MAIN TENDENCIES IN TELEVISION TOWER CONSTRUCTION

JÁNOS KATONA[1], *Architect,*
S.L. SHAMBINA[2], *PhD, Ass. Professor,*
[1]*DVI Architecture, Guangzhou, China*
[2] *Peoples' Friendship University of Russia, Moscow*

TV towers are some of the tallest man-made structures and, because of their high visibility, they represent an open field for Architecture to experiment and develop new daring solutions. This paper analyses the most significant and inspiring designs produced in the past 100 years and attempts an insight over the future development of antenna structures in the XXI Century.

KEYWORDS: construction, towers, Shukhov, hyperboloid, shell,structural frame, highest structures.

Together with radio masts, TV towers are some of the tallest man-made structures. The terms "masts" and "towers" are not to be confused: while the first are usually held up by stays or "guys", towers are proper self-supporting or cantilevered structures. This paper deals with the latter ones only. The towers are designed to support aerials for telecommunications and broadcasting and in doing so they not only represent an instrument but also a symbol of the Age of Information inaugurated in the beginning of the XX Century. For this reason architecture has been trying to seize and shape them in the urban context in a process of constant evolution and struggle for new daring solutions.

The origins of TV tower architecture can be traced back to the Russian engineer Vladimir Grigoryevich Shukhov (1853–1939) who pioneered the industrial design of modern tower structures. He introduced new geometric shapes and applications including hyperboloid, gridshell, tensile and diagrid shell structures. Besides tower structures, V.G. Shukhov contributed to significant design advancements for oil reservoirs, pipelines and ships, and patented a number of revolutionary new structural forms. His analytical work on non-Euclidean hyperbolic geometry and his constructions are considered a milestone in this field and still a strong inspiration for contemporary design.

Shukhov designed almost 200 original towers all over the world. Shukhov's goal was to minimize the use of materials, time and labor in the construction of large objects and the same time to strengthen their structural frame so that they could be more resistant, taller and slender. On fig.1 it is shown the first Shukhov's hyperboloid tower built for the 1896 All-Russia Exposition in Nizhny Novgorod: a 37m steel diagrid tower, which was also the first example of hyperboloid structure in the world. The tower was eventually moved to Polibino (Lipetsk Oblast, Russia), where it is still standing.

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Consequently his works followed the principles of construction simplification and efficiency whenever possible, given the materials and techniques available at that time.

His most renowned work is probably the Shabolovka Tower (fig. 2), also known as the Shukhov Tower, a 160m high hyperbolic gridshell steel structure built between 1920 and 1922 in Moscow. On fig. 2 it is possible to see the inner view of the grid shell structure of the Shukhov Tower. The innovative aspect of the tower is revealed in at least two elements: on one hand the lightness of the structure enhances the wind load bearing performance, that is a fundamental attribute for high structures; on the other hand the stacked sections of hyperboloids allow the shape of the tower to taper more at the top with an overall slender effect. Shukhov later proved that increasing the number of stacked sections equals to increasing the tapering of the tower to the point of reaching a conic shape.

Fig. 1.

Fig. 2.

Later on in the 20th century experimentation not only followed the path of geometric innovations, but architects started to explore new combinations of materials – mainly concrete and steel – and new shapes, as demonstrated by the work of the Spanish Architect Santiago Calatrava who designed the Montjuïc Communications Tower (Barcelona, 1992) (fig. 10), a unique and particularly fascinating example of creativity and technical mastery.

Fig.3.
Kobe Port Tower, 108m, Japan, 1963

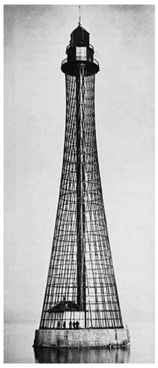

Fig.4.Stanislav-Adzhyhol Ligh-thouse, 64m Ukraine, 1911

Fig.5.
Aspire Tower,300m, Doha (Qatar), 2006

Their high visibility and the great variety of experimentation focusing on them made TV towers increasingly popular and well known to the point of launching a real international competition for building the tallest one – a title currently held by the Skytree of Tokyo with its 634m steel structure completed

Fig.6
Oriental Pearl Tower, Shanghai

Fig.7 Canton Tower, Guangzhou

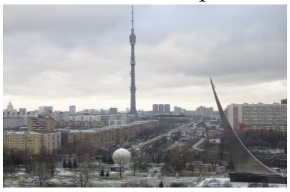

Fig.8
Ostankino Tower
Moscow

Fig.9
AMP Tower
Sidney, Australia

Fig.10
Montjuïc Communications Tower, Spain

Fig.11
Dragon Tower, Harbin, China

in 2011.

The East of the world in particular has brought the competition to daringly high levels: five out of the top 10 tallest structures in the world are located in China and eight are in Asia. They are: N.2 Canton Tower (fig. 7) in Guangzhou (600m), N.5 Oriental Pearl Tower (fig. 6) in Shanghai (468m), N.8 Tianjin Radio and Television Tower in Tianjin (415m), N.9 Central Radio and TV Tower in Beijing (405m), N.10 Zhongyuan Tower in Zhengzhou (388m). Leaving out only N.3 CN Tower in Toronto (553) and N.4 Ostankino Tower (fig.8) in Moscow (540 m).

Another interesting trend emerged in the latest years is the extension of TV towers to other purposes than telecommunications: over time TV tower structures have developed to include spaces for public visitors ranging from the most common observation decks and restaurants to museums and entertainment facilities of all kinds. These new functions – in some cases necessary to pay back the financial investments for the construction and the maintenance of such colossal structures - require additional planning in terms of space organization,

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safety measures and services management for large crowds of people. The Skytree alone welcomes about 100,000 visitors per day.

