Desert Roofscapes: Reinterpreting Vernacular Forms

JASON F. CARLOW
American University of Sharjah

Keywords: desert architecture, vernacular architecture, performative design, parametric thinking

This paper presents new methodologies for the design of roof canopies for extreme desert climates based on performative aspects of vernacular architecture from the Middle East and North Africa (MENA) region. The research and design explorations have been undertaken within the context of an undergraduate, architectural design studio at American University of Sharjah. The research methodology for the studio included a survey and case studies of various traditional building types, technologies and materials to uncover design strategies. Lessons for climatic performance such as solar shading, natural ventilation and using thermal mass for cooling were important aspects of the precedent research, as were aspects of structural, material and aesthetic performance. In addition to a series of vernacular buildings, students were also asked to investigate a number of contemporary examples of architectural enclosures and roof systems. Students experimented with computational means of hybridizing concepts, technology and geometry from the two categories (vernacular and contemporary) into a prototypical envelope system. Through multiple, design exercises, the studio encouraged an iterative approach to design. The studio considered how parametric tools and or parametric thinking can be put to work to blend architectural forms to achieve canopies that perform in desirable ways and can adapt to different sites, structural spans and programmatic criteria. With the use of digital design tools and techniques, an experimental approach toward building design aims to create prototypes for a better performing building envelope.

INTRODUCTION

This paper presents design research for the investigation of building envelopes that respond better to environmental conditions within the extreme, desert climate of the Persian Gulf region and the development of projects that interpret the formal and material aspects of traditional architecture in novel ways. The curriculum of the design studio was structured in oppositional critique to architecture built in recent years within the Gulf region that is either not sensitive to the local climate or that uses traditional design motifs in a nostalgic, neo-Orientalist manner.

The adoption of generic building types and use of globally available, mass-produced envelope systems has made much of the Gulf's architecture less energy efficient. Many examples of contemporary architecture in the rapidly developing Gulf region do not differ significantly from those found in other global cities. With the rapid influx of capital investment in the Gulf starting in the 1980's, the globally established construction method of exposed glass curtain walls were employed extensively in almost every commercial high-rise building façade in the Gulf[1]. The relatively heavy reliance of buildings in the Middle East on energy consumptive air-conditioning systems is in part due to the inability of façade systems to block solar radiation or increase the potential for natural ventilation on the surface of buildings. Due to rapid development and the importation of building designs from elsewhere in the developed world, little learning or knowledge from traditional or vernacular architectural examples is applied to many newly built buildings in the UAE.[2]

Through his architectural practice, research and writing, Hassan Fathy made a strong argument for the understanding and respect of traditional modes of building in contemporary design. "The solutions provided by generations of traditional societies, which used only natural sources of energy in their vernacular architecture, may be of great help in opening new fields for research and application." [3] Published by the United Nations during the aftermath of the global energy crisis of the early 1980's, Fathy's book, *Natural Energy and Vernacular Architecture,* is focused on publishing examples and analysis of traditional architecture from hot and arid climates for the benefit of future generations of architects and designers. In the foreword to the book, Walter Shearer calls for a re-appraisal of traditional architectural solutions to address contemporary problems. "The field of vernacular architecture," Shearer writes, "offers an abundance of concepts that can be of use today in solving the critical housing situation now facing millions in the Third World."[4]

The research and design explorations presented herein have been undertaken within the context of an undergraduate architectural design studio at the American University of Sharjah, entitled *Thick Skins,* and instructed by the author. The work is specifically focused on developing methodologies for the design of roof canopies for desert climates that is based

Figure 1. Examples of vernacular buildings assigned to students for case study research included palm leaf (arish) dwellings, Bedouin tents, Musgam mud huts, perforated pigeon towers, faceted muqarnas ceilings, as well as wind scoops and wind towers from across the MENA region.

on performative aspects of vernacular architecture from the Middle East and North Africa (MENA) region. A key research question in the studio sought to address how, through digitally-driven design and parametric thinking, the intelligence of vernacular architecture from the region can be integrated into the design of a prototypical pavilion. Building intelligence in the context of the *Thick Skins* studio refers to various types of performance, climatic, structural, material and formal, as defined by each student investigator.

