

Masdar City: As an Example of Sustainable Facades and Building Skins

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Abstract—Abu Dhabi is highlighting the importance of moving towards sustainable design and planning, through its strategies and policies that are supported by Estidama and the Abu Dhabi 2030 Vision. The effect of Masdar City is quintessential on an educational level as many of the new designs in relation to sustainability can be better explained to students, since Masdar is a living example of how sustainable workspaces and architecture can be developed in an oil rich state. Masdar's diversified façade designs represent a living of how traditional building screens can be developed within a contemporary context, and explored using different materials, to revisit the mashrabiya screen as an architectural veil that shapes the identity of the spaces behind it. The screened facades of Masdar shaped by environmental design criteria such as the Siemens Headquarters, the Incubator building and Masdar Institute help explain the works of Le Corbusier and Hasan Fathy and how they approached environmental design contexts. Designed by Foster and Partners Masdar undertakes the role of disseminating sustainable design through a communal dialogue between its buildings and visitors that experience how sustainable building materials, as applied on buildings facades can improve spatial configurations and sustainable living.

Index Terms—sustainable design, Abu Dhabi, Masdar, perforated screens

I. INTRODUCTION

The reintroduction of perforated screens traditionally known as mashrabiya on the facades of Masdar city in 2006 represents innovative forms of reconciliation with local building traditions, especially that perforated screens have existed in the UAE as part of its heritage, yet were restrained in the early seventies by the constraints of building materials and existing technologies. In 2008 Abu Dhabi government introduced an initiative titled Estidama, meaning "sustainability", which promotes sustainability through a system of ratings for new buildings such as villas and private residences and is gradually being introduced to public buildings. Estidama which rates buildings on a "Pearl" system represents an attempt to shift the notion of architectural design from "Function follows Form" and architecture of the spectacle as witnessed in Dubai in the last decade, to more environmentally based design and building skins that aim

to set new standards that are less dependent on mechanical cooling systems.

II. MASDAR CITY

Designed by Foster and Partners Masdar City created an urban enclave that acts as a living, open air museum for innovative use of building skins, and revived interest in the design of mashrabiyya screens as treatments for the hot humid environmental climatic context of Abu Dhabi. It also manifests a model of educating the community through their immersive experience that links theory to practice as manifested by the facades of many of the buildings in Masdar City such as the Siemens Headquarters, the Incubator Building and Masdar Institute. These buildings allow for a contemporary visualization of Le Corbusier's design theories such as the use of brise Soleil, on facades that are free from the spaces they veil, the use of pilotis to raise the building above the ground and allow for uninterrupted landscapes, and to use of the roofs of buildings as gardens; in the case of Masdar they are used for harvesting energy through photovoltaic panels. This represents a milestone in sustainable design, especially in oil rich Gulf States that in past decades developed architecture that was characterized by large glass facades, and increased the dependency on mechanical cooling systems, and lack of social and public space. Many of Abu Dhabi's buildings created in the 1970's and 80's have large glass surfaces that can be retrofitted via screens and insulation materials to increase their thermal efficiency and reduce heat gain. Here sustainability as a communal educational system becomes integral in architectural design in order to preserve resources for future generations. [1] Masdar City through its urban setting also revives the nostalgic ideology of Hasan Fathy, who attempted to create a sustainable human settlement in New Gournah, in Luxor/Egypt through the use of local materials and building techniques i.e. create architecture that is homegrown without interdependency on the State. Fathy later published his vision in a book titled "Architecture for the Poor: An Experiment in Rural Egypt", published in 1969/1976. While the project of New Gournah failed as local residents refused to resettle in it, Fathy's ideas inspired new generations of architects and planners, that attempted to integrate vernacular technology with modern architectural principles. In Masdar this is seen in the clustering of buildings and the use of terracotta tiles and

perforated screens to provide privacy within an urban fabric that is closely knit to recreate spaces of social gathering and interaction. Designing architecture with an understanding of the importance of precedents, and regional vernacular expression is highlighted by Masdar's buildings that do not replicate the ideas of Le Corbusier or Hasan Fathy, rather revisit them to create buildings with facades that are designed so that daylight is distributed adequately in each room and used as the main light source for a greater portion of the year, and thereby reduce the demand for artificial lighting.

