PREFAB architecture
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The modern architecture of curtain walls

The wonderful world of prefabrication is not always all about precast concrete construction. A significant part of prefabrication encompasses on-site assembly of factory produced components such as those made of glass or metal, etc. This issue of PREFAB Architecture features three distinctive designs of prefabricated projects using curtain walls.

Curtain wall is a lightweight external wall system that is hung on the building structure. Synonymous with modern architecture, it is characterised by grids of infilled material such as glass, metal, stone or a combination of these. Its flexibility allows architects to create striking designs for new buildings and refurbishment of old buildings.

Key design considerations for curtain walls include movement control, rainwater control, thermal insulation and acoustic control.

Movement control includes design for sufficient strength and flexibility to accommodate movement arising from wind and temperature variation acting on the curtain wall. In addition, attention must be given to building movement due to creep, sway and temperature changes.

In the past, sealants were commonly used for joint treatments. As sealant will deteriorate or due to poor workmanship, rainwater sometimes penetrates the building. As a result, designers these days incorporate suitable drainage systems in curtain walls, which redirect rainwater out of the building to control rainwater penetration.

Coatings on the glass panels can enhance the thermal insulation of curtain walls.The use of double glazing not only furthur enhances the thermal insulation of curtain walls but also their acoustic performance.

Curtain walls offer new dimensions and excitement in architectural designs. However, the successful adoption of a curtain wall system requires the architect, main contractor and curtain wall specialist to work closely to achieve the desired effect the best possible way for all parties concerned.

by Ang Lian Aik

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The ICON of TOTAL Learning

by Chew Ee Sin
RSP Architects Planners & Engineers (Pte) Ltd

Feature roof trellis rises dramatically above the building block

The Institute of Technical Education represents a new icon in the new millennium and in line with this concept, the planning of the ITE Regional Campus at Simei Avenue campus is student focused and creates a conducive environment in line with the institution's total training concept. The buildings are grouped into three main curvilinear blocks, namely, Administration, Technology and Business Blocks, forming a strong and unique geometric layout with a central focus - The Forum. This is the heart of the campus where students and staff gather, interact and exchange ideas.

From the start of the project, the team realised that the tight construction schedule would be a critical factor in the construction of the campus. They decided to adopt standardisation and modularity in conjunction with the design of repetitive clusters of laboratories, workshops and lecture rooms, but maintaining a dynamic architectural language and identity.

Such an approach allowed the extensive use of precast concrete structures, steel structures, unitised curtainwall systems, aluminium cladding façades, prefabricated sunshades and balustrades.

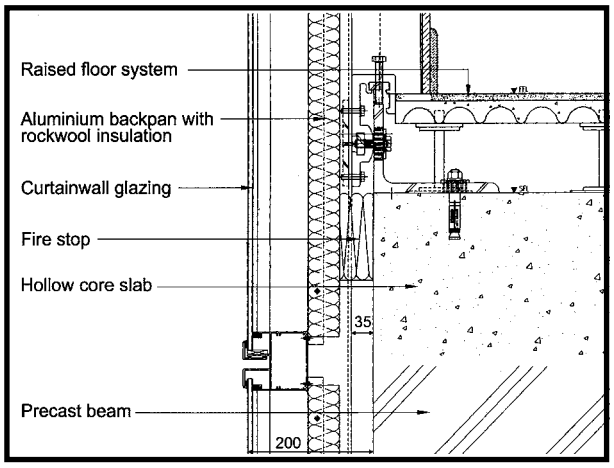
Precast Concrete Construction

Precast structural systems made up for more than 30 percent of the overall concrete volume and achieved a ten day construction cycle for a typical floor. More than 12,000 structural precast units were fabricated and erected within six months, including precast columns, beams, hollow core slabs, walls and staircases. With the use of precast structural elements, the even surfaces required only skim coat finish in lieu of plaster and paint; formwork and staging were eliminated and M&E and architectural work could be carried out concurrently. The fast completion of structural work also allowed early commencement of architectural trades, which increased the overall speed of construction.

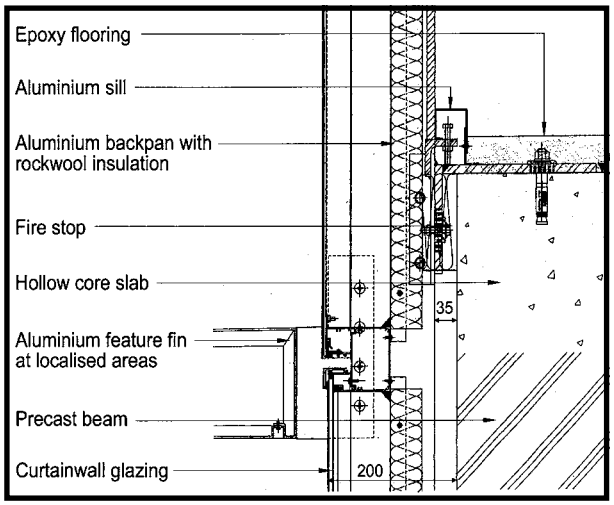
Curtain wall façade at the entrance to Technology Block

Installation of unitised curtain wall panels

Construction of Forum steel structure



Unitised curtain wall detail at Laboratory with raised floor system



Unitised curtain wall detail at Workshop with epoxy flooring

Steel Structures

The concept of greenery was elevated from the 1st Storey environmental deck to the 3rd Storey Forum, a 44 m diameter circular landscaped deck with earth infill for planting. Constructed of prefabricated steel structures supported by three concrete tapering columns, the Forum emerged at the heart of the campus imbued with a sense of centrality and focus of the campus.

