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A BUILDING ENVELOPE EVOLUTION PRESENTED ON WORLD EXPOSITIONS PAVILIONS 1851 - 2012.

I. INTRODUCTION

The undertaken dissertation problem concerns mainly an envelope or an external *building skin*, understood as the "packaging" of the interior usable space [2]. The concept of an envelope is synonymous with the terminology: *elevation*, *external wall*, *outer shell*, *façade*, *curtain wall*, *enclosure*, *cover* or *a modern building skin*. An envelope applies to non-structural vertical walls (a façade) and horizontal partitions (a roof/covering) as well as a three-dimensional forms that can cover the entire building. The metaphor of a *building skin* in the architectural context is recalled by Wigginton and Harris as applies to a skin's complex functions related to bodily protection, temperature and humidity control as well as response to external stimuli [3].

The PhD thesis entitled "A building envelope evolution presented on World Exposition pavilions 1851 - 2012", was under preparation in the Department of Civil Engineering, Architecture and Environmental Engineering, Technical University of Lodz, guided by Prof. Eng. Arch. Nina Juzwa. The object of the research concerns evolution of a large scale building's envelope and modern tendencies. The investigation was separated into two parts.

The first part describes the problem in terms of historical and contemporary solutions. It presents an envelope's attributes - form, structure and materials. The topic is fulfilled with ecological and functional solutions.

The second part of the research analyzes World Exposition pavilions. The research collects all important pavilions, highlights significant historical developments (1850-1980) and examines 120 pavilions that used an envelope (1980-2012) with reference to their geometry, materials, structure and incorporated technologies that have a positive impact on the environment.

II. ARCHITECTURE OF WORLD EXPOSITION PAVILIONS 1850 - 1980

In the long history of World Exposition pavilions have introduced a number of innovations related to an envelope's form, structure and materials. The golden period of historical fairs was the second half of the nineteenth century. Expositions presented large exhibition halls with structures that eliminated internal columns. The first official Expo object - The Crystal Palace (Paxton, 1851), completely changed the approach to the building design, due to its non-structural and prefabricated outer wall built up with glass and iron. The Galerie des Machines (Dutert, Contamin, 1889) opened a new era for large-scale objects, by introducing the engineering construction system into architecture.

The second important period started in 1920's and concentrated on the concrete skeleton structure and external attractiveness based on the glass façade . The World Expositions contributed the well-known L'Esprit Nouveau Pavilion (Le Corbusier, 1925) and The German Reich Pavilion (van der Rohe, 1929). Both used modern concrete structures filled with light and non-structural walls. In addition, the Finnish Pavilion (Aalto 1935), the Czechoslovakian Pavilion (Krejcar, Bolivka, 1935) and the Brazilian Pavilion (Nemeyer, Costa, 1939) implemented materials innovations. Out of the three, the Scandinavian building skillfully integrated traditional cover material with modernism proportions. The two others responded to the inadequate glass properties, concerned energy and comfort, by introducing thermal glass and *brise-soleil*.

The third culmination point was reached in the 1960's with innovations associated with structure, form and a new aesthetics. The Philips Pavilion (Le Corbusier, 1958) for the first time presented a unified three-dimensionally curved envelope. The Biosphere (Buckminster Fuller, 1967, fig.1) introduced a division between the occupational core of the pavilion and the independent envelope. At the same time it tried to isolate the indoor climate conditions by using steel-and-glass dome. Furthermore, the pavilion applied a novel digital optimization to the structure and innovative self-regulating sun shades. Now it is claimed to be the first responsive envelope. The experimental impact of World Expositions was recognized in grid structures (Festival Plaza, 1970, Tange), tension skins (West German Pavilion, 1967, Frei) and air supported roofs (USA Pavilion 1967, Davis, Chermayeff) [4].

III. ARCHITECTURE OF WORLD EXPOSITION PAVILIONS 1980 - 2012

After accomplishing many of the utopian projects at Expo '70 Osaka, the world has changed drastically. The oil crisis ended an optimistic race aimed at extending the size and volume. The publication *Limits to the Growth* by the Club of Rome warned about too intense use of natural resources. There was no sense of competing any longer. The construction industry began to search for energy-efficient, resource-efficient and later ecological solutions. As a consequence, modern structures and enclosure materials were developed. New techniques and technologies allowed greater freedom of form types and a new envelope aesthetics [1].

Recently, architects have shaped the contemporary envelope searching for a compromise between aesthetics, economy and practicality. First of all, a modern envelope tends to uniqueness. Its task is to break through and distinguish among a wide variety of objects. Visual appeal results from the individual approach and unconventional attempts to surprise the viewer. To be remembered it tries to strongly affect observers emotions. Second, an important role in shaping the envelope is put into the structure. Particularly, architects tend to minimize the amount and weight of materials in forming the structure. Also modern cladding become lightweight and while the new materials provides the same properties as traditional load bearing solutions [5]. Thirdly, the concept of the envelope changed towards technology, ecology and function. The outer skin is responsible for a number of complex functions, such as savings and energy production, as well as ensuring user comfort. Results benefit the environment and determine the architecture's attractiveness [6]. Following Velikov and Thun, thanks to functional solutions, envelope does not concentrate only on aesthetics but also has a specific goal to achieve [7].

