# 10 The Masdar Institute's GRC Residential Facade

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Masdar Institute - Use of GRC in Sustainable Construction

Like many Middle-Eastern states, Abu Dhabi built its economy on oil production. However, it is almost unique in recognising that we must develop alternative energy models if we are to reduce the environmental impact of our contemporary lifestyles. Masdar, the Abu Dhabi Future Energy Company, was established in April 2006 and is an organisation committed to advancing the development, commercialisation and deployment of renewable energy solutions and clean technologies, such as power generation from a range of renewable energy sources, including a 10 MegaWatt solar photovoltaic farm at the city's edge. The new city of Masdar [picture 01] is the result of that initiative. Masdar City is liveable, sustainable and, now the first resident community are living and working at the Masdar Institute, the educational heart of the city is now operational.

Masdar City also has far-reaching significance in global terms – it looks at architecture and infrastructure together on a large scale, something that can only be done at the level of community planning. This combination of infrastructure and buildings is critical to sustainability, but such holistic thinking relies on the support of political initiatives and enlightened commercial clients. With Masdar City, the Government of Abu Dhabi has shown great leadership in this respect.

Quality of Life

To be successful, a sustainable initiative must result in a place where people want to live, work or visit – the city must 'lift the spirits'. In Masdar City, there is a focus on the public realm – on transport, streets and squares – everyday places that are easily taken for granted but have a real impact on the way that we live. [picture 02] The masterplan incorporates a variety of community spaces, all contained within a safe, primarily fossil fuel-free development. Integrated with its surroundings, the city will offer something for everyone, from intimate courtyards and gardens, to sports fields and shopping streets.

Providing comfort in a desert climate is a principal concern. Green parks separate the built-up areas, capturing and directing cool breezes, while providing cool, pleasant oases throughout the city. Carefully planned landscape and water features will aid in reducing ambient temperatures, while enhancing the quality of the streets.

A number of devices – such as colonnades, whose shadowy recesses offer respite from the sun – have been shown to bring the radiant temperature down by 20 degrees compared to open desert. Planting, green canopies and water not only help to lift the spirits, but encourage further drops in temperature. Other vernacular devices, such as wind towers, which encourage cooling air currents, can also help to modify the microclimate. Cumulatively, all of these devices have the effect of prolonging the pleasant, moderate season in the city. [picture 03]

The large urban square at the base of the windtower in the Masdar Institute neighbourhood [picture 04] – a civic landmark as well as a cooling device – is animated by café seating, shaded by the buildings and mature trees. The square offers a place of recreation and social interaction – a counterpoint to the intense research environment of the laboratories.

The Masdar Institute

The Masdar Institute, the first part of the development to be built, houses the city's first residents – it is the first building of its kind in the world to be powered entirely by renewable solar energy. This community, independent of any power grid, currently generates a surplus of 60 percent of its own energy needs, processes its sewage and dry waste on-site, which is recycled, and pioneers many energy saving concepts. It is a bold experiment which will change and evolve over time – already it houses twelve separate pilot research projects for energy generation with potential world-wide applications. The design of the masterplan is flexible to respond to these new technologies, anticipating things which have yet to be invented – many of which will be developed in the Masdar Institute.

The city is anchored by its educational heart: the Masdar Institute. In collaboration with the Massachusetts Institute of Technology (MIT), the graduate-level, research-driven institution provides courses focused on education and research in advanced energy solutions, sustainable technologies and environmental policy. The first six buildings on its campus [picture 05] are already complete and occupied, and the students and researchers are Masdar City's first resident community. It provides the catalyst for the rest of the masterplan, which will continue to take shape as new phases start on site.

But the Institute is more than a working prototype – it is as liveable as it is sustainable. As well as state-of-the-art labs, the neighbourhood incorporates cafés, landscaped paths, public squares and residential accommodation of the highest quality. Most significantly, the Institute campus is fully integrated with the city – its social and public spaces are open to all [picture 06-07]. From the flexible 'plug-and-play' laboratory facilities to the dynamic social and community spaces, the aim has been to create a great place to study and work that will attract the best international talent to achieve Masdar's strategic aims.