The prefabricated steel structures, cladded with aluminium panels, added to the lightness of the dramatic rooflines over the three curvilinear blocks and the Spectators Gallery.

Architectural Statement

The unique architectural character and distinct identity of the Regional Campus could be attributed to various creative design approaches employed in this project.

The role the façade played in the development was quite significant. The choice of unitised curtain wall system and aluminium attained a high standard of workmanship and added to the vision of a modern and progressive world-class institutional development.

The external envelope of all three building blocks generally comprised curtain wall and aluminium cladding. With a consistent floor-to-floor height of 5,250 mm, modularity of the unitised curtain wall panels and aluminium cladding was established easily. The choice of façade system also ensured the accuracy of fabrication in the factory and ease of installation on site.

Construction of precast structures

The design of the curtain wall façade was accentuated with the integration of aluminium fins as sun-shading elements. It also maximised daylighting via the external glazing, thus saving on air-conditioning operating costs.

To create a comfortable and conducive educational environment for the staff and students, the team achieved sound insulation and reduction of heat transmission through curtain wall panels consisting of double-glazed laminated glass at the east and west facing façades. Similar curtain walls were installed at the building blocks fronting the MRT line and main roads, so as to isolate the classrooms from the MRT and road traffic noise.

Elevated landscape at the heart of the campus

Environmental Issues

The corridors on every floor at all blocks were detailed to address environmental issues in relation to driving rain and sun-shading while allowing natural lighting into the circulation space. At the same time, the various M&E services along the corridors such as air-con ducting, electrical cable trunking, water piping were designed to be concealed neatly.

A corridor design feature comprising a 3.6 m module, made up of aluminium ceiling, horizontal rain screening aluminium fins, perforated aluminium panels, tempered glass balustrades, stainless steel handrails and fins was created. Innovative light fittings were integrated in the design to provide lighting at the corridors.

Vista along Garden Walk

Entrance from the junction adjacent to Singapore Expo

These modules were prefabricated in the factory and installed along the corridors. The corridor features represent a dynamic architectural language to the campus, and at the same time they contribute to better construction detailing with more secure connections, safer working conditions and faster installation time.

Conclusion

By establishing regular grids at all blocks and integrating modular orthogonal rooms within a curvilinear building, the campus managed to extensively adopt precast structures and prefabricated architectural elements while maintaining the unique geometry of the curvilinear blocks.

Unitised curtainwall articulated with aluminium sunshading fins, aluminium cladding, corridor sunshades and balustrades represent the bold architectural tectonics and synergy to the learning hub. The curved facades and lightweight feature roofs accentuate the dramatic vistas and perspectives of the campus.

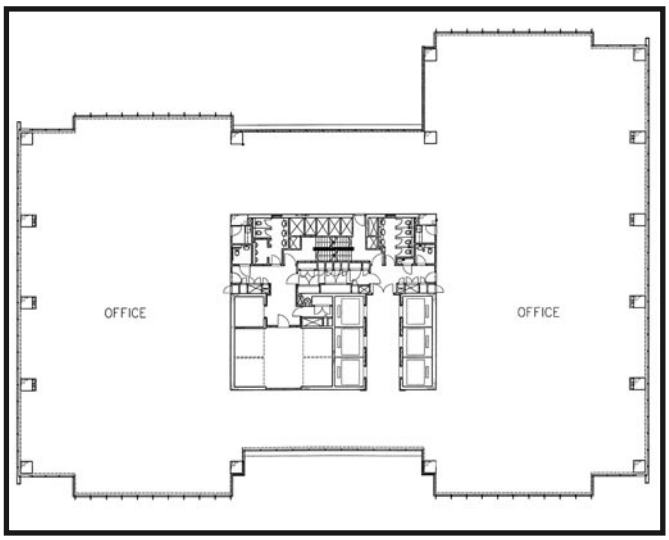
With the use of prefabricated systems and features, the time for fabrication, delivery and installation was shortened, a higher quality of workmanship was also achieved and most importantly, the campus, with a total constructed area of 180,000 sq m was completed within a tight schedule of 20 months.

