Tall Buildings, the Increasing Gap between Fantasy and Reality: Iconic Opportunities in Need of Direction

Tall buildings pose one of the most challenging design problems that we face. What is being constructed today will impact our environment for many decades to come. Skyscrapers are not readily demolished. They are massive buildings with extremely significant structures that must create livable spaces for thousands of people (inside and outside) as they engage the city and which need to remain viable for a significant duration.

Although the technology of building tall has advanced significantly in the past 15 years, it has not necessarily kept pace with the fantasy visions of towers that we see in renderings and competition entries many of which ignore material and construction realities. Many of these proposals may include genuinely inspirational ideas, but they still belie construction. The present situation may require that we step back and reconsider the tall building type to understand how we can effectively build upon current technologies to create a more socially and environmentally responsive building type. There is a need to reconcile current digital fantasies with the technical realities of *what we can do* in light of *what we should do*.

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Structurally and geometrically speaking we live in interesting perhaps even permissive times. Advances in three dimensional computer modeling software and structural detailing software have lifted almost any restrictions from the shape of buildings or elements. Efficiencies are possible even with odd geometries and non-repetitive parts given the flexibility of CAD assisted fabrication machinery. This has enabled an increasing number of highly unique towers.

THE REALITIES

The typology of the 21st century tower has evolved from a commercially driven optimization problem to a dynamic, compelling and often controversial area of design. With increasing migration to urbanize the planet, the tall building is being looked to as the solution. However the questions “how tall” and “how dense” have not been properly addressed. To this point the challenges of tower design, particularly in terms of height and safety have been seen as belonging to the field of engineering. There has been limited exploration of design solutions in the architectural curriculum as the problem was considered too banal in contrast to the potential of most mid to low-rise typologies. This has resulted in a huge gap between the digital fantasies of tall buildings (whether created by architects or students) and their urban and technical realities. Tall building design and construction has developed as an area of technical specialization that is not widely engaged by the architectural curricula.

Architects are practising in a global environment. The tall building type is just one of many that seem to be replicated in different climates without much consideration of environmental impact or cultural differences. Factors and precedents that influence architectural design are increasingly global due to internet based media. This tends to encourage a liberal attitude towards design that can work against specific climate and site responsive solutions as a direct result of copycat proliferations of designs. Much development is also proceeding that uses current tall building types, without significant understanding of the social implications of such density. Tall building construction in Asia and the Middle East has outstripped Western areas, creating urban conditions without precedent. Although early iterations of tall buildings in the developing world were based on North American typologies, more recently these regions are creating increasingly iconic versions that have never been tested, either technically or socially.

THE EVOLUTION OF A TYPE

The tall building is a discrete architectural type. It is normally useful to understand the causal aspects of its evolution to determine which aspects will be of the most benefit in pushing the idea forward. If tower type buildings are symbols of the ideals and aspirations of the civilizations of any period in history, what should our current response be based upon *our* technical achievements?

FROM INTERNATIONAL STYLE TO ICONIC STYLE

The design of tall buildings has changed significantly over the past 50 years. Where once each major North American city aspired to own their version of the Seagram Building that Mies van der Rohe first constructed in New York City in 1958, now such repetition is not desired. The age of the iconic skyscraper has come to be dominated by a combination of the preference for the stylistically unique in conjunction with the quest to build tall. The uniformity and rectilinear nature of International Style architecture that dominated tall building design through the better part of the 20th century has given way to unrestrained expression that is reliant on pushing the limits of technology. Technology would include the structural capabilities of materials and systems as well as the methods used to calculate and fabricate. This encompasses many evolving areas of digital design.