Impact of Masdar City: potential application for other cities

Masdar City is already fulfilling its strategic goal to become a centre for the development of new sustainable technologies. A range of pilot projects are underway at the Masdar Institute, exploring alternative forms of transport, cooling devices, such as wind towers, and new potential sources of power, including solar thermal cooling. It has also been possible to apply some of the region's wealth of expertise in mining to conduct further analysis into the use of bore holes for geothermal heating. If geothermal heat can be developed and commercialised by Masdar City, it could become a major contributor to helping meet some of the region's enormous cooling load.

Flexibility is a key consideration of Masdar City's planning – the masterplan is designed to incorporate these emergent technologies and to respond to lessons learnt during the implementation of the initial phases. In this way, each phase of development brings positive benefits for the next. Expansion has been anticipated from the outset, allowing for urban growth while avoiding the problem of sprawl that besets so many cities

Masdar City has already contributed substantially to the Abu Dhabi Urban Planning Council's Estidama sustainable building code. Masdar City experts have worked with the Abu Dhabi Department of Municipal Affairs (DMA) on their world-class building codes that will substantially improve Emirate-wide building efficiency in water and power consumption.

Many of the lessons learned at Masdar City in the field of sustainable urban development, planning and design are being shared with the UPC, the DMA, Department of Transportation, Centre of Waste Management and other government regulators and policymakers, as these Emirate-wide bodies seek to maximise the sustainability of the city as a whole. From smart utility metres and

solar panels on buildings to solid waste standards and street widths, Masdar City is a constant partner to Abu Dhabi in the development of its urban planning and energy policies and strategies.

Residential Façade Design

It is within this larger sustainable context of the Masdar City Masterplan and the realisation in the first phase of the City, the Masdar Institute that the selection process led to the choice of GRC as a construction material.

The design concepts for the residential façades differ from the other building within the campus such as the laboratories and Knowledge Centre, in that they are designed to allow for natural ventilation. Circular openings in the roof of the balconies provide cooling ventilation. The interiors of the apartments can be naturally ventilated during the winter days and often typically in the evenings. The interiors of the apartments are thermally lightweight and highly insulated to allow for rapid cooling. This is because of the periodic nature of occupancy of the apartments.

The main concept for the residential façades was to have a self-shading façade, designed to respond to their orientation, as well as shading the adjacent buildings and the street below. This was developed using a series of both physical and computational modelling techniques to help determine the eventual built form. The façades were designed as multiple layers, comprising an external balcony/screen layer, inner façade and insulation layer. External balconies provide excellent shading of the main residential envelope façade, while each layer provides a functional response to dealing with the harsh desert environment. [picture 08]

The balcony spaces and vertical mashrabiya screens and shading devices form this first layer and were designed to provide excellent shading. Their curved forms provide directed oblique views down narrow streets, while maintaining privacy – the close proximity of the building facades, as specified in the Masdar City masterplan massing concepts, was the key challenge in this respect. Jean-Marc Castera developed these screens specifically for the Masdar Institute through an understanding of the historical secular Arabic art of the past and the recent scientific research into mathematical geometry. Drawing on octagonal symmetry and avoiding monotony, the patterns were developed at different scales to allow the screens to have a degree of depth visually. The moulding possibilities of the GRC fabrication allowed for this to show through in the final installed elements, where the main areas of the GRC panels are typically only 25 to 30mm thick. The result was a contemporary reinterpretation of the mashrabiya screen, which protected the secondary inner layer, including windows.

