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Digital Workflow for the Re-envisioning and Conservation of Eastern Architectural Screens and the Engagement of Digital Tectonics

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From Manual to Hybrid, Parametric Mashrabiya: Digital Workflow for the Re-envisioning and Conservation of Eastern Architectural Screens and the Engagement of Digital Tectonics

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Abstract: This research seeks to bridge the gap between traditional artisans and emerging digital craftsmen generated by the Arts and Crafts movement of the late nineteenth century and the third Industrial Revolution (Krugh 2014; Economist 2012) now underway via material culturalism as outlined by Grier (1996). Mashrabiya, an Eastern patterned screen, represents an architectural construction that is rooted in cultural and functional parameters, but whose craftsmen have become essentially extinct due to industrialization. In looking at the preservation and redesign of this archetype, the digital tectonic (Beesley and Seebohm 2000) becomes a powerful agent in reconciling tradition with contemporary manufacturing via 3D printing. The authors are exploring the cultural foundations of the Mashrabiya in order to understand how these act as measurable parameters in the re-envisioning of the construction. This paper presents the background, relevant work, and the workflow for the first array of 3D-printed Mashrabiya, exploring their viability and re-insertion into architecture.

Keywords: Mashrabiya, Culture, Craft, 3D Printing, Parametric Architecture, Heritage Conservation.

I. Introduction

Material culturalism is defined by Grier (1996) as the study of a subject matter that takes in the 'biosocial environment' from cultural buildings and landscapes. These valuable collections of artifacts reflect the lifestyles, interactions, environments and eras of people's parents. Material culturists believe that the study of objects and artifacts and the circumstances in which they were made reveals unique perspectives and data that have not been well documented. Islamic Architecture is a rich cultural example with its delicate and geometrically advanced artifacts and production methods (Kaplan 2002). Analysis into historic archetypes, specifically Mashrabiya, can significantly influence the current and future design of architecture facade treatments that could comply with the harsh environmental conditions in the Middle East.

John Fenny (1974) poetically describes the silken masks of the Mashrabiya as symbolizing the "legendary mystery of the Orient." Within Eastern cultures, this architectural construction is a three-dimensional, carved wood lattice structure whose primary function is to control visual privacy as well as temperature and lighting in interior spaces (Samuels 2011). The Mashrabiya, as studied by Hassan Fathy (1986), represents an architectural screen that has five functional dimensions that are achieved through parametric variation in the material thickness and member density: controlling the passage of light, controlling the air flow, reducing the temperature of the air current, raising the humidity of the air current, and ensuring the privacy of the inhabitants within the *Haramlak* or *Harim* (women's quarter) in the courtyard houses of Saudi Arabia, Egypt, Turkey and other eastern countries (see Abdelgelil 2006; Almurahhem 2011).

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Figure 1: The Craft of Mashrabiya Making Using Lathing Tools
Source: http://qanzaman.blogspot.co.uk/2013/01/blog-post_9979.html

This vernacular architectural construction requires significant craftsmanship in developing the individually hand-turned parts that work together in the overall assembly (Figure 2). As these craftsmen have become more and more scarce, the architecture has continued to become a caricature, losing much of its cultural value and passive performative functions. The high cost of manufacturing these constructions and maintaining their performance is simply no longer feasible under the historic model of production (Abdelgelil 2006). Similar to the notion of *Undrawable Architecture* documented by Dritsas and Yeo (2013, 834), these constructions are "underpinned by tacit tectonic knowledge passed along generations which was never formalized, and a product of artisan craftwork of phenomenal complexity that was manually re-produced but never rationalized."

Figure 2: The Luxury Craft of Mashrabiya Making
Source: Authors

With the propagation of 3D printing technologies during the past two decades, the conservation of this architectural screen may potentially be found in the performative analysis of existing Mashrabiya in order to inform new parametric models. These can then be subsequently

programmed into site-specific variants and produced via large-scale 3D printing. As digital fabrication technologies continue to proliferate throughout architectural design discourse and practice (Kolarevic 2003), the conception of a digital tectonic (Beesley and Seebohm 2000) becomes a powerful agent in the conservation of a historic architectural legacy.

