World Expos and architectonic structures. An intimate relationship.

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Takara Beautilion. World Expo 1970 Osaka. (Source: Sachio Otani, Osaka Prefectural Expo 1970 Commemorative Park Office).

In 1851, the date of the first World Expo, electricity was not yet used for lighting or as a power source, the internal combustion engine did not exist, neither the radio nor the telephone had been invented, and the first motorised aeroplane had yet to take off. In architecture, the use of industrial iron was just beginning, while steel was not yet used in building. Reinforced concrete had not been invented. Stone, wood and brick were still the main construction materials used. Since this date, Expos have borne witness to and been the venue of the advances that have transformed the world which we know today. Expos have been, and continue to be, places in which nations have substituted fighting on the battlefields with competence in fields of technological and industrial development, education and culture; the true engines of worlds past, present and future.

1. EXPOS AND STRUCTURES

From an architectural perspective, the structural contributions of the Expos have had enormous relevance and historical significance, intrinsically and permanently linking Expos to the history of architectural structures.[1] The role of Expos as exponents of cutting-edge structural development came about for various reasons. In the first place, the chronological interval in which Expos develop constitutes a period of huge structural productiveness. From the first that was held in 1851 to the present day, Expos have witnessed significant developments in the field of structures: the development of iron engineering in the 19th century, the invention of reinforced concrete, the appearance of glued laminated timber, the development and far-reaching spread of space frames, the birth of cable networks and textile membranes, the development of pneumatic structures, as well as the revolution in the field of applied computer science. Consequently, we can find buildings that are bona fide paradigms of the history of structural systems.

On the other hand, competition between nations to display their technological power would lead to a race in which each Expo aimed to outdo the structural achievements of the previous one. This gave rise to novel constructions, which in turn led to advances in the spans reached, the appearance of new structural typologies, and experimentation with new materials or research into new shapes.

Other aspects favoured greater creative freedom in the field of structures. The transient nature of these events meant that certain issues such as durability could be avoided; together with the purely representative or symbolic conception of numerous buildings which lacked a particularly rigid programme, the fact that many of them were built through architecture competitions enabled earlier research to be put into practice and the pioneering application of patents, as well as the implementation of new ideas that were in need of complete development or prior technological experience. On the other hand, the universal nature of these events granted these novelties widespread dissemination, brought about both by the

[1] As to the study of the structures in Expos, please refer to López-César, I. (2017). *World Expos. A history of structures*. Barcelona, Spain: By Architect Publications & Bureau International des Expositions (BIE). https://issuu.com/udc3/docs/world_expos._a_history_of_structure

millions of people who visited Expos, and by the publication of the buildings and proposals presented to the various competitions in specialised journals.

2. THE INFLUENCE OF THE EPHEMERAL

Another aspect that is intrinsically linked to Expos is the transitoriness of its architecture. While some of the edifications associated to these events were built to stay, it is true that most of them were provisional. For this reason, exhibition architecture has usually been referred to as "*ephemeral architecture*". One must therefore reflect on the relative nature of this term. From the perspective of time, if we take the existence of a man as a point of reference, then little architecture is "*ephemeral"* since inert molecular structures tend to outlive us. On the other hand, if we take the last thousand years —an insignificant period of time in geological terms— as an example, then a considerable portion of architecture has been "*ephemeral"*. In short, "*ephemeral"* is normally used as a metaphor for our own existence, as if the fate of our architecture was other than to dissolve into the earth.

It is therefore reasonable to value this type of architecture not for its longevity over time, but for the historical impact it has had. It is no wonder that several Expo buildings are to be found in classic handbooks of modern architecture history, in spite of having physically disappeared. We could ask ourselves whether the historical-architectural relevance of the Eiffel Tower would have been less had it been taken down at the end of World Expo 1889, according to plan.

These reflections are not futile, given that the world in which we currently live is perversely drifting towards a tendency to disparage anything that does not generate an immediate and direct economic benefit; this type of short-lived architecture is sometimes seen as an expense of little use, and its cultural component and huge influence beyond the events for which it was created is forgotten.

3. WORLD EXPOS STRUCTURES AND THEIR INFLUENCE PERIODS

As we consider the development and the influence of structures built for Expos, several periods can be identified, as will be developed below.

3.1 THE FIRST PERIOD: GIGANTISM

The first period spans from the first World Expo held in London in 1851 to the beginning of the 20th century. It is characterised by the development of a considerable number of Expos with huge structural protagonism, linked to the peak of iron architecture and engineering. This is the period of the Industrial Revolution, characterised by structural gigantism, the impressive colossal iron-structured buildings. Each Expo strived to outdo the previous one, in a process that aptly illustrates the nature of these events as areas of exhibition and rivalry among nations in terms of technological development.

