Title: A Case Study for Sustainable Vertical Urbanism

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A Case Study for Sustainable Vertical Urbanism

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Abstract

This paper explores a range of design principles for achieving a socially sustainable residential community in a very tall environmentally responsive building. The goal of this study is the exploration of possibilities for both high-rise and very tall development providing levels of indoor-outdoor amenity usually associated with street level, horizontal housing and in particular focusing on social relationships. Further, the case study demonstrates a strategy for the ecological rehabilitation of degraded, low quality urban land or topographically difficult sites. The case study investigated the design of a building as a platform for supporting healthy ecosystems. The design also demonstrates a significant degree of façade and unit orientation flexibility while maintaining effective structural and spatial planning solutions. The architecture achieves responsiveness for a diverse range of climates without limiting amenity or functional adaptability. The complexity of the brief demanded close collaboration of the diverse disciplines within the design team.

Keywords: Ecosystem, Very Tall, Residential, Sustainable, Urbanism, Innovation

A Case Study for Vertical Sustainable Urbanism

Architectural Strategy

The case study demonstrates principles for achieving a socially sustainable residential community in a very tall building while providing levels of living amenity usually associated with street level, horizontal housing.

Further, the case study design provides a strategy to upgrade and ecologically rehabilitate degraded, low quality urban land or topographically difficult sites. The research was guided by a key question of what could be the next stage for development of ecologically sustainable development (ESD) principles for very tall residential buildings.

A core theme of the design investigated the building as a platform for supporting healthy ecosystems and flexible architecture (see Figures 1, 2, 3).

Richard Mann is a principal architect with over 30 years experience and he is the founding director of Ecosystem Architecture. Richard has successfully designed environmentally responsive, sustainable medium rise and high rise residential and commercial buildings in the Middle East, China, Malaysia and Australia.

Richard Mann是一名具有30年从业资历的建筑师, 也是ECOSYSTEM ARCHITECTURE的创办人。他在中东、中国、马来西亚与澳大利亚等多地成功完成包括环境响应、可持续的中高层住宅与商业楼等多个项目。

Andrew is a Principal of Arup and structural engineer with a passion for design, integration and innovation. His expertise includes tall buildings, long-term serviceability of structures, seismic analysis and design, and long-span lightweight roof structures.

Andrew是奥雅纳公司(Arup)的一名董事, 也是一名对设计、一体化及创新设计有强烈兴趣的结构工程师。他擅长高层建筑、建筑长期效应的研究、地震分析与设计以及大跨度轻质屋盖结构设计。

Elke Haege has an international reputation for innovative landscape architecture and is a registered and award winning landscape architect and qualified consulting arborist who is dedicated to the development and sustainable connection to natural systems. Elke is an executive committee member of the Australian Institute of Landscape Architects (AILA), is part of AILA's National Education Advisory Panel and has lectured at the University of New South Wales.

Elke Haege是一位国际上广为认可的创新型景观建筑师, 也是一名注册景观建筑师和合格的咨询园艺师, 她致力于景观设计与自然生态系统的连接。Elke是澳大利亚景观建筑师研究会(AILA)的执行委员会成员, 也参与了AILA的国家教育指导委员会, 同时在新南威尔士大学任教。
Internationally, architects and engineers have adopted ESD methodologies based on various models. Precinct based ESD principles are now widely adopted for town planning.

It is increasingly acknowledged that the basis of global, regional and local economics is underpinned by healthy ecosystems. (Dasgupta, 2001)

The design of healthy ecosystems delivers important benefits, two of which are;

1. Advantage of microclimate design in modifying living environments for residents.
2. Re-connecting people with nature while living in a very tall building.

Architecture as Infrastructure
Architecture has the potential to generate diverse possibilities for infrastructure design.

The apartments of this case study were designed as units to be built within allotments in a very tall building typology. Deep soil gardens are integral to each apartment and this amenity differs from current conventional design in that this integration of amenity contributes to a genuine opportunity for indoor/outdoor life style (see Figures 6, 7, 9, 10).

Accelerated construction processes would become feasible with this separation of building segments through the greatly increased advantage of paralleling construction processes (see Figure 1).

Increased affordability could be achieved through viable, flexible costing models of construction and marketing.

In the long term, the building is designed as a platform for change, so that it is supportive of adaptive re-use.

The case study was designed to be built with current technologies and construction processes.

Decoupling the Apartments from the Structure
Significant opportunities become possible for providing residential units responsive to life cycle changes with the apartments designed as discrete, flexible entities within the structure.

The primary structure is designed for a long life of hundreds of years while the apartments are suited to respond to socially and culturally relevant cycles for intergenerational change.

This design enables apartments to respond to a growing family’s needs and financial capacity, as well as changes in social demographics. Enduring social and community relationships benefit thus contributing to sustainable neighborhoods.