Facade articulation of curtain wall, aluminium cladding and sunshading fins

Project Team

Client: Institute of Technical Education
Architect: RSP Architects Planners & Engineers Pte Ltd
Structural Engineer: RSP Architects Planners & Engineers Pte Ltd
M&E Engineer: Squire Mech Pte Ltd
Quantity Surveyor: Davis Langdon & Seah Singapore Pte Ltd
Landscape Architect: Sitetectonix Pte Ltd
Interior Designer: RSP Interiors Pte Ltd
Main Contractor: Kajima Overseas Asia Pte Ltd
Precaster : Eastern Pretech Pte Ltd

The building illuminating the waterfront at night



Typical office floor

Prominent landmark within new Downtown skyline

by Chan Sui Him & Tan Chee Kiang
DP Architects Pte Ltd

The winning design for the One Marina Boulevard development featured a cost-efficient approach to all aspects of the design, yet at the same time placed a lot of emphasis on buildability.

The 32-storey, 169 m tall building is located at the gateway to the new Downtown at the junction of Raffles Quay and the proposed Marina Boulevard. Besides offices, which occupy most of the development, the building features a 600-seat auditorium, various meeting rooms and training rooms at the 7th to 9th storey, retail spaces at the basement underpass mall as well as elevated parking space, among other facilities.

Sky lobbies carved out of the building form provide an opportunity for vertical landscaping for the building and for outdoor rest and retreat.

Structural System

The typical office floor plate is designed as dual blocks connected to the central service core by a circulation strip. Each floor plate is a column-free rectangular space with a depth of 20m. The typical office floor has a 3 m clear ceiling height to correspond with the large column-free interior space. The larger rectangle floor plate faces the sea and the smaller rectangular floor faces the city. Both blocks have the narrower façade diagonally facing east and west. This configuration provides maximum clear view towards the sea and city.

The requirement, dictated by the client's brief necessitated the use of a simple form. This requirement facilitates a high degree of modularisation and standardisation of building components. The simple form and vertical

expression also contribute towards achieving the desired architectural expression of grandeur. Components of the plans are also repeated wherever possible to maximise standardisation.

Unitised Curtain Wall and Granite In-fill System

The project involved a cost-efficient approach to the design for which the detailing was kept straightforward and practical. This led to the façade design using a fully unitised curtain wall system. The 32-storey office tower comprises a total surface area of 29,200 sq m of unitised curtain wall inclusive of 1,450 sq m of super clear low iron tensile spider glass structure and 2,300 sq m of granite installation.

In terms of design, the architect collaborated with the curtain wall fabricator to reconcile between fabrication constraints and design articulation to achieve a highly buildable façade system that is architecturally pleasing.

Modular lines in relation to the structural grid were used to regulate the treatment of the external surface of the building. Panel sizes were kept to the maximum allowed so as to be easily handled by the vertical hoisting facility and vehicular transportation. The panels comprising a combination of glass, aluminium and granite panels were all factory assembled under strict quality control. The precise fabrication technique allowed the design of crisp and intricate details that would not have been possible with in-situ construction. The use of modular and standardised panel sizes sped up fabrication and kept the cost down.

Evolution and improvement of the unitised system has led to the advent of new innovative infill such as granite, in place of mere conventional glazing. This is evident at the perimeter rooftop of the building.

Design Concepts and Principles

The design for contemporary unitised curtain walling system is based on a number of key concepts and principles. The essence lies in understanding the working of the 4-way joint between adjacent curtain wall panels. This is a critical junction because it addresses the interfaces of split mullions and split transoms,where crucial design considerations for water tightness and movement tolerance are articulated.

The second concept is the pressure equalisation system at the stack joint, which comprises the four elements of the rain screen, the pressure equalisation chamber, air seals and weep holes. The main objective of this system as its name implies, is to equalise the pressure differences between the inside and outside so as to minimise water seepage through capillary action.

The next principle is to design for movement joints that have sufficient tolerance for thermal movement, live and dead load deflection, wind load and possible ground movement. The design for an adjustable bracket joint completes the basis of a unitised curtain wall system. This jointing method provides flexibility for site adjustment during installation to achieve better alignment of the façade.

The façade comprises a combination of glass, aluminium and granite panels

4-legged spider at stainless steel column

4-way joint of typical curtain wall

Bracket detail at stack joint

Tensile Glass System

Another interesting façade system in this project is the tensile spider glass wall. The tensile spider glass wall system represents the architect's intention to have a sleek and elegant glass wall framing to expose the public activities within the building. The aim was to have a design with bare minimum structural frame support via stainless steel tension rods and spider clamps onto super clear low iron glass.

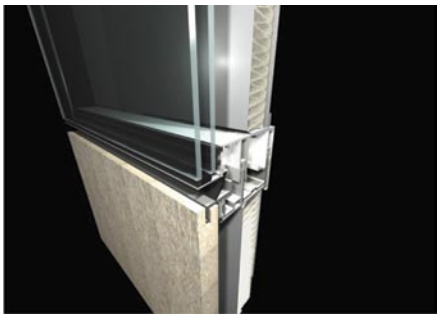
The spider glass wall spans from the first storey mezzanine to the 11th storey of the building, approximately 37.2 m high and covers a total area of 1,450 sq m. The entire system features three key components comprising a glass roof with climate reactive sunshades; a spider glass wall; and a glass soffit, all of which are using one of the largest spans of super clear low iron glass in the region. These high quality glasses are all 100 percent heat soaked to reduce the possibilities of voluntary shattering due to the presence of nickel sulphite.