In this sense, the Crystal Palace built for the Great Exhibition of 1851, is pivotal to this development (See Figures 1, 2 and 3). The Crystal Palace is an authentic architectural synthesis of the Industrial Revolution, as it uses iron and glass on a large scale, with a modular logic, thus standardising the components of the new industrial production system. It was a building of colossal dimensions, with a length of 563 metres. The innovative interior space was based on a gigantic scale, in which the structural elements were reduced to their smallest dimensions, thanks to the use of iron. The total interior-exterior transparency was also innovative; only a few constructions were as advanced, such as the *Jardin des Plantes* in Paris (Rouhault, 1833), the Greenhouse of Chatsworth (Paxton, 1837) or Kew Palm House (Turner, 1846).[2]

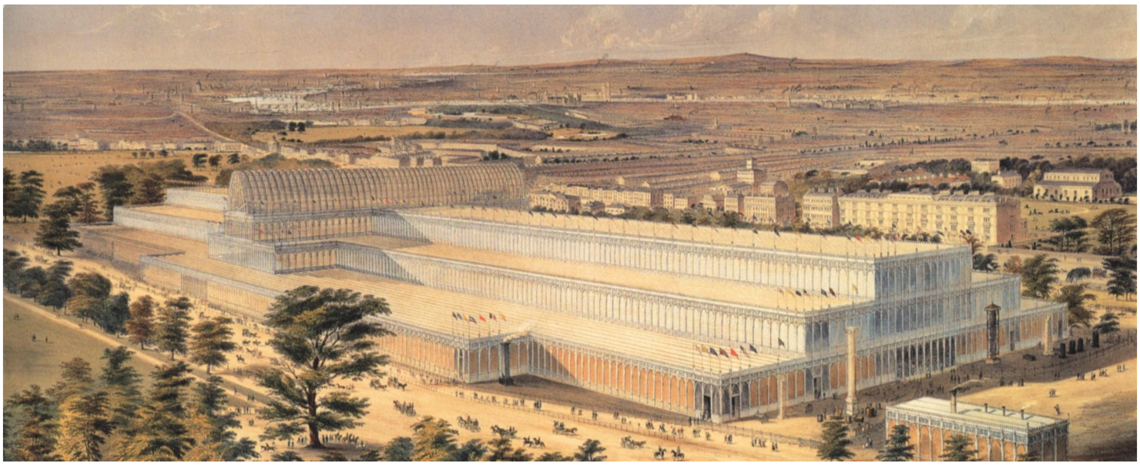

Figure 1: Crystal Palace. Joseph Paxton. World Expo 1851 London. (Source: Dickinson).

Figure 2: Crystal Palace. Joseph Paxton. World Expo 1851 London. (Source: Dickinson).
Figure 3: Crystal Palace. Joseph Paxton. World Expo 1851 London. (Source: Dickinson).

The profound impression of Crystal Palace as a symbol of modernity led to many countries wanting to have their own "Crystal Palace", with hundreds of interpretations of this

[2] To further understand the influence of the Crystal Palace from an architectonic-structural point of view, please refer to: López-César, I. (2014). The structural contribution of the Crystal Palace to the 1851 Great Exhibition held in London. An extension of the traditional historical approach. *RITA Revista Indexada de Textos Académicos*, (2), 76-83. http://openarchive.icomos.org/1511/

architectural concept made throughout the world, such as the Munich Kristallpalast (1853) or the Crystal Palace of the Exhibition of the Industry of all Nations held in New York in 1853 (Carstensen / Gildemeister) (See Figures 4 and 5).

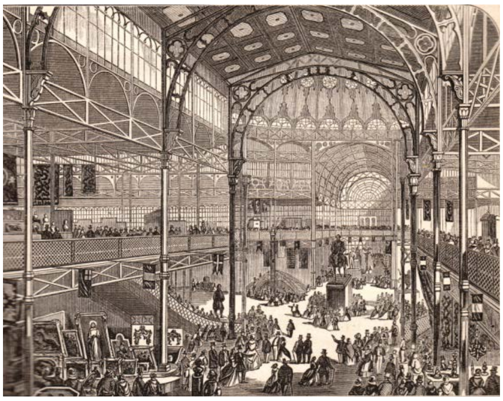

Figure 4: Crystal Palace of the Exhibition of the Industry of all Nations, New York 1853. (Source: Mallet).
Figure 5: Crystal Palace of the Exhibition of the Industry of all Nations, New York 1853. (Source: Mallet).

During this period, the competition for the building with the largest span —or separation between structural supports— was to a great extent taking place at Expos. Thus, the Expos held in Paris in the years 1855, 1867, 1878 and 1889, witnessed an evolution in the structural typologies used, as well as in the architectural concept of space. The evolution could be exemplified firstly with the *Palais de l'Industrie* at World Expo 1855 (See Figures 6 and 7), still using stone façades – reminiscent of religious architecture with three vaulted naves, although in this case, the structure was made out of iron and the roof out of glass – and then with the *Palais des Machines* at World Expo 1889 Paris. (See Figures 8 and 9).