MIXED METHODS OF DESIGN AND RESEARCH

The research methodology employed in the design studio is a mixed methodology that draws upon case study analysis combined with reflective design practice and practice-based enquiry. Students were assigned different precedent projects to analyze. Design prototypes were developed through a process of reflective practice in which formal and performative characteristics of case study projects were hybridized into new forms. Prototypes were then tested across a series of sites with different constraints and qualities in order to allow students to think iteratively about the application of a prototype to various conditions.

The studio curriculum included a survey and case studies of various traditional building types, technologies and materials. The case study phase of research sought to identify design intelligence and design opportunities embedded within traditional architecture. Building types selected (Fig. 1) included examples of architecture and envelopes that make use of a limited palette of materials and seek to mediate the often extreme conditions of a desert climate. The projects, ranging in context from the UAE, the MENA region, southern Asia and southern Europe, were chosen by the studio instructor for the students in order to introduce a broad set of issues related to deep, performative roof systems and building envelopes. Understanding and analysis of the precedent projects helped students to formulate climatic, structural and material strategies for their design endeavors.

The resultant analyses uncovered strategies as to how various examples of vernacular architecture were intelligently adapted to a tropical desert climate over hundreds of years or were built with limited tools. Identifying strategies for solar shading, harnessing winds to increase natural ventilation, using thermal mass for cooling, utilizing simple modes of construction and interpreting cultural and structural repercussions of building form, were important aspects of the precedent research. In addition to a series of vernacular examples, students were also asked to investigate a number of contemporary examples of deep architectural enclosures and thick roof systems. Contemporary case study projects included the roof of the Menil Collection building by Renzo Piano Workshop, the Confluence Park concrete structures by MATSYS, the Serpentine Pavilion by Alvaro Siza and Eduardo Souto de Moura and the Nordic Pavilion at the Venice Biennale by Sverre Fehn among others. Students collected and produced original graphic information about each building, building type or technology (including diagrams, drawings and images) in order to identify modes of performance and strategies for the design of new building envelopes. The studio worked in a coordinated manner to produce a catalog of analytical diagrams that uncovered rules and patterns associated with each given precedent.

Using information from their case study analysis, students experimented with new ways of blending concepts, technology and geometry from the two categories (vernacular and contemporary) into an adaptable, prototypical roof and envelope system. An approach based around hybridization of traditional building typology with digital design and production technologies has precedence in contemporary architectural practice. The *Afterparty* project by MOS Architects was one such example. MOS architect's project, developed in 2009 for the urban courtyard of the P.S.1 gallery of the Museum of Modern Art in New York City, was a pavilion that provided shade and created its own microclimate. The architectural design and materiality of the project was in part based on a contemporary adaptation of traditional thatched roofs, linking the project to more primitive architectural forms and material systems.[5]

The hybridization exercise within the *Thick Skins* studio required the adoption and mixture of performative, formal and material aspects from the original case studies to develop new prototypes. Considerations of which attributes of the prototypes were adaptable was an important consideration for the lesson. Students employed digital modeling and scripting tools (i.e. Maya, Rhino and Grasshopper) as well as other 2D and 3D tools (physical models, sketches and drawings) for hybridization. In many cases, students redrafted two-dimensional architectural elements from their case studies and recomposed them in three dimensions.

The assignment asked students to consider how parametric tools, and or parametric thinking, can be put to work to blend architectural form to achieve canopies that perform in desirable ways and can adapt to different sites, spans and programmatic criteria. As defined by Wassim Jabi, "Parametric design is a process based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode and clarify the relationship between design intent and design response."[6] In the design studio, students employed digital tools to encode dimensional, performative and programmatic parameters from case study projects, the studio brief and given site constraints. There were students in the course who, through the use of software platforms such as Grasshopper, were able to dynamically adjust and control design criteria such as scale, orientation and porosity. Work flow, modeling definitions and scripts for digital models enabled students to easily generate multiple design options based on subtly different data inputs. Other students were less reliant on digital platforms for design investigations, but nonetheless were encouraged through the studio curriculum to employ parametric thinking. According to David Karle and Brian M. Kelly, "Parametric thinking is a way of relating tangible and intangible systems into a design proposal removed from digital tool specificity and establishes relationships between properties within a system. It asks architects to start with the design parameters and not preconceived or predetermined design solutions."[7]

Through the prototyping exercise, students explored the potentials of variability in roof systems through the use of digital drawing and modeling programs combined with direct, hands-on material exploration. Students engaged in non-linear processes, navigating between research, design and production to investigate various technologies and materials. Students worked with both traditional and contemporary tools available in the design studio and fabrication labs to create three dimensional building envelope studies that investigated patterns of module distribution, thickness and porosity.