Two primary types of spider articulation are adopted. The four-legged spider is implemented at the intermediate junction between glass panels, while the two-legged spider is implemented at the corner junction of glass panels and structural steel columns. The structure of the tensile frame is executed through fine networks of pre-stressed cable trusses and reduced to their simplest form of expression to minimise the visual impact of mechanical components required for the suspension and bracing. The result is no doubt one of sleek refinement and elegance.

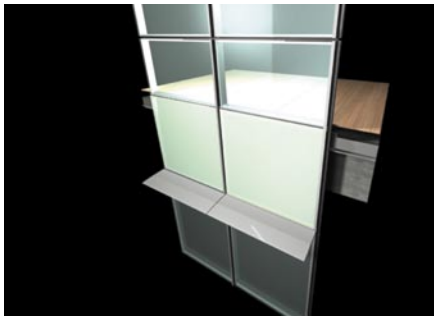
Conclusion

In its urban context, the building stands out as a vertical form characterised by its purity and simplicity in what is otherwise a busy looking skyline.

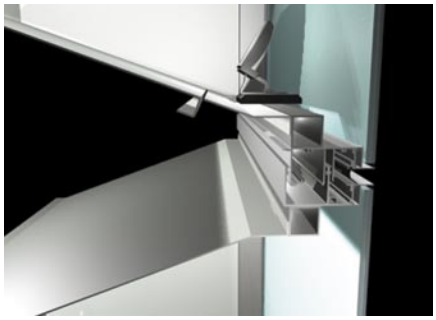
A consistency of geometric form not only results in more efficient office spaces but also creates a sense of stability. The simplicity of the glass and granite curtain wall system together with the proportions of the building form create an elegant façade and a contemporary corporate image.