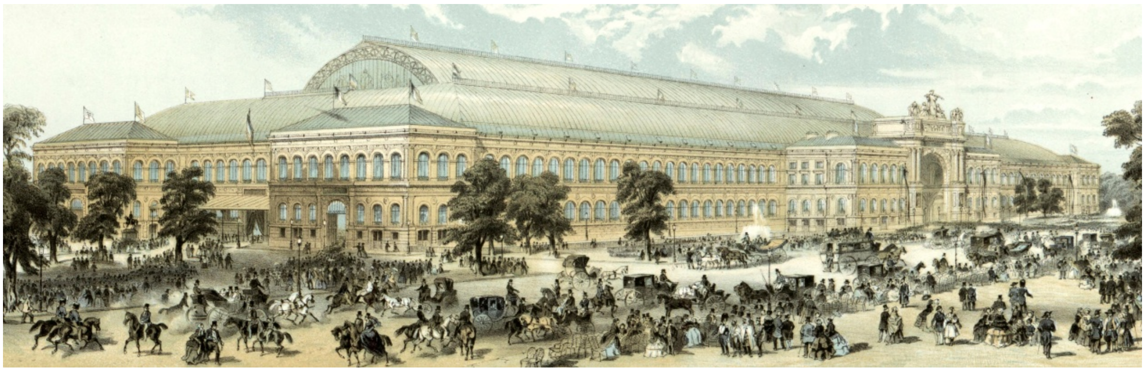

Figure 6: Palais de l'Industrie. Barrault and Bridel. (Source: Barrault).

Figure 7: Palais de l'Industrie. Barrault and Bridel. (Source: Loyer).

In the latter, an unprecedented modernity is achieved. The wrought iron structure is completely bare, devoid of all ornaments. The gigantic three-hinged arches with a depth of 3.7 metres offered a strong industrial vibe, while at the same time, being posed delicately on the ground, using the smallest possible supporting surface. The space, of unprecedented dimensions, and flooded with light, overwhelmed the visitor and impressed the world. The largest covered space ever built then was St. Pancras Station in London (Barlow, 1868), with a span of 73 metres, that is currently still in use. The *Palais des Machines*, with 110.6 metres, was a new world record. But, undoubtedly, the most remarkable feature of this building was its influence on future constructions, since it served as a prototype for numerous railway stations built later both in Europe and in the United States. Thus, for example, Reading Station in Philadelphia (Kimball, 1893), the Broad Street Station in Philadelphia (Wilson Bros, 1894) (Figure 10), or the *Marché aux bestiaux* in Lyon (Garnier, 1909) (Figure 11) were direct heirs of the *Palais des Machines*.[3]

Figure 8: Palais des Machines. Dutert and Contamin. World Expo 1889 Paris. (Source: Dunlop).
Figure 9: Palais des Machines. Dutert and Contamin. World Expo 1889 Paris. (Source: Dunlop).

Figure 10: Broad Street Station. Wilson Bros, 1894 (Source: Meeks).
Figure 11: Marché aux bestiaux Lyon. Tony Garnier, 1909 (Source: Giedion).

[3] To learn more about the backgrounds and ramifications of the *Palais des Machines* de 1889, please refer to: López-César, I., and Estévez-Cimadevila, J. (2015). The Palais des Machines of 1889. Historical-structural reflections. *VLC arquitectura Research Journal, 2*(2), 1-30. http://dx.doi.org/10.4995/vlc.2015.3598

The competition for colossal constructions also developed vertically, with the Eiffel Tower being the clearest demonstration of this from the period. With its height of 300 meters, and its iron aesthetic, it could be seen from almost everywhere in Paris. It was the tallest building ever built by man, constituting the vertical icon of an era of extraordinary technological development. Furthermore, it gave a huge boost to the development of the elevator as it was the very first time elevators were designed to ascend 300 metres. The Eiffel Tower also opened the doors to further development of the tall buildings of the early 20th century.[4,5,6]

3.2 THE SECOND PERIOD: THE SILENCE

The second period encompasses the interval between the beginning of the 20th century and Expo 1958 in Brussels. In the first part of the 20th century, after the First World War (1914-1918), World Expos primarily turned towards the display of decorative *objets d'art*, diversifying into small pavilions and abandoning their industrial roots. Behind this was a twofold crisis; on one hand, an economic crisis, and on the other, what we have called an ideological crisis based on the prolongation of the war and its terrible cruelty originating in the development of arms brought about by industrialisation. In this sense, doubts began to be cast on the idea of technology and industry as guarantees of welfare and infinite progress. As a consequence, Expos relinquished the construction of a sole, large building, of a *Palais de l'Industrie*. The Second World War (1939-1945) would also signal a digression in the development of Expos. While it is true that some interesting constructions were built during the inter-war period, there was generally no place for large-span typologies in the pavilions erected at this time. Furthermore, it is hard to find small-scale buildings showcasing any structural innovations worthy of mention. With a few exceptions, technological exhibition yielded centre stage to the recreation of historicist styles, to classical and even regional reinterpretations, and to scattered appearances of rationalist or neoplastic architecture.

