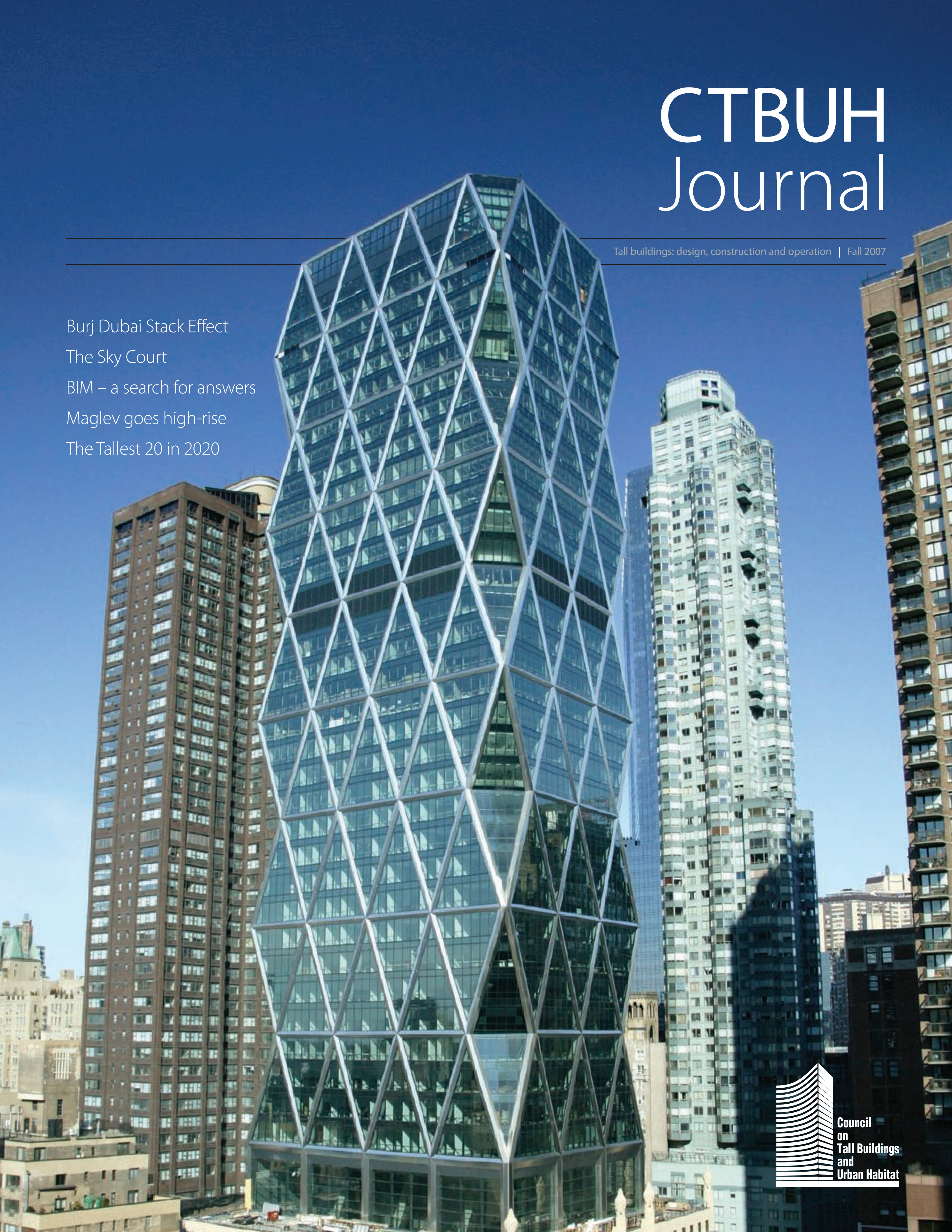
CTBUH Journal

Tall buildings: design, construction and operation | Fall 2007



Council on Tall Buildings and Urban Habitat

Welcome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Welcome to the *CTBUH Journal*, the publication for the Council on Tall Buildings and Urban Habitat.