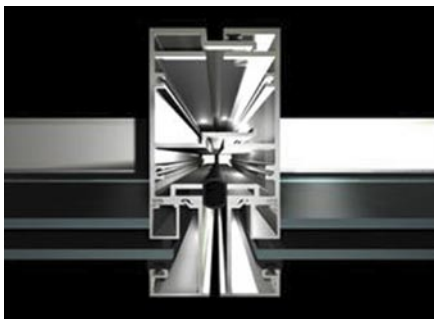
Granite infill curtain wall



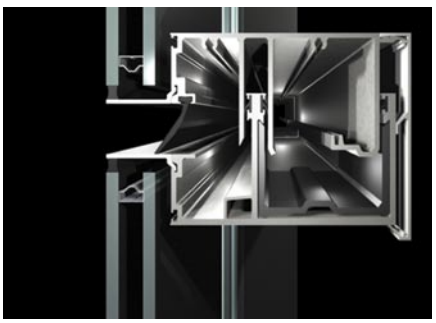
Unitised curtain wall



Lightbox-transom detail at stack joint



Split mullion of typical curtain wall



Split transom of typical curtain wall

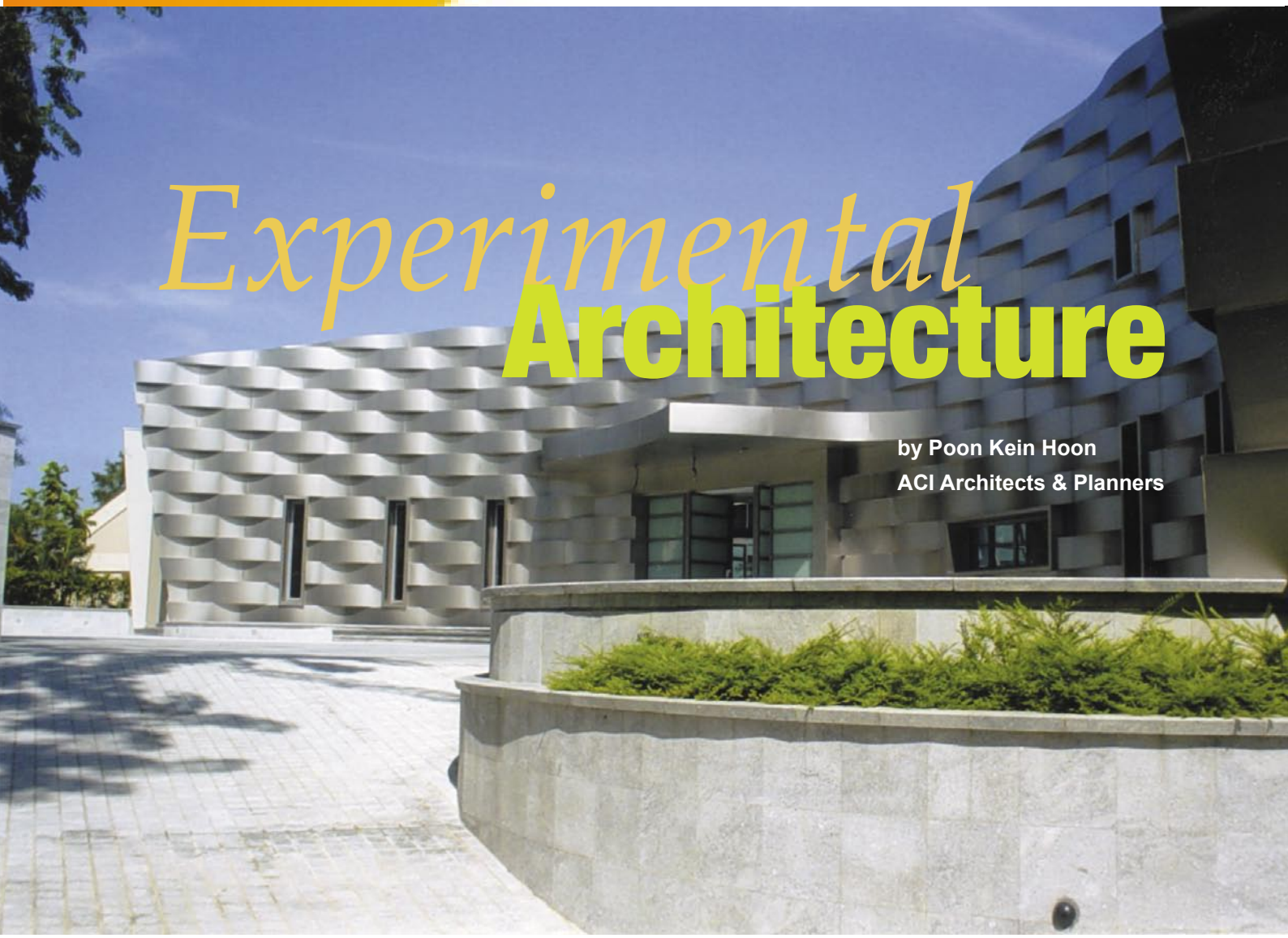
Glass box enclosing carpark lift lobby

The team used advanced technical solutions to create a high quality grade A office building with column free interior spaces within a short construction time frame of 24 months. The design and construction of this 32-storey building with a 7m deep basement were done within the constraints of existing authorities' requirements to arrive at an innovative and elegant tower. The end result is a building that meets the client's expectation and the proud achievement of a prominent landmark within the New Downtown skyline.

Acknowledgement: Parts of the article were adapted from Channel News Façade (an in-house publication of Facade-Master Pte Ltd), Issue 2, April – June 2004.

Project Team

Client: Singapore Labour Foundation
Project Manager: SLF Management Services Pte Ltd
Architect: DP Architects Pte Ltd
Structural Engineer: P & T Consultants Pte Ltd
M&E Engineer: Beca Carter Hollings & Ferner (SEA) Pte Ltd
Quantity Surveyor: Davis Langdon & Seah Singapore Pte Ltd
Façade Consultant: Connell Wagner Pte Ltd
Main Contractor: Samsung Corporation – Tiong Seng JV
Façade Contractor: FaçadeMaster Pte Ltd



Experimental Architecture

by Poon Kein Hoon
ACI Architects & Planners

The titanium woven ribbon facade at the front porch with ramp leading to the semi basement

The owner of the Bungalow at Ford Ave wanted a special architectural concept for his new residence. His search resulted in an experimental project, a building which expressed the many facets of quality design, from the elevated placement of the living room to the overall geometry, sensitivity to the environment, adoption of new materials and construction methods, a combination of elements with meticulous refinement of detailing. The team that carried out this project not only involved the architects, engineers, builders, suppliers, manufacturers, designers, but most of all, the owner himself. Eventually, a buildable sculpture that the owner refers to as "not just a building but a piece of art" evolved.

