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Integrated Design Strategy of Building Water-green Environment Based on Urban Form

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Abstract

The urban morphology research usually focuses on the city of the past, which is mostly consisted of the artificial elements. However, today's design of urban space is not only to fulfil the living, transportation, aesthetics need, but more and more to think about the ecological sustainability and to comprehensively use the natural elements such as water and plants. It is also changing the relationship between the buildings and other physical elements in the urban space to a large extent, and will eventually bring about the new urban form. However, existing design generally focuses only on specific technique or physical element such as green roof, and lacks on exploring the integration value of them and its potential impact on generating a new urban form.

This article collects 34 well-known water-green utilization design cases, and explores the possibility of integrated design and future forms on the basis of form analysis and summary. Firstly, based on Karl Kropf and Paul Osmond 's discussion of the elements of urban form, the water-green elements of the cases are classified on three levels: vertical interface, horizontal interface, internal and external space. Secondly, the evaluation of ecology, landscape, and engineering of the form of elements in the cases is made, and evaluate the integrability of the relationship between the water-green elements and their impact on urban form. Finally, structure a prototype, to explore feasible integrated design strategies and analyses their potential impact on the future urban form.

Keyword: *urban form, rainwater, greenspace, integration design*

The new elements of urban form

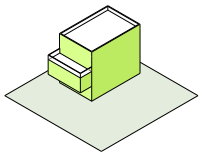
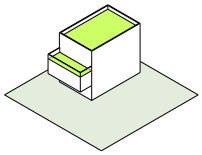
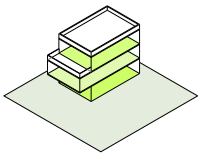
The basis of the research is the analysis of M. R. G. Conzen (1960), Gianfranco Caniggia (2001), Karl Kropf (2013), and Paul Osmond (2009) on the relationship and hierarchy of elements of urban form. M. R. G. Conzen proposed "plan unit", and his town-plan analysis takes the plot as the primary element, the town plan consists of the street system, plot pattern and building arrangement. Gianfranco Caniggia proposed "tissues", his spatial framework is a composite hierarchical structure based on elements, structures of elements, systems of structures and organisms of systems, corresponding to the materials, structures, rooms, buildings, as well as urban organizations, urban residential areas, and towns of the built environment. In order to describe the urban form more comprehensively and accurately, Karl Kropf integrated these two morphological traditions. He combined the elements into a strict hierarchical structure concept, enriched the overlapping set, coordinated the early concepts, and adapted to various specific forms. He added some areas, including open space. On the basis of Kropf 's research, Paul Osmond formally introduced the hierarchical

open space, which contained both built, unbuilt elements, the built space is the artificially paved surface, the unbuilt space contains natural surfaces such as trees, shrubs, grass and water. However, he also only discussed these natural elements at the level of outdoor ground, while they are not just fixed on the outdoor ground and not separated form building in today's city.

With the increasing demand for eco-city, people pay more and more attention to using the natural elements such as water and green plants in the built environment reasonably and efficiently, so that the building itself forms a "natural system" of energy circulation. It is changing the relationship between the buildings and other physical elements in the urban space to a large extent, and will eventually bring about the new urban form. Therefore, we need to extend the previous morphology study to explain the upcoming new city.

The changes of the city are mainly reflected in the following three aspects (Table 1): At the level of vertical interface, it has changed from opening holes in a solid wall in traditional buildings to vertical greening and facade planting in modern ecological buildings, the facade has broken the state of pure artificial, added natural elements and produced new forms; At the level of horizontal interface, the traditional artificial roof has been transformed into a green roof, and then derived into a landscape architecture fully integrated with nature, that is, the relationship between architecture and natural elements has changed from mutual independence to complete integration; At the level of internal and external space, from the enclosed internal garden of traditional buildings, it has gradually evolved into the contemporary building, with green elements growing inside.

Table 1. Table showing the changes of the city in the three levels.

