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Sustainability of architecture as a conceptual basis of Norman Foster's projects

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Abstract: In the XXI century, the desire to meet international standards of sustainable development has become key for the world architectural leaders implementing projects in different countries. This desire includes the aspect of energy efficiency. Energy efficiency is one of the requirements for qualitative and consistent functioning of the material structure in modern conditions. This article considers the projects of Norman Foster, which in different natural and climatic conditions, demonstrate expressive regional artistic images and the resilience of architecture to natural and man-made challenges through innovative design and technical solutions. The interest of the authors, in the objects considered in the article, was piqued by the unique construction of the Palace of Peace and Concord, which was designed for one of the coldest cities in the world and the innovative approaches to the construction of the Red Sea Airport, whose design solutions are suitable for the southern cities of Kazakhstan, which have a sharp continental climate.

Keywords: architect Norman Foster, sustainable architecture, Palace of Peace and Concord, Red Sea Airport, natural-climatic factors in architecture

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Introduction

One of the global pillars of modern architecture is the concept of sustainability, which provides for the consistent development of material systems under various natural, climatic and functional-technological conditions. At the global level, the issue of sustainability is reflected in the programme adopted by the United Nations

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in 2015, where in paragraph 11 'Sustainable Cities and Human Settlements' it is noted that sustainable architecture is an integral part of a secure world (UN General Assembly Declaration, 2015). Architectural sustainability is not just a question of the strength of structures and materials. The notion of 'architecture sustainability' also includes issues of adaptation to changing conditions of use, socio-economic and cultural change (Ingels, 2015; Kisamedin, 2012; Kuc et al., 2015; Kuczynski, 2020). Socio-economic and political changes, scientific research and innovative technological developments all contribute to the introduction of new ideas into contemporary architecture, which is enriched by original engineering solutions and expresses unique cultural images. The motivation for new approaches to architecture in Kazakhstan was the country's independence in 1991. With the relocation of the capital from Almaty to Astana in 1997 the architecture and construction of Kazakhstan received a powerful impetus. In a short period, Kazakhstan's capital city transformed from a provincial Soviet city into a modern avant-garde 'park' of architectural premiers (Abdrassilova & Danibekova, 2021; Baitenov & Issabayev, 2016; Galimzhanova, A. & Glaudinova, 2011).

The strengthening of international ties has opened up new opportunities in architecture and construction. International competitions were held to design the capital's facilities, renowned foreign architects were involved along with Kazakhstani specialists, and projects that combined local traditions and global trends in architecture were implemented. These included the design of new facilities in Astana, such as the Palace of Peace and Harmony (arch. N. Foster) (Meuser, 2015 & 2017). The Palace of Schoolchildren (arch. N. Yaveyn), the cinema-concert hall "Kazakhstan" (arch. M. Nicoletti), the shopping and entertainment complex "Khan Shatyr" (arch. N. Foster), all of which involved the active participation of foreign architects (Meuser, 2015 & 2017). These unique buildings and constructions can be classified as examples of avant-garde architecture, which give a unique appearance to the young capital of Kazakhstan (Chikanayev, 2008). The projects of foreign architects expressed current ideas, adapting to the modern realities of our country, accelerating progressive technological and artistic trends. The great achievement of the projects of foreign architects and companies implemented in Astana were advanced technological solutions: the post-Soviet market economy facilitated the attraction of foreign investors, new technologies, modern building materials to Kazakhstan (Abdrassilova et al., 2017; Abdrassilova & Onishchenko, 2021). One of the outstanding examples of modern Kazakhstani architecture is the Palace of Peace and Harmony, built in Astana in 2006 and designed by architect Norman Foster (Foster, 2006).

1. Subject and method of analysis

The article presents completed projects by Norman Foster. In various natural and climatic conditions, these objects demonstrate expressive regional artistic images and the resilience of architecture to the challenges of nature and man through innovative design and technical solutions. An equally important element is energy efficiency as a requirement for the qualitative and consistent functioning of the material structure in modern conditions.

The buildings Palace of Peace and Concord and Red Sea International Airport were selected primarily for analysis. The Palace of Peace and Concord is located in the capital of Kazakhstan Astana. The Red Sea International Airport is an international airport in northwestern Saudi Arabia in Hanak in Tabuk province.

2. Results and discussions

In 2003, as a result of an international competition for the construction of a new public building, the Palace of Peace and Concord in the capital of Kazakhstan, a design by internationally renowned British architect Norman Foster was declared the winner. The construction of the facility was associated with the International Congress of World and Traditional Religions held in Astana in September 2003.