STRUCTURAL LIMITS

Towers represent the limitations of the technology of the time as the height of the tower is directly connected to the tensile capabilities of materials in conjunction with the arrangement of the gravity and lateral load systems. Historically the lateral load systems in particular served to limit the geometry of tall buildings. Generally the lateral load resistance system was married to the core area of the tower where bracing and reinforcement systems could be concealed and have


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Figure 1: The Burj Khalifa, Dubai - an icon setting the standard in the race to build extremely tall. The building tapers dramatically to the point of the top portion of the tower having no occupiable area but serving mostly to set a height record.

little impact on the architectural expression of the building. Gravity loads could be accommodated by an increase in the mass or size of the lower structure, but wind loads transformed tower types into vertical cantilevers which required significant tensile resistance towards the lower part of the building. The taller the tower the more severe was the problem. Technologically this was answered by the application of steel bracing systems as well as a tendency to decrease the floor area of the building over the height of the structure to decrease the cumulative loads.

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The structural systems used in Super and Megatall towers (a building is classed as a Megatall building by the Council for Buildings and Urban Habitat if the height exceeds 600m and Supertall if the height exceeds 300m) are substantially different in terms of their impact on the architectural spaces within the building than the simpler framed systems of the past. Core and outrigger systems, megacolumns and diagrids have permitted an unprecedented increase in the height of buildings.

BUILDING MASSING

The development of these new structural systems when conjoined with composite construction methods (these include concrete filled steel tubes as well as concrete encased steel sections), have permitted the height of the tall building to reach 828m, with projects underway such as the Kingdom Tower in Jeddah, Saudi Arabia that should push that to 1,000m. Typically these Megatall buildings tend to use a massing that triangulates the tower, positioning more floor area at the base to minimize the area and wind loading towards the top. Supertall buildings have less need to triangulate their overall form and can take on a narrower, straighter profile.

The massing of tall buildings falls into three general types. Non-tapering towers land cleanly on the ground; tapering towers enlarge significantly towards the base whereby the base condition is an integral part of the tower structure; or towers engage a podium which is normally using a separate structural system

Figure 2: The realities of the achievements of current tall building methods bear no resemblance to digital designs of skyscraper dreams. The *megacolumns* of the CTF Tower by KPF in Guangzhou, China are extremely gargantuan as is naturally required by buildings whose height will exceed 530m when complete.

and language from the tower building. The podium is not used to reinforce the tower structure and varies in height and size according to its program. The choice of its massing directly impacts the quality and character of the urban environment. The existence of a widened base or podium distances the activity of the tower (the people entering and exiting) from the exterior environment. The width of the base condition determines the distance between adjacent tower elements which impacts the climatic condition of the spaces at street level in terms of light access.

FAÇADE DESIGN

Prior to the invention of the aluminum curtain wall cladding system, the stylistic preferences for tall buildings included façade design that was dominated by traditional looking stone or terra cotta cladding. Stylistically this worked with the steel framing methods of the time. The resulting setback style created a tall building geometry that aligned with the technical limits on framing typology of the time. The materiality of the façade systems for these early skyscrapers supported a natural extension of the masonry oriented stylistic preferences of the time. The detailing of the façade system usually created a differentiated base condition that engaged directly with the streetscapes. Many early skyscrapers included natural ventilation and operable windows. The floor plates were small to allow for access to daylight and view.

The aluminum curtain wall system that dominated architectural design for the last half of the 20th century was a product of the International Style and created a uniform appearance that did not differentiate by location, climate or culture. An urban fabric developed that was consistent, rectilinear and extremely corporate to the point of being cold in its feel. Aluminum curtain wall systems tended to be sealed and relied entirely on HVAC systems, a practice that has continued and which is not responsive to contemporary environmental concerns, climate or geographic location. The size of the floor plate increased due to the dependence on mechanical space conditioning and also distanced the occupant from daylight and views.

Although highly efficient climate responsive façade systems are being used in contemporary construction, tall buildings are tending towards the use of less complex or deep systems largely as a function of cost. Changes are being seen with respect to a reduction in floor plate size to permit access to view and daylight with some towers beginning to reintroduce sporadic natural ventilation. Some towers are incorporating double façade techniques, although these instances are still extremely rare.