3.3 THE THIRD PERIOD: THE STRUCTURAL REBIRTH

The third period covers the interval between Expo 1958 in Brussels and Expo 1992 in Seville. After the Second World War, Expos once again became reference points for the important technological advances developed in the field of architectonic structures. This aspect is seen clearly in the enormous level of progress made in Expos in terms of diversity in structural typologies and new materials: the huge development in structures based on tension —cable

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[4] Cf.: López-César, I. (2015). La Torre Eiffel. La construcción de un coloso. *National Geographic. Historia, (155), 118-135.*
https://www.researchgate.net/publication/328902437_La_Torre_Eiffel_La_construccion_de_un_coloso_NATIONAL_GEOGRAPHIC_HISTORIA_n155_pp_118-135

[5] Cf.: López-César, I. (2017). La Torre Eiffel. L'ardita costruzione del colosso di Parigi. *National Geographic. Storica, (99), 92-109.*
https://www.researchgate.net/publication/328902564_La_Torre_Eiffel_L%27ardita_costruzione_del_colosso_di_Parigi_NATIONAL_GEOGRAPHIC_STORICA_n99_pp_92-109_Maggio_2017

[6] Cf.: López-César, I. (2017). De Eiffeltoren. De bouw van een kolos. *National Geographic. Historia (Holland / Belgium edition), (2/2017), 78-93.*
https://www.researchgate.net/publication/328902502_De_Eiffeltoren_De_bouw_van_een_kolos_NATIONAL_GEOGRAPHIC_HISTORIA_Holland_Belgium_edition_n22017_pp_78-93

nets, pre-stressed membranes—, the great steps forward taken in space frames, pneumatic structures —which in part developed thanks to the technology of the Cold War—, or the use of new structural products derived from wood.

In the wake of the extraordinary structural achievements of Expos in the 19th century, the World Expo that would inaugurate this new era of splendour was Expo 1958 in Brussels. 1958 truly was the year in which the World Expo would steal the limelight in structural innovation that had languished since the turn of the century, with a few isolated exceptions. From this point onwards, there have been several Expos of great structural significance, among which we can specifically highlight Expo 1958 Brussels, Expo 1967 Montreal, Expo 1970 Osaka and Expo 1992 Seville.

During the 19th century, World Expos identified with iron architecture, iron being a cutting-edge material. In this new era, there were many structural, typological and material representations; while a specific typology may have been predominant, Expos with structural protagonism could be related to a variety of them. An example of this is Expo 1958, which was primarily characterised by tensile structures that were cable-stayed or based on cable nets; nevertheless, glued laminated timber with synthetic adhesives played a leading role at the same time, as did some examples of space frames. Cable nets and space frames typified Expo ’67 in Montreal. On the other hand, Expo ’70 in Osaka gained importance thanks to the presence of pneumatic structures and space frames, although there was also room for cable nets and pre-stressed membranes. Expo ’92 in Seville stood out in particular thanks to the appearance of pre-stressed membranes and cable nets, with the additional presence of other typologies such as space frames and even some pneumatic structures.

In short, during this brilliant era, the number of structurally significant buildings in World Expos greatly increased, with individual pavilions devoted to different countries, various regions of the host country and innumerable private companies.

At this time, Expos were a great opportunity for utopian architectural trends to materialise. In 1960, architect Richard Buckminster Fuller proposed to cover part of Manhattan with a geodesic dome, with the aim to create an environmental control or an artificial atmosphere (Figure 12). Fuller indicated:

> *“We have calculated a dome with a diameter of two miles to cover part of Manhattan. From the inside there will be uninterrupted contact with the exterior world. The sun and moon will shine in the landscape, and the sky will be completely visible, but the unpleasant effects of climate, heat, dust, bugs, glare, etc. will be modulated by the skin to provide a Garden of Eden interior.”* [7]

At Expo 1967 Montreal, Fuller built the United States Pavilion (Figure 13), which had a computerised climate control system and controlled shading systems according to the position

[7] Fuller, R.B., Krausse, J. (Ed.), and Lichtenstein, C. (Ed.). (1999). *Your private sky. The art of design science.* Zürich, Suiza: Lars Müller Publishers.

of the sun. It constituted the closest approximation to his previous approaches. Probably, the apogee of the space race might also have had its influence in these proposals of controlled atmospheres that, after all, were expressing the utopia of human settlement in other worlds.

Figure 12: Proposal of a dome over Manhattan. Fuller, 1960 (Source: Fuller).
Figure 13: Pavilion USA at World Expo 1967 Montreal. Fuller. (Source: Nelson).

