Taller

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Summary

This paper will explore some of the basic issues of the modern skyscraper: how it came to be, why we have a need to go tall, and how we can best design and execute these tremendous structures.

Keywords: supertall, skyscraper, scale, high-rise buildings

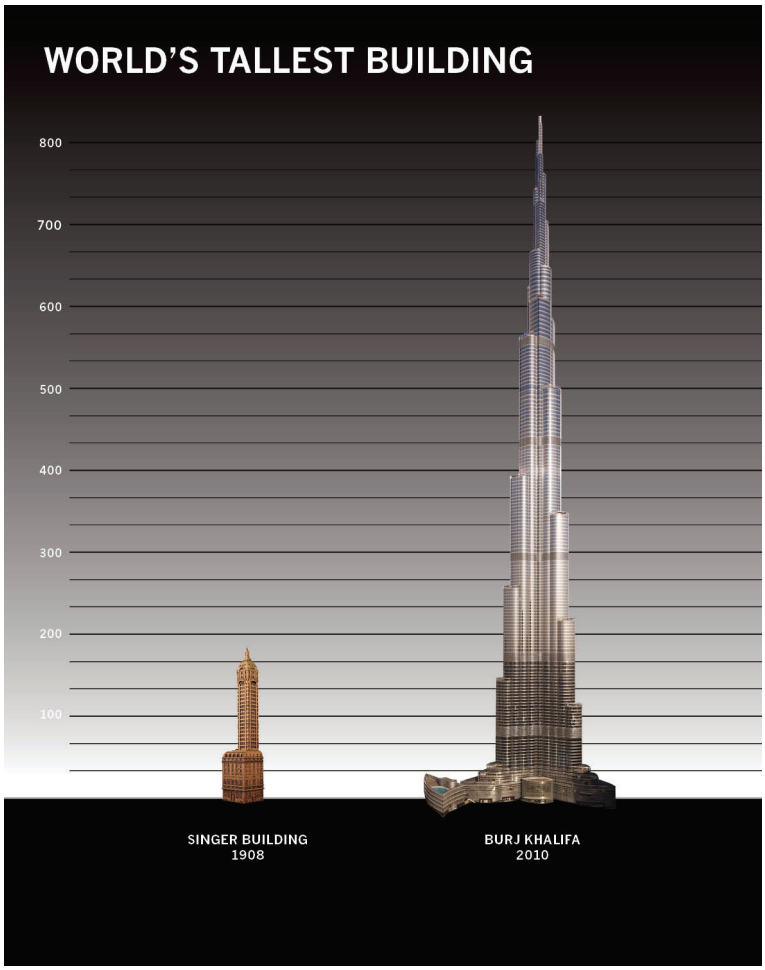

Figure 1 : The Evolution of the World's Tallest Building

1. Introduction

Man seems to have an innate desire to experience the world from high places. First apparent in the Tower of Babel and manifested recently by the Burj Khalifa, man strives to go taller. Skyscrapers are dreams rendered in steel and concrete. They provide testimony to the ingenuity and emerging techniques used to design and execute them. Moreover, they are acts of optimism. Skyscrapers happen in places full of excitement, dreams and ambitions. They represent the optimism of the city and country in which they reside, and of the clients, architects, and engineers who design and dream them.

To grant some historical perspective on the evolution of the skyscraper, it is important to note that from the beginning of civilization until the development of the modern elevator and structural frame in the mid-nineteenth century, most people lived within 7 stories of the ground. One hundred years ago, New York's Singer Building (1908-1968) was the tallest building in the world at 187m and 47 stories. Today, the Burj Khalifa stands over four times taller at 828m and more than 160 stories (Fig 1). Man will continue to push the boundaries of height, but why? How will man achieve tall and taller?