WORKING WITH STRUCTURE AS AN EXPRESSED AESTHETIC

The structural typologies of towers can provide a starting point for re-engaging in their design. Changes in tower form and appearance can largely be attributed to technological changes and the development of new systems and material combinations. The completion of the SOM designed John Hancock Center in Chicago in 1969 marked a pivotal change in the design of tall buildings. The move of the diagonal bracing system to the façade and its directed use as part of the architectural aesthetic opened the design possibilities for the tower type. The use of diagonals in the expression allowed for more variety in façade treatments which led many designers away from the rectilinear façade systems that had led to extreme uniformity in urban fabric.

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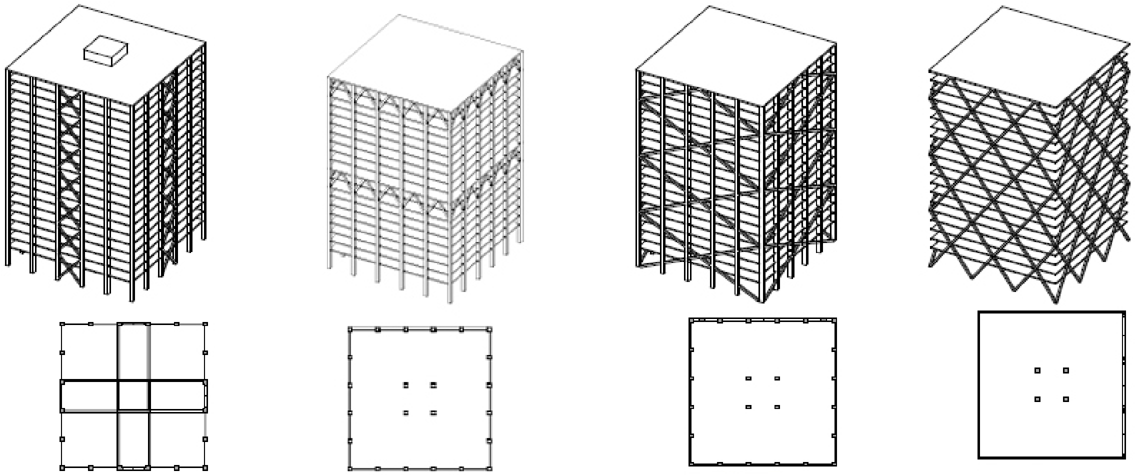
Figure 3: The realities of the achievements of current tall building methods bear no resemblance to digital designs of skyscraper dreams. The double façade system of the Shanghai Tower by Gensler must respond to extreme loading issues as the building will be 632m when complete. Its megacolumns occupy the floor area of a typical office space.

This ability to express the structure fuelled other changes in tall building design including a deviation from the use of standard rectilinear tower profiles and differentiated expression throughout the façade to reflect the placement and role of the bracing system. Where the aesthetic impact of the braced rigid frame and belt truss have had minimal impact on overall tower design, the braced tube and diagrid have had a huge impact on tower forms and thereby the experience of these towers in the urban environment. The scale of the bracing members on the braced tube is large enough to allow the bracing system to determine the shape of the tower. This is reflected rather discreetly in the tapered form of the John Hancock Center and more directly in the triangulated setback shape of I. M. Pei's Bank of China in Hong Kong (Figure 5). The Bank of China introduces the potential for the large scale diagonal as a modular device to suggest changes in the building massing.



Braced Rigid Frame

Belt Truss

Braced Tube

Diagrid

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Figure 4: The basic methods of the expression of lateral bracing systems on tower types. [1]

As a means to engage creativity in the design problem, the diagrid has ultimate flexibility as it need not adhere to any rectilinear patterning to accommodate load paths and structural arrangements. Diagonalized grid structures – diagrids - have emerged as one of the most innovative and adaptable approaches to structuring towers and other building types in this millennium. The use of diagrids as a contemporary formal structural language for towers started in the early 2000s, examples being Swiss Re (2004) in London, England, and the Hearst Magazine Tower (2006) in New York City. Foster + Partners was the design architect of both buildings and Arup responsible for engineering the London project with WSP Cantor Seinuk providing engineering services for Hearst.[2] Over the last 12 years, variations of diagrid structures have evolved as the system has proven to be highly adaptable in structuring a range of building types, spans and forms. What is common to most applications is the ability of the diagrid to provide structural support to buildings that are non-rectilinear, adapting well to highly angular and curved forms. This has been particularly exploited in the design of iconic towers such as Aldar HQ in Abu Dhabi which has adopted a circular elevation or The Leadenhall Building in London designed by Rogers Stirk Harbour and Partners which has come to be known as "The Cheesegrater". The perimeter diagrid in its purest form is capable of resisting all of the gravity and lateral loads on the structure without assistance of a traditional core, enabling some very unique deviations from structural types that are entirely dependent on a core for stability.