Our Fall highlights are a look at stack effect in the Burj Dubai; how Sky Courts may be the future of tall buildings; contemplating BIM; and how Maglev could revolutionise vertical travel in tall buildings.

Country profiles and updated members listings round off.

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Front cover: Hearst Tower, New York, winner of the CTBUH Best Sustainable Tall Building Award 2007. photo: Michael Ficeto/Hearst Corporation

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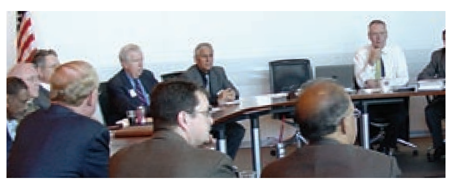

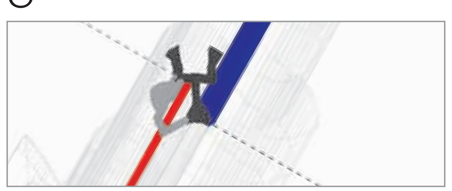

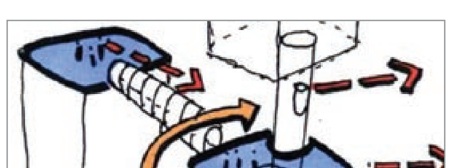

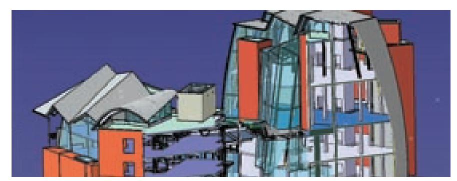

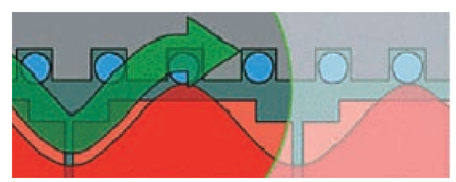


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CTBUH news and events

Council

It has been a momentous quarter for the Council, since publication of the Summer CTBUH Journal. This edition of the Journal comes hot on the heels of the inaugural annual meeting of the new Steering Group, held at the Illinois Institute of Technology on 25th October (for a full report of this meeting, see pages 4-5). Resulting from the meeting, we now have the unanimous endorsement of the steering group to expand the Council in line with recent successes in fund raising and the multitude new initiatives started and planned. This expansion will begin with a search to fill three new full-time positions; a new Research Director, a Head of Publications, and a Production Assistant.

Our 6th Annual Awards Dinner, which followed the Steering Group meeting on the evening of the 25th October, continued the positive vein of the day (see the full report on pages 6-7). Over 200 people joined us to celebrate the considerable lifetime achievements of honorees Lord Norman Foster of Foster & Partners (awarded the Lynn S. Beedle Achievement Award) and Dr Farzad Naeim (awarded the Fazlur R. Khan Medal). In addition, and for the first time, this year we celebrated team achievements in creating excellence in tall building design with two new awards - Best Tall Building, which went to the Beetham Hilton Tower, Manchester, UK; and the Best Sustainable Tall Building, which went to the Hearst Tower, New York (above). We finished the evening by celebrating the appointment of the Council's new fellows; Leslie E. Robertson and Chandra K. Jha.

Congress 2008

Plans for the 8th World Congress Dubai are progressing excellently. Massively over-subscribed with paper submissions, the peer review process is complete as this Journal goes to press and as Chair of the Scientific Committee I can report that the quality could hardly be higher. Key presentations will include the Mayor of Chicago Richard Daley, head of the City of London planning authority Peter Rees, former Governor of the State of New Jersey and head of Whitman Strategy Group Christie Whitman, renown structural engineers Werner Sobek (Werner Sobek Ingenieure), William Baker (SOM) and Robert Halvorson (Halvorson & Partners); and world-famous architects Rem Koolhaas of OMA, Hani Rashid of Asymptote, Robert Fox of Cook + Fox, Adrian Smith of Adrian Smith + Gordon Gill and Ken Yeang of Llewelyn Davies Yeang.