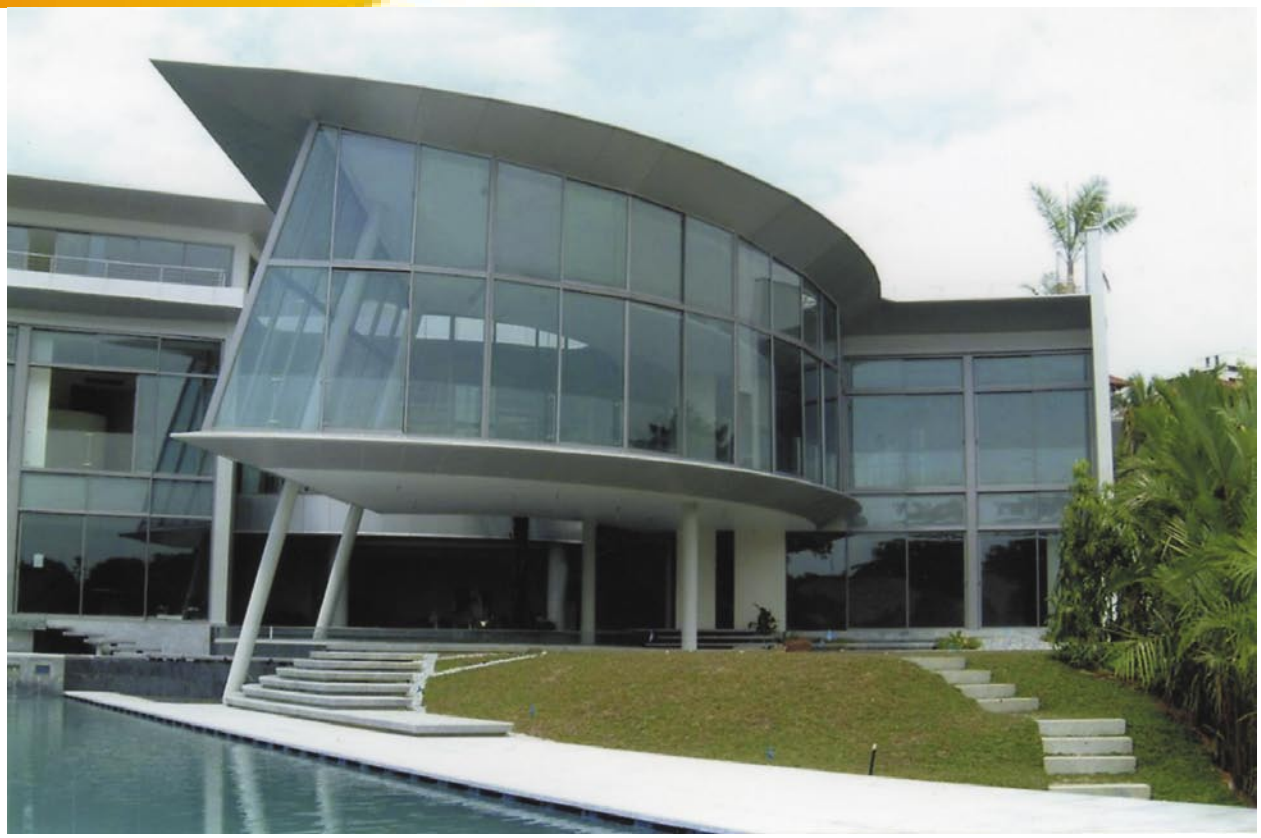
Design Concept

The 2-storey house is situated on a challenging triangular site with a slope. Capitalising on this slope and following the terrain of the site, a semi basement was created to provide additional activity space for the family. With one side used as an underground garage and the other side fully open to nature, the house blends beautifully with its surroundings via its orientation, the seating of the structure and the façade treatment.

During the architectural conceptual stage some major decisions greatly influenced the structural design and construction method. The series of curved walls not only act as articulated features but also as major load bearing elements for the whole building.

The building appears anchored firmly in the ground at the front porch with the introduction of a solid curved wall. The division of functions between the two blocks is emphasised through the nature and skilful apposition of the materials employed. Overall, glass dominates behind the huge curved titanium wall. The building is separated by an internal courtyard which is in turn 'drowning' in glass. A full height curtain wall was introduced at the northern façade to allow light to enter all the private spaces.

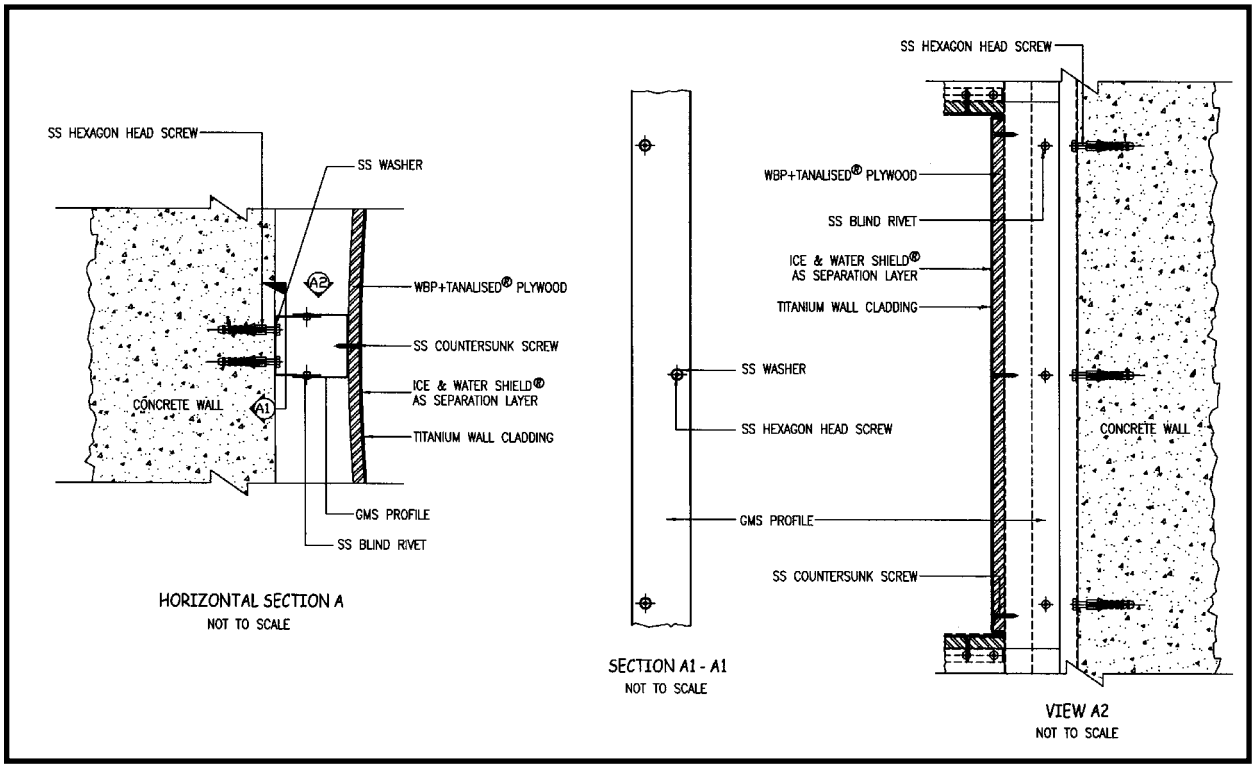
The elevated living room, shaped like an ark, is the last part that was erected. It stretches out to embrace