Three levels	The changes			
Vertical Interface	 Diagram	 Traditional facade	 Planting trees on the facade	 Vertical greening
Horizontal Interface	 Diagram	 Traditional roof	 Green roof	 Landscape architecture
Internal and External Space	 Diagram	 Enclosed internal garden	 Green between inside and outside	 Water-green inside the building

The use of green-water element in the building and site

This article uses 34 well-known water-green comprehensive utilization design cases, and explores the possibility of integrated design and future forms on the basis of summarizing specific operation methods. Firstly, the water-green elements of the cases are classified on three levels: vertical interface, horizontal interface, internal and external space.

Secondly, a relatively subjective evaluation of ecology, landscape, and engineering of the form of elements in the cases is made, and evaluate the integrability of the relationship between the water-green elements and their impact on urban form. In terms of ecology, it can adjust the physical environment, purify the air, and increase the humidity in the air. In terms of landscape, green roof and vertical greening can be used to create healthier environment. In terms of engineering, it includes several measures such as water conservation, water saving, and water purification to realize water recycling.

Finally, structure a prototype, to explore feasible integrated design strategies and analyses their potential impact on the future urban form.

● Case Collection and Analysis

This paper collects 34 water green comprehensive utilization cases distributed in many countries, mainly in Asia, such as Singapore, China (Figure 1). Then, classify these cases according to vertical interface, horizontal interface, internal and external space, and site. The following is a simple analysis of these cases, including their features, a subjective evaluation of their ecological, landscape, and engineering effects (Table 2-5).

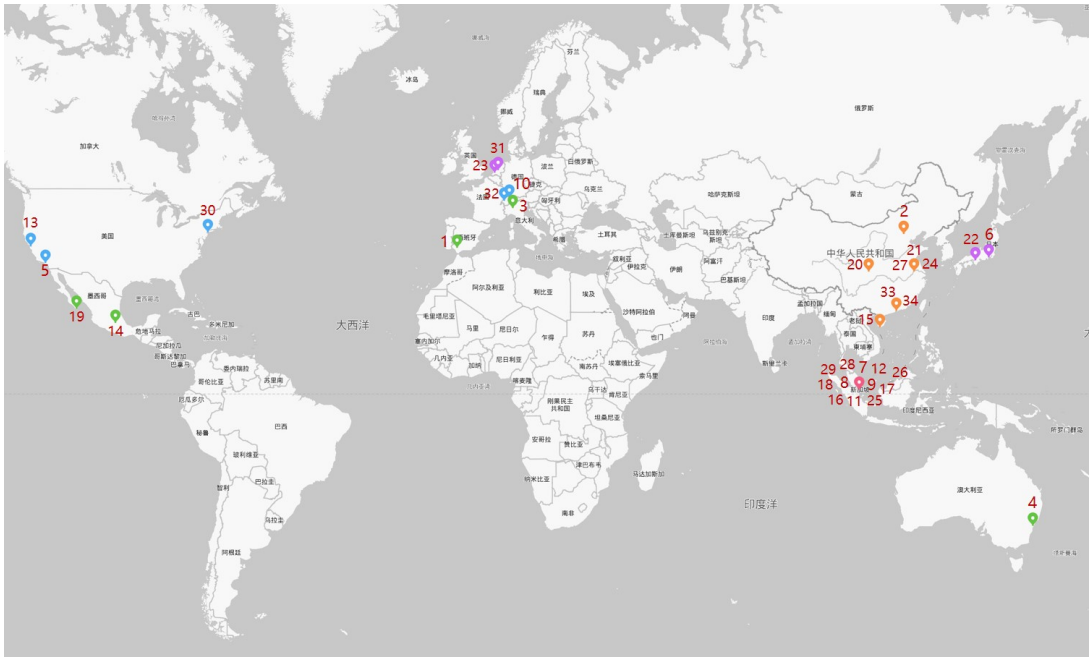


Figure 1. *This photograph shows the location map of these 34 cases.*

Table 2. Case 1-12 profile of vertical interface.