The site for the initial, prototype assignment was generic. There was no specific program other than a 10m x 10m roof over a non-air-conditioned space. Project constraints were therefore determined by the general climatic conditions of the Gulf Region, material systems, production technology, module size, structural limitations, natural ventilation, solar performance and human scale.

Students were asked to be strategic and specific about how performance is defined in their projects. While a studio-wide focus on performative aspects such as solar shading and the facilitation of natural ventilation set broad goals for every project, a number of students developed parallel goals for other aspects of architectural performance through the development of their designs. Aesthetic goals for the appearance of lightness or thinness became important themes for some projects, while the patterns of shadows cast or certain atmospheric qualities became relevant in other projects. Students were encouraged to build performance-based models to better define and understand the structures, forms and other criteria they were investigating.

In subsequent design exercises, preliminary prototypes were adapted to and tested across a series of three sites: a long and linear pedestrian path, a wide and tall infill site between two existing buildings and a free-standing pavilion in a public space. Students were encouraged to experiment with multiple material systems, different structural strategies and scalar shifts. Forcing students to contend with contextual, formal and material adaptation helped them to better understand the realities of contemporary architectural practice in a rapidly developing region where projects are subject to shifting time constraints, budgets, sites and programs. Working across a series of sites also allowed students to focus on how the envelope systems would need to adapt to maintain their defined performance criteria.

Figure 2. Wind tower hybrids. Rim Sibai's project (left) sought to reinterpret a traditional masonry Dubai wind tower through a clustered structure of hollow tubes that create a naturally ventilated space. Habibah Salman's project reinterprets canvas wind towers into a sculpturally shaped pavilion, composed of modular, cylindrical tubes. Thick Skins Studio.

The studio works were designed through a process of reflective practice in which students developed solutions based on a set of constraints, framed within a project brief. A basic explanation of reflective practice is described by Donald A. Schön as follows:

> A designer makes things. Sometimes he makes the final product; more often, he makes a representation - a plan, program or image - of an artifact to be constructed by others....He shapes the situation, in accordance with his initial appreciate of it, the situation 'talks back,' and he responds to the situation's back-talk...In a good process of design, this conversation with the situation is reflective. In answer to the situation's back-talk, the designer reflects-in-action on the construction of the problem, the strategies of action, or the model of the phenomena, which have been implicit in his moves.[8]

According to Laurene Vaughan, "the situated nature of practice-based enquiry ensures that research undertaken will produce knowledge that both deepens understanding and provides tangible applications for practice."[9] That is to say that for the *Thick Skins Studio*, the process of design will yield solutions that help to deepen the disciplinary knowledge of designing for desert environments. The process of applying a prototype to a series of sites, an iterative design process, helps to create a feedback loop for students to draw conclusions. "Research through designing uses the knowing of doing to achieve productive outcomes which in turn indicate the knowing and knowledge used in their production."[10]

DESIGN INVESTIGATIONS

Thirteen students tested thirteen prototypes over the course of the semester on a series of differently scaled site conditions and contexts. For the purposes of this paper, only some of the studio design investigations are described in detail. The projects chosen represent a range of design outcomes derived from different types of vernacular case studies.

Several of the students in the course researched and analyzed traditional wind towers and wind scoops in the vernacular case study segment of the semester. Examples ranged from mono-directional scoops in Cairo and Hyderabad, to the multi-directional wind towers of Dubai and Persia. Each of the following projects combined traditional ventilation devices with other contemporary examples of roof systems to prototype new, free-standing pavilions and enclosures.

Through her project, Rim Sibai sought to reinterpret the typical, masonry Dubai wind tower (Fig. 2, left). Wind towers evolved in Dubai as a result of particular social, technical and climatic conditions.[11] The wind towers of the historical, Bastakiya area in Dubai are invariably square in cross section, with four vents, separated by diagonal vanes. They rise several meters above roof level and typically descend a meter or so into a ground floor living room. They range from over eight meters for a two story house, to about five and a half meters for a one story building with a low parapet. The orientation of most of the wind towers in Bastakiya coincides with the prevailing north-west afternoon sea breezes. Traditionally, the four-sided towers channel prevailing winds downward into houses to cool domestic spaces in hot weather.