The 700+ page book that will be produced in conjunction with the Congress will be an important publication, documenting the very latest in multi-disciplinary thinking in tall buildings. Several major sponsors are also confirmed, including Emaar at the Platinum level, the AECOM group at Gold-Plus, Gale International and the WSP Group at Gold and Atkins and Woods Bagot at Silver. In addition there are only a few exhibition booths left, with confirmations from Arup, Boundary Layer Wind Tunnel Laboratory, CPP, Turner and Value Engineering Associates, as well as the main sponsors listed above.

The World Congress will be a seminal gathering of all those involved in the inception, creation and operation of tall buildings, at this unprecedented time of global activity and growth in our industry. The full line up of speakers and sponsors, as well as online registration, can be found at the Congress website: www.ctbuh2008.com

Next Quarter

There will be no Winter 2007 edition of the CTBUH Journal. Instead all organizational members in good standing will be receiving the fruits of another new CTBUH initiative – the inaugural special edition of the CTBUH / John Wileys & Sons collaboration on the

Journal of The Structural Design of Tall and Special Buildings. This special, multi-disciplinary edition contains papers on subjects as diverse as the economics of tall buildings to the soon-to-be-completed wind turbines of the incredible Bahrain World Trade Center towers. Contributing authors include Bill Baker of SOM, Shaun Killa of Atkins and Dr. Ken Yeang of Llewelyn Davies Yeang.

We continue to work on new initiatives, and innovative ways of disseminating information on tall buildings (witness the 'Tallest 20 in 2020' article, profiled on page 24-25). On the back of the recent improvements in this Journal, our website has undergone a further upgrade, with a full content management system which now enables numerous people to contribute to the valuable resource of technical papers and information on tall buildings it is becoming (www.ctbuh.org).

This is an incredibly exciting period for the Council, especially as we implement the vision for growth and consequential increase in output and relevance. We hope to involve our rapidly increasing organizational and individual membership in that. In the meantime, we wish you all a happy upcoming festive period and look forward to seeing you in Dubai in a few months time.

All the best.

Antony Wood
CTBUH Executive Director

Burj Dubai Stack Effect

Passive stack effect mitigation measures taken in the design of the world's tallest building: Case Study of the Burj Dubai

Stack effect in buildings is the same as stack effect in chimneys. That is to say, in a chimney, stack effect is the draft produced by the difference between the temperature of the flue gas within the chimney and the outside air. The force of the draft is a function of both temperature difference and height of the flue. During periods of extreme weather, this effect becomes evident in buildings of even modest height, although the temperature differential is much less than in a chimney. Those of us that live in temperate and cold climates are familiar with the upward movement of air in wintertime. This is especially noticeable at the entrances to buildings, elevator shafts, stairwells, dumbwaiters, mail chutes and mechanical shafts. Stack effect also occurs in warm and tropical climates, especially in the summertime. We sometimes describe this phenomenon as "reverse" stack effect because the flow of air is downward. With "normal" stack effect, the air in the building has a buoyant force because it is warmer and less dense than the outside air. With reverse stack effect, the cooler more dense air is inside the building and wants to drop downward and flow out of the building at its' bottom. This latter case of "reverse" stack effect will be the most prevalent type encountered in the Burj Dubai.