"The Palace of Peace and Concord" is widely known by the unofficial name of "Foster's Pyramid". The artistic image of the building in the form of a pyramid reveals a regional picture of the world: the square base (61.8x61.8 metres) symbolises the earth, while the top of the pyramid represents heaven, eternity (Figs. 1 and 2). Compositionally, the structure expresses the idea of the centre of the universe and the unity of different religions.

Fig. 1. Perspective of the Palace of Peace and Concord, Astana (*photo Y. Onichshenko*)

The Pyramid's architecture uses innovative techniques that have placed it at the forefront of modern construction: British engineers used unique movable articulated structures at the base of the pyramid, capable of responding to seasonal temperature variations by contracting and uncompressing with an amplitude of 6 cm.

Fig. 2. Structural unit of the building's movements (*photo Y. Onichshenko*)

The main problem for the pyramid-shaped project was the extreme climate of Kazakhstan; it was difficult to make the pyramid resistant to temperature fluctuations. The city of Astana is the second coldest capital in the world, with an annual average daily temperature of 3.50°C: the air temperature drops to –40.0°C in winter and rises to +35.0°C in summer (Ravenscroft, 2021). It was possible to adapt the building to the natural climatic conditions by means of a kinematic frame, which allows the pyramid-shaped building to move: the walls of the building shrink in the winter cold and expand in the summer heat. With a pyramid shape where the four faces converge at one point, expansion and contraction of the walls would have led to an imminent disaster, the triangular surfaces would simply have fallen in. Therefore, the structural engineers placed 40 column supports under the pyramid on special sliding platforms, of which 36 columns can move in almost any direction, only 4 columns are rigidly fixed (Fig. 3).

The foundations of the Astana Pyramid were laid during the summer, when temperatures were positive. In parallel with laying the foundation in Kazakhstan, the entire above-ground part of the structure was manufactured in England, which included 1,000 triangular sections of patented glass and metal. In 2006, in winter the sections were delivered to Astana to the construction site and the Pyramid was assembled according to the established scheme, like a construction set (Zhabigenov, 2006).