Sibai's project reinterprets the large towers into a hovering field of narrow, extruded, square tube profiles by hybridizing Dubai's vernacular towers with the *Solar Pavilion 1* project by SITU Studio.[12] In SITU Studio's project, cardboard tubes are bundled together into a canopy to provide shading. In the hybridized version, the canopy is designed to be self-structural as well as shade and facilitate the transfer of wind to the area below. Mechanical connections between the tubes and tensile cables that run through the overall roof structure were developed and tested in various iterations of the design. Through their structural depth, the wind-channeling tubes form a truss which is able provide compressive and tensile support for the prototypical rooftop. The project investigates the use of reflective, translucent and opaque coatings on the metal tubes to visually dematerialize the project mass.

Similarly, Habibah Salman's project, (Fig. 2, right) reinterprets a set of earlier, more primitive canvas wind towers from 19th Century Dubai into a sculpturally shaped pavilion, composed of modular, cylindrical tubes. The project utilizes a straight forward methodology of packing cylindrical tubes into a large volume and using a series of Boolean operations to remove mass from the volume. Spherical volumes are trimmed and strategically subtracted from the overall mass to provide spaces for inhabitation below and the capture of prevailing winds above.

Akhila Velloorkunju's project was developed out of the hybridization of traditional wind-scoops from the 18th and 19th century Hyperabad and the graduation canopy at Sci-arc designed by Oyler and Wu Collaborative.[13] The project (Fig. 3, top) reconfigures the vertical wind scoop from Hyperabad into layers of fabric and wood slats woven over and into the depth of a curving, three-dimensional, steel tubular space frame. Elements are designed with two or three corners of the diamond shaped space frames connected to the ground-scape or building facades with the remaining corners stretched upward like a sail to catch wind and provide shading for the areas below. Space frames are clustered in groups or organized in a linear fashion to create continuous spaces and reinforce each other structurally.

Rewan Shaaban's project was based on the hybridization of a wind tower from Cairo, with Renzo Piano's louvered roof from the Menil Collection building in Houston, Texas. Unlike the four sided wind towers prevalent in Dubai, the traditional wind scoops in Cairo were mono-directional. In the project, the linear extrusions of the Menil Collection roof louvers were reconfigured into undulating wave shapes, designed to catch the wind and direct it downwards into the space below. Throughout the development of the project the original performative intent of Renzo Piano's louvers was expanded into a canopy that mediated sunlight and channeled prevailing winds. The re-imagined louvers in the proposal are cast in glass-reinforced concrete and are more curvilinear than their Houston-based counterparts (Fig. 3). By changing the form and profile of the louvers, the canopy is transformed into furniture for seating, dining and pavers that create a surrounding hardscape in the same material language as the canopy.

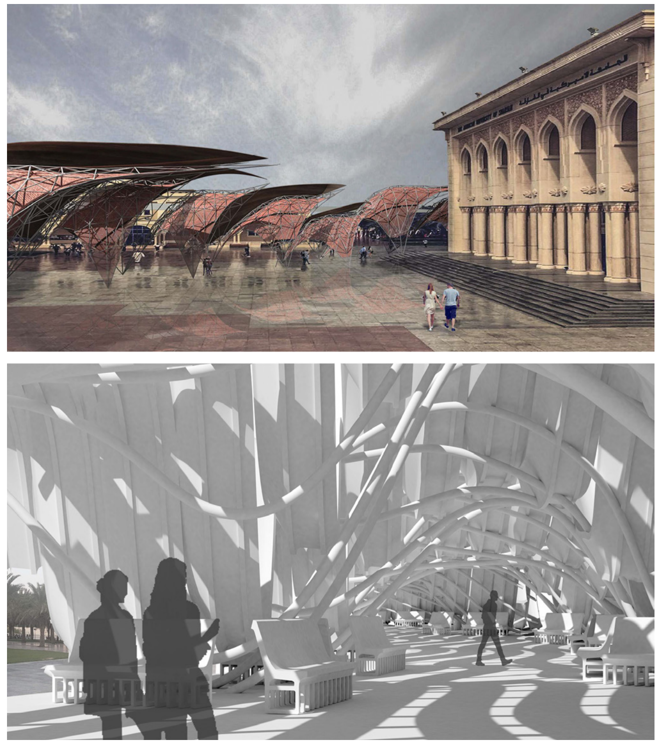

Figure 3. Akhila Velloorkunju's project (top) reconfigures a traditional wind scoop from Hyderabad into layers of fabric and wood slats woven over and into the depth of a curving, three-dimensional, steel tubular space frame. The project below by Rewan Shaaban is a hybridization of a roof mounted wind scoop from Cairo, with Renzo Piano's louvered roof from the Menil Collection building in Houston, Texas. Thick Skins Studio.