Why is understanding stack effect important? Stack effect can impact the function, systems performance, equipment specification, energy use and operations of a building; especially a tall one. Although the physics that causes stack effect is known; its' impact on individual buildings and specific locations within those buildings can differ greatly. Environmental variables, such as the air temperature, atmospheric pressure, humidity, combined with the air tightness of the exterior wall and existence and height of vertical pathways for air transfer within the building will influence the magnitude of the effect. The magnitude of the effect can turn a mere annoyance into a larger problem affecting building operation and even safety. It is unpleasant to the occupant to experience the sound and feel of air rushing up or down an elevator shaft or whistling through gaps in even closed doors. During certain times of the year, the rush of air when opening the entry doors into the lobby of a tall building not only makes it difficult to negotiate the entry, but think of the cost to the environment due to the loss of expensive conditioned (heated or cooled) air. Some tall buildings even have experienced problems with doors to exit stair shafts being forced open or held closed at certain times, due to stack effect. This problem can be serious if during an emergency the occupants trying to use those doors are elderly, very young or physically impaired. It is therefore important for the designer to understand this phenomenon so as to make provisions in the design to minimize, mitigate or accommodate this effect as well as to advise the Owner on issues that may arise in the on going operation of his building.

The purpose of this paper is to outline the challenges related to stack effect faced by the Burj Dubai design team and to describe the measures taken to mitigate them. The writer hastens to add that this process is still ongoing and will continue through construction and into the operational life of this super tall, unique structure.

Burj Dubai

The Burj Dubai (Tower of Dubai) will be the world's tallest structure when completed in 2009. The superstructure is currently under construction on a site in Dubai, UAE, formerly occupied by the military. At over 160 stories in height, it will be the centerpiece of a 3,700,000 m² (40,000,000 ft²) residential, office and retail development. The final height of the building is currently confidential, but when completed, this ultra-modern multi-use skyscraper will be in excess of 700 meters (2300 ft), significantly exceeding the height of the current record holder, the 509 meter (1670 ft) tall Taipei 101.

Fig 1. Burj Dubai under construction

The 280,000 m2 (3,014,000 ft²) reinforced concrete Tower is primarily Residential but, it also contains a 5+ star Armani Hotel and Service Apartments, Corporate Office Suites and several floors at the top reserved for Communications and Broadcast equipment. The 180,000 m² (1,940,000 ft²) Podium is primarily utilized for Parking and Building Services, however, it also contains Hotel related Amenities such as the Ball Room, Restaurants and Retail. The client is Emaar Properties PJSC, the Project Manager is Turner International and the Main Contractor is Samsung.

Currently under construction, as of July 21, 2007, the Burj Dubai has surpassed the height of Taipei 101 (currently the tallest completed building in the world) and is scheduled to be topped out sometime in 2008. Refer to figure 1, showing the Tower under construction. Figure 2 is a rendered image of the Tower as it will look upon completion at the end of 2008. Furthermore, in order to understand the magnitude of the potential stack effect, refer to Figure 3 which graphically compares the height of Burj Dubai to the five next tallest buildings in the world.

The Design Team

The SOM design team in Chicago was fully interdisciplinary. SOM services included architectural, structural, building services and interior fit-out design and ran from concept design stage in the form of a limited competition through full construction documents. An important aspect of the SOM team was that individual members had experience on the design and operation of several of the top ten tallest buildings ever built. Those structures included Sears Tower and John Hancock Center in Chicago and Jin Mao in Shanghai. Because of this experience, as the design phase commenced, RWDI, a specialist consultant in wind engineering, located in Guelph Ontario, was added to the team. Their expertise included an ability to provide a computational basis for the stack effect forces.

The Physics Behind Stack Effect

As previously stated, the magnitude of stack effect, and its' potential impact, will vary with the temperature difference between inside and outside, the height of the building or shaft and the location within the building or shaft. Excepting the effect of wind, for a given location in the building, the stack effect force will vary with the temperature differential, therefore, it follows that one can generalize that stack effect will vary with the season of the year and time of day. Knowledge of the absolute and relative magnitude of the seasonal and diurnal temperatures permitted the analysis to be undertaken.

Assuming external air pressure and barometric pressure are constant over the height, the pressure difference that results from either normal or reverse stack effect is expressed using the following equation:

$$\Delta P = K_s \left(\quad\right) h$$

where: ΔP = pressure difference, in H_2O (Pa)

T = absolute temperature of outside air, ${}_0R$ (K)

T_1 = absolute temperature of air inside shaft, ${}_0R$ (K)

h = distance above neutral plane, ft (m)

K_s = coefficient, 7.64 (3460)

The neutral plane is the elevation where the hydrostatic pressure inside the shaft is equal to the pressure outside the shaft.

