent properties can find many shells. Although some limitations were encountered in the curved bending strips, such as the limited range of parabolic curves a strip can make, they expand the possibility of a formwork beyond solving one shell only.

### 3.3 La Hoja: Swapping Roles

In 2021, we got a commission to design an outdoor pavilion in a chef’s house. However, unlike the traditional architectural design path, the initial ideation of the pavilion’s geometry was proposed by the master builder with a shell representing an olive leaf, a cherished tree in the Spanish Levantine food culture. His design was developed through a sketch model (Fig. 12). Moving onwards, we wanted to develop this idea structurally and architecturally to host a space for a dining table for ten people. The builder developed the initial model but this time using small representative tiles, which inferred both a level of abstraction of the geometry and an approximation to a load-bearing shell structure.

After the conceptual design, we started a structural form-finding to make a pavilion from

**Fig. 12** Design development of the Leaf. Top: Early models by the vault maker. Down: Modelling developed by the architect



three edge arches where the variation of the height of each arch results in a leaf representation. This was achieved by extruding one pillar of the pavilion above ground level so that the catenary arches resulted in asymmetrical curves. The height of the arches also responded to the orientation of the pavilion to shelter from the afternoon sun but let the late evening sun enter. The play of the different heights gave an abstracted leaf-shaped shell seen from a specific angle facing the entrance of the chef's property. The resulting thrusts from the pavilion were calculated using graphic statics, with three sections in the edge arches and a section in the centre of the vault (Fig. 13). The horizontal thrusts were contained in reinforced limecrete foundations of 200 by 200 mm with rebars of 12 mm diameter. Three vertical pillars were extruded to receive and anchor the edge arches. The thickness of the pavilion was determined by the maximum thrust, resulting in a maximum thickness of 120 mm and a minimum thickness of 100 mm, which translated into three layers of tiles with different mortar thicknesses.

The construction of the pavilion was facilitated through a tile vaulting workshop. Participants of builders, architects and structural engineers worked together under the supervision of the master builder. The pavilion's construction started with the installation of formwork for the edge arches, which was reduced to the minimum through bending metal strips of 5 by 500 mm sections supported by extendable scaffolding props with changing height to govern the geometry of the edge arch (Fig. 14). An additional strip was installed inside the vault to provide a visual guide for the trainees.

During the workshop, the vault's construction started spirally from the edge arches towards the centre of the vault. After the workshop, the master builder will add two more layers of tiles, one exterior and one interior. For the interior coursing, we will use fast-setting plaster of Paris to add the tiles and then refill the grouts with the waterproofing lime-based mortar. The extra- and intrados layers will need carefully executed coursing which is hard to achieve in a workshop with novice builders and trainees (Fig. 14).

The design and construction of the leaf pavilion show that while the building site is one of the most probable spaces of interaction and decision-making in tile vaulting, other dynamics