Halah Fadhil's project (Fig. 4, bottom) combines the architecture, materiality and re-configurability of traditional Bedouin tents with the rigid form of the *Cloud Canopy* project designed by Maddison Architects for Federation Square in Melbourne.[14] The hexagonal matrix of the *Cloud Canopy* project is given greater flexibility and depth by extruding hexagonal cells upwards and downwards to create thin and thick roof zones as well as structural columns and suspended furniture. Fabric panels integrated into the modular roof framework provide shading and help to channel prevailing winds downward into seating areas below. A system of ropes and pulleys allow visitors to adjust specific areas of the lower ceiling plane to create an interactive pavilion. Similar to traditional tents, by raising and lowering the ceiling, visitors can control privacy, shading and airflow in the zone under the canopy.

Laura AlDhahi's vernacular architecture research investigated the legacy of arish architecture from the Gulf Region of the Middle East. Arish structures are traditionally made from the woven fronds of date palm trees and reinforced with branches from mangrove trees. The lightweight structures are predominantly composed of tightly woven walls and roofs that provide shade and privacy. Other areas of the structure have looser weaves of palm fronds to create open screens or windows.

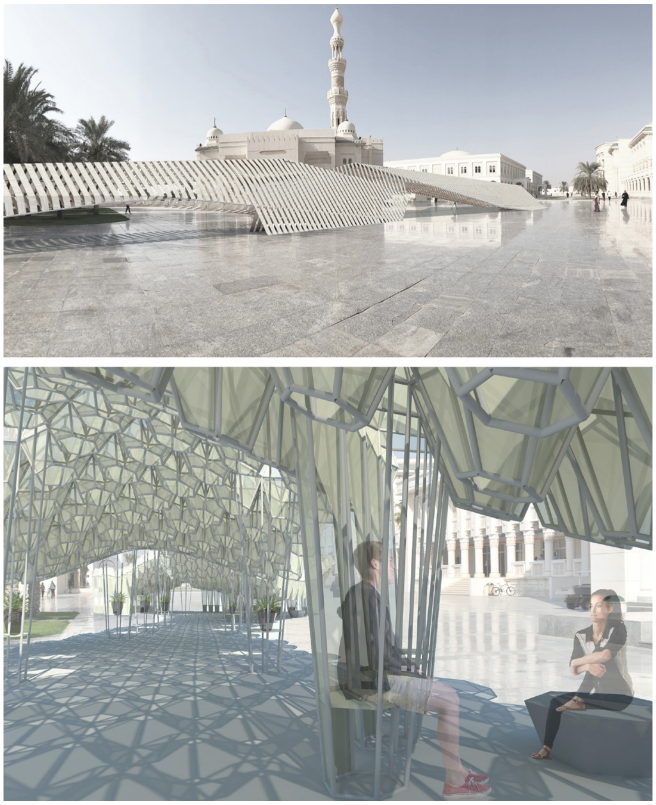

Figure 4. Halah Fadhil's project (bottom) features fabric panels integrated into a modular roof framework that provide shading and help to channel prevailing winds downward into seating areas below. Laura AlDhahi's vernacular architecture research investigated the arish architecture from the Gulf region (top image). Thick Skins Studio.

AlDhahi's design project (Fig. 4, top) also worked with an interlacing of linear elements, reinterpreted as aluminum louvers which conceptually weave together wall, floor and roof components into a continuous structure. Like arish huts, the louvers are tuned to adjust for denser and looser areas to control air and light penetration into the structure.

Shaden AlKalouti's project (Fig. 5, left) originated by hybridizing a case study of the earthen Musgam huts of Niger with concepts adapted from the *Confluence Park* concrete canopies by MATSYS.[15] Musgum huts are typically conical in shape and adorned with a pattern of protruding bumps that direct rainwater down the building sides, provide scaffolding for the maintenance of the structure and identify whether the inhabitant is male or female. In the development of the design project, the patterned exterior bumps on the traditional domes were reinterpreted as perforations that would also sunlight and winds to pass through the structure. Perforation size and proximity were adjusted to provide increased open areas for prevailing winds and constrained to shade from sunlight. The overall structure was designed as a fabric-cast, concrete form that would be hung upside down when cast to anticipate and resist vertical structural loads when installed.