To give one an idea of the potential magnitude of stack effect in a super tall building, we can make the following assumptions:

Internal Temperature:	+21° C
External Temperature:	+46° C
Height of Shaft	700 meters

The resulting magnitude of the pressure differential at the top and bottom of the shaft, discounting wind effects and the effect of the HVAC system, would be +320 Pa and -320 Pa respectively. For those more familiar with imperial measure, that would be a pressure difference of over 6 psf from the neutral plane at the midpoint of the shaft or about 13 psf between the top and the bottom.

As the design reached maturity in late 2005, RWDI completed their analysis and released their final report. That report became the basis by which the "active" and "passive" mitigation measures were developed and implemented on the project.

Fig 2. Rendering of Burj Dubai.

The Sky court

A viable alternative civic space for the 21st century?

'The city square has for centuries been a place for social interaction, trade and commerce, information exchange, religious and political address, festivities and sporting events; an urban hub that can embody a multiplicity of function and adapt over time through changing socio – economic needs.

The effects of industrial capitalism and secularism however, have not only seen the fall of public man but the slow disintegration of the public realm. Coupled with population growth and the increasing density through re-migration to inner city centres, we have witnessed a fundamental shift from the figurative places of the past towards the increasingly dense high-rise objects of the present. If we continue to build dense and high, should we not be creating recreational spaces in the sky as viable alternative civic spaces for the 21st century to replenish the loss of public domain and civic realm?

This paper puts forward an argument for sky courts as a viable alternative space as an accompaniment, rather than replacement, to the traditional street and square. I establish whether there are any similarities, conflicts or common traits between the established semi-public domains of the privately owned square and arcade with the sky courts, and draw conclusions as to their viability as alternative civic spaces in dense (high-rise) urban developments of the 21st century'.

Codes of conduct and agreements in civil society have helped shape the urban environment. The street and square, predominantly owned, governed, and managed by the state, have for centuries provided a stage set and theatre for civil society to be both actor and spectator in public – a forum to engage in social, economic, cultural or political activity, and in so doing convert space into place.

Secularism and industrial capitalism have not only led to 'the fall of public man' (Sennett, 1976) but also to the decline of the public realm. Coupled with population increases (an estimated growth from 2.5 billion people in 1950 to at least 9.2 billion people by 2050)is the knowledge that, in 2007, more than half of the people in the world will be living in cities (UNFPA, 2005). We will see further inner city densification and the continued eradication of public open space.

Such changes have historically spawned alternative spaces within new building typologies that have sought to readdress shifting patterns in civil society and to help replenish the loss of open space for social interaction and recreation. These semi-public domains, such as the 18th century court (for meeting), the 19th century arcade (for promenading), and the 20th century internal street and roof garden (for recreation), attempted to recapture elements of public life within what were essentially privately owned and managed objects of speculation, outside of the jurisdiction of the state. This set up new and interesting relationships between public and private and provided opportunities for interaction across the disparate class divides of a changing society.

With the continued shift away from the figurative open spaces of the street and square to dense, high rise developments in increasingly densified inner city locations, should we not be advocating the need for recreational and civic spaces in the sky as an alternative space for the 21st century, just as the court, arcade, internal street and roof garden were in the 18th, 19th, and 20th centuries?

Despite the plethora of urban design reports aimed at creating a consensus that good quality civic spaces should be a political and financial priority, there seems to be little published planning policy guidance that stipulates ratios of built up high-rise development to open public (or even semi–public) space within the tower. If planning policy guidelines suggest particular regional ratios of built up area to public open space (often 3:1 of the site or 5:1 in inner city locations) (GLA, 2001), should there not be a similar provision made for skyscrapers that seek to amalgamate the low rise mix used development into the high–rise to create vertical extensions of the city?