The elevated and ark-like living room

an internal courtyard where a landscape pool is situated to enable cross ventilation and daylight to penetrate through. The flat plate floor slab is supported by only four steel columns and covered by a steel roof truss and metal roofing. The roof panels are divided into repetitive panels before transporting to the site and levelled to provide superior flatness. Simplicity, clean and lightness in the architectural expression of the ark was the theme for the structural engineer employed in setting up the structural concept and system.

Interplays of reflection



Connection details of titanium facade

The Load Bearing Walls

The building structural system comprises a series of load bearing walls including the front curved wall façade and a number of columns on the opposite façade. The load bearing curved walls have both aesthetic and structural functions. The constant radius of the curved walls forms repetitive panels and minimises the amount of formwork required. The panels also accommodate the vertical and horizontal windows or door openings easily.

The load bearing walls also contribute to the horizontal stability of the building. They eliminate the need for a structural core or interior shear walls. The increase in interior floor space gained by eliminating columns can be substantial and provides flexibility for the internal partition layout. In order to achieve a reflective surface to the bare concrete, the front curved wall is covered with titanium sheets in repetitive bands of woven ribbon form to capture the flow of changing southern light.

The Glass Technology

The house's unique architectural style is derived from the creative use of forms and materials. It is visible from the surrounding road and yet provides the owner with the utmost privacy. The horizontal and vertical window openings emerge out of the metallic wall, watching the street silently. Upon entering the main entrance doors, the northern facade opens up like a theatre with wings made of glass and aluminum sunshades. An ornamental pond situated inside the open courtyard extends out into the garden and creates interplays of reflection with the glass facades.

The two wings surrounding the entrance foyer are linked by a curved corridor with the semi-private spaces such as dining room and dry kitchen on the left and the private spaces such as bedrooms and family room on the right. One end of the curved corridor leads to the transparent ark-shaped living room. The feeling of unity and calm in the place is enhanced by the uniform treatment of the glass facades. The glass facades are made up of a series of glass fenestration systems using the latest glass technology.

Extensive use of prefabricated metal roof

The curved corridor linking the private spaces and the ark-like living room

Vertical Sliding Window

The vertical sliding window is designed and operated using the concept of a counterweight pulley system whereby the weight of the top panel will assist in the lifting of the bottom panel. With such openings, a cross ventilation effect that presents the occupants with a comfortable living environment is achieved. Before the actual framings and glass are erected, the sub-framings are installed around the openings so as to minimise damages to the glass facade due to wet trades.

Curtain wall with Vertical Sliding Window

The unitised curtain wall framings are assembled in the factory with glazing for all the fixed panel areas. These prefabricated units are transported to site using custom-made pallets. With prefabrication, better site productivity and quality are achieved. The vertical sliding windows are then fixed to the openings on site.

Glass balustrades

Project Management

The design of this project was assisted by using a physical model and 3D CAD from inception to detailing. The client, the designer and the contractor were able to visualise the building in the virtual world and thus have a better understanding before it was put up on site. It also expedited the problem-solving process for the challenges the team faced.

Project Team

Client: Mr Cheong Keng Hooi
Architect: ACI Architects & Planners
Architectural Design Consultant: Design Bube
Structural Engineer: HCE Engineers Partnership
M&E Engineer: M&P Consulting Engineers (S) Pte Ltd
Landscape Architect: Stephen Caffyn Landscape Design
Quantity Surveyor: YHL Partnership
Main Contractor: Actus Builders Pte Ltd
Titanium Façade Contractor: Sheet Metal International Systems Pte Ltd
Glass Façade Contractor: Seiko Architectural Wall Systems Pte Ltd
Metal Roof Contractor: Thye Hong Management & Services Pte Ltd