The authors are interested in the implications for new *digital craftsmen* and fabricators whose knowledge can be harnessed in order to program relevant input data to generate assemblies that not only support performance from a functional vantage point but also inform a cultural trajectory. Interesting questions emerge regarding the replacement of manual labour with digital programmers: Will cultures allow for the replacement of the craftsman with the programmer? Can the cultural interactions be distilled down to quantifiable parameters that drive CNC equipment?

Notably, the authors are not directly interested in replicating historic Mashrabiya. In contrast, the aim is not to achieve the efficient reproduction of culturally frozen artefacts but instead to contribute to the evolution of the architecture, thus fostering new knowledge acquisition through observation, manufacture, and recursive analysis.

In the work presented in this paper, 3D-printed forms are developed parametrically and analysed. While this is a fully digital process, the work seeks to reconcile traditional cultures with contemporary manufacturing in the preservation of a traditional architectural archetype. This work additionally seeks to alleviate the impact industrialization has had on traditional culture and artisans, stabilizing the architectural construction and enabling future instantiations of Mashrabiya.

II. History of Mashrabiya/Relevant Work

a. Defining Mashrabiya

The Mashrabiya can historically be traced back to the Mamluk and Ottoman periods in Egypt (1517~1905) (Abdelgelil 2006). Since then, several culturally specific Mashrabiya have evolved according to their context and region. The definitions discussed here are related to the meaning and the functional and regional characteristics of the Mashrabiya. A Mashrabiya is defined in the Oxford Dictionary of Architecture (Curl and Wilson 2015) as a timber 'lattice screen' that is often intricate, geometric and beautiful in Islamic architecture. The word Mashrabiya is argued to be derived from the Arabic verb Shareba, which means 'to drink' (Kenzari and Elsheshtawy 2003; Elshorbaji 2010). This connection derives from the clay jars (Jara) containing water placed inside Mashrabiya inner shelves to passively cool the air current. Another important cultural connection of the Mashrabiya is Mashrafiya, derived from the Arabic word Sharefa, which relates to the high position of the openings and the fact that Mashrabiyas overlook lower spaces and passers-by (Almurahhem 2008; Aljowder 2014). The form is also argued to overlap with another archetype known as Rawashen, which is found in the Hedjazi houses of Saudi Arabia (Almurahhem 2008) or the Shanasheel of Iran and Iraq. It is also thought to be linked to the Ottoman Empire Heremlik window grill termed Kafe (Sedky 1999). The term usually describes a projected bay or protected closed balcony with small openings so that the female inside the dwelling can look outside without being seen from the outside. As Sidawi (2012) clarifies, unveiling may violate the Islamic requirement for women to have privacy; the veil (head and body cover) enables them to remain covered to non-kinsmen. Outside the Middle East, Hui (2005) argues that Architecture treatments such as the Brise Soleil and Claustrum can also align with the functions and role of Mashrabiya within a facade.
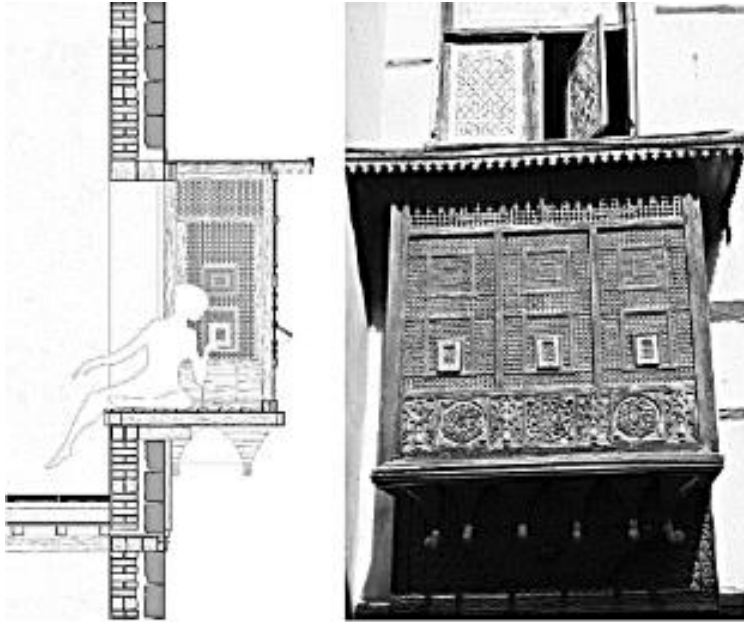
Figure 3: Mashrabiya Form within the Facade.
Source: Ficarelli (2009)