The notion of sky courts is not an alien phenomenon. Diodorus Siculus, in the 6th century B.C., recorded the ancient gardens of Babylon as a series of planted terraces supported on stone arches 23 metres above the ground and mechanically irrigated by the Euphrates River. Vignola's Villa Giulia in Rome manipulated levels, to afford high-level views from raised terraces, where Julius III could enjoy an evening's entertainment. Le Corbusier's Fourieresque social condensers in Marseilles and Berlin also capture an element of recreational open space for amenity, health and well being for the occupants of his Unite's.

This paper puts forward an argument for sky courts as a viable alternative space within highrise development as an accompaniment rather than as a replacement of the traditional street and square. Using the hotel, arcade and skyscraper as historical precedents to demonstrate how the eradication of public space has been compensated for by the incorporation of semi-public spaces, it will illustrate the shift of urban precedence from the figurative public space of the square to the private iconic object of the high rise. These models will allow us to consider the following questions:

Why do we need sky courts?

Does the sky court embody similar public domain characteristics like the square or arcade? If so, can the sky court be a public domain?

Can the sky court be a viable alternative space for the 21st century, and if so, how?

From hotel, to arcade, to social condenser

Up until the 18th century, the city was determined from the outside – in. Rationalized outdoor rooms of voids dictated the city; the buildings' solid form accommodating the urban idiosyncrasies by acting as contiguous in-fill elements that reaffirmed the predominance of space over object. By the middle of the 18th century, 'public space was implicitly traded for the private object, a deal that formally represented the beginning of the end of the res publica' (Dennis 1986). The emergence of the hotel (a noble's city residence) responded to changes in the built environment and its social patterns. Its incorporation of a semi-public court enabled members of civil society to enter the private curtilage of the site to promenade, meet and congregate. As the court was not public, the policing, management and maintenance fell to its owners. Such a philanthropic approach by minor members of the aristocracy allowed them to feel that their contribution would benefit civil society through the provision of such space. The court sought to replenish and support the primary figurative (and also symmetrical) void of the public square. (Figure1).

The figurative (semi-public) void within the urban infill of the hotel is a microcosmic analogy of the traditional city and an attempt to recapture open space for the greater good of civil society through a public – private interface.

Fig 1. Hotel Corzat, off Place Vendome, Paris, France.

Fig 2. Galleria Vittorio Emanuelle II, Milan, Italy

The birth of industrial capitalism in the 19th century saw the creation of the arcade as a reply to civil societies' need for a managed alternative space that offered shelter from the elements with the ability to promenade and view products in public. Being managed and maintained by the speculative property owner, the arcade's semi – public pedestrian thoroughfare provided an environment that was free from the tyrannies of social disturbance and traffic for the burgeoning bourgeoisie.

This space provided a link between two existing public squares or streets and was either bordered or covered by a building, which had its own use. Unsurprisingly, it became the symbol of cultural progress for newly established nations seeking recognition in a way not dissimilar to modern developing countries showing newfound independence, wealth or power by building skyscrapers. (Figure 2)

Industrial capitalism was the catalyst for the creation of the arcade as an object of private speculation. It also demonstrates how a public – private interface can create semi-public domains for the benefit of civil society. In the 20th century, continued social and economic change saw a need to create more housing out of slum clearance and a revision of existing infrastructures to cater for new modes of transport. Modern city planning and the consequent embrace of the private object building over public figurative void saw the determination of space from inside – out. This caused the erosion of public space. Rationalised solids (i.e. core structure and service elements) dictated the building within the city; the void spaces becoming the habitable space left over. High-rise structures' reconciled this loss by incorporating an element of public space within the private curtilage of the development. Such a move towards sustainable microcosms of urban life with supporting recreational facilities, indoor streets and outdoor raised plazas, owed much to the early vision of Fourier and then Le Corbusier, spawning a legacy of high density development or skyscraper design. At the same time, however, it signaled the death knell of how the spaces were to be used by the public. (Figure 3).