**Fig. 13** Structural design and analysis of the Leaf using graphic statics

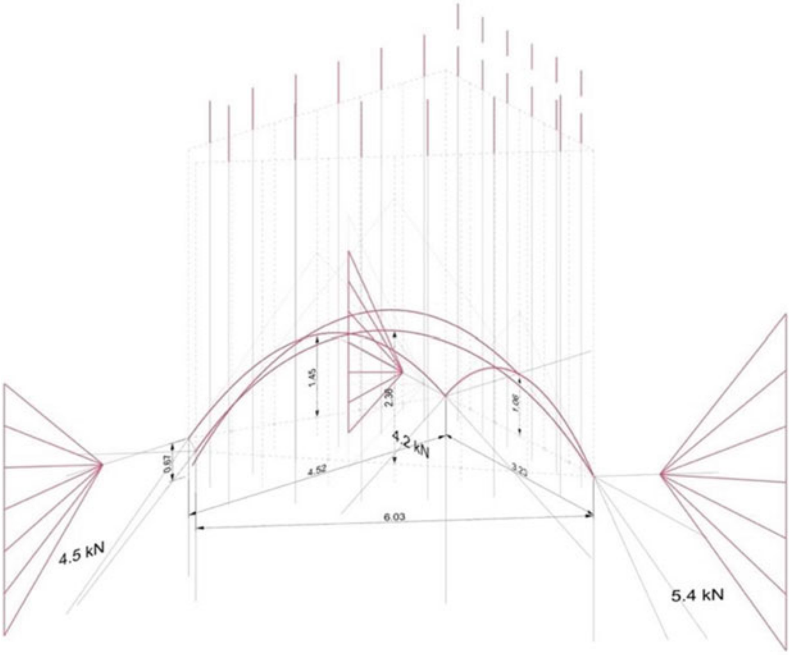


**Fig. 14** The leaf after the workshop

happen outside the site too. Alteration in the hierarchy of design decision-making occurs at different stages and the design prompt for the project was initiated by the master builder, not the architect. However, through co-working with small-scale conceptual design models, the initial and literal configuration of the Leaf was developed into an architecturally useable pavilion, governed by its function and structural constraints as an unreinforced load-bearing shell generated through a series of catenary arches. This process suggests a shift from the usual design flow depicted by the institutional profession, to more open-ended design processes where architects can supplement and support builders with their design knowledge.

### 3.4 Las Cuevas: Digital Modelling for Site Uncertainty

Digital technology can offer a much-enhanced environment for designing and construction. However, this does not always have to result in offsite complex operations or onsite machinery. Technological tools such as digital modelling, VR and 3D Scanning can push traditional construction systems to new possibilities without radically changing their processes. In the following example, we used photogrammetry to understand the existing conditions of our intervention and base our design decisions on a more informed study. The project is located in the mountains of Xixona in Spain, where our vault design is intended to rehabilitate a cave dwelling. The cave-dwelling typology is ubiquitous in mountainous Spain from Malaga to Valencia; their sizes and complexities depend on the mountains' geology and the site's typography. The caves in our site were excavated in the 1940s out of a small fold in the mountain formation. The mountains belong to the Iberian Subbaetic System, most of which is a mix of soil, marl and marly limestone. Therefore, after the caves were abandoned for a long time without any maintenance, they suffered local collapses of lumps of soil and marl (Fig. 15). The two caves were originally purposed as barns for animals and space for food stock. Each had an average of 10 by 4 m in which two tile vaults were needed, firstly as a structural support of the inside the caves to prevent any further collapses and secondly to provide a usable space as a multipurpose hall.

The existing conditions of the caves and their natural formation resulted in many challenges. First, it was hard to get an accurate survey, but we had a schematic drawing only. Second, while the master builder can build the curved parabolic vaults without much guidework, a detailed study was needed to plan how this section varies to accommodate the changing height of the cave. Finally, because of the cave's delicate situation, it was essential to avoid heavy excavations during the construction. To respond to all these challenges, we started by making a three-dimensional model of the caves using photogrammetry. We used Meshroom software to compound the images into a model and simplify it to an overall surface and a series of sections (AliceVision 2018). The 3D scanned model became the envelope of the design inside which we studied, with the client and master builder, iterations of vaulting solutions (Fig. 16). The iterations were guided by the existing geological features of the site to respect the current section of the two caves, avoid heavy excavation and heavy infill operations between the cave and shells. The developed design comprised a domical vault geometry in the first cave with three arches at the entrance to elevate its height to the maximum. In the second cave, we proposed a parabolic undulating barrel vault. The two caves were connected using an existing door that was also vaulted (Fig. 17).

The structural design was developed using graphic statics of sections in the cave. The result from the study had details, plans, sections of the shells and zones of their different layers to vary their thickness according to the calculated weight of soil applied to them. The vaults had between three or four layers of tiles of 40 mm with around