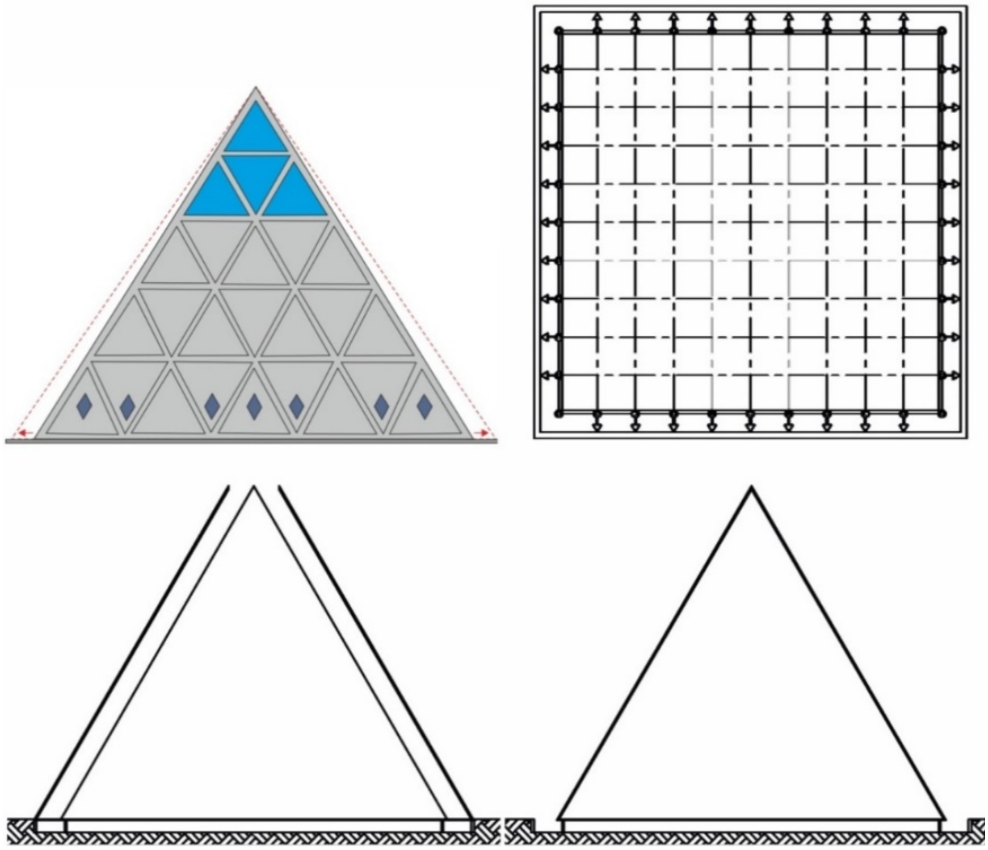

Fig. 3. Column traffic patterns in winter and summer (*developed by the authors based on Onichshenko research*)

The interior design of the Palace is also unique. The Pyramid has five lifts, all moving diagonally at a 60 degree incline, similar to those installed in the Eiffel Tower and the Luxor Hotel in Las Vegas. The building has a total area of 28,000 m^2 and houses: a contemporary art centre, exhibition halls, art galleries, press centres, offices of religious organisations, a library and a restaurant (Zhabigenov, 2006). At the base of the Pyramid there is a 1,350-seat concert hall, the ceiling of which is both a reflective lens and the floor of the inner atrium. The natural lighting of the building is organized through an atrium which allows for a leisurely view of all levels of the pyramid with its hanging gardens. The design uses a sophisticated optical mirror system which allows sunlight streaming through the glass top of the pyramid to illuminate the interior space. The top of the pyramid is decorated with a stained-glass window by artist Brian Clarke, depicting 130 doves symbolising the nationalities of the people living in Kazakhstan. The building's lighting design, done by a German company, also makes the Pyramid visible at night from both sides of the Ishim River that divides the city of Astana into two parts.

The Pyramid in Astana occupies a special place in the architecture of modern Kazakhstan: it demonstrates a synthesis of avantgarde artistic form and innovative engineering solutions. In general terms, the building is a moving mechanism that responds to seasonal fluctuations in temperature. According to George Kirilis, Pyramid's design engineer, 'the shape of the Palace building, as well as its ability to interact with its environment, is unique. This is exactly the kind of innovative approach that every engineer should strive for'.

The architectural firm Norman Foster is demonstrating innovative engineering solutions in every major project, in every geographical setting: almost 20 years after the Pyramid in Astana, Foster + Partners is implementing the latest sustainable development principles in the Red Sea International Airport in Saudi Arabia, which began operations on September 21, 2023.

Airports, as high-tech facilities, pose a complex set of problems for the environment of their host territories (Permyakov & Krasnova, 2019; Rastyapina & Korosteleva, 2016; Tolegen et al., 2022a; 2022b). In an interview with Dezeen in London, Norman Foster expressed his views on the carbon footprint of air travel: 'In relative terms, the carbon footprint is small and must and can be reduced, and it is Foster + Partners that will play a significant role in reducing the carbon footprint of aviation by designing green airport terminals' (Ravenscroft, 2021). But in addition to the negative environmental impact of airports, environmental factors in turn affect the sustainable operation of the facility. Creating a comfortable indoor and outdoor microclimate, reducing the energy consumption of the structure, the use of renewable energy sources – both architectural and engineering solutions are used to achieve these goals.

The Red Sea International Airport is designed to handle one million passengers per year. It will cater for people visiting the Red Sea Project tourist complex being developed in the same area and will include a hotel on stilts over the Red Sea and a resort built amidst the Saudi Arabian sand dunes by Foster + Partners.

The shape of the airport was inspired by the surrounding desert: visual images show a series of five dune-like passenger boarding and disembarkation pods arranged radially around a central space (Fig. 4).

These pods contain departure lounges, spas and restaurants, spaces with greenery. Each of the five pods can operate independently as a 'mini-terminal', meaning some parts of the airport can be closed during periods of low demand to reduce energy consumption (Dolgova, 2018).

"The Red Sea International Airport was conceived as a gateway to one of the most unique resorts in the world", said Gerard Evenden, head of studio Foster + Partners when the project was first unveiled in 2019 (Ravenscroft, 2021).

The two wings extending on either side of the main terminal will house the airport's ancillary facilities, including baggage handling areas. According to the studio, the planning solution will reduce the overall footprint and energy requirements compared with standard freestanding ancillary buildings.