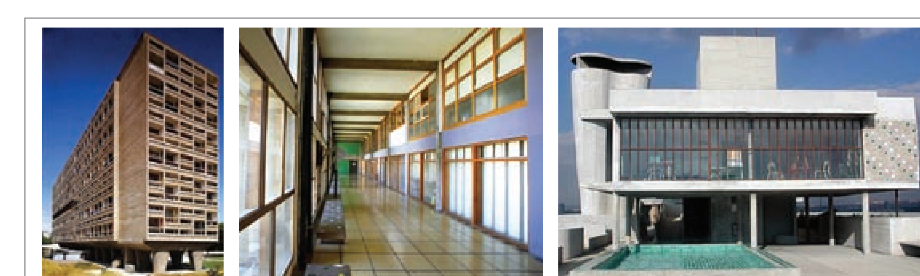


Fig 3. L'unite d'habitation, Marseilles, France

The Tallest 20 in 2020

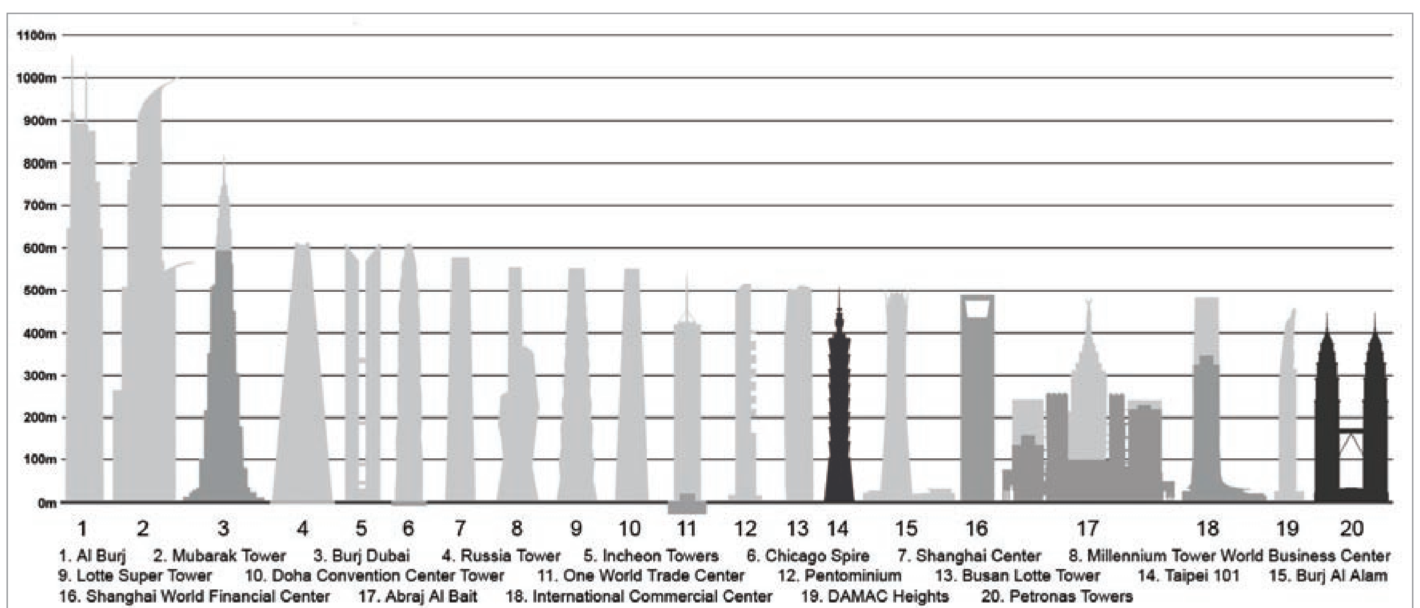
CTBUH Research Coordinator, Philip Oldfield looks ahead

There can be no denying that we are currently experiencing a boom in tall building construction like never before. Even considering the golden age of the skyscraper in New York in the 1920s and 30s, we are most likely undergoing the greatest development of high-rise buildings ever, certainly from a global perspective. In light of this trend, recent research by the CTBUH has anticipated what the tallest buildings in the world may be in a decade or so – what will be the Tallest 20 in 2020? Strict criteria have influenced the putting together of this list; buildings included in the research are either built, under construction or considered real proposals. A real proposal can be considered such if it has a developer and full professional design team who are currently progressing the design beyond the conceptual stage. Furthermore the research only considers projects that are within the public domain – there may well be other proposed buildings that would make the list, but are for client / project confidentiality reasons not yet publicized.