Sustainability as criteria of design explores the use of a diverse range of materials such as terracotta tiles, aluminum and recycled steel as well as GRC screens to create buildings that have good thermal insulation properties. They also create a visual collage and montage that spans the boundaries of regional heritage(s) and modernity. The use of screen facades to create energy efficient buildings is visible independently in the design of the facades of the buildings and their spatial arrangement which is orchestrated to create shaded corridors that allow cool air to circulate within them thereby creating stack ventilation effect. Stack ventilation is also manifested in the consistent presence of courtyards of different sizes in Masdar's buildings and elevating them on colonnades that allow an uninterrupted flow of cool air between the buildings, taking advantage of temperature stratification in Abu Dhabi and reviving Le Corbusier's ideas to create sustainable public spaces that are also spaces of social interaction, complemented by trees, water canals and recreational enterprises such as shops and cafes. The Siemens Headquarters building is a good example of a building designed along the lines of Le Corbusier's *brise soleil*, the façade of the building works as a light filter, which controls incident light and determines the outward view by means of the apertures. The use of the *brise soleil* as dominant architectural feature works not only aesthetically, and pays tribute to its antecedents of the modernist era, but also constitutes an important element in the control of the room's climate and light levels. In Abu Dhabi unscreened sunlight can heat a room to an extent where it is not comfortable to stay in it. [2] The geometrically perforated mashrabiya's act as an architectural expression for the interrelation of past and present and as a reflection of a diversely social, and a modern city that is re-shaping its identity with sustainability as an underlining theme. Embedded in the culture of modern architecture is the directive that a façade ought to fit tightly around its building, like a well-fitting suit, the louvers of the Siemens building are situated at an appropriate distance from the glass surfaces to allow for their technical and aesthetic value to function appropriately. Here screen façade has been used extensively but appears neither by too big or too small for the building that it circumambulates. [3]

The Siemens HQ building represents a good example of a building that reinterprets the past and is also rated as a LEED Platinum building because it makes use of sustainable and energy efficient materials and building techniques. (Fig. 1) Designed by Sheppard Robson to use

45% less energy than typical office buildings, it also incorporates several interesting characteristics such as the nine courtyards that penetrate its cubical form reviving the traditional function of courtyard in desert architecture which allowed cool air and natural-light to become integral part of the vernacular expression. The roof top is also covered by photovoltaic panels to generate energy harvested from the sun. The new materials used on the façade as a building skin highlights the endless possibilities of creating new building skins of existing building stock of downtown Abu Dhabi to refurbish them as an initiative is to valorize the pioneering ideas and to reinforce their relevance to contemporary sustainability and re-establish connections between people and places. [4]



Figure 1. Siemens Head Quarters Building Masdar

Described sometimes as a box within a box the Siemens HQ building with its double façade insulated from the sun via a lightweight aluminum shading system revisits the Habitation in Marseille designed by Le Corbusier. As an early example of modernity and tradition, the Marseille Habitation is perhaps the most copied prototypical model for social housing used in the Middle East. Its facade was designed to screen out the sunlight and reduce dependency on air-conditioning, it reflected Le Corbusier's vertical approach to vernacular design and the creation of social space beneath the building and on its rooftop. The separation between the vocabulary emanated by the façade and its duplex interior units accentuates the importance of façade screens and building skins as a veil for the spaces behind them let alone the creation of well-designed open plan interiors. Siemens building takes this concept a step further through the shape of its external shading devices that have a three-dimensional persona and cover almost all of the glazed areas. The external shading system enabled also the use of clear glass to enhance daylighting as opposed to tinted glass that was used extensively on the building glass block towers of Abu Dhabi in the past decade. Concrete undecorated facades of the modernist era are referred to by the grey color of the facades of the Siemens HQ building, and the variation in the form of the shading systems, characterized by light-weight aluminum fins, creates a strong architectural language with lineages to Le Corbusier's brutalism architecture. The plaza beneath the building allows the cool breeze to flow up to the roof of the building through nine courtyards/light shafts in the

buildings' structure and double skin facade, cooling public spaces without energy costs.



Figure 2. Incubator Building Masdar

In Masdar there is wide range of material usage manifested in its buildings, these materials range from solid GRC and clay tiled buildings to semi-translucent glass façade buildings. The Incubator Building exemplifies the latter, it is glass building that in its lack of ornaments and functionality revisits Mies van der Rohe's modernist designs. Its glass facades covered with fretted glass incline upwards leaving little room for any decoration emphasizing the texture and patterned roundels facades. (Fig. 2) The Incubator Building with its shaded facades reflects an emphasis on vertical and horizontal forms and integration between external landscape with interiors through the utilization of steel and glass. Mies Van der Rohe's building materials can be appreciated due to their purity from ornamentation. The Incubator's facades and planned courtyard created a building that shifts the attention of the visitor to the purity of its forms and tectonics of its glass facades. It is also home to the first LEED CI-certified office in Abu Dhabi, Alpin Limited, and offers office space to General Electric Ecomagination Center. The building represents an initiative to the active partnership between private enterprises and the UAE Government to promote a culture of sustainability. The building circumambulates around a planted green courtyard and exemplifying how form follows function is accentuated through its slanted facades that reduce solar radiation.