The second inner layer was a combination of solid aluminium glazing panels and timber-framed windows where the extent of solid and glazed elements was developed with an average glass to solid ratio of 35% to minimise heat gain. Openings in the inner or second layer of the façade vary according to their position – the upper floors are more exposed, so approximately 25% is glass, while the shaded lower floors have a greater percentage of glazed area, around 45%. The timber framed windows (for excellent performance) were place to provide the best light distribution with minimum glazing area. A high level clerestory and vertical slot windows in the walls maximise daylight and reflect light into the apartments. Glazing locations are based on Ecotech calculations to determine orientation, overshading of façades, window and screen placements to reduce heat gain.
This inner layer of 90% recycled aluminium reflects light within the balcony and its thermal qualities of high thermal conductivity allowing it to cool down quickly.

The third and final layer was the use of a high level of insulation within a well-sealed inner façade. This ensured that any heat gain of any of the external elements would not be radiated within the apartment themselves or any infiltration or exfiltration occurred. This approach concentrated on minimising the influence of the façade on any residual affect on the mechanical control of the internal environment. The aim being to conserve the energy used to cool the apartments by

minimising the extent of the conditioned air being lost through the façade as well as additional heat being radiated in. This set the U-values of the scheme to be a U-value 0.25 W/m2K for all solid walls and 1.1 W/m2K for glazing. [picture 09]

While Masdar City's supply chain was put in place to ensure the city met its sustainability goals, a secondary objective was to support the development of a local and regional sustainable construction materials industry and to provide information and expertise to help suppliers improve the sustainability of their products and their production processes.

Masdar City is a challenge requiring original thinking and advanced technological solutions, but it offers a compelling opportunity for change. Most importantly, by embracing this challenge in such an extreme climate, the project has applications for both new and existing cities around the world.

As a result of this thinking, the original intent was that the GRC for the residential apartments should be made locally in Abu Dhabi to minimise material transport and embodied energy. The lightweight façades also serve to minimise and limit the embodied energy in their fabrication and construction.

Conclusion

Foster + Partners' masterplan for Masdar City aims to establish the world's first carbon neutral, zero waste desert community. It is rooted in a sense of place, shaped by the specific climate of Abu Dhabi. Its form is inspired by traditional desert settlements, which are compact and oriented so that the buildings provide shade and channel cooling air currents. The use of Glass Reinforced Concrete has helped in meeting this challenge with its inherent properties and in its manufacture, fabrication and physical attributes.

Shifting focus yet further, what makes Masdar City especially significant is the fact that it offers a blueprint for the sustainable twenty-first century city, not just in Abu Dhabi or the Middle East, but worldwide. Its design springs from the recognition that to survive, we have to change, and that with change can come a better way of life. Imagine such a city in an American, European or Far Eastern context and while it might not look the same its attractions would be equally strong. It is a classic example of 'thinking global, acting local' and never has that exhortation been more appropriate. [picture 10]

Residential Façades Key Facts:

• Multiple layers of façade using GRC mashrabiya screens, solid and glazed elements act to minimise heat gain.

• Curved forms provide directed oblique views in narrow streets while maintaining privacy.

• Patterned GRC screens designed by Jean-Marc Castera provide privacy control.

• Staggered undulated façade to provide self-shading from high sun.

• Modular, with a limited number of types, so much assembly can be done offsite. Balconies can be lifted into place with all cladding installed on pre-assembled lightweight steel frames.

• As screens increase in density, and size and number of façade window openings decrease, the more sun a façade receives.

• Deep openings in inner-most façade reduce heat gain while creating dramatic lighting effects.

• Glazing locations based on Ecotech calculations to determine orientation, overshading of façades, window and screen placements to reduce heat gain.

• High level shaded clerestory to maximise daylighting, penetration through bounced light deep into the apartment.

• Fully sealed envelope to provide very high level of air tightness (3m3/m2/hr) (current minimum by UK Code is 10m3/m2/hr @ 50Pa).

• Lightweight/ low thermal mass, highly insulated façade and internal finish act as fast responsive system to suit space use / cooling.

• Inner layer of 90% recycled aluminium reflects light within balcony and is lightweight enabling it to cool down quickly.