In 1960, Hungarian architect Yona Friedman proposed his "Spatial City" (Figure 14). It was conceived as a large multi-layered structural grid, that could be installed above rivers, lakes or existing cities. The architects of the Japanese Metabolist Movement and the English Archigram Group were deeply influenced by these proposals. As an approximation of the previous urban approach, the Metabolist Kenzo Tange and Yoshikatsu Tsuboi built the Festival Plaza at Expo 1970 Osaka (Figures 15 and 16). It was a spatial megastructure, which could be crossed in some areas between its two layers and, ultimately, be inhabited.

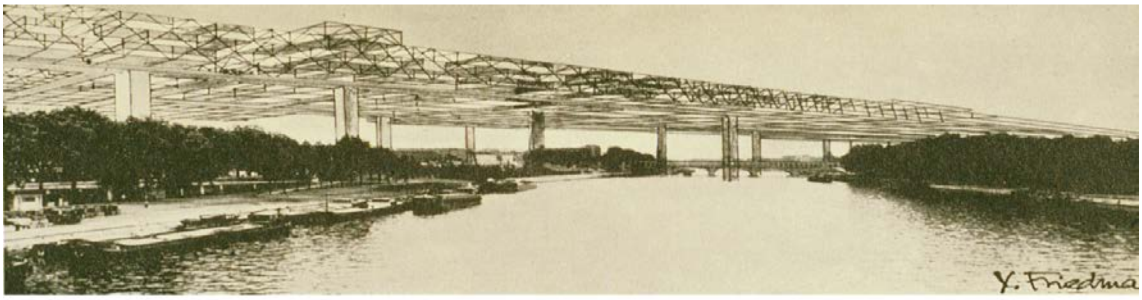
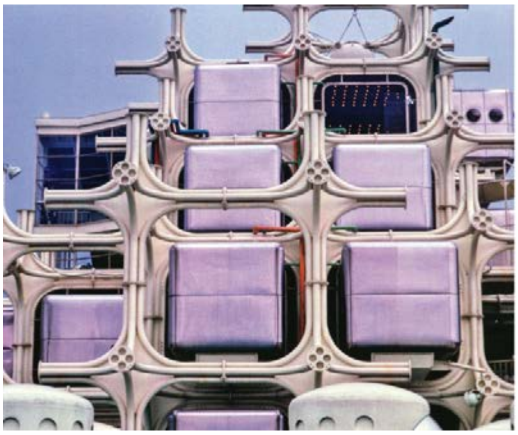


Figure 14: Spatial Paris. Yona Friedman, 1960. Superposition of a spatial grid over Paris. (Source: http://hbt-lako.blogspot.com/2014/11/yona-friedman-ville-spatiale.html)
Figure 15: Festival Plaza. Tange and Tsuboi. World Expo 1970 Osaka. (Source: Japan World Exposition Osaka 1970: Official Report).
Figure 16: Festival Plaza. Please note the inhabitable zone inside the spatial grid. (Source: Japan World Exposition Osaka 1970: Official Report).

The Takara Beautilion Pavilion (Figure 17), built for Expo 1970 Osaka by Kisho Kurokawa —another Metabolist Architect— consisted of a spatial structure that allowed the aggregation of housing capsules. This metabolic proposal was in line with the Japanese social reality of the moment: a large demographic explosion, limited island space and a highly mobile population, with 10% changing cities every year[8]. Here, we observe how this building connects with other previous utopian proposals such as the Archigram Network (Peter Cook, 1966) (Figure 18), in which the urban fabric was configured based on spatial mega-structures to which prefabricated capsules were added according to requirements.



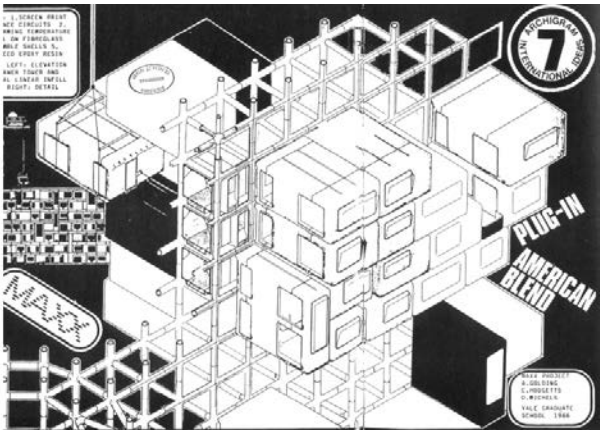


Figure 17: Takara Beautilion. Kurokawa. World Expo 1970 Osaka. (Source: Garn).
Figure 18: Archigram Network. Peter Cook, 1966. (Source: Emili).

Furthermore, we can see that Expos have also been opportunities for the construction of entirely innovative structural typologies, with an extraordinary influence on ordinary architecture in their aftermath. An example of this is the German Pavilion at World Expo 1967 Montreal, designed by Frei Otto (Figure 19). Its construction was a huge conceptual progress in the design of structures formed by cable networks, evolving from the use of geometrically known forms to free forms. Its influence was gigantic and later on thousands of structures based on this concept were built all over the world. However, its most notable sequel was the spectacular roofing of the Munich Olympic Games 1972 (Otto, Isler, Leonhard) (Figure 20).