III. TRADITIONAL BUILT ENVIRONMENTS AS PRECEDENTS FOR SUSTAINABILITY

The reinterpretation of traditional building environments, with as shaded courtyards, narrow pedestrian streets and buildings that are cantilevered or raised on columns In a modern city the use of indigenous materials such as adobe buildings or reed huts locally known as the Arish is not an easy task since its can also be critiqued as freezing architecture in time and space. Sustainable design cannot only rely only on environmental criteria but also needs to be a catalyst for

good quality of life and good services for all including local culture and traditions. [5] In course on Architecture and the Environment at Abu Dhabi University a group of 20 students visited Masdar and then were assigned to experiment with precedent designs of Le Corbusier and Hasan Fathy. The aim was to link theory to practice, students were divided into groups and were given the task of investigating and creating physical models that reflected on brise soleil and adobe architecture utilizing several environmental techniques such as the use of courtyards, screens, domes and vaults. Students also explored the problems that emerged from the use of mud namely the cracks that developed as the material dried and the deformations in shapes in relation to the shrinkage of materials. (Fig. 3) They also explored the effect of light shade and shadow on domes and vaults simulating reflection of sun on flat roofs versus curved roofs. The physical models created were quintessential for student understanding of traditional architectural building techniques, regional architecture, its materials and the problems faced by Hasan Fathy in New Gournia. They also better understood the thermal characteristics of thick adobe walls versus thin walls with double skin facades as alternative solutions to reduce the head gain of buildings. Such examples allowed the integration and understanding of closely-coupled human-environments, based on a hands-on-learning bases and how local heritage can promote new ideas.



Figure 3. Student works recreating local wind towers-barjeel, and courtyard house with adobe models

Traditionally geometrically carved screens have been used on stucco or wooden square shaped or rectangular surfaces as mashrabiya screens in the Islamic World from Moorish/Hispanic Spain to Mughal India. Historically geometric principles were used to generate various three-dimensional architectural elements. [6] To highlight elements of sustainability within a contemporary context students experimented with the tectonics of materials, and how traditional elements such as wind towers can be created in various materials to reflect on the contemporaneity of sustainable design that is founded on regionalism and architectural precedents. Here the role of geometry in architectural building traditions was revisited and examined within a practical and theoretical context to highlight how rules for the creation of perforated screens as part of the overall design of the façade must have existed yet had been overshadowed. Physical modelling supported theoretical frameworks and helped breach the gap between sustainable design in theory and in practice.

It also highlighted the importance of humanistic values and sustainable connections between people and places and the use of traditional knowledge and materials especially the exceptional advantages of mud/earth/terracotta as a sustainable construction material. It has been proven more effective as part of a hands on learning process to explain to students the key objectives of screens in relation to window design that being to create a gradual transition through which the eye can gradually get used to rather than be exposed to the intense light outside. In addition students were able to explore how traditional wind-towers *barjeel*, functioned and connected different aspects of sustainable design such as materiality, perforated screens, in relation to the design of courtyards, atriums and interior spaces, to create pleasant transitional environments between outdoors and indoors that are less dependent on mechanical systems. (Fig. 4)



Figure 4. Student model examining local wind towers-barjeel, with wood.

IV. REVISITING VERNACULAR FORMS SUSTAINABLE DESIGN AND MICRO-CLIMATE

There is no doubt that today the Arab world, and especially Gulf State cities are becoming urban, at rapid rates these emerging modern cities are complex products of human activity, and there is a growing worldwide attention to sustainable development, where the needs of today's generation do not conflict a modern city that is automobile oriented. Today contemporary buildings in the city need to control the indoor environment to an occupant comfort zone, in order to create productive and livable spaces. Thus, dealing effectively with the city's modernity and climatic conditions warrants the need for contemporary screens that provide a possible solution to reduce the effect of the sun. [7] Today Masdar City sets a more prominent example through its revisiting of the past, and reinterpretation of traditional building environments as its buildings are planned to achieve the cooling effect