From the perspective of educational exploration, expressive structural systems can be used to engage the students as they require significant understanding and involvement. As expressed structures such as diagrids are highly visible aspects of tower design, architects need to understand their details in order to properly inform the design. This is in contrast to the corporate driven towers that relied on a regular column/beam/core system where the most compelling design issue was the efficiency of the core and the specification of the curtain wall system.

THE IMPACT OF ADVANCED COMPUTER MODELING

It is likely no coincidence that the birth of the contemporary diagrid building type came at a time when computer assisted drawing was hitting its stride. The development of BIM (Building Information Modeling) has been critical to ensuring the successful design and fabrication of highly complex steel structures. Geometric complexity requires a very high level of accuracy and makes the assessment of loading on members and connections far more challenging than rectilinear structures that can be reduced to simple, determinate transfers of load. Where computer programs such as Catia allowed Frank Gehry to create irregular curved forms, BIM programs such as "Xsteel" were created to assist in engineering, detailing and fabricating the steel that supported these unusual forms. The transition of "Xsteel" to "Tekla Structures" in 2004 added significantly more functionality and interoperability to the previous software. The use of software like this is essential in the collaboration required in diagrid and other complex steel framed buildings.

The ability of digital structural and fabrication tools to keep pace with digital modeling has enabled an unprecedented level of geometric experimentation in the design of buildings. Take for example the case of Capital Gate in Abu Dhabi, designed by RMJM Architects and completed in 2012 (Figure 6, right). The primary design objective of this project was to create a unique and iconic tower.[3] Its historic timing was well positioned to take advantage of digital design tools to create the form of the building as well as to detail, calculate and fabricate the structure. The tower has more than 800 unique structural nodes. There is no uniformity in the angles, connections or members. Its backwards lean of 18° is possible through a combination of the strength of the perimeter diagrid and the tensioning of the concrete core. The lean of Capital Gate exceeds that of the Puerta de Europa Towers (1996) in Madrid, designed by Johnson/Burgee Architects, by 3°. The Puerta de Europa towers use identical geometries and rationalized details that related to the full range of technical limitations of the time in which they were constructed.[4] The leaning towers form a gateway to the city adding greatly to the vitality of the Plaza de Castilla where they are situated.

Where 20th century towers tended towards repetitive planning which aligned with the technical limitations of drawing and structural design of the time, contemporary towers can exploit the growing digital capabilities and the interoperability of software systems that allow geometries to be translated from the design office, to the engineer and to the fabrication equipment. Within this it becomes important to reconcile structural and material realities with digital dreams. The opportunities of the diagrid and other steel structures lies in the understanding of the fabrication and erection of the systems as part of the design problem.

Although certainly not exclusive to this structural type, the diagonalized core and diagrid structural systems tend to be used on towers that interact directly with their urban setting; i.e. without an enlarged base or podium. The self sufficiency of the structural system to withstand lateral and gravity loads allows for slender


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Figure 5: The use of the diagonal as a form giving device transforms the Bank of China into an iconic tower that is visually distinct from the surrounding more traditional skyscrapers in Hong Kong.

towers with good access to daylight. There are many precedents available for study that have used natural ventilation systems and double façades in conjunction with diagrids (Swiss Re and Capital Gate) as the structural type tends to be used on high end, iconically driven projects.

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Figure 6: (left) The Puerta de Europa towers in Madrid (1996) as compared to (right) Capital Gate in Abu Dhabi (2012).