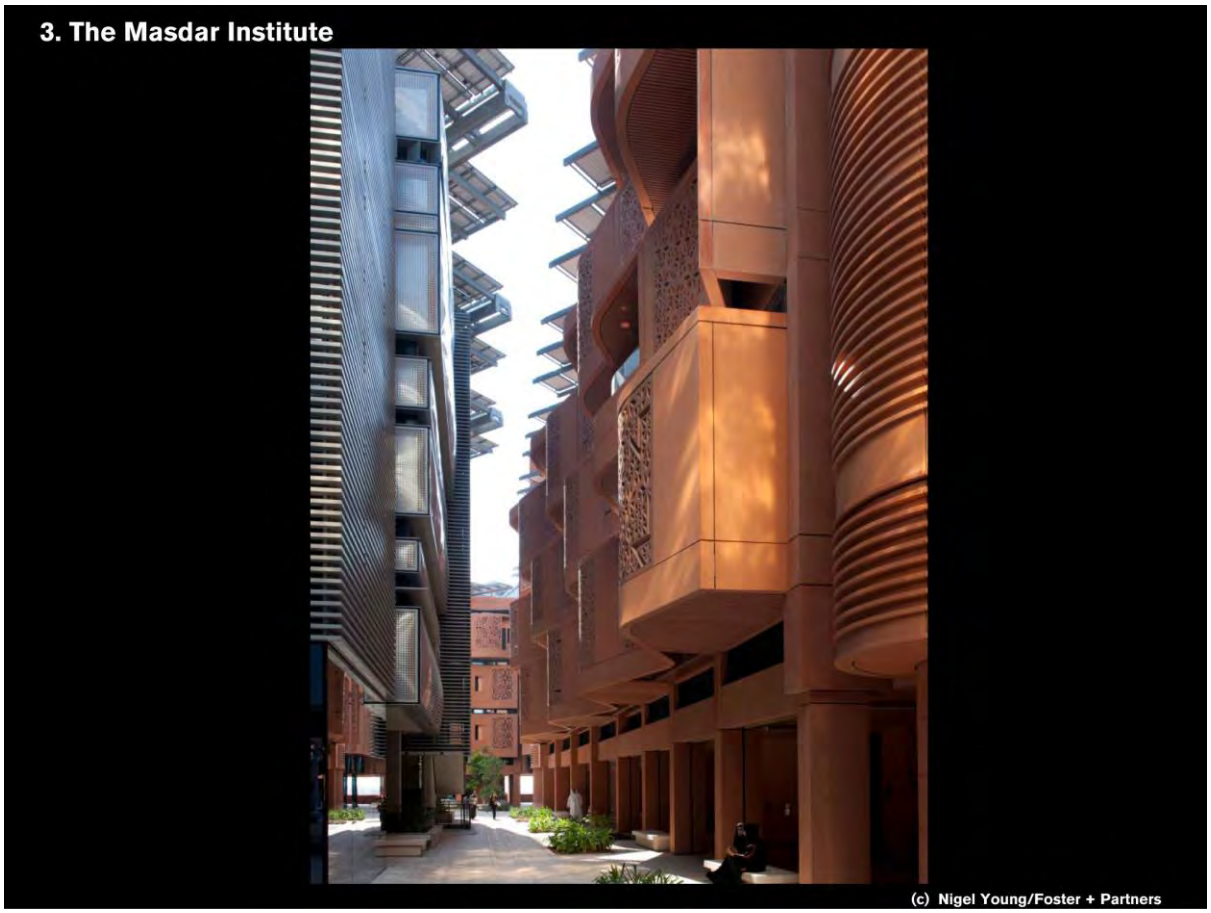
• The double skin allows for convection to ventilate the cavity and mitigate any additional heat gain.