Fathy's (1986) five functional roles of Mashrabiya, as described above, define its essential functions. Environmentally speaking, Ficarelli (2009) explains how the window elements automatically activate a convective cycle that is capable of moving air masses from a higher pressure zone to that of a lower pressure zone. Socially, the role of Mashrabiya evolved into a product for gender segregation, home seclusion and a veiling norm regulator. Nevertheless, it also mediates the architecture and interior experiences, allowing female occupants to observe exterior life without being observed themselves. Almurahhem (2008) adds another dimension through illustrating a poetic picture of the space behind the screen. She visualizes it as a sensory experience provoker, where women not only socialize and gossip with other neighbouring females but may also use it to hear their children play outside or to call for road merchants to buy objects of daily use.

A complementary theme is the relation between Mashrabiya and light. Ghiasvand et al. (2008) explain how in Muslim culture light is a "symbol of divine unity"; Aljowder (2014) supports this view through her research on the relationship between light and visual privacy. Both scholars agree that the Mashrabiya enables the passage of divine light which modifies other elements and forms patterns. Ghasvand (2008) suggests that with the right light coming through the pierced screen, the facade resembles lace. Light and shadow also add dynamic rhythms to architecture and its forms, giving texture to smooth surfaces. However, summer light can be harsh and cause severe temperature increases in the interior. As Samuels (2011) and Aljowder (2014) note, Mashrabiya screens fulfil this cultural need by responding to and blocking direct light and reducing solar gain.

Furthermore, Mashrabiya panelling craft emerged from Egypt; this had both social and environmental purposes (Fathy 1986; Alshareef 2001; Kenzari and Alshestawi 2003; Abdelgelil 2006). The fine techniques of turned wood produced lattice-like panels and sun screens. The screen construction used fine wood since good wood was scarce and expensive. The basic principle of Mashrabiya is straightforward: it is a lattice constructed of turned oval shapes joined and composed together by short turned and ribbed links (Williams 2008).
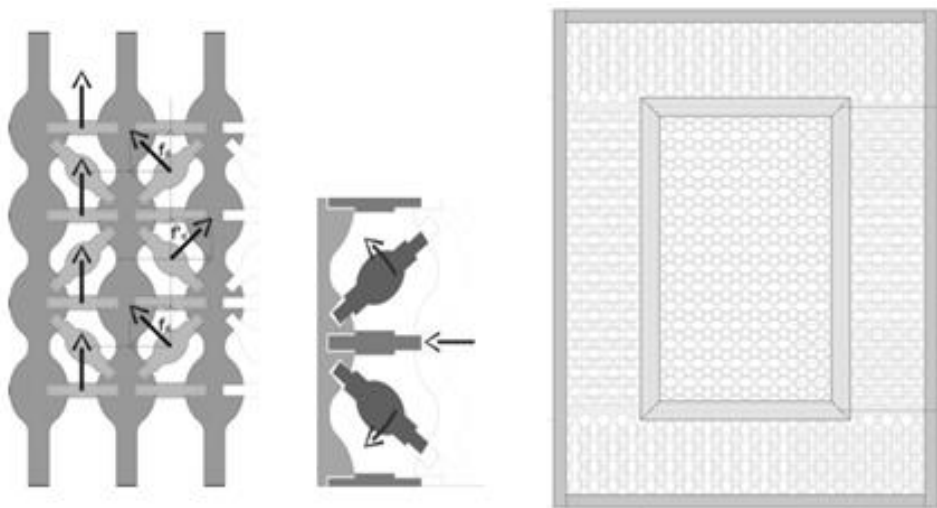
Figure 4: The complex geometric structure of the Mashrabiya screen, where each element is shaped individually and then all the elements are assembled together by a master builder.
Source: Benedetti et al. (2010)