SPACING, URBAN ARRANGEMENT AND CLIMATE

The increase in the density of our urban environments is inevitable and is desired as a means to preserve agricultural land and limit urban sprawl. However not all density is supportive of a rich urban life. Beyond issues of the relationship between the height of inhabitation and its relationship to the landscape described as *Biophilia* [5], the height and spacing of buildings impacts the climatic condition at grade. There are extremely important lessons that need to inform the positioning of tower types in order to allow solar access in cold climates and provide shade in hot ones. Dense urban environments will also modify the wind regime which can result in spaces that can be either too windy or too still. The nature and width of the roadways adjacent to towers will impact the viability of street life. Car oriented cities and elevated roadways adjacent to towers can serve to negate their connection to pedestrian life.

One of the preoccupations of our impression of the skyscraper as an urban type is its reading as part of the skyline. While skylines might be important indicators of the character and identity of a city, they do detract from the more important detailing of the engagement of dense buildings with the streetscape and much design focus is spent in detailing the silhouette and the top of the tower. The frequently seen images of Chinese cities highlight other issues associated with increased urban density such as pollution and air quality which become necessary to discuss when looking at the relationship between tall buildings, urban density and livable cities.

There are many highly vibrant cities that use tower types in dense configurations. Although there are many cultural differences between New York City and Hong Kong, both cities thrive on density. The densities in both cities make use of the patterns of existing urban blocks to limit the size and scale of their tall buildings. Although there are some instances of extensive podium structures that cause the towers to be set back from the street edges, many towers tend to directly engage the streetscape. This creates a direct connection between the occupants of the tower and life on the street.

Made from scratch cities, such as Dubai, begin with a tabula rasa situation, meaning that the size and configuration of the tall buildings does not need to respond to a previously determined city plan. Although there is a tendency to consider new cities such as Dubai with a broad, uniform brush, the neighbourhoods that support the new tall buildings within Dubai are quite varied. While Marina Bay (Figure 7) has chosen a highly compacted development of less singular towers that achieves significant shade at the street level, Business Bay houses many more iconic structures, including the Burj Khalifa (Figure 1). The urban plan is more dispersed resulting in a more hostile environment at grade as a direct result of the increased spaces between the buildings. This makes the environment inhospitable in 45°C temperatures.

When examining urban issues, there is nothing inherently wrong or right about "iconic looking towers". In dense urban situations the pedestrian precinct is mostly influenced by the bottom levels, so if the cladding or form of the overall tower is innovative or banal it does not necessarily influence the vitality of the urban space if the grade related condition supports urban activity. It is not the tower itself but rather its position and condition at grade that either supports or dampens urban activity.

Tower buildings and density in and of themselves do not determine the success of the urban spaces at grade. It is worthwhile to look more closely at the variations in street life and urban culture as relates to the specific location and setting of the tower. Even within what would be considered vibrant cities, such as Hong Kong (Figures 9 and 10), we can learn how to create better street environments by examining this condition.

THE EDUCATIONAL POTENTIAL OF CONTROVERSY

Recent stylistic and structural changes in tower typology have potentially made them a more engaging building type to study as well as perhaps a more contentious one. From the point of view of architectural education this provides an interesting opportunity for debate, particularly with reference to project proposals as they are introduced in the media as many of these blur the lines between digital design, technical aspirations and present realities.

Perhaps one of the most discussed projects of 2012/13 has been the Sky City project by China Broad Group (Figure 11). There seems to be a tendency for Supertall tapered towers such as the Burj Khalifa, Kingdom Tower and Sky City to be positioned in relative isolation as a way to accentuate their iconic status. If this is accompanied by a self-sufficient programmatic intention, such as that of Sky City, the proposed 838 m/220 storey tall prefabricated tower in Changsha, China, there is likely to be a negative impact on city life. The majority of promotion for Sky City illustrates the building as an extremely isolated element. Its self-sufficient building program is designed to agglomerate land around the building for use by its occupants, but will they have any other need to leave the building?