The strategy provides significant potential for modifying designs to suit climate and cultural diversity.

Minimizing the Tower Footprint
The building is elevated 32m above ground level in order to maximize ground level landscaping and recreational areas, creating opportunities for urban parkland, forests and orchards.

Climate
The main climatic zones considered in the case study were (see Figures 9, 10):
• Temperate: Operable screens to provide wind shielding and or solar load management.
• Hot Arid: Solar shading screens; dust storm blocking screens.
• Tropical: Solar shading screens providing enhance breeze flow as well as wind shielding.
• Cold & Cool Temperate: Screens for solar heat gain retention (standard double glazed louvers) and wind and snow protection; hydronic heating of the unit module would act as a potential outdoor recreational area during the long winter months as well as assisting with heating the apartment.

Design Flexibility to Suit Different Building Heights, Fire Escapes and Lift Capacities
The open core design accommodates different lift and fire escape capacities depending on the project height and unit numbers (see Figure 8).

Single Apartment Depth & Open Core
Cross flow ventilation is provided for all apartments by opening the core to create an atrium. Air flow is facilitated through the tower from all directions (see Figures 6, 7).

The porous building involves and reflects the progress of daily and seasonal cycles. Weather protection is provided by overhead walkways, screens and enclosing porous diaphragm bracing walls (see Figure 11).

A sense of enclosure is added by solid balustrades and high level glazed screens shielding communal parks.

The Reconnection of Residents with Nature
Soil based gardens are incorporated throughout the design. The advantage of soil based gardens provides carbon capture interface with the atmosphere as well as creating sustainable ecosystems, microclimates and opportunities for indoor – outdoor living in a high-rise building (see Figures 9, 10, 11).

The 32m high pocket parks are also fitted with dedicated BMUs for tall tree landscaping maintenance and glazed weather screen cleaning (see Figure 1).

Apartment Adaptability Over Time and Design for Disassembly (DFD)
Inherent in the design is the ability of apartments to be changed, added onto or upgraded over their life. Building Maintenance Units (BMU) suitable for constructing and ongoing maintenance of the apartments are integral components of the tower, with each wing having its own dedicated BMU.

The vertical lift capability and allotment design generates the feasibility for residents to build their apartment incrementally to suit their needs and level of affordability. The flexibility of the design supports the differing financial and social needs of the residents.

As residents age in place they may wish to downsize their home. The design allows for apartment disassembly of excess space and residents are able to remain at their original address with their social links intact.

Should residents develop mobility impairment through illness, accidents or aging, the design facilitates installation of prefabricated residential lifts to provide full accessibility throughout a two level apartment. The case study also provides for single level living design options.
Aging in place with on-site flexibility of accommodation encourages strengthening of social relationships and neighborhood cohesiveness. Stability of social relationships and neighborhoods would therefore be strengthened. Numerous prefabricated construction systems are now available in the market for providing high quality, high levels of sustainability and amenity. A number of these systems are incorporated in the design.

Fire Safety
The recently published CTBUH study, “Roadmap on the Future Research Needs of Tall Buildings” highlighted the acknowledged prominence of safety as an issue in tall building design. The Case Study has adopted a number of robust strategies to provide a high level of occupant safety as follows:

1. Fire compartment design with apartments forming separate fire compartments within each module with each 16M x 12M x 18M module performing as a separate fire compartment.
2. High density of fire escapes providing rapid alternative egress for residents. Fire escape travel is highly visible and easily navigable.
3. Multiple hose reels per wing at each level.
4. Gravity fed water storage tanks (in services zones).
5. Sprinkler system.
6. Designated fire resistant level construction for apartments and claddings.
7. Rapid smoke exhaust.

Services
Location of services within the atrium junction of the modular party walls ensures that duct risers are fully accessible without the privacy of apartments or allotments being intruded upon for maintenance or upgrades. The services risers and branches remain clear of structural zones (see Figures 6, 7).

Finance Models
Separation of superstructure and apartment construction systems provides the possibility for different financial methods being useful for:

1. The superstructure funding using very long term private investment, government and local authority sources of finance.
2. The apartments may be financed by conventional market home loan products or consumer credit.

Affordability can be facilitated by the combination of different financial instruments.

The design presents opportunities for different financial instruments being used for home finance.

Passive Design Principles
Passive design principles have been adopted to optimize the provision of thermal comfort for residents without the need for air-conditioning. The design achieves solar access and protection, natural light and ventilation, large thermal mass values, microclimate design as well as a high level of insulation. Building envelopes are layered within the enclosing structure providing active climate modification design opportunities to suit various latitudes and orientations.
All apartments enjoy complete cross flow ventilation conditions that can be modified in their intensity with integrated perimeter screens in response to height, orientation and climate.