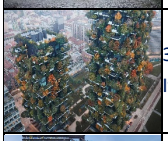
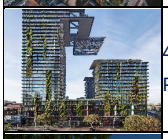
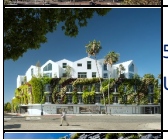
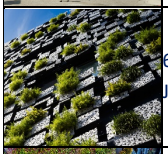
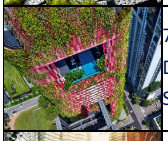
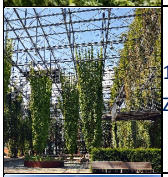
Case	Features	Ecology	Landscape	Engineering	Evaluation
 1. Seville expo UK showrooms	Artificial water curtain wall	Cooling and heat storage	The transparency and fluidity of water form a special landscape	"Circulating water" for rainwater collection can be used as water curtain	
 2. Beijing Expo China Pavilion	Waterfall- Water curtain	Water storage, prolonged water	The sinking "well" forms a waterfall landscape, like a water curtain cave	Rainwater collection system, rainwater can be used to irrigate terraces to form ecological microcirculation	
 3. Vertical Forest, Italy	Planting trees around the balcony	Adjust the indoor temperature and purify the air	Plants change with the seasons	Energy-efficient irrigation system; planting	
 4. One Central Park, Sydney	"Plant curtain wall	Adjust the indoor temperature and purify the air	Facade texture formed by climbing vines and green leaves	Waterless irrigation system	
 5. Gardenhouse, USA	Green exterior wall, green view atrium	Regulate the microclimate	The plants themselves form the unique texture of the building facade	Planting	
 6. Green Cast, Japan	Random dotted vertical greening	Regulate the microclimate	Vertical greening organic facade made of cast aluminum panels	Sustainable rainwater recycling system: water pipes, downpipes and rainwater collectors are integrated behind aluminum panels	
 7. Oasia Hotel Downtown, Singapore	Green exterior wall, sky garden	Regulate the microclimate	The exterior walls are decorated with green plants; interspersed in the sky gardens of different heights	Irrigation system, planting	
 8. The Green Heart of Singapore Marina One	Shared central space —vertical oasis	Regulate the microclimate	The central area presents a multi-level three-dimensional oasis, imitating the natural form of the tropical rain forest valley	Rainwater collecting	
 9. Khoo Teck Puat Hospital, Singapore	Three-dimensional garden	Regulate the microclimate	Three-dimensional greening covers sunken courtyards, flower ponds, terraces, balconies, green corridors, and roof gardens	Rainwater recycling system	
 10. MFO Parks, Zurich	Vertical green park, open green atrium	Water storage, prolonged water, and regulate the microclimate	The atrium is made of a three-dimensional metal mesh structure, with many hollow corridors and overhanging platforms, covered with climbing plants	Rainwater collecting, irrigation system	
 11. Parkroyal on Pickering, Singapore	Three-dimensional garden	Water storage and purification, prolonged water, regulate the microclimate	Sky garden, reflecting pool, landscape waterfall, green platform and vertical green wall	Rainwater recycling system	
 12. Cornwall Gardens, Singapore	Open-air garden, cascading terrace, green courtyard	Regulate the microclimate, adjust the indoor temperature	Terrace steps garden view, waterfall-like green garden	Biological ponds are rainwater collection areas, and recycled rainwater is used to irrigate green plants	

Table 3. Case 13-24 profile of horizontal interface.