**Fig. 15** Caves interior before the rehabilitation, screenshots are taken from a photogrammetry model

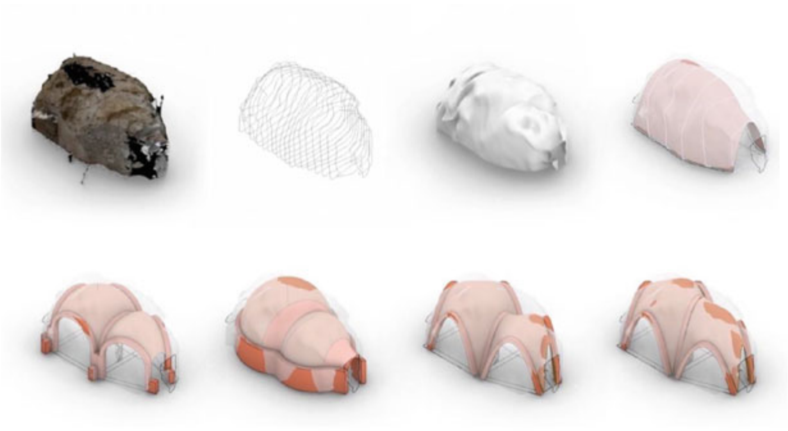


**Fig. 16** Design iterations in dialogue with the client and cave geology

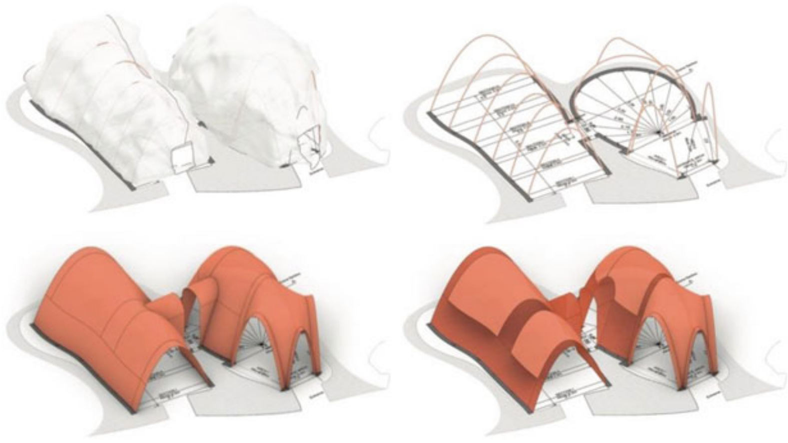


**Fig. 17** Design of the two caves. Top: the guidework in caves, down: geometry and layers of the proposed vaults

10 mm of mortar. The infill between the cave and the tiles was made with construction waste of the tiles and plaster. Ribs above the tiles were also made in locations where the cavity between the shell and the caves was superior to 400 mm. The construction started with implementing a detailed plan of the foundations of the vaults, where the builders excavated a 250 mm deep canal and filled it with lime concrete. Because of the constant parabolic section of the vaults, a series of span and height ratios were sufficient to describe the geometry, which the skilled master builder could describe with light fibreglass guidework he occasionally used to mark the section of the vault (Fig. 18). For a formwork, the same walls of the caves were used to make the first arches. The use of local materials, construction waste and infill, and the minimal reliance on falsework have all resulted in a near-zero waste construction of structural shells as a rehabilitation project of the caves. The vaults were eventually plastered with earth rendering and finished with white lime wash, floors of the caves were paved using compacted mud flooring (Fig. 19).

The cave project of Alicante presents an example of the potential support to vernacular construction through utilising tools from digital technology. While photogrammetry is accessible with photos, its instant use paved for more informed decision-making that gave both architects and builders the power to accommodate and implement the design of the shells. The digital space created using this technology became the