**Embodied Energy:**
The design of the structure provides for a long life cycle which, coupled with the apartment prefabricated construction systems, contribute to a significant lowering of the embodied energy of the building.

For example, apartments constructed from Cross Laminated Timber (CLT) and other appropriate systems would contribute to a significant reservoir of carbon storage. The gardens similarly contribute significantly to the carbon storage cycle.

**Water:**
Water supply, treatment, storage and recycling have been embedded in the design parameters. Capacities for fresh water, fire services and irrigation for the landscaped microclimates have been incorporated in the design.

**Transport & Urban Regeneration**
The design achieves a high residential density while providing a recreational amenity usually associated with street level housing. This design approach could be utilized for brownfield and degraded sites and other appropriate urban locations. Public transport efficiencies could be increased with the higher urban densities generated.

A density of approximately 1000 people per hectare has been achieved on a selected site of six hectares, or 60,000m². This compares with established inner city suburbs in say Sydney that extend for approximately 50 hectares, providing an equivalent population and level of amenity as the case study.

**Social Sustainability**
The design adopts the principle of creating opportunities for meaningful social interactions as one proceeds through the building. The porous structural diaphragm shear wall provides a transition between the private and public domains for each apartment.

Six communal recreational parks are interspersed through the tower as well as pocket parks for more contemplative and quiet recreation.
Structural Strategy

The structural system systematically combines the planning and functional characteristics of the spaces with structural efficiency, modularity, and flexibility – whether 100m or 1000m tall.

To suit a variety of geographic, social, financial, risk and safety variables, the structure is able to be constructed from a variety of materials.

The structural solution comprises:

Primary Frame with Design Life >100 and up to 500+ years.
The primary framing, (see Figure 4) is intended to be fixed for the life of the building.

- Plan form structural grid 13.2m x 18m;
- Fixed diaphragms at 16m vertical spacing;
- Shear walls as necessary located on the 13.2m grid of each block, exchanging with columns/frames as required for function. Where shear walls are unnecessary or can be eroded with height, these revert to a column and beam system with non-structural infill walls pending construction efficiency;
- Continuous, perforated tube shear walls are located at the inside face of the apartments in each tower wing. Perforation is graded increasing bottom to top aligning with structural performance. Large openings can be provided at the ground plane;
- The shear wall tube links across the garden levels between selected blocks. These connections are achieved within 32m (double module) heights. The connections vary in elevation on each of the three corners, forming a macro-helix arrangement and a continuous vertically braced tube;
- A concrete design is the base scheme materiality. Reinforced, pre-stressed/post-tensioned, insitu, precast, or other permanent formwork systems could be all feasible for the design. Benefits of concrete include thermal mass, acoustics, fire resistance, robustness, geometric flexibility, materials handling capability, reduced trade complexity (geographic flexibility), high recycled industrial waste content, and inherent durability;
- Clad steel or steel/concrete composite frame alternatives are feasible, particularly in regions of poor foundation and/or

1. 1 bedroom apartment (Source: Ecosystem Architecture and Elke Haege Landscape Architect)
high seismicity where mass reduction is critical. High recycled material content is preferable;

• Clad timber or hybrid concrete/timber or steel/timber alternatives such as CLT bearing walls are also feasible at lower building heights. Durability is of greater consideration.

Secondary Framing with Design Life > 50 to 100+ years.
Secondary framing does not contribute to overall lateral stability or gravity support framing.

• Mid-height floors between fixed diaphragms;
• Bottom "false" floor in each module for services reticulation and planting;
• Egress, plant, and public floor areas between fixed diaphragms;
• Service pods/risers, lift shafts, and egress stairs;

Tertiary Systems with Design Life of 30 to 50+ years.
Tertiary framing is associated with the residential dwellings and support spaces wholly within primary structural and fire compartments. These structures can be modified or changed at will without adverse impact on the building stability or gravity load carrying capacity.

Preferable systems are light-weight, fire resistant, dry trade sub-assembly and prefabricated systems to suit future modification or disassembly such as:

• Cross-Laminated-Timber (CLT) construction for materials handling, trade skills, carbon capture, and renewables; &
• Structural insulated compressed strand board panels coupled with CFC, terracotta, phenolic resin and other claddings.

Wind Effects
The building plan form and vertical perforation reduces susceptibility to dynamic structural response due to vortex shedding.

Landscape Strategy
The landscape functions in many roles within, upon and underneath the ground. There are 3 main and multifunctional landscape elements.

风的影响
建筑物的平面形式和垂直通透性降低了结构响应的动态特性，因涡旋脱落而引起的结构响应。

景观策略
景观在多种角色中起着作用，包括地面之上、之下以及周围。有三大主要的多功能景观元素。
Environmental

Typical modelled calculations demonstrate that the landscape component in surface area alone equals 2.75 times of a landscape with the same site area (6Ha). These calculations are based on a vegetated site, however it is likely the site would be a brownfield site to start with.