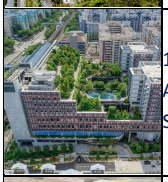
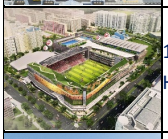
Case	Features	Ecology	Landscape	Engineering	Evaluation
 13. Oakland Museum of California	Stepped roof greening	Water storage, regulate the microclimate	The building is integrated with the site by stepping back the terrace, and various plants are planted on the roof to create a green garden	Rainwater collection, roof planting	
 14. Toledo Alcazar Mansion, Mexico	Terrace garden	Water storage, regulate the microclimate	Green terrace stepped back	Rainwater is collected, processed and used for irrigation	
 15. Intercontinen-tal Sanya Resort	Sky garden, waterscape courtyard	Passive energy-saving design (air convection, shaded courtyard and planted roof)	Local seasonal landscape utilization	Rainwater is collected for recycling roof planting	
 16. Oasis Terrace, Singapore	Terraced garden platform	Plants promote natural ventilation, rainwater recycling and mutual penetration	Adopt a series of garden platforms sloping towards the canal	Rainwater collecting, roof planting	
 17. Kampung Admiralty, Singapore	Green roof, rain garden	Water storage and purification, regulate the microclimate	Green plants and waterscape: falling roof garden, rain garden	Rainwater is collected and filtered as it flows from the top of the building to the lower layer, and then flows to the middle layer by gravity for plant irrigation, waterscape	
 18. Our Tampines Hub, Singapore	Ecological community garden on the roof	Water storage, regulate the microclimate	Green and open shared space	Sustainable Ecosystem: rainwater and food recycling for roof planting	
 19. Solaz Los Cabos, Mexico	Green roof	Regulate the microclimate	Three large curved terraces, stepped form; Integration with the surrounding environment	Roof planting	
 20. Jintai Village Reconstruction	Stepped planting roof, vertical courtyard	Water storage, adjusting the indoor temperature	Echoes the terraced farming and integrates with the environment	Rainwater collecting, roof planting	
 21. Nanjing Green Expo Park-Office Building	Green roof	Water storage, green shading effect, regulate the microclimate	The new form of roof greening, one by one, with seams in the middle, can daylighting	Rainwater collection for irrigation	
 22. Namba Parks, Japan	Roof garden, ecological commercial building	Regulate the microclimate	The roof park, spanning multiple blocks, with green plants, rocks, streams, waterfalls, miniature ponds and outdoor terraces	Rainwater collecting, roof planting, circulating water irrigation	
 23. Library Delft University of Technology	The roof is connected to the ground	Insulate and waterproof, regulate the microclimate	Pedestrian turf roof provides a relaxing place	Turf roof, ecological curtain wall	
 24. Jiangpu Street Neighborhood Center, China	Landscape architecture, super large three-dimensional park	Water storage and purification, regulate the microclimate	Utilizing the park landscape and terrain height difference to form a continuous landscape space	Rainwater recycling system, roof planting	

Table 4. Case 25-32 profile of internal and external space.

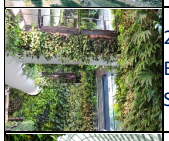
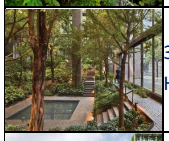
Case	Features	Ecology	Landscape	Engineering	Evaluation
 25. Jewel Changi Airport, Singapore	Indoor waterfall, green plants	Water storage, adjusting the indoor temperature	Indoor waterfall landscape (water mist and lighting effects), green plants	Rainwater is collected and used for irrigation of green plants, and the creation of waterscape	
 26. Marina Bay Sands, Singapore	Indoor canal, artificial waterfall	Water storage, adjusting the indoor temperature	Pouring once an hour, the water volume of 22000 liters/min makes the skylight a spectacular indoor waterfall	A huge environmental protection device that collects rainwater and makes it flow into the canal	
 27. Nanjing Pengxin Aquatic City, China	Artificial canal	Water storage, regulate the microclimate	The semi open block integrates natural elements such as green plants and water	Water circulation system	
 28. Cecil Office Building, Singapore	Indoor three-dimensional greening	Adjust the indoor temperature	Plant climbing plants on walls, balconies, roofs and other places to form a green wall	Irrigation system, planting	
 29. Gardens by the Bay, Singapore	Vertical garden	Water storage and purification, regulate the microclimate	Man-made mountains covered by green plants combined with waterfalls	Rainwater collecting	
 30. Foundation Headquarters	Green inner garden	Adjust the indoor temperature	There is a stepped garden in the atrium; Shared indoor landscape	Planting, covered Platform	
 31. Kop Zuidas Leisure Complex, Amsterdam	Three-dimensional greening	Adjust the indoor temperature	The green landscape flows seamlessly from the inside to the outside, blurring the boundary between the roof and the outer wall	Rainwater collecting, planting	
 32. Blur Building /Cloudscapes	Water mist effect created by water	Purify the air and increase humidity	Mainly for landscape function, it becomes a building in the clouds and mist	The water is drawn from the lake, filtered and sprayed in a fine mist	

Table 5. Case 33-34 profile of site.