The most startling feature of the Tallest 20 in 2020 (shown below) is that we can see in little more than a decade, the world's current tallest building – Taipei 101 – actually stands at 14th, while the Petronas Towers, currently 2nd and 3rd, will be 20th. Furthermore iconic buildings such as the Sears Tower and Empire State Building, the latter of which has been in the tallest 10 for over 70 years, are nowhere to be seen. In fact, only one building on the list – The Petronas Towers – was completed prior to the collapse of the World Trade Center in 2001. The likely prospect of further mega-tall projects developing over the next few years may exaggerate these statistics further.

Geographically and programmatically too this list also provokes interest. Twenty years ago, if you had predicted the next world's tallest building, it could be confidently assumed that it would be located in North America, be of steel construction and office program. Today almost the exact opposite is true – the world's tallest proposals are currently located in Asia, are concrete construction and house residential or mixed-use functions. Certainly the Tallest 20 in 2020 reinforces this idea; of the buildings shown, nine will be in Asia, eight in the Middle East, two in North America and one in Europe. In terms of program, only three of the buildings solely accommodate office function, two of which are already complete.

The ambition of the world's tallest buildings has never been just about commercial return on a plot of land, but also the creation of an architectural icon that is recognizable around the world. Here too, we are experiencing a significant change in focus, with the latest generation of mega-tall buildings designed to promote and represent the vitality of the city they are located in to a global audience. This shift from corporate to city (or even government) ambition is reflected in the very titles of these new tallest proposals. Whereas once we had icons such as the Sears Tower or Chrysler Building, we now have the Burj Dubai, Russia Tower and Shanghai World Trade Centre. In fact of the twenty buildings set to be the world's tallest in 2020, eight are in some way named after the city or country they are located in.



A wealth of information is available in the PDF.

It is not only the tallest 20 buildings that are set to change in the coming years, but also the number of super-tall buildings (those with a height of 300 metres or more) that are undergoing a significant transformation. As of October 2007, there are 35 completed tall buildings in the world that are 300 metres or above in height. At the same time there are over 55 such buildings currently under construction. As with the Tallest 20 in 2020, these new super-tall buildings are predominantly located in Asia and the Middle East, but notably also in newly emerging skyscraper cities such as Moscow, Panama City, Kuwait City, Chongqing and Santiago. In fact, recent research by the CTBUH suggests there will be in advance of 130 of these super-tall buildings completed by 2020; this means in little more than a decade we will have almost quadrupled our stock, and with more and more new proposals developing each month, the likelihood is this figure will continue to grow.

In the wake of 9/11, many questions were asked of the high-rise typology; is it a viable proposition for our future cities? Should we continue to build tall following the collapse of the World Trade Center Towers? Judging by the unprecedented levels of tall building activity today, the answer is surely a resounding yes. It seems the vast quantities of research that has – and continues to be – undertaken in a quest to improve tall buildings post 9/11 has reassured Governments, city authorities, financers and developers of the benefits of this typology. Within the next two years, the Burj Dubai is set to be completed at over 800 metres in height, some 300 meters taller than the world's current tallest, Taipei 101. With new high-rise proposals continually striving for these massive heights, the dizzying realization of a mile-high tower is perhaps not that far away.

An expanded version of the 'Tallest 20 in 2020' is available for download from the CTBUH website at http://www.ctbuh.org/Portals/0/Tallest/CTBUH_Tallest2020.pdf

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