b. Relevant Work

The Mashrabiya concept is very popular in the field of Architecture, interior design, furniture and product design. Almerbati et al. (2014) described and analysed several projects and products from different fields which used modern technology to revive the Mashrabiya concept. The following focuses on three cases from academic research, the production market and architectural product concepts that have used either craft skills or parametric data and technology to define their final product. The criteria for selecting these projects were their dependency on a combination of manual or digital craftsmen skills.

1. Mischer'traxler Gradient Mashrabiya Table (2012)

The designer duo mischer'traxler, in collaboration with digital and manual craftsmen, designed a new product that was commissioned by the Carwan Gallery. They relied on the skills of a Lebanese woodworker and CAD software to create a table that visualizes how Mashrabiya elements are crafted and composed. By capturing the complicated process of lathing around 650 individual elements and assembling them together, they emphasized the difficulties of the Mashrabiya craft. Notably, this product does not have the social or environmental functions originally associated with the Mashrabiya; instead, it has been designed for aesthetic and geometric purposes only, with a positive score of identity notations (http://www.mischertraxler.com/projects_gradient_mashrabiya.html).

2. Mey and Boaz Khan's ecooler (2010)

In their heat-beating product, named ecooler, the Israeli designers Mey and Boaz Khan based their design on the environmental and light infusion character of Mashrabiya screens and old clay jars. Merging the two concepts into a network of hollow mould clay pieces allowed water to cool the tile and the air that passes by it. This product carries the identity of the Orient but cannot be adjusted to fit several contexts or scales as the crafting technique is limited to the mould that has been created (http://www.greenprophet.com/2010/10/mey-boaz-kahn-ecooler/).

3. Samuels' CIM and CNC Mashrabiya model (2011)

In his research titled 'Performance and Permeability' William Samuels (2011) made a conscious environmental decision to produce a Mashrabiya-inspired screen to be used in Australia. The researcher took into consideration the sun, light and materiality as well as the visual quality created by each proof of concept model. The few models he created relied on the digital craftsman skills he acquired and were supported by the scientific knowledge he obtained. Even if the final result was not aesthetically significant, the process and the product created utilized modern CIM and CNC technology that was not available to local craftsmen.

III. Workflow

a. Parametrizing Culture through the Digital Tectonic

Much of the work done in the field of parametric design, as its etymology suggests, is in search of valid parameters that lend meaning and evaluation to the infinite variations that can be produced. Often these parameters are found in the metric evaluation of different features in design and construction (Kolarevic and Klinger 2008). As Moussavi (2008) observed, this is similar to architectural design: "Architecture needs mechanisms that allow it to become connected to culture… Architecture progresses through new concepts that connect with these forces (visible or invisible), manifesting itself in new aesthetic compositions and affects." The traditions of the Mashrabiya unite a variety of functional, cultural and material conditions into an architectural manifestation of the boundaries between these dimensions. However, at the core of the design is an understanding that the human body acts as a reference point for the development of the product. The architecture protects the privacy of the *Harim* and enables the individual behind the screen to comfortably view exterior spaces.