Case	Features	Ecology	Landscape	Engineering	Evaluation
 33. Vanke Community A1-B2 and Bus Station, China	Three-dimensional park	Water storage, regulate the microclimate	The undulating terrain of the park becomes a three-dimensional green space, platforms, green corridors, sunken courtyards	Rainwater collecting, roof planting	
 34. Shenzhen Shenwan Street Park, China	Rain garden, ecological wet pond	Water storage and purification, prolonged water, regulate the microclimate	The 10m high waterfall falls, forming a stacked waterfall landscape, and finally returns to the wetland water cycle to irrigate the waterscape	Rainwater circulation system: water storage and purification, used for green irrigation and landscape water replenishment	

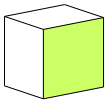
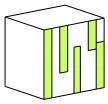
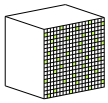
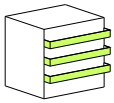
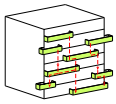
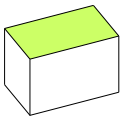
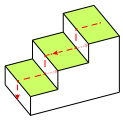
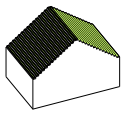
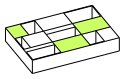
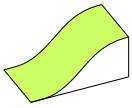
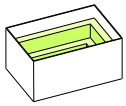
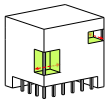
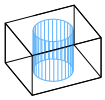
● Summary of Specific Operation Technique

Firstly, in terms of spatial relationship, cases are summarized graphically according to the vertical interface, horizontal interface, internal and external space. Then we make a comprehensive evaluation, that is, the degree of impact of these different forms on future urban morphology.

From the perspective of urban morphology, the different forms of these three levels have ecological, landscape and engineering effect. At the level of vertical interface, only the changes in the two-dimensional

facade texture have a small impact on the urban form, followed by the three-dimensional traditional platform, and the staggered protruding platform has a greater impact; At the level of horizontal interface, it is only the change of the roof texture, which has little impact on the urban form, when the interface is connected with the interior, such as the stepped form , there is a tendency to extend to the interior space, which has a greater impact on the urban form; At the level of internal and external space, the water-green elements that grow inside the building have little impact on the urban form, when the water-green elements extend from the outside to the inside, the internal and external space penetrate each other, which has a greater impact on the urban form. All in all, if the ecological interface is deep, that is, there are changes in space and internal and external relations, it will have a greater impact on the future urban form. Below you can find Table 6.

Table 6. Table showing the different forms in the three levels.

Vertical Interface	 The whole face	 Vertical texture	 Horizontal texture	 Punctate texture	 Terrace	 Staggered terrace
Horizontal Interface	 The whole face	 The stepped form	 The new form	 The sunken	 Landscape style	
Internal and External Space	 The internal	 Penetration	 Penetration			

The Prototype of the New Urban Form

Choose forms that have greater impact on the city form among the three levels, then carry out an integrated design that combines the water-green elements of the horizontal and vertical interfaces with the internal space, forming a prototype of a new urban form (Figure 2).