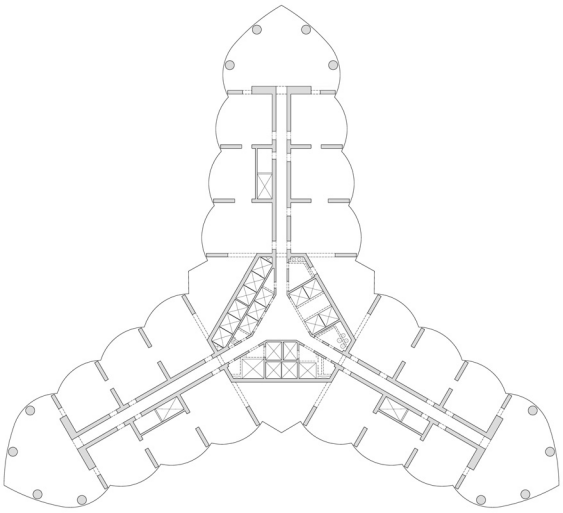

Figure 2: The Buttressed-Core

2. The Need for Tall

Aside from personal ambition to create something iconic and inspirational, those who design and develop skyscrapers know their intrinsic value. They can become unofficial symbols of the cities in which they inhabit, drawing tourism and driving economic growth. At a fundamental level, these thin, vertical structures house a great number of people and services, conserve valuable land, and are more efficient than massive, sprawling ones. And, as recent studies prove, density can be a good thing. In 2008, The Brookings Institution released a study entitled "Shrinking the Carbon Footprint of Metropolitan America." In their findings, the Greater New York Area- an epicentre of tall building design- ranked 4th on Brookings's list of American cities with the smallest carbon footprint. New York's carbon footprint measured 1.495 metric tons per capita, bettering the national average by nearly 50%. The authors noted that "residential density and the availability of public transit are important to understanding carbon footprints." Simply stated, developing dense urbanization moves us toward achieving our environmental goals. Tall buildings have a major role in creating urban density.

3. Clarity of Vision

Once we understand why societies have a need for tall buildings, we must then explore how these structures are designed and realized. In my own practice, I believe that the development of a successful tall building starts with clarity of vision. One must have a chief organizing idea, rooted in engineering principles that guide its development. Towards this end, it helps to distil the idea down to its essence. I personally subscribe to Fazlur Khan's technique of describing structural systems with a series of sharply defined, paired adjective and nouns. Framed-Tube, Braced-Tube, Bundled-Tube and Super-Frame are just a few examples. This succinct use of language mirrors the purity of the structural system, while its brevity leads to an understanding of the essentials and sets up a hierarchy of importance. In the case of a tall building, structure is the armature upon which everything rests. Any problems or lack of clarity that is structurally related will cascade through the design and construction. This does not mean, however, that one has to design a simple box. At first glance the Burj Khalifa looks to be quite complex, but it was based on a very simple idea (Buttressed-Core, Fig. 2) and was designed to incorporate construction technology that enabled it to be built very quickly. Although the floor plate varies greatly from top to bottom, the centre section of the building is virtually unchanged for 156 stories (Fig 3). This allowed for a tremendous amount of efficiency and speed of construction, as the non-typical parts (the ends of the wings) could lag a few stories behind without effecting the overall schedule. Distilling complex ideas into simple solutions requires deliberate forethought and concentrated effort, but is a worthy pursuit. Clarity of vision leads to clarity in the structure and fosters the organization of space and ease

Figure 3: Construction Technology of the Burj Khalifa

of construction. Returning to the intrinsic idea of the building gives the design process lucidity and direction and also helps one make essential decisions when confronted with the unique situations that arise when creating a building of great size.

4. How to Build It

Along with clarity vision, design teams must also seek clear construction concepts. A designer should never propose a structural system without at least one idea of how to build it, because if there is at least one way to build a structure, there very well may be several ways to build it. The unfortunate corollary is that if the designer has not or cannot think of a way to build it, it may be unbuildable. While the contractor may have a better plan to construct the structure, it is important for designers to have an awareness of construction issues during the design process. On my own projects, I regularly invite contractors to review and comment on the proposed structure.