IV. INNOVATIVE ENVELOPE DIRECTIONS

Among many design directions, envelope shaping is dependent on four significant tendencies: unconventionality, lightness, energy efficiency and user-related comfort. Unconventional aesthetic is still one of the most important direction in shaping contemporary envelope. Besides visual attractiveness the building envelope has grown in importance in environmental solutions associated with resource-efficiency, energy-efficiency and user-related comfort. If one considers different goals, each trend is an individual approach. In most cases the solutions are comparable.

IV.1 UNCONVENTIONALITY

The architecture of the contemporary exhibition object is strongly motivated by visual qualities. It aims to be exclusive, unique and exceptional. The task is to identify and distinguish the object among many other interesting solutions. The attractiveness of the envelope can be achieved by a non-schematic approach to form (Japan Pavilion, 2010), material (Pavilion of Christ, 2000) or structure (Trade Fair Hall 26, 2010). Each of these solutions involves an individual solution. Implementation of an unique envelope is often an experiment, the results of which may prove to be an exceptional success or a spectacular failure. Nowadays, the most common solution in achieving a unique and expressive envelope is a three-dimensional curvature of the enclosure (Spain Pavilion, 2010) or an experimental material (UBPA B3 Pavilion, 2010). Simple geometry of the envelope is often combined with expressive materials. Under opposite conditions, a multi curved surface is combined with uniform surface, keeping attention rather to the geometry, not to the detail. Unconventional form is created by complete building skin - multi curved envelope that eliminates the difference between the roof and the façade, like a "package" of the building (Israel Pavilion, 2010). All the unique forms and structures are appealing, especially the unobvious and 'impossible' to build ones (Kuwait Pavilion, 1992). Furthermore, innovative materials are introduced (Cyclebowl, 2000). In opposition, the demand for traditional materials has risen, changing the common attitude to creative application (Spain Pavilion, 2005), recreating vernacular direction and ornamentation (Poland Pavilion, 2010).

IV.2 LIGHTNESS

The lightweight and resource-efficient trend in envelope design results from the attitude to reduce the consumption of raw materials and to encourage the use of renewable, recycled and reused substances. Lightness is the result of the opportunities introduced by a skeletal structure of the external wall and its infill. Reducing the weight of the envelope is an effect of structure optimization and the use of thin cladding materials. The most popular method of this resource strategy is associated with highly efficient steel structure connected with lightweight glass façades (UK Pavilion, 1992). Further lightness is achieved through independent self supported skins - a combination of structure and envelope in one element, for example, a single-layer grid shell constructed from triangular modules (Israel Pavilion, 2010). Resource-efficiency applies tension structures combined with membrane cover. Such materials are high strength and practically weightless, for example an ETFE film (La Sed Pavilion, 2008). An equally light envelope is possible to obtained through low-tech construction techniques and the use of simple materials.

IV.3 ENERGY-EFFICIENCY

The envelope is a key element in the energy-efficient building. It enables positive effects from cyclically changing climatic factors. Modern solutions operate on two backgrounds: savings and energy production. Both are mainly associated with solar radiation and modern technologies for the processing of renewable energy into usable form. Solar radiation determine the buildings geometry and transparency according to variable daylight strategies and seasonal differences. The process of savings in cold periods of the year concentrates on increasing profits from sun energy and reducing heat losses (Italy Pavilion, 2010). In summer, energy-efficiency refers to reducing excessive impact of the sun on the building's interior (United Arab Emirates Pavilion, 2010). The passive methods of solar energy are primarily concerned with glass façades. Active methods on the envelope focus on producing energy. Modern solar panels allow the incorporation of photovoltaic cells in the vertical walls to increase surface area capable of producing energy (Switzerland Pavilion, 2010). They are the first energy-efficient systems aimed to express the technology through specific aesthetics. Currently, saving and energy production systems enable full integration of solar technologies with basic construction techniques such as glass BIPV façades (Alsace Pavilion, 2010), semi translucent BIPV foils (Japan Pavilion, 2010) or opaque components, like roof tiles. In this

USER-RELATED COMFORT

The comfort of users refers is one of the most important features of the architecture is necessary to ensure satisfactory conditions and protection against abnormal weather conditions. Achieving an appropriate comfort through envelope results from controlling natural lighting, emphasizing natural ventilation and providing acoustics. Adjusting comfortable lighting is achieved by appropriate types of façade blinds (Kinetic Pavilion, 2012) and semi-transparent cladding materials (Japan Pavilion, 2000). Natural ventilation is the result of double glass façades (Expo Building, 2008), buffer façades with an open-work exterior layer (Canada Pavilion, 2010), atriums (Italy Pavilion, 2010) and solar chimneys (Japan Pavilion, 2010). The sound protection follows geometry, double façades and special windows (Madrid Case Pavilion, 2010). Comfort focused solutions are often similar and even identical to energy-efficient methods. However, even the most efficient building may be impossible to operate, if it does not provide satisfactory conditions for everyday use.

V. HIGHLIGHTED REFERENCES

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