The synthesis of these trends - pursuit of innovative and more aesthetic shapes, dynamic applications of hyperboloids, competition for record beating designs, commercialization - can be envisaged in the acclaimed masterpiece of the 2010 Asian Games: the Canton Tower (fig. 7). Located in Guangzhou, PRC, it is the second tallest TV tower and the fourth tallest freestanding structure in the world (following the Burj Khalifa, (829m, Dubai), the Skytree (634m, Tokyo) and the Abraj Al Bait (601m Mecca)). The Canton Tower project was assigned in 2004 to the Dutch studio Information Based Architecture which won the international competition held by the Guangzhou Government for designing a structure that would represent the city's opening to rapid progress and modernization. Guangzhou is currently the fastest expanding city in the fastest developing region of China, as well as a hub of strategic importance for the whole South East. With the collaboration of the international engineering consulting firm Arup, construction works took place from 2005 to 2010, when the tower was opened to the public. Its structure is made of simple elements – columns and rings – twisted over the central axis to create a tightening "waist" in the central portion of the building.

The twist is possible thanks to two ellipses surfaces – located at the foundation level and at the very top of the tower (450m) above which a 150m antenna is placed – that are rotated opposite to each other. The rings are places on the inner part of the columns so that the outer view is dominated by vertical elements enhancing the slender effect. The designers' aim was exactly that of realizing a tower that would not look massive or imposing, and that would reflect the dynamic spirit of Guangzhou with asymmetry and grace. At the same time, the rings have a dominating effect from the inside and produce a more enclosed feeling in the 37 accessible floors, while tapering is amplified at the top to further stress the tower twist. As for the inner spaces, the Canton Tower features an extremely broad variety of amenities besides the TV transmission facilities: observatory decks, gardens, exhibition spaces, shops, conference rooms, restaurants, computer gaming spaces, an open-air skywalk, a 4D cinema and even a gravity machine on the top, as well as an underground metro station and shopping center.

Future perspectives. In the panorama of modern TV towers it is actually hard to find truly original and innovative models – a situation only partially justified by the necessity of shaping structures according to the criteria of safety, popularity and tourism. Has TV towers Architecture – still a relatively recent application – already come to a dead-end? Advancements in this field have undoubtedly slowed down in the last decades, but antenna structures have arguably exploited all their potential and what holds back a new generation of accomplishments is only the next leap in material and building technology. This is likely to be focused on the types of materials – such as graphene that is lighter and can be brought to have a higher resistance than steel, the incredibly light

Titanium foam or the artificial spider silk; which with their new material properties will also result in new shapes. Another re-emerging, sustainable material is bamboo – which has better tensile strength properties than steel, renewable (it is the fastest growing plant in the world), flexible and resists to pests. New techniques for joints are being developed (earlier they were lashed or pinned which due to the wet-to-dry changes of the seasons loosened with time); one of them is that of after bolting the joints injecting mortar with a san, cement and lime ratio of 4:1:1. Also new structural principles will be invented or existing ones will become easier to put into everyday life use - like «tensegrity» (or floating compression), a term invented by the American Architect Buckminster Fuller (1895 – 1983) in 1960 and referring to the synergic effect produced by components in balanced tension and compression to create a mutually supportive ensemble. Tensegrity structures present a real challenge for construction techniques because each element must be first set into place by a network of tension wires, but have proven to be very steady. In 1968, following Fuller's calculations, sculptor Kenneth Snelsons produced the first tensegrity large scale tower, the Needle Tower (fig. 12) (18m), which is still standing and displayed at the Hirshhorn Museum and Sculpture Garden in Washington. David Geiger's Olympic Gymnastics Arena in Seoul (1980) was the first of a series of large structures employing hybrid tensegrity structures including the Georgia Dome (1988) and the Kurilpa Bridge in Brisbane, Australia (2011). Open structures relying entirely on tensegrity haven't been attempted yet, but developments in the physics of tensegrity are likely to unlock new perspectives for TV towers including the possibility of building higher, stronger and lighter structures, with an entirely new range of shape variations and a potentially lower cost. The most spectacular TV towers – the results of more than 100 years of architectural developments. They are nowadays located in major cities and constitute essential landmarks of the world's most famous skylines.

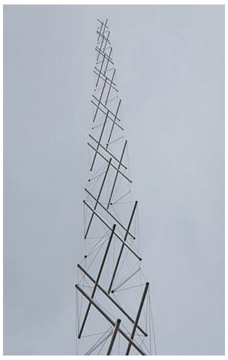

Fig.12
Views of the Needle Tower:

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Images: courtesy of DETAIL (Des Architekturportal)

ОСНОВНЫЕ ТЕНДЕНЦИИ В СТРОИТЕЛЬСТВЕ ТЕЛЕВИЗИОННЫХ БАШЕН

КАТОНА ЯНОШ[1], *архитектор*,
С.Л. ШАМБИНА [2], к.т.н., доцент
[1]DVI Architecture, Гуанчжоу, Китай
[2] Российский университет дружбы народов, Москва

Телебашни являются одними из самых высоких искусственных сооружений. Из-за их высокой видимости, они представляют собой широкое поле для архитектурных экспериментов и разработки смелых конструктивных решений. В работе анализируются наиболее значимые и впечатляющие проекты телевизионных башен, построенные за последние 100 лет, а также делается попытка представить перспективы развития конструкций таких сооружений в XXI веке.

КЛЮЧЕВЫЕ СЛОВА: строительство, башни, Шухов, гиперболоид, оболочка, несущая рама, высочайшие конструкции.