As suggested by Beesley and Seebohm (2000), the digital tectonic designates an interest in the chemistry between the culture, the form, and manufacturing. As we look at the end of the Arts and Crafts movement in 1910 and leap towards the third industrial revolution, the cultural study informs a geometric ordinance system whereby highly tuned constructions are informed by cultural parameters and assembled in digital spaces. Reflectively, the religious requirement for Muslim women to be veiled can be well satisfied through the use of a hybrid and parametric Mashrabiya as suggested in this research (see Figure 5). Looking directly into the manufacturing of these new constructs, 3D printing enables a new *digital craftsman* to emerge to fill the gap resulting from the loss of the traditional artisan. These new digital craftsman are versed not only in the negotiation of digital space, but also in the negotiation of cultural, social, and performative functionality that must result from the manufacturing process.
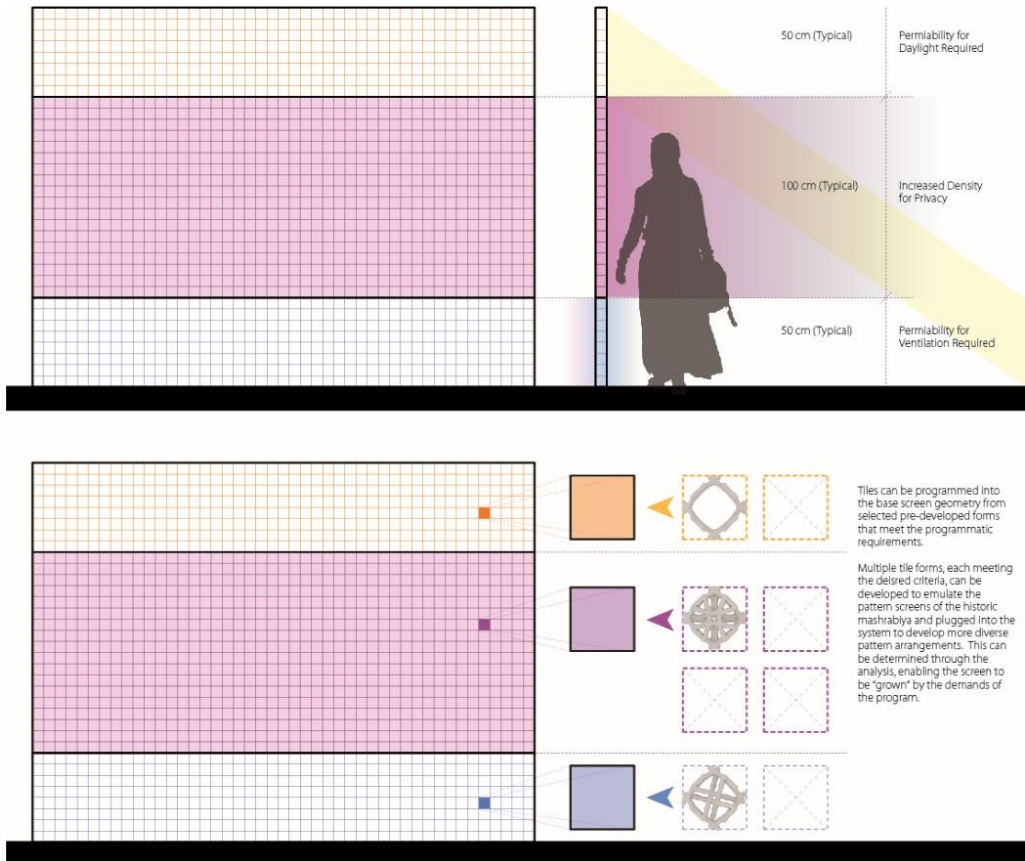
Figure 5: Diagram of performative variables found in cultural study and translated into digital parameters
Source: Authors

Just as the Tea House in Japan is rooted in cultural, spatial, material, procedural and philosophical considerations, the Mashrabiya cannot escape the history of several hundred years that it emerged from. While a rather simplistic evaluation might suggest that it is a construction that is meant to maintain a boundary, we see an advanced evolution, avant-garde by some measures, that began to embed other considerations over time, including ventilation, daylighting, air cooling and humidity control. Again, similar to the Tea House, you become aware of yourself and your proximity to spaces and the spaces become aware of you. In looking at the parametrization of the cultural conditions surrounding the Mashrabiya and its specific functionality, we hypothesize a new digital tectonic that mediates between the traditional culture and contemporary manufacturing. Ko and Liotta (2013, 329) posed a similar question when thinking about the Digital Tea House: "What would this diagrammatic and methodological approach produce when combined with a culturally meaningful function?"