Projects such as Sky City can present discussions to students regarding building use as well as the impact of building size and floor area dimensions on its

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Figure 7: Although the density of Dubai is often criticized, there are distinct benefits to the close spacing of the narrow, square plan towers that provide much needed shade in an environment that does not naturally support vegetation.

Figure 8: Times Square must accommodate winter conditions so benefits from interspersed mid-rise buildings that allow better access to light.

function. These will naturally reference some of the experimental work of Modern architects such as Le Corbusier with his plans for Ville Radieuse and the constructed Unité d'Habitation experiments.

The illustration of Sky City in relation to the skyline of Chicago (Figure 11) provides a better idea of its enormity. What program fits at the lower level where the distance to windows might measure in terms of city blocks? Does this arrangement create useful or livable density?

SUSTAINABLE DESIGN

The case of Sky City allows for a discussion of prefabrication and sustainable design as the project proposes a construction scale of from 3 to 7 months (varies as a function of reporting), which contrasts significantly from actual tall building construction in China at the present time. The stated green systems can be discussed as they relate to the massing of the building as well as the material palette of other skyscrapers that are claiming to be sustainable. The idea of the Sustainable Skyscraper was the focus of the 2012 CTBUH Congress "Asia Ascending: Age of the Sustainable Skyscraper City" that was held in Shanghai.[7] Having attended the conference it was clear that the notion of the sustainable skyscraper remains an oxymoron and fairly elusive, requiring significantly more research and exploration. The proceedings from this conference form part of an extensive resource library that is hosted by CTBUH which is fully accessible for student research without charge.[8]

SOCIAL MEDIA AND DISCUSSION

Social media is an easy way to encourage students to engage in debate and discussion outside of the classroom. Two recent news items, "Benidorm Skyscraper Built Without an Elevator"[9] and "The Dragonfly: A Giant Vertical Winged Farm for New


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Figure 9: The Causeway Bay area of Hong Kong has very few "iconic" tall buildings but is kept alive with intense retail.

Figure 10: The streets of Hong Kong are not all bustling. The new International Commerce Center designed by KPF is not located in a retail district. Even the glazed nature of its base condition cannot create street life.

Figure 11: The China Broad Group Sky City Skyscraper employs a tapered massing arrangement that is accompanied by a setting that isolates the building from its urban setting. The image shows the tower superimposed on the city of Chicago, providing a better idea of its size. Interestingly this promotional image created by the China Broad Group is intended to put the tower project in a favorable light.[6]

York City"[10] have fostered some very interesting student comments, criticisms and suggestions when I posted the items on their class Facebook page. The pairing of these two particular projects, one an actual project with a somewhat ridiculous problem and the other considerably more visionary, is useful in encouraging reflection that reinforces practical considerations while also looking for the potential in innovative ideas. Speculative projects that also include detailed technical and system suggestions like the "Oasis Tower: Spiralling Vertical Farm for Dubai"[11] can provide a forum for discussion in terms of the necessary changes, extensions and inventions that build upon present day technologies in order to allow for projects like these to be constructed. Urban life issues should also be included. Comparisons with actual projects, in this case the Burj Khalifa as it has a similar setting and climate, are useful in assessing its viability.

CONCLUSION

The tower type has evolved dramatically as a result of technical innovation, a drive to increase urban density and digital explorations. It is no longer limited to a directed corporate exercise in efficiency with repeated floor plans and limited variations in cladding design. Our future urban fabric needs to be re-engaged into architectural design education as the means to close the gap between open ended digital speculation and the realities and potential of actual construction. There are many topics and areas of discovery that can be explored. The ideas presented in this paper provide a brief introduction to some of the areas of investigation that can be very rich and compelling for both students and faculty.

The contemporary tower type supports explorations in typological studies, the technical aspects of construction, façade design, sustainable design as well as urban design.

ENDNOTES

All photos taken by author unless otherwise noted.

1. Illustration by Vincent Hui, Ryerson University. Adapted from *Understanding Steel Design: An Architectural Design Manual*, Birkhäuser, 2012.
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