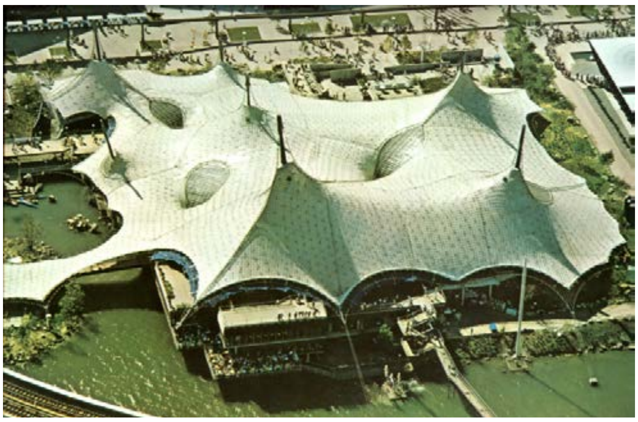


Figure 19: German Pavilion at World Expo 1967 Montreal. Frei Otto. (Source: Nelson).
Figure 20: Roofing at the Olympic Games in Munich in 1972. Frei Otto, Isler y Leonhard. (Soure: Otto).

[8] Martín-Gutiérrez, E. (1990). El movimiento metabolista: Kisho Kurokawa y la arquitectura de las cápsulas. *Boletín Académico. E.T.S. de Arquitectura de A Coruña,* (12). http://hdl.handle.net/2183/5206

Another example that underlines the role of Expos as catalysts for new structural typologies is the United States Pavilion, built by David Geiger at World Expo 1970 Osaka (Figures 21 and 22). It was a new structural typology: a low-profile pneumatic vault reinforced by cables. It reached dimensions of 83.5 x 142 meters. Geiger affirmed in 1970:

> *"It is difficult to design a long-span roof at low cost to resist 150 mph winds (241 Km/h). This demanded a deck with an aerodynamic cross-section. The cables make possible a very shallow dome. The U.S. Pavilion is an air-supported structure with the largest span ever built, as well as being the lightest for its span".*[9]

Some examples of the extraordinary influence of this pavilion are the Pontiac Silverdome (Figure 23) —Geiger 1975, 160 x 220 m—, the BC Stadium Place in Vancouver (Figure 24) —Geiger, Berger, 1983, 190 x 232 m— or the Tokyo Dome (Figure 25) —Sekkei, Komuten, 1988, 180 x 180 m—.

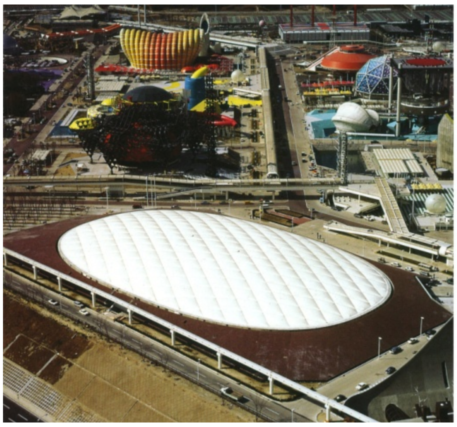


Figure 21: USA Pavilion at World Expo 1970 Osaka. David Geiger. (Source: Ishii).
Figure 22: USA Pavilion at World Expo 1970 Osaka. David Geiger. (Source: Herzog).

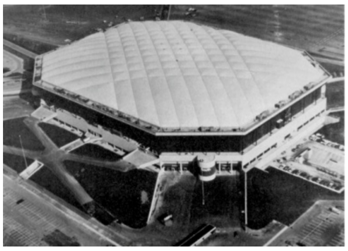
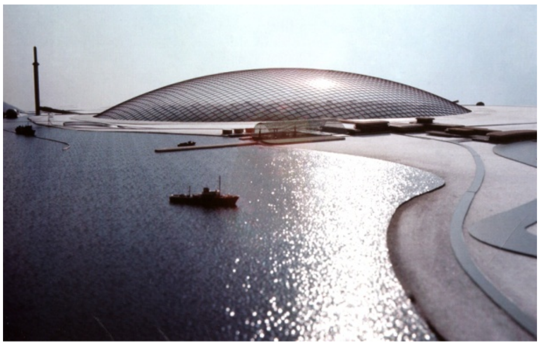


Figure 23: Pontiac Silverdome, Michigan. Geiger, 1975. (Source: http://www.columbia.edu/cu/gsapp/BT/DOMES/TIMELN/timeline.html)
Figure 24: B.C. Place Covered Stadium. Vancouver. Geiger y Berger, 1983. (Source: http://www.columbia.edu/cu/gsapp/BT/DOMES/TIMELN/timeline.html)
Figure 25: Tokio Dome. Sekkei and Komuten, 1988 (Source: http://www.columbia.edu/cu/gsapp/BT/DOMES/TIMELN/timeline.html)