Aashika Shibu analyzed the pigeon towers of Egypt and Persia as a precedent study. The structures are notable for their perforated facades, built to house pigeons and collect their manure for farming. Double layered walls created more roosts for pigeons and generated cooler interior spaces through natural ventilation, convection and shading. Her proposal reinterprets the thick masonry walls of vernacular pigeon towers into thin, folded sheets of metal (Fig 5, right). The project retains a perforated surface to control the penetration of wind and sun through the pavilion walls and roof. Double skin surfaces are connected by integrated cylindrical struts to make a thick sandwich that can absorb solar energy and provide a rigid structural envelope.

CONCLUSIONS

The design of the studio curriculum sought to build off of Hassan Fathy's advice for looking to vernacular, climatically-responsive architecture to create a methodology for designing building envelopes that respond better to local conditions. The main objective of the studio was to analyze vernacular architecture for performative aspects and to use those attributes to create better envelope and rooftop prototypes. The relationship between the vernacular examples emulated and the final prototypes were different in each case. While some traditional buildings provided geometric or formal criteria for design inspiration, their materials were not necessarily important to the final results. For other projects, formal or shape based attributes were inconsequential, and students projects relied more on the details of buildings. In each case, the definition of performance (structural, material and environmental) became critical to the reinterpretation of vernacular forms for each project. Therefore the value of vernacular is not necessarily in its appearance or its precise form or material but in the way the buildings for elements of the buildings performed. As the curriculum asked students to reconfigure their prototypes to three different sites (with different structural challenges) over the course of the semester, students were forced to prioritize their own definitions of performance over materials or form.

The curricular guideline that asked students to combine vernacular architecture with contemporary examples of architecture was critical in allowing students to move past the imagery of traditional forms and apply contemporary tools to their design projects. Given the shift in production methods, material supply chains and labor resources, many of the vernacular architectural examples would be difficult, if not impossible to economically rebuild in the construction industry of today. The contemporary precedent projects allowed students to better understand the materials, tools and processes that are used to create modern architectural facades, roofs and envelopes.

By asking students to complete multiple design exercises, the studio encouraged an iterative approach to design. The prototypical roof systems students developed over the course of

Figure 5. Shaden AlKalouti's project (left) originated by hybridizing a case study of earthen Musgam huts with the *Confluence Park* concrete canopies by MATSYS. Asshika Shibu's work reinterprets the double-layered, perforated masonry walls of vernacular pigeon towers into thin, folded sheets of metal (Fig 5, right). Thick Skins Studio.

the semester were not singular design solutions but are meant to be adaptable in nature. The studio considered how both parametric tools and or parametric thinking can be put to work to blend architectural form to achieve canopies that perform in desirable ways and can adjust to different sites, spans and programmatic criteria. This pedagogy encouraged students to work quickly through projects and focus more on the principles and process of design, rather than singular design solutions.

The addition of performance analysis software into the design process would further strengthen the pedagogy of iterative design. Wind, temperature and structural modeling programs could be used to run comparative analysis on vernacular case study models as well as student design models. Quantitative analysis of structural, temperature, shading and air movement data would provide student designers with more definitive ways to measure, adjust and enhance performance.

The use of digital design tools combined with a foundational understanding of the climatically responsive capacities of traditional architecture led to an experimental approach toward building design. Within the context of the Gulf region where building facades are often decorated with geometric surface patterns meant to suggest a connection with Islamic architecture or Arabic culture, the studio aims to create prototypes for a better performing building envelope, and an architecture with meaning (and performance) that is more than skin deep.

ACKNOWLEDGEMENTS

The author would like to thank all the students who participated in the *Thick Skins Studio:* Shaden AlKalouti, Laura AlDhahi

Hayat Almousa, Mohammad Aslam, Rim Sibai, Halah Fadhil, Akhila Velloorkunju, Fatma Oualha, Navaz Pirbabaie, Aya Rahmy, Habibah Salman, Rewan Shaaban and Aashika Shibu. Thanks also are extended to guest critics, Erik L'Heureux, Kristof Crolla and Emidio Piermarini. The studio would not have been possible without the leadership of Dean Varkki Pallathucheril and Head of Department George Katodrytis of AUS or the generous sponsorship of Arada Developments, LLC.

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