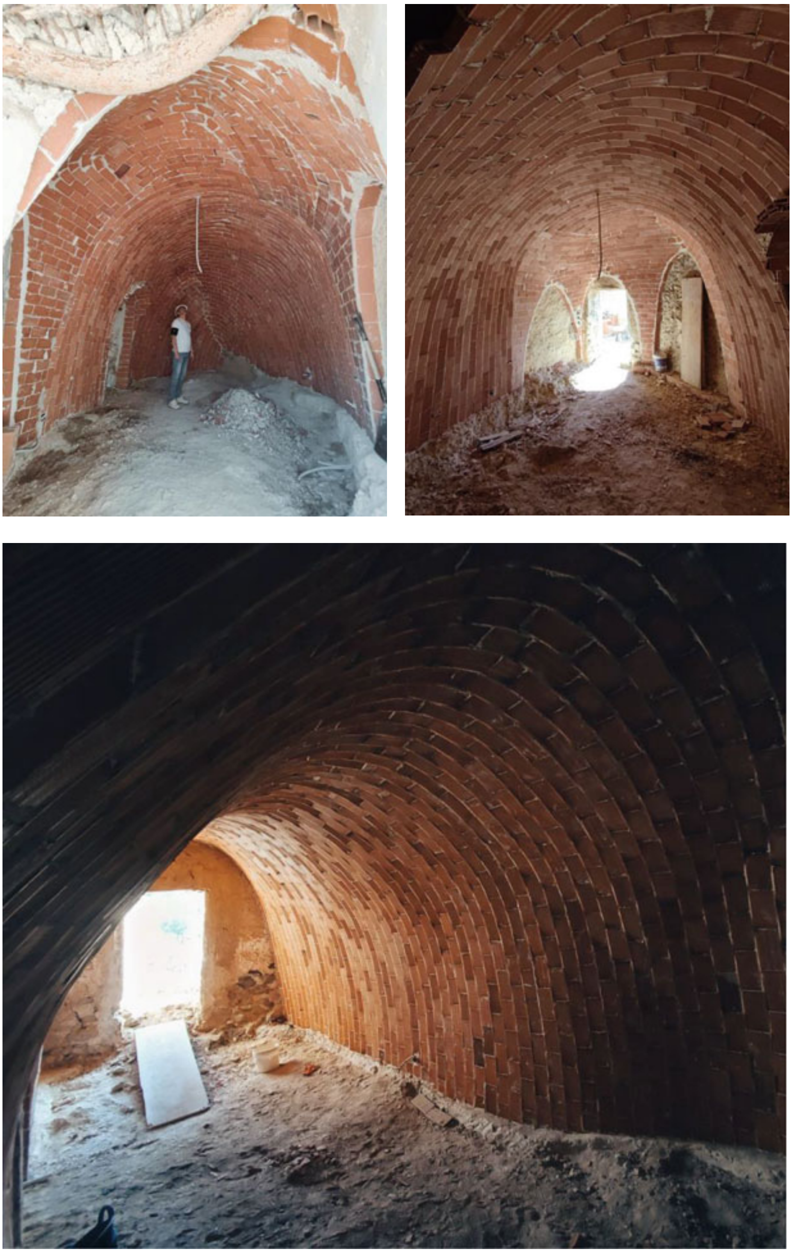


**Fig. 18** Vaults under construction

canvas for sketching and commenting on how to make a minimal but innovative intervention that lessens the use of material and reduces building operations. With demystifying the cave's complexity, the design development output was reduced to a floor plan and a diagram showing the zones of three or four layers in the vaults and supplemented by bent rods to describe the changing section of the vault.

**Fig. 19** Vaults after plaster rendering

## 4 Discussion: From *Withoutcisim* to the Architecture Relational Agency

In this essay, we examined four cases of tile-vault experiments to illustrate several possibilities of working with crafts communities and local making methods (Table 1). In each experiment, the focus was on one aspect of 'craft'. In FabricArte pavilion, the primary concern of the investigation was the 'time' of construction, which pushed for an unusual fabrication method in tile vaulting. In Bending Parabola, the scheme was to devise a 'tool' that helps builders visualise complex vault shapes. In la Hoja, the goal was to decentralise the architects' design process and adopt a 'design' initiated by the builder. In the

**Table 1** Summary tile vaulting experiments

| Project | Aim | Challenge | Method | Output |
|---|---|---|---|---|
| Fabricatre | Craft-based vaults prefabrication | Accelerate construction time | Designing cutting pattern | Manufactured floor system |
| In situ | Regenerative formwork | Tools for onsite form-finding | Controlled bending as a regenerative tool | Bending-active formwork for floor system |
| La Hoja | Co-design | Develop design ideas from Artisan's input | Design through models | Curriculum of tile vaults training |
| Cuevas | Design for uncertain scenarios | Drafting instructions without plans and sections | The use of 3D photogrammetry | Working in digital spheres |

Caves of Xixona, the aim was to support the traditional system of tile vaults with the 'technology' of 3d photogrammetry in cases where conventional methods of designing are complex. Time, tools, design and technology are the main challenges that face vernacular building crafts in today's highly industrialised construction. Yet, they are also the very same features that render building crafts resourceful in their use of local materials and low-carbon processing methods.