through shade, and the use of screens patterned with Islamic designs to ensure a comfortable indoor climate. Perforated screens and building skins have been used to provide comfortable interior environments and privacy in buildings on windows, balconies, rooftop crenellations and terraces as handrails. In addition latticed screens were used produce an aesthetic effect for providing a traditional appearance to the buildings associated with cultural events such the historic buildings in Al-Bastakiya quarter in Dubai. Geometry and its infinite possibilities to produce patterns for perforated facades, or prefabricated screens that can act as double skins for modern buildings and allow interplay of light, shade and shadow, according to needs of the design. The main difference between Masdar City and earlier antecedents that addressed environmental design is that Masdar advocated itself as a center for innovation in renewable energy and clean energy production that also takes into consideration local building traditions, climate and cultural context. This contemporary interpretation of local forms within a contemporary context has intern redefined the essence of sustainable design and coupling modernity and tradition in design for forthcoming generations of architects.



Figure 5. Masdar wind tower and residences with screens and photovoltaic panels.

Abu Dhabi's interest in fostering sustainable design is clearly manifested in its Urban Planning Council policies and Estidama Guidelines that further cement iconic projects produced by well-known architects and iconic projects such as Norman Foster's contemporary wind-tower in Masdar City, Jean Marc Castera's reinterpretation of mashrabiya screens (Figure 5) and Jean Nouvel's design of the Abu Dhabi Louvre that introduces a new vocabulary of sustainable architecture emerging in Abu Dhabi and shaping its identity as a modern Arab city. The neo-Islamic styled dome of designed by Jean Nouvel creates a micro-climate beneath it that allows light to penetrate its skin creating different patterns on medina styled urban fabric below it. The design of the Abu Dhabi Louvre re-introduces the geometry of Islamic Arabesques to a massive domical structure creating an important icon, and manifests the

importance of redefining traditional forms beyond the post-modern interpretation. The perforated dome covers a 180-metre- wide central space and creates a micro-climate beneath it that allows light to penetrate its skin creating different patterns of shade and shadow. [8]

The Abu Dhabi Louvre's perforated dome design employs Islamic patterns to reflect the endless possibilities that were adopted and developed overtime to create new visions of environmental design that are only possible with today's structural technology and materials. The geometrical patterns of the perforated dome are combined, duplicated, interlaced, and arranged in intricate combinations creating a building surface of the complex Islamic ornaments that were usually applied on flat surfaces. The geometry of the steel dome, highlight the endless possibilities that were adopted and developed overtime from simple geometrical forms. The building also address environmental design from the re-interpretation of regional grammars of ornament and spaces manifested in the spaces of organic nature created below the dome interlacing with water canals. The use of water as an element of the natural environment combined with the infiltration of light from the perforated dome, creates new paradigms of environmental design and an interplay of shade and shadow The Abu Dhabi Louvre reflects on the dynamic nature of architecture and its development overtime to create a new venue for sustainable design that is meant to be experienced by all, within a collective and communal context, that can be viewed as a regional trend to experiment with sustainable forms and regional decorative forms that were also a natural production and reaction to the surrounding environment.

V. CONCLUSION

In Abu Dhabi new applications of regional and traditional designs create new venues for sustainable design that goes beyond the social perception of environmental design in association with a specific social class. On the contrary sustainable design in Abu Dhabi is advocated to cater to a societal composition in Abu Dhabi that consists namely of multinational Arab and expatriate communities and that are aware of the importance of environmental design. The use of the contemporary geometries reinterpreting mashrabiya screens represents an inevitable necessity adhere to global changes in the realm of architecture to produce new forms that are iconic and aesthetically pleasing. The visibility of such geometries on a large scale in the form of building skins and curved surfaces such as the Abu Dhabi Louvre dome reflects the new interpretations of traditional patterns that

can be integrated onto modern buildings. They also highlight the available technologies and materials for building skins to reduce glare and create more comfortable and sustainable indoor environments. The facades of the Siemens HQ, the Incubator, and Masdar Institute represent a modern interpretation of a ideologies explored by the pioneers of architecture such as Le Corbusier, Mies Van der Rohe and Hasan Fathy that addressed the production of environmentally oriented urbanism beyond the norms of Classical architecture. Their use of Concrete, steel and glass and molded earth as building materials create a new image of architecture is manifested today by the buildings of Masdar that offer new interpretations of social space and improved communal lifestyles and standards of living in the Gulf. Such new building typologies integrate many sources of knowledge in addition to the multi-ethnic background of practitioners in architecture and the experience of star architects that transgress the boundaries of freezing tradition in time or applying it within a post-modern pastiche. The materiality and design of the buildings in Masdar City offer an opportunity to create numerous scenarios of sustainable design that is culturally and environmentally oriented.

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