Fig. 4. The Red Sea Airport, by Foster + Partners, Hanak, Tabuk, Saudi Arabia
(official representative of Foster + Partners Architects)

Norman Foster's studio aims for the airport to achieve a LEED Platinum sustainability rating. The airport will be run 100% from renewable energy sources, both during construction and in the future: zero-use of disposable plastic will be implemented during operation.

In order to create a comfortable environment for users, the airport's architecture uses planning and structural engineering techniques that level out the harsh environmental factors:

– the terminal roof will extend away from the building, creating shading for both the ground and the air side of the airport;
– the overall shape of the terminal building has been designed so as to protect the interior environment from the sun's rays through self-shading and to significantly reduce the overall energy demand for cooling the building;
– a large proportion of the glazing of the façade faces north in order to increase daylight penetration without compromising solar efficiency (Ravenscroft, 2021).

In addition to the main terminal building, an airstrip and a dedicated seaplane runway as well as three helipads are being built on the compound.

Described by its developers as "the world's most ambitious tourism development", the Red Sea Project aims to turn a chain of 90 undeveloped islands off the west coast of Saudi Arabia into a tourist destination. What's important to the architecture of the complex is that it aims to emphasise local identity and express the cultural specificities of the area. "Inspired by the colours and textures of the desert landscape, the design aims to create a tranquil and luxurious journey through the terminal and become a transit hub for visitors arriving by both land and air", according to the authors of the project (Ravenscroft, 2021).

As a result of the analysis of the projects presented in the article we can conclude that the resilience of architecture in a variety of natural, climatic and engineering conditions is a conceptual basis for the projects of Foster + Partners.

We have identified methods to increase the resilience of architecture to natural factors in low and high air temperatures, used in the reviewed projects Table 1.

Table 1. Engineering the resilience of architecture to natural factors in Norman Foster's designs (*own research*)

Architectural object	Factors	Problems	Ways out of the problem
Palace of Peace and Concord, Foster + Partners, Kazakhstan, Astana (Figs. 1 and 2)	Severe climate (temperature variations from –40 to +35°C)	Prevent the pyramid-shaped building from collapsing	Fully kinematic frame that reacts to temperature fluctuations by compression or expansion.
	Request to save the energy consumed by the building	Reduction of energy costs	Natural illumination of a five-storey building by creating a light well reinforced with optical lenses.
Red Sea Airport, Foster + Partners, Umluj, Tabuk, Saudi Arabia (Fig. 4)	Environmental pollution	Creating a "green building"	Configuration that reduces power consumption; Use of environmental materials; Complete rejection of single-use plastic; Forms of waiting rooms to redistribute the load during periods of low demand.
	Hot climate	Creating a shadow	The location of the glazing on the north side to avoid overheating; The shape of the roof, creating shading for the ground and air parts of the airport.

Conclusion

The reviewed examples of structures built under the projects of Foster + Partners demonstrate modern methods of increasing the adaptability of architecture in harsh natural and climatic factors.

The analysis reveals the methods used in modern architectural and engineering solutions to create sustainable public complexes using the example of two structures in contrasting climatic situations: in Astana, the second coldest capital in the world, and in the desert in Saudi Arabia.

In Astana, the Pyramid's architecture used innovative techniques that put the site at the forefront of modern construction:

– unique articulated structures at the base of the pyramid, capable of responding to seasonal temperature fluctuations by contracting and uncompressing with an amplitude of 6 cm to solve the problem of structural mobility (in response to external temperature fluctuations);
– natural lighting of a five-storey building by creating a light well reinforced with optical lenses.

Unlike Astana, where low winter temperatures were the main climatic problem, the airport in Saudi Arabia needed protection in a hot desert environment. To this end, the architects used both architectural and engineering solutions:

– a configuration that reduces energy consumption;
– the use of sustainable building materials, a total rejection of single-use plastic;
– adaptability of the waiting rooms to redistribute load at periods of low demand;
– north-side glazing to avoid overheating;
– the shape of the roof creating shading for the ground side of the airport.

The temperature in the territory of our country can be extremely low and the highest temperatures are recorded in the southern cities of Kazakhstan. The Palace of Peace and Concord building is the first realised experience of a unique structural and technical solution to a complex problem related to natural and climatic conditions in one of the coldest cities in the world. The Red Sea Airport object is of interest as an opportunity to introduce promising innovative technologies in the construction of public buildings in Kazakhstan with a sharply continental climate. Both of these objects are of great interest as they demonstrate the ways of solving architectural issues in the conditions of the sharp continental climate of our country.

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