- The increased surface area provides approximately 3 times the active carbon storage in the soil than on a ‘Greenfield’ 6Ha site.
- Carbon will also be stored in the trees on all levels. Calculating just the ground level (3399 proposed native hardwood trees at approximately 20 years old), 92 Tons of carbon will be stored which is 336T of CO2 equivalent¹.
- Carbon storage in soil and trees is dynamic with carbon being taken out of the atmosphere and converted into the soil or vegetation. Some carbon and CO2 will be released through transpiration, photosynthesis and breakdown. The calculations are a net balance for ground level planting only, modelled for a temperate - subtropical zone.
- The above ground landscapes will provide almost the same amount of carbon as in the ground level.
- The landscape will assist to control climatic influences via deflecting wind, framing views, providing shade, sun or cooling.
- The landscape is flexible and dependent on the climate and context of the building. Example scenarios have been devised for desert, tropical and sub-tropical zones e.g.) Middle East, South-East Asia and Northern Europe.
- Water will be captured and reused, waste will be composted and reused and sharing of resources has been developed.

Cultural

The ground floor landscape is intended as a working urban forest that references a new version of the ‘Old English Common’: a communal functional forest and meeting area. The new version ‘common’ will be functional, communal and provide a ‘green lung’.

Ground-plane landscape forms part of the surrounding neighborhood by diffusing boundaries to become integrated and inviting. The landscape continues under each tower embracing the arrival experience.

Social

Above the ground floor, elevated private and communal gardens function in providing health benefits including:

- Passive and active outdoor recreation (local pocket parks, sport zones, parks)
- Places to meet, gather and interact and relax
- Improving air quality (reducing airborne particulate pollutants)
- Views (private and communal) of landscape (proven to make people calmer, healthier and productive.
- Connection to nature (biophilia)

Similar to ‘The City Beautiful Movement’ emphasis on health, efficiency and wellbeing is a function of the landscape design. Applying simple principles from ‘The City Beautiful Movement’ to high-rise sky allotments, much improved living environments set this building apart from apartment living.

Providing flexibility in style, configuration and material use gives each module uniqueness (not accomplishable in regular apartment developments). This individuality makes the sky allotments more closely aligned to row houses/terraces than regular apartments, adding to the living standard. This flexibility allows for changing household dynamics further contributing to wellbeing and stability.

Conclusion

As a conclusion to this paper a summary of the set of design principles generated by this case study could contribute to achieving more socially, economically and environmentally sustainable very tall buildings.

1. Open core planning to facilitate breeze flow, natural ventilation, solar access, flexibility of services and vertical transportation.
2. Open core planning to generate conservative slenderness ratio values to reduce wind force structural loadings and therefore contribute to robust, simplified structural forms and parallel construction processes.
3. Open core planning and glass lifts for social engagement and observation of social activities happening in the various communal and pocket parks. Vertical journeys as socially valuable experiences.
4. Decoupling of building forms to reflect life cycles and purpose e.g. apartment building envelope separated from tower structure.
5. Flexibility for change in individual apartments while avoiding disturbance to neighboring units or common areas.
6. Ease of accessibility for service risers and horizontal routing.
7. Strict adherence to privacy coupled with multiple opportunities for social engagement.
8. Planning of the journeys for arrival and departure from home as opportunities for social engagement.

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7. Strict adherence to privacy coupled with multiple opportunities for social engagement.
8. Planning of the journeys for arrival and departure from home as opportunities for social engagement.
9. Fire safety design through integrated fire engineering, fire compartmentalization and space planning.

10. Structural and architectural design focusing on each building element contributing multiple roles to the building function. For example the high degree of modularity of the design and the continuous, porous diaphragm internal skin.

11. Rationalized construction processes to achieve a high degree of parallel construction processes.

12. Scaling elements that contribute to apartment streetscape identification and urban context (see Figure 5).


14. Passive design principles to achieve high levels of thermal comfort coupled with very long life cycles.

15. Robust detailing for operable wind and solar load management screens.

16. Simple building forms to suit maintenance accessibility for Building Maintenance Units.

17. Diversified and comprehensively sited landscaping integral to private and communal spaces.

18. Indoor/outdoor living potential for all private as well as socially interactive spaces.

19. Equivalent levels of high quality amenity for all apartment types regardless of size.

20. Articulated building structure/infrastructure as separate systems from apartment building fabric to facilitate opportunities for multiple public or private financial models being applicable for achieving affordable housing.

21. Optimize the site and the building above it to generate an extension of the land capacity in order to support healthy ecosystems for the benefit of the urban environmental and quality of life for the residents.

References (参考书目):