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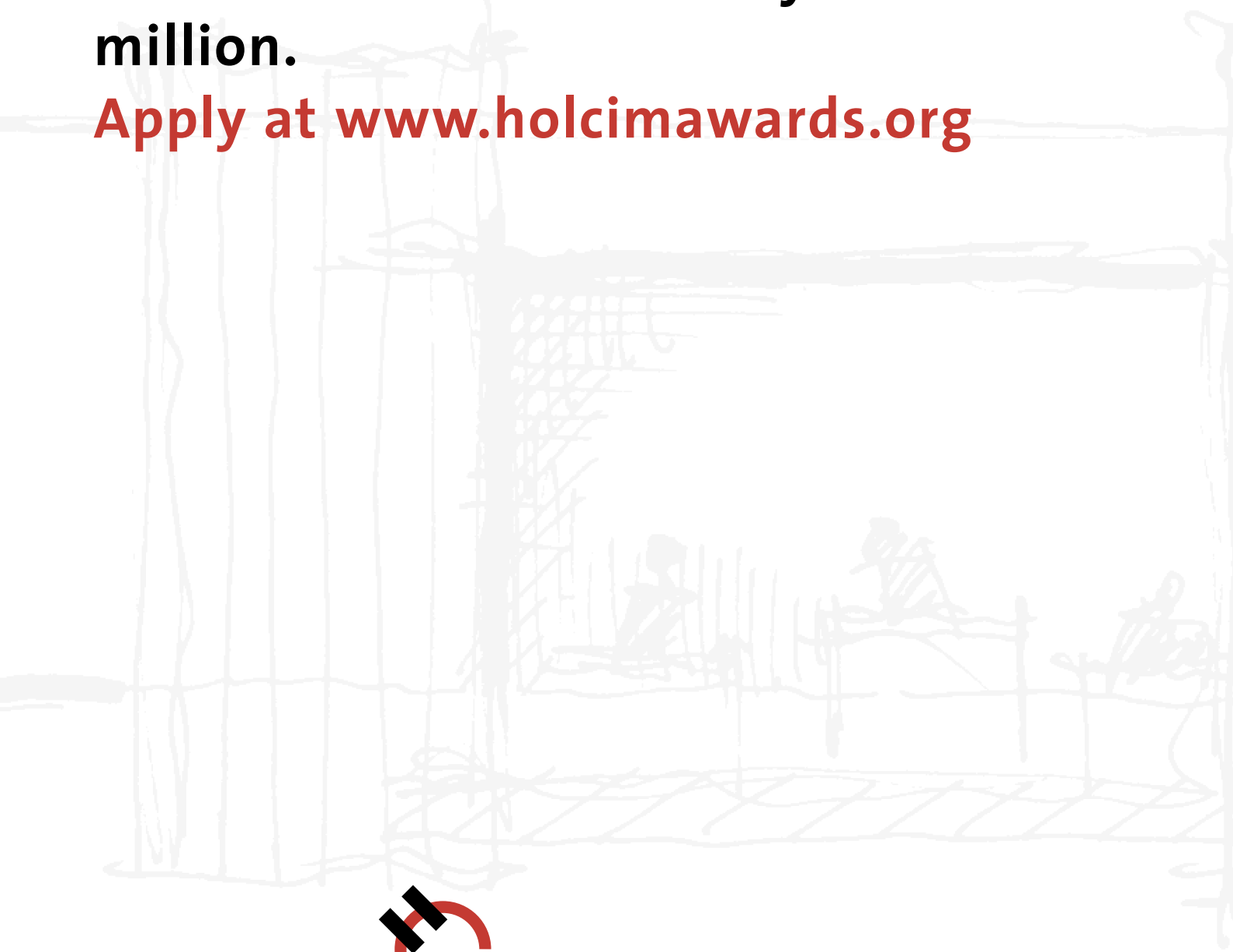

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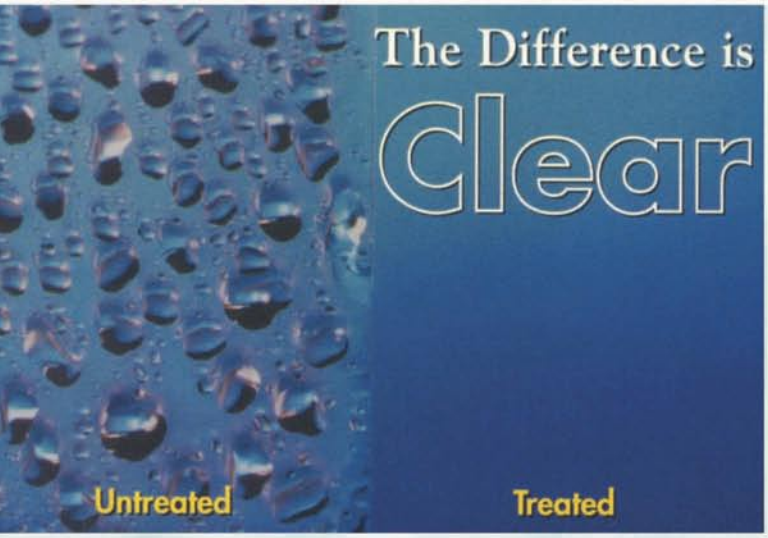

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Mr. Richard Lai, Principal Architect,
ADDP ARCHITECTS

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