b. The Digital Craftsman and the Traditional Artisan

As noted by Amit Zoran (2011, 324) in his Hybrid Basketry work, "contemporary 3D printing and traditional craft rarely meet in the same creation." Zoran observed that the artifacts generated by 3D printing are intrinsically reproducible and this is in stark contrast with traditional craft. Conversely, however, parametric tools are dominating the landscape and additive manufacturing enables the physical manufacture of completely unique operations just as easily as it allows for repetition. Just as the artisans of past epochs worked to understand both the tools and materials

required to accomplish their craft, digital craftsmen are becoming aware of the functional limitations of varieties of technologies, embedding that knowledge, just as the craftsmen did, into the new digital constructions that constitute their craft.

The study of the historic Mashrabiya exposes a direct link with mathematical and geometric representations that can be directly engaged with in the programming of algorithmic designs. Digital craftsmen can take the opportunity to inform these traditional motifs with functional design parameters that can be adjusted through graphic algorithmic modelers (Grasshopper 3D). Zones in the design are designated in the initial diagram (Figure 5), where daylighting, privacy and ventilation are articulated against the variable dimensions of the opening. Just as with Mashrabiya of the past, the occupant becomes the point of reference for the zoning, using the height of their eye level to set maximum privacy considerations. From this point, the geometric pattern is given a viscosity that is again driven by the algorithmic design process. The members gain thickness and dimensions, and are also blended together through the analysis in proximity to the maximum privacy datum; this geometric dimension is developed through the use of T-Splines (Figure 6).
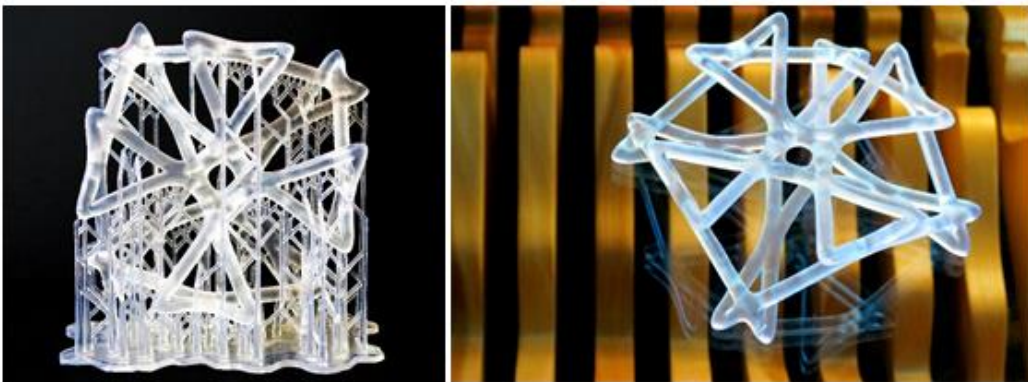

Figure 6: 3D printing enables the production of parts that cannot be made in any other fashion, 10 cm by 10 cm test prints of Mashrabiya screen modular units using Form 1 printer
Source: Authors

3D printing is selected as the ideal manufacturing process, as, at times, these constructions achieve a complexity that extends beyond multi-axis CNC milling. Once again the digital craftsman is tasked with embedding the limitations of the tool into the programming of the parametric model. Member thickness cannot fall below certain structural minimums without substantially weakening the overall construction.