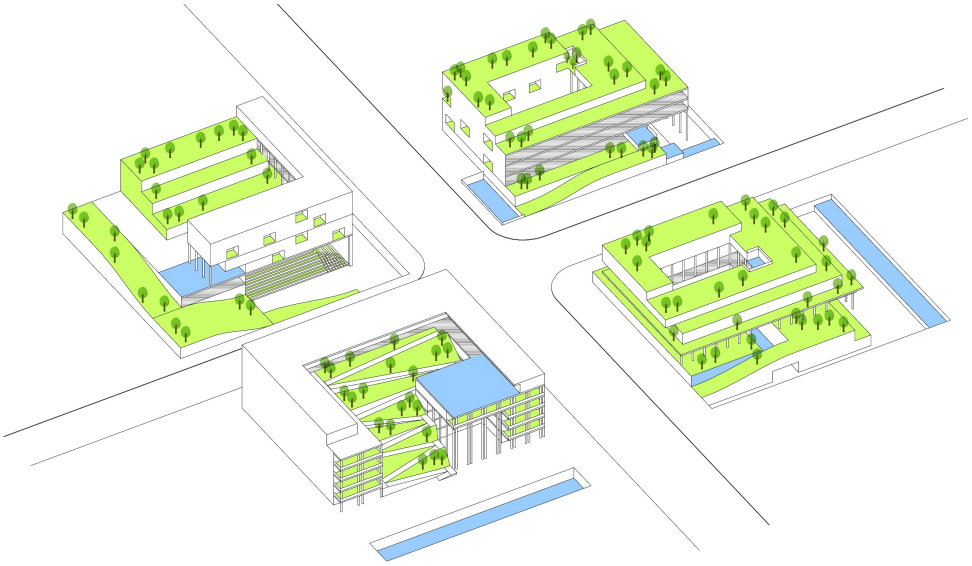


Figure 2. *Exploration of the prototype of the new urban form.*

Design Operation Exploration

Finally, we make a design operation exploration——the corridor design competition (Figure 3-4), and carry out relevant integrated design. It brings new forms to architectural design, space experience and urban form. There is a comprehensive design of water-green elements in this design: the roof cistern has functions of rainwater collection and waterscape, when rainwater flows from the top of the building to the lower level, it forms a vertical interface multi-level waterfall and a horizontal interface rain garden, and interacts with the internal space. This forms a sustainable landscape ecosystem.

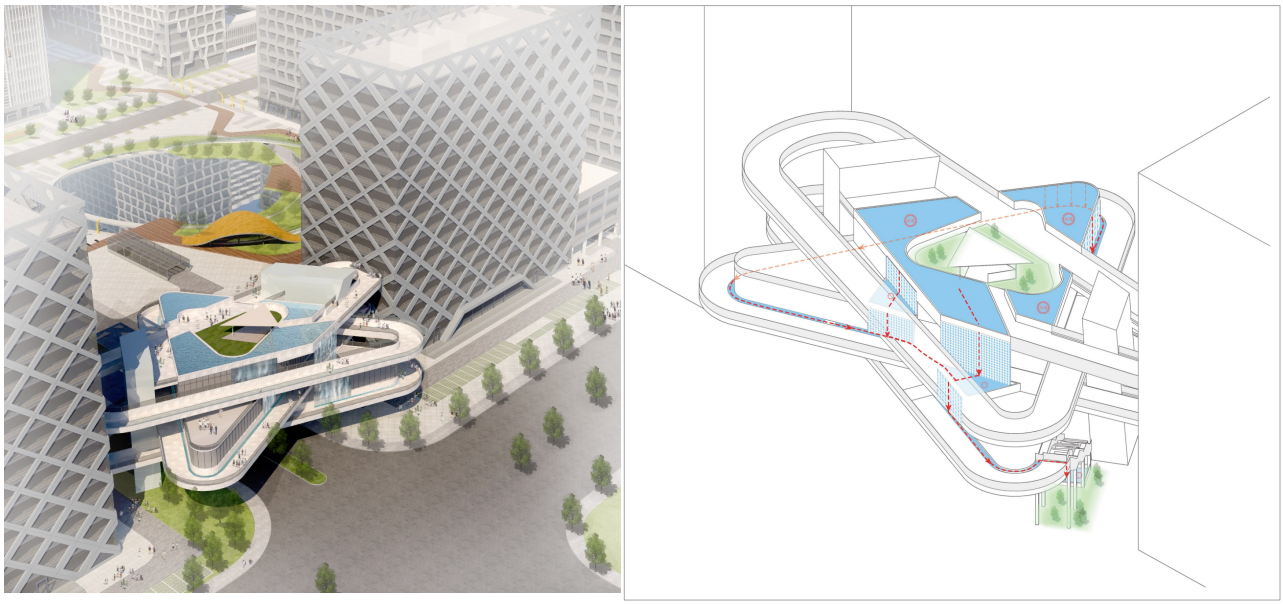


Figure 3-4. *A bird's-eye view of the plan and related analysis.*

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