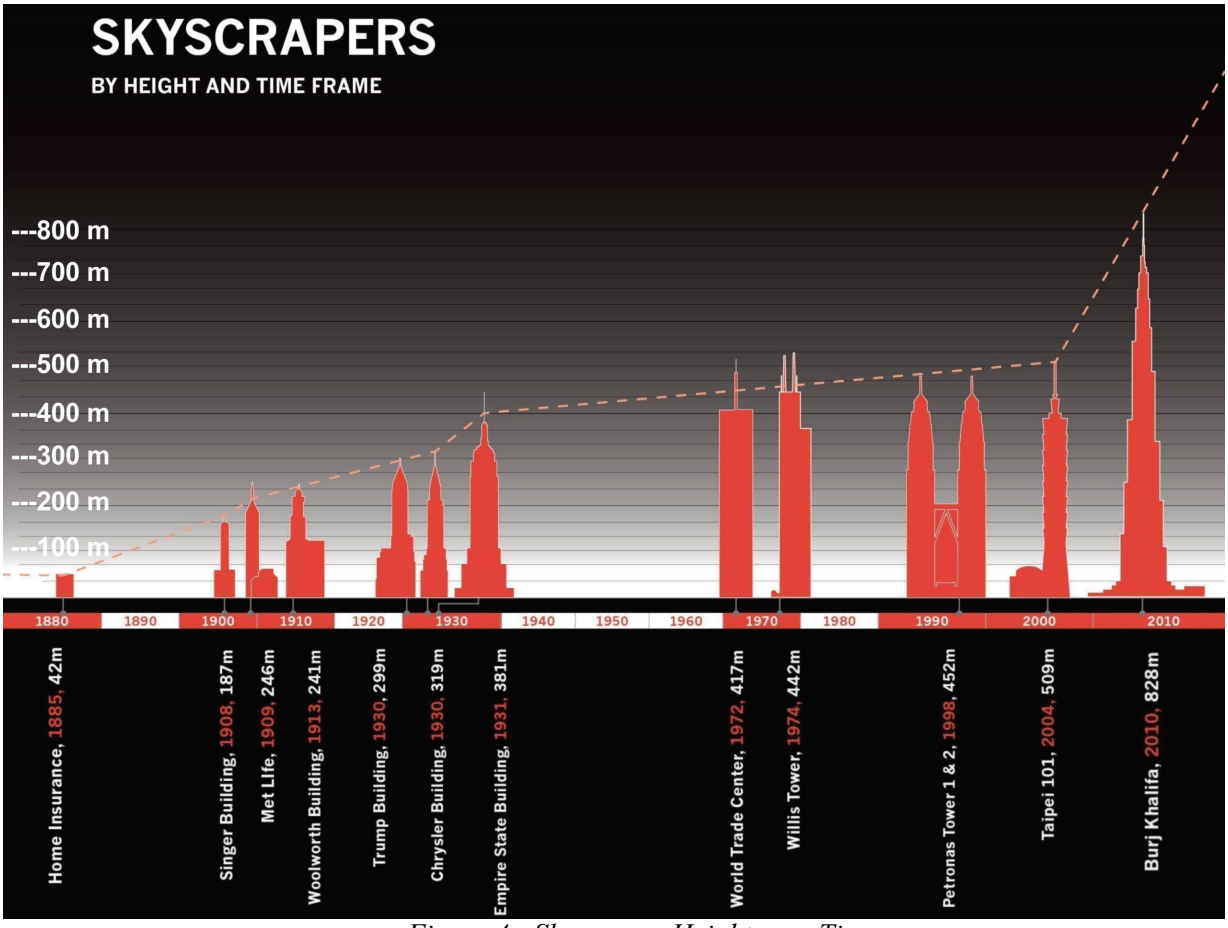

Figure 4: Skyscraper Height over Time

5. Issues of Scale

Issues of scale are also a major consideration in the development of tall and supertall buildings, with slenderness being a key factor. In general, the taller the building, the wider the base must be. For example, think of a person spreading his feet to avoid toppling in the wind: the wider the stance, the more stable the person. Therefore, as a building becomes taller, the base becomes proportionally bigger and bigger. The Willis (nee Sears) Tower has a base that is 69m by 69m. The distance from the glass to the core is 23m. This system is at the limits of its scale. Many of the world's tallest buildings have a base that is roughly square (i.e. point towers). If the Willis Tower (or any point tower building) were to double in height, it would also grow in width and depth, and the floor area would grow cubically (2^3) and increase by a factor of 8. For example, if the roof of this steel tower were to be rescaled to 610m, the base would grow to 95m and the total area in the building would increase from a very large 410,000sm to an astronomical 1,100,000sm. In addition to the huge cost of finishing and fitting out such enormous building areas, there are also limits on

the economic ability of a given urban real estate market to absorb this much area. Furthermore, there are practical limits concerning the distance from the core to the window to allow light to enter the interior space. Extreme building areas also lead to extremes in elevator and mechanical systems. Given these parameters, the steel framed tube of the Willis Tower is currently at its upper limit at 442m. If one were to propose a taller solution, a new system must be used.

One solution to the tall building problem is to decouple issues of slenderness ratio from issues of lease span. The overall structural proportions are set by the economics of structure. Depending on the overall shape of the tower and the speed of the wind, the base dimensions of a tower with steel vertical elements should be in the range of 5:1 to 8:1, while a tower with concrete vertical elements should be in the range of 6:1 to 10:1. However, the depth of the floor plate should match the function of the space. Office space is usually 9 to 18 meters deep, with 12 meters being a common value. A residential unit can also vary quite a bit, but 9 meters from the corridor is common.

To go "beyond tall" in issues of scale, it is necessary to develop systems that do not require excesses in depth, area or time. Figure 4 chronicles tall building height over the past 130 years and demonstrates that leaps in height are only made when new structural systems are developed to confront the issues of scale. Future growth will only be realized when designers can look beyond the point tower to create structural armatures of reasonable cost that can accommodate appropriate building areas with highly useable lease spans and can be constructed within a reasonable time frame.