In addition, the influence of the USA Pavilion at Expo 1970 Osaka is evident in various plans to realise human settlements in inhospitable areas, such as the one proposed for City in the Arctic (Otto, Tange and Ove Arup 1971) (Figures 26 and 27). Today we see these proposals as

[9] Geiger, D. (1970). U.S. Pavilion at Expo 70. *Civil Engineering-ASCE.* March. http://www.columbia.edu/cu/gsapp/BT/DOMES/OSAKA/cable.html

utopian projects, but in 1970 confidence in technological progress and energy optimism undoubtedly led to great expectations.[10]



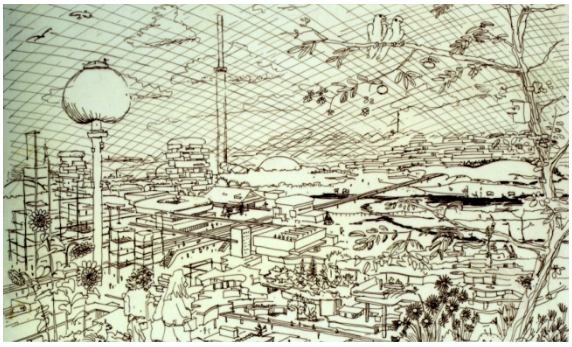


Figure 26: Proposal for the Arctic City. Otto, Tange y Ove Arup, 1971. (Source: Otto).
Figure 27: Proposal for the Arctic City. Otto, Tange y Ove Arup, 1971. (Source: Otto).

The pavilion of the United States at Expo 1958 Brussels, also called the "bicycle wheel" pavilion, for its radial structure of 92-metre-diameter cables (Stone, Aubert, Cornelius) (Figures 28 and 29), was extraordinarily innovative. Although with variations, it gave rise to other constructions with a similar typology as, for example, the Utica Auditorium (Zetlin, Seltzer, 1959) (Figure 31), or Madison Square Garden in New York (Severud, 1962) (Figure 30) .

Figure 28: USA Pavilion at World Expo 1958 Brussels. Stone, Aubert and Cornelius.
Figure 29: USA Pavilion at World Expo 1958 Brussels. Stone, Aubert and Cornelius. (Source: BIE Archive).

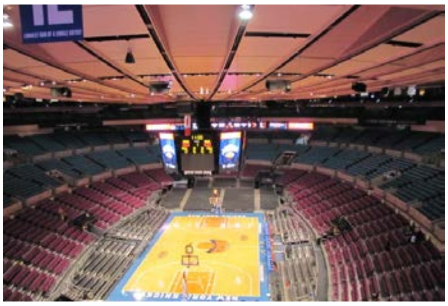


Figure 30: Madison Square Garden. Severud, 1962. (Source: Wikimedia Comons, A. Nieto Porras).
Figure 31: Utica Auditorium. Zetlin and Seltzer, 1959. (Source: Wikimedia Comons, Doug Kerr).

[10] NB: Between 1945 and 1972 the consumption of oil in the West had multiplied, reaching figures unknown until that time. This increase in consumption and cheap access to this raw material is especially evident in the United States and Japan. The first oil crisis took place in 1973 after the decision of OPEC to stop exporting oil to countries supporting Israel during the October War; thus leading to an increase in oil prices and to the acceleration of the global economic recession.

Other innovations at Expo 1970 Osaka, such as the Fuji Pavilion (Kawaguchi, Murata) (Figure 33) —the largest pneumatic high pressure structure ever built—; the Mush Balloons (Oki, Aoki) (Figure 32) —an interesting hybrid between pneumatic and deployable structures—; or the floating theater (Kawaguchi, Murata) (Figure 34) —with positive pressure zones and others negative—, reinforce the innovative and investigative character of architectural experimentation featured in Expos.



Figure 32: Mush Balloons presented at Expo 1970 Osaka. Oki and Aoki. (Source: Japan World Exposition, Osaka 1970. Official photo album).
Figure 33: Fuji Pavilion at Expo 1970 Osaka. Kawaguchi and Murata (Source: Japan World Exposition, Osaka 1970. Official photo album).
Figure 34: Floating Theater at Expo 1970 Osaka. Kawaguchi and Murata (Source: Herzog).

3.4 THE FOURTH PERIOD: THE AWAKING OF THE SUBSTAINABLE AWARENESS

The last period defined here encompasses the final two decades of the 20th century, partially overlapping with the last fragment of the previous era or qualifying it. In this last stage, we observe the growing demand for large, diaphanous spaces capable of housing large crowds of visitors. Thus, enormous sports or multi-purpose spaces, new airport terminals, transport transfer points, and new railway stations all competed for the structural cutting-edge protagonism that had formerly been so closely linked to World Expos.