Notably, the described digital model generates a rather static construction, with zones essentially stacking onto each other to fill the void in the construction. However, since these parameters have been programmed dynamically, the culture is able to evolve through the dynamic modification of the parametric model. The digital craftsman presides over a scenario where the user group (or culture) is able to intensify or dissolve the various parameters that define the Mashrabiya. The digital craftsman becomes a facilitator for the level of privacy needed at the user level. Furthermore, as more cultural or functional variables (architectural programming, for example) emerge and are programmed into future instantiations of the Parametric Mashrabiya, the resultant forms will continue to evolve alongside the culture. In addition, the advantage of the units' shape is linked to the fact that they can be digitally crafted to fit various patterns from both 2D surfaces and complex 3D interlaced geometries, some of which are too highly complex to be created using other mould-based manufacturing techniques.

Conclusion

The research presented articulates a design process that seeks to develop contextual understanding and to develop a digital tectonic for Mashrabiya design. This work is still in its preliminary phases in terms of its exploration of culture, parametric model development and interrogation of manufacturing processes. The frameworks of the material culturalist , digital tectonic and digital craftsman suggest a sequential methodology that enables the parametrization of cultural values into a model that enables the continued growth of both the architectural archetype and culture. As the Parametric Mashrabiya continues to evolve through recursive analysis of material culture within various Eastern cultures, it will continue to gain design intelligence. Simultaneously, the embedding of these intelligences does not preclude each of the features continued intensification or termination, enabling cultural evolution/revolution. Furthermore, the parametric model also enables the articulation of detailing that is adaptive to the required spatial constraints, daylighting and performative needs that extend beyond the outlined cultural criterion, enabling these new forms to continue the evolution of the tradition. The merits of the proposed design maintain the shari'a (Islamic law) of dwellings' privacy while improving the lighting through the upper wider designed latticework. Although privacy considerations are no longer strictly followed in modern building codes in the Middle East, the proposed parametric design treats the upper latticework in a way that harmonizes social and environmental needs.

Finally, the Parametric Mashrabiya enables the digital craftsman to apply new construction and manufacturing methods to a traditional craft. While 3D printing of the Mashrabiya might be equal to or greater than the present cost of fabrication when taking into account longevity and scale, it is not unreasonable to assume that as the technologies continue to evolve this cost will decrease while the lack of artisans will likely only intensify, subsequently increasing the cost of construction. The research continues to explore the material limits of these construction processes and materials, seeking to optimize the fabrication to enable greater performance, strength and longevity while simultaneously reducing costs (Figure 7).

Further research in this subject area is intended to bridge the gap between historical and traditional craft object preservation and their regeneration in contemporary interiors and architecture facades. This will enable both culture and identity to be sustained, especially in Muslim countries in the Middle East, such as Bahrain. Focus groups with professional architects and manufacturers as well as possible end users can determine the social as well as the aesthetic and functional appeal and the acceptance of the new hybrid and parametric screens while considering their economic cost. Thus, they can be used to examine the rise of the new 'digital craftsman' and his role in sustaining heritage in Muslim countries' future architectural language.
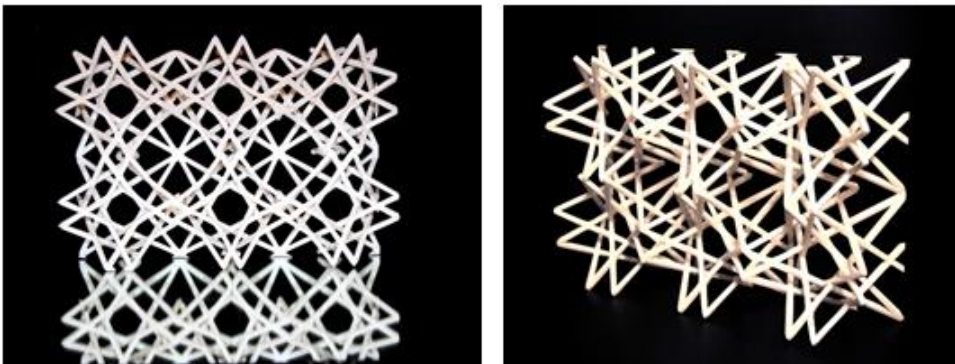

Figure 7: Images of 3D-printed Laser Sintered Plastic for Focus Group Consideration in Bahrain
Source: Authors

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