6. Wind and Gravity

In addition to issues of scale, the shape of a supertall tower and the ways in which it manages gravity are of critical importance. Simply stated, the shape of a tower and how it interacts with the wind is probably the single most important *structural* parameter. A building with a “bad” shape can lead to forces that are so large as to render the project unfeasible. Even small changes in the shape of a tower can dramatically affect the wind forces and change the economic viability of a design. Similarly, the tower's ability to manage gravity is essential. Gravity is reliable and should be used to a designer's advantage. Using gravity forces and gravity framing to help resist the wind and other lateral forces greatly improves the economics of the tower.

7. Why Many Buildings Don't Get Built

However, in order to truly understand what it takes to go taller, architects and engineers must look beyond theory to examine the reality of actually getting one's structure built. Those who engage in developing and designing tall, iconic towers are aspiring for something beyond the mundane. And yet, despite the best of intentions, they often doom the project with impractical design. Common attributes of unbuilt towers include the following:

1. The structure is too complicated.

The shape of the tower and its structural system are unnecessarily complex and lack overarching ideas that give organization to the building.

2. The structure is too difficult to construct.

If a building is not based on a simple, clear idea or systematic approach, it is an amalgamation of special conditions, transfers, and non-typical conditions, which are difficult to build.

3. The structure is too slow to build.

Buildings are built one floor at a time (at least for now), so if the building is overly complicated and difficult to erect, it will also take a tremendous amount of time to construct. Because tall buildings often consist of over 100 stories, even an efficient design will take a long time. The phrase "time is money" is certainly applicable, but time is also risk. The longer the length of time between construction and occupancy, the greater the risk of the project being affected by fluctuating financial markets and political climates.

4. The structure uses too much material.

Many unbuilt designs are not based on clear structural principles and as such, require more brute force than finesse to make them work. Consequently, the amount of material (structural steel, reinforced concrete or rebar per square meter) can far exceed normal construction usage.

5. The structure has too much floor area.

In recent years, there have been proposals for supertall buildings with as much as 1 million square meters of floor area, leaving the structure commercially impractical. A related issue is that the floor plates are just too large. The distance from the window is excessive and as such, large floor plates can doom a project.

8. Irrational Exuberance

Another concern of modern tall building development is the fact that many of today's proposed designs exhibit an irrational exuberance. This trend is based on creating forms for the sake of forms, without necessarily having any intrinsic value other than the desire to create something iconic. In the ideal situation, a structure is iconic because it is also substantive. The skylines of cities around the world, particularly in the Middle East and Asia, are full of a-typical skyscrapers that are trying to standout in a crowd of other towers that are also trying to stand out. The net result is that they drown each other's presence, like a cacophony of voices in a crowded restaurant where no one voice is distinct.

What has allowed this to happen? The computer.

The advent of the computer has enabled architects and engineers to create designs that never would have been possible in the not too distant past. It has launched us into a completely new era of tall building development. And yet, while the dawn of the computer is paramount to the future of tall buildings, we must not become dependent upon them to do the designing for us. Design and analysis are two very distinct practices. In the past, designs had to be rational because they were limited by an engineer's ability to calculate, as well as the contractor's ability to fabricate. Today, the computer can be useful in making more efficient systems, but it can also enable the design of extremely complex forms that are very inefficient by traditional standards. While computers undoubtedly provide modern designers with the opportunity to create structures that would have previously been unfathomable, professional discourse is needed to determine how we can best use these tools to address the needs of our clients, our culture, and our environment.

Because computers can facilitate extremely unique and complex structures, modern supertall designers may find themselves asking: "Because we can, does it mean we should?" The scope of this discussion is vast and forces one to examine his/her personal position on ethics and aesthetics. Some may argue that if the client can afford an extra expensive structure, where's the harm? Others may say that, in this era of limited resources, designers have an obligation to resist designs that use a greater amount of material than other, more efficient solutions. Quite simply, our profession is at a crossroad: the world has limited resources, but seemingly unlimited creative opportunity. As professionals, we are charged with balancing humanity's need for inspiration and growth with the demands of economy and efficiency. Consider the Eiffel Tower: it is an extremely inefficient way of creating a restaurant, but Paris, and the world, would be much diminished by its absence. Where is the balance?

9. Conclusion

Given these parameters, one begs the question: How tall can we go? At the risk of cliché, I would venture to say that "the sky is the limit." Every day, advancements are being made that will allow the construction of taller, more efficient buildings in shorter amounts of time. By studying the issues of scale and considering constructability and economy, architects and engineers can work together to produce iconic, substantive structures that will launch the next generation of Tall.

10. References

[1] BROWN, M., SOUTHWORTH, F., and SARZYNSKI, A. *Shrinking the Carbon Footprint of Metropolitan America*, Brookings Institution, Washington, 2008. p. 3.