The culmination of this period was World Expo 2000 Hannover. Themed *"Man, Nature, Technology",* it was the perfect ideological frame for the use of structural materials that were recyclable as well as procured with the minimum of energy consumption, particularly those derived from wood. After the era of optimism in terms of energy resources and the excesses of industrialisation, this environmental criteria opened up a new path, which appears to be predominating not only in the World Expos held during the first decade of the 21st century, but also in a considerable part of architecture in general.

Two structures exemplify this new spirit: The Expo Roof (Herzog, Natterer) (Figure 35), that constitutes a shining sample of the vast structural possibilities of wooden materials. And the Japanese Pavilion (Shigeru Ban, Frei Otto) built around a structure of cardboard tubes (Figures 36 and 37).

Figure 35: Expo-Roof at Expo 2000 Hannover. Herzog and Natterer. (Source: BIE Archive).

Figure 36: Japan Pavilion at Expo 2000 Hannover. Ban and Otto. (Source: BIE Archive).
Figure 37: Japan Pavilion at Expo 2000 Hannover. Ban and Otto. (Source: BIE Archive).

3.5 THE FIFTH PERIOD: THE TECHNOLOGICAL REVOLUTION

In the first two decades of the 21st century, there has been no significant fundamental development in new architectural structural typologies. The buildings are essentially sustained by the same typologies, although they do showcase new designs and formalisations arising from the freedom granted by new computer resources. In many cases, the architecture has even achieved a certain level of plastic or sculptural innovation.

This aspect of formal experimentation is not new; the architecture of Expo pavilions has been quite suitable for this purpose, given that it lacks a rigid functional programme and has often aimed at causing an impact among the public. What has happened is that the previous lack of existing calculation tools guided this innovation towards highly rational, structural shapes that were based on the logic of the physical laws governing our world. Nowadays, computer technology has provided us with practically limitless calculation, representation and manufacturing resources that facilitate the exploration of areas beyond this physical rationality.


Figure 38: Vanke Pavilion (Libeskind) at Expo 2015 Milano. It is a bright example of the new architectonic formalisations that can be achieved with the help of new computer tools. (Source: BIE Archive).

Figure 39: Nur Alem at the Expo 2017 Astana (Smith / Gill) is one of the largest spherical buildings built so far, with a diameter of 80-metres. The organisers aimed at making this structure an icon for Kazakhstan that would be part of the legacy of the Expo and become the Energy Museum. (Source: BIE Archive).

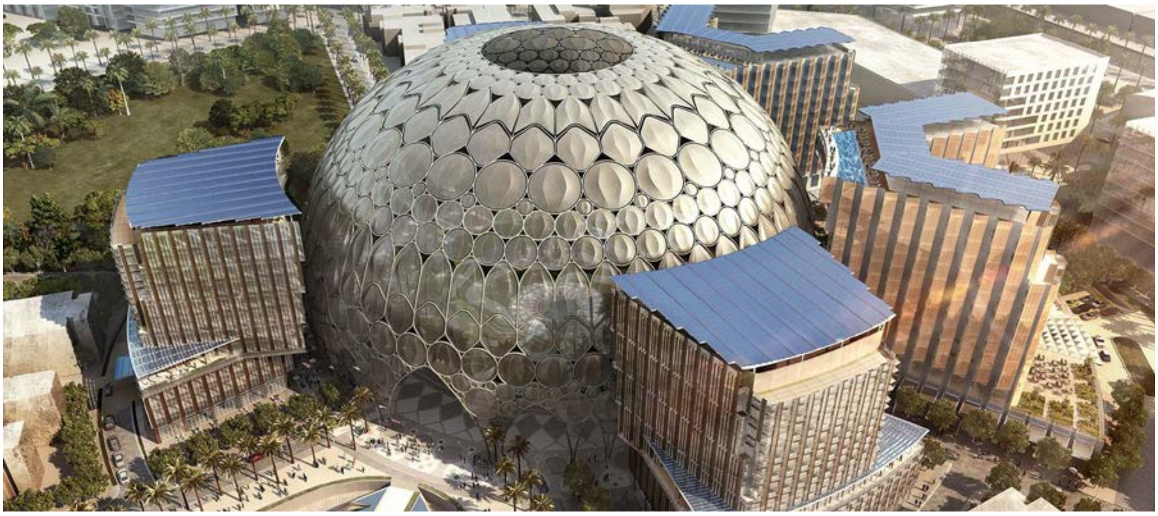


Figure 40: Al Wasl Plaza at Expo 2020 Dubai (Smith / Gill). New resources avaliables for structural calculations have permitted the development of the innovative design of the interconnected rings of this gigantic 150-metre diameter metallic dome. (Source: AS+GG)

In short, the evolution of these periods has led to a mannerism in architecture in general terms that has been brought about by computers; this will undoubtedly mark an era that will be justly valued with historical perspective. While this phenomenon may prove to be positive from the perspective of plastic experimentation and innovation in space creation, we should be prudent and not forget that the machine is merely a means; the ultimate aim of architecture should unquestionably be mankind.

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