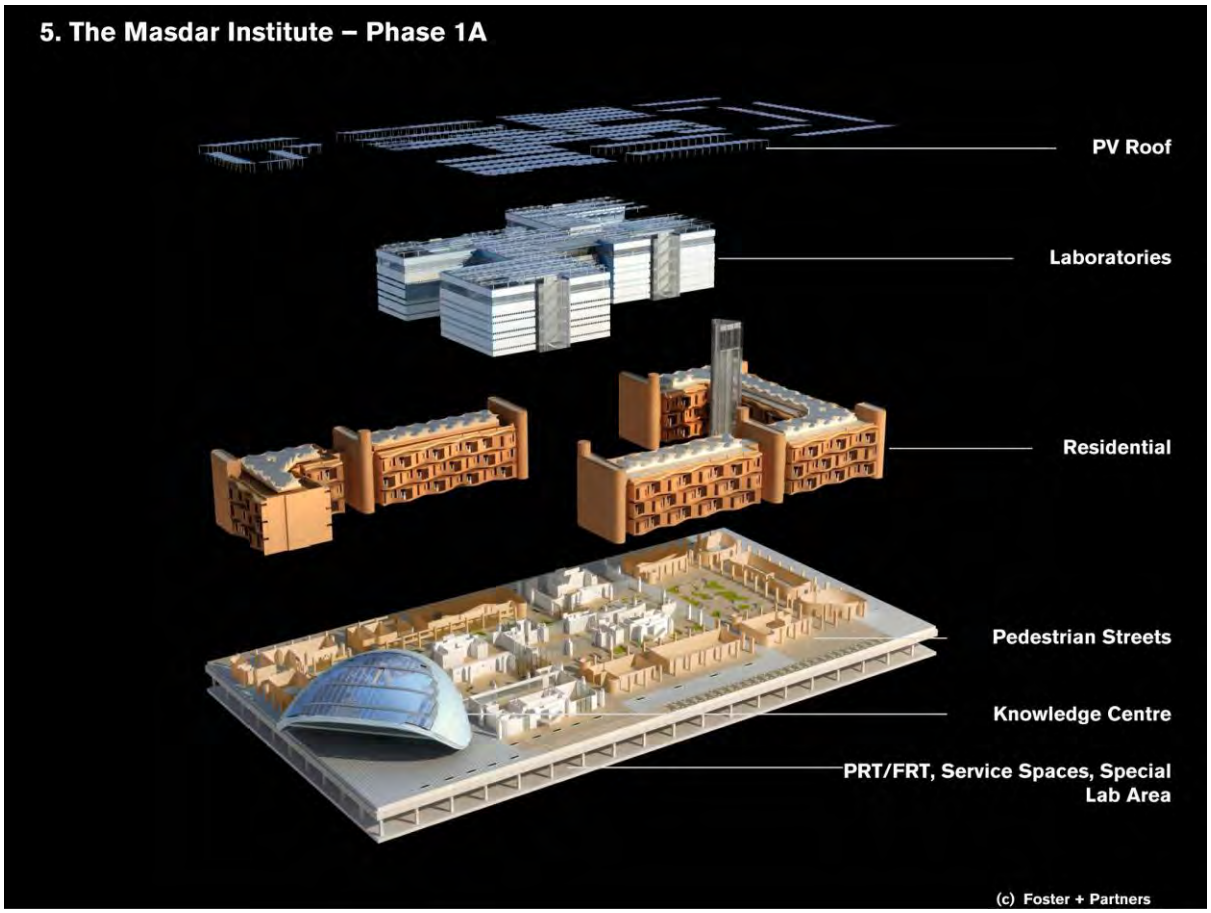
• Highly insulated U-value 0.25 W/m2K for solid wall and 1.1 W/m2K for glazing.

## 1. Masdar City Masterplan

## 2. The Masdar Institute

(c) Nigel Young/Foster + Partners





## 6. The Masdar Institute - Social Courtyards

(c) Foster + Partners

## 7. The Masdar Institute - Social Courtyards

(c) Nigel Young/Foster + Partners

## 8.Residential Facade – Modular unit on Site

## 9. Residential Facade – Completed Facade

## 10. The Masdar Institute