Studies of architectural theory and history understood architecture by the presence or absence of the centralised design agent, *with* or *without* architects, resulting in dismissing or patronising how non-architects build. In contrast, the overall learning from these experiments shows that it is possible to move beyond this *withoutcisim* to an explorative domain between crafts and architectural design through a consistent, long-term and objective-oriented collaboration. This collaboration is conditioned with a relational, not hierarchical, agency. In psychology and education studies, the relational agency is 'the capacity to offer support and ask for support from others, which expands the resources available to actions on objects' (Edwards 2005). This methodological framework of collaboration between disciplines consists of establishing three main action points:

1. **Establish a common language**: Designers should engage with the complexity of crafts by illustrating their processes, not products. A new wave of such documentation is needed beyond documenting to 'save the past' but to open crafts to change and mutate in line with the transition to green building strategies. Architects can expand ethnographic studies on crafts to physical and digital modelling drawings of steps of making and computational coding of craft grammars and typologies. National and international institutions can contribute to establishing this common language by encouraging designers to work on encyclopaedic and digital databases. The outcome of this methodology can enhance the understanding of policymakers and designers about the potential future role of the existing network of makers as small enterprises and holders of cultural significance. Such understanding is crucial in the transition to a greener construction to secure decent work and growth of these enterprises.
2. **Aligning oneself in joint actions**: Designers should include crafts communities and vernacular knowledge in the current research on the manufacture and prefabrication of replicable low-carbon building components such as floor and façade systems. This includes shifting the focus from a site or project-specific collaboration to endeavour building systems through iterative prototyping. Craftspeople can contribute with more than their handwork making; they can expose nuances of how existing digital and industrial fabrication methods can be applied in different ranges of technologies. Therefore,

working with craft does not mean relinquishing the essential tools of architectural modelling and engineering testing but being preparade for a recalibration of these tools as the design grows. With such inclusion, research institutions in public and private domains can include low-tech and small-scale factories currently facing post-pandemic challenges. These small-scale factories can be an active part of developing sustainable cities and communities.

3. **Work beyond formal institutional channels**: To move to more amble and environmental matters, architects should engage with practices embedded in many forms of habitation ranging from cities' historical centres to informal settlements and from urban-to-rural settings. There is a need to expand the definition of building crafts beyond the heritage institutions' approach that only grants them value because of their cultural-historical significance. This collaboration can operate in various spaces, ranging from digital spaces of open-source building libraries to settings of informal construction. This role of designers will be needed in the highly urbanised globe where they can engage with builders and self-construction actors in informal areas to deal with improvisation, quick test-and-approve and modifications. Keeping an open-ended system with an error threshold is crucial for building craft inclusion in architecture. The skill of the builder and the preparation of empirical models by architects determine the elasticity of this system.

The proposed threefold dialogue explained several goals in the UN 2030 Sustainable Development Goals, from those related to the decent work and economic growth of local enterprise specified in goal 8 to the enhancement of innovation and supporting the small factories in SDG 9 (industry and innovation). Moreover, the dialogue main core is to bridge design for climate action, specified as SDG 13, with sustainable cities and communities. While a lot is being explored about participatory design and the inclusion of users in the planning process, there is a lot yet to be done on participatory construction, where local actors can also be part of shaping cities built environment. The work along these three points could link the thinking of the future architecture of resourcefulness with the societal and economic conditions of today's building practices. Future research is needed to understand and develop how to implement the three points at national and policy-making levels. Similarly, future research on different crafts and cultures of making is required in order to expand and build on the findings of this essay.

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