Approaches to mitigation of climate change at all stages of the life cycle of a construction facility

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Abstract. At the beginning of the 21st century, the world scientific community recorded the growth of climate change. This led to further study of climate change and forecasting its impact on economic sectors, including construction. The article discusses the features of climate change impact on the life cycle of capital construction facilities, measures to adapt construction facilities to climate change and mitigation measures. The aim of the article is to assess the degree of climate change influence during the entire life cycle of a capital construction facility. During the analytical study, the consequences of climate change in Russia that affect the life cycle of a construction object, and proposed adaptation measures at each stage of the life cycle. The article contributes to the theoretical substantiation of the impact of climate change on the construction industry and, in particular, on the life cycle of a capital construction facility.

1 Introduction

Today, one of the most important tasks of the construction industry development is to adapt to the influences of various external factors. Due to the dynamic growth of climate change in the economy, the world community has directed its efforts to study climate change and reduce its negative impact on various sectors of the economy, including construction.

At the border of the XX – XXI centuries, all world scientific communities came to the conclusion that climate change is actively taking place in the world, directly affecting socio-economic processes in countries, energy sustainability, agriculture, construction and housing, and the quality of life of the population as a whole.

Construction sites are the largest sources of greenhouse gas emissions, which contribution to global emissions is estimated to be one third of the total. Energy consumption by buildings and structures based on fossil fuels and electricity throughout their entire life cycle is accompanied by constant emissions of greenhouse gases, which in turn are the direct cause of climate change [1,2]. From the point of view of greenhouse gas emissions management, the life cycle of a construction object differs from the usual life cycle of the investment and construction project. In the first case, energy consumption is considered during the production stages of the life cycle of the construction object (Table 1).

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Table 1. Production stages of the life cycle of a construction facility.

Production stages	Energy costs
1. Production of building materials	- extraction of natural resources for raw materials; - processing of raw materials; -production of building materials.
2. Transportation of building materials	- delivery of raw materials to manufacturing facilities; - delivery of ready-made products to the construction site.
3. The construction process of a building / structure	- the energy spent on the work of construction machines, mechanisms; - the energy spent on the operation of the construction site.
4. Building/ structure operation	- lighting; - heating and ventilation; - ongoing technological processes; - other needs.
5. Demolition of a building / structure	- demolition, dismantling; - transportation of construction waste; - recycling / disposal of construction waste.

2 Materials and Methods

It is worth noting that the operation stage, as the longest period in the life cycle of a capital construction facility, accounts for more than 80% of greenhouse gas emissions from the total volume. Thus, reducing energy consumption at the stage of building operation is extremely important for reducing greenhouse gas emissions and the impact on climate change by the construction industry [3]. The influence of climate change is accompanied by such phenomena as the increase in the freeze-thaw cycle in winter, the increase in the amount of liquid precipitation in winter, the increase in the number of days with extreme temperatures (winter and summer season), and the reduction in the permafrost area [4]. Reducing the risk of climate change is achieved by a set of measures to adapt the capital construction facility to changes and also by mitigating them.

Adaptation to the risks of constant climate change should be carried out throughout the entire life cycle of the construction site. It consists in ensuring the required sanitary and hygienic indicators, comfort, safety, and efficiency of building operation at all stages of the life cycle, taking into account the economic feasibility of the decisions taken and aimed at reducing the vulnerability and vulnerability of the construction site to climate change.

Mitigation of climate risk in the construction industry is associated with reducing the risk of climate impact and is achieved by reducing such indicators as energy costs, carbon dioxide emissions, as well as creating an environment with a sustainable water cycle [5].

The identification of priority measures and technologies for adaptation and mitigation to mitigate the effects of climate change should be carried out based on the totality of national conditions of a particular country as determining factors.

This is due to the fact that certain natural and economic conditions in a country or a particular region, as well as their combination, can influence the effectiveness of measures and the introduction of adaptation and mitigation technologies to mitigate the impact of

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climate change on construction sites in different ways. The main and most important conditions to be assessed are: the economic development of the region, the level and trend of urbanization, the prevailing geographical conditions, the state of the general fund of construction facilities, the capabilities of the region's industry and the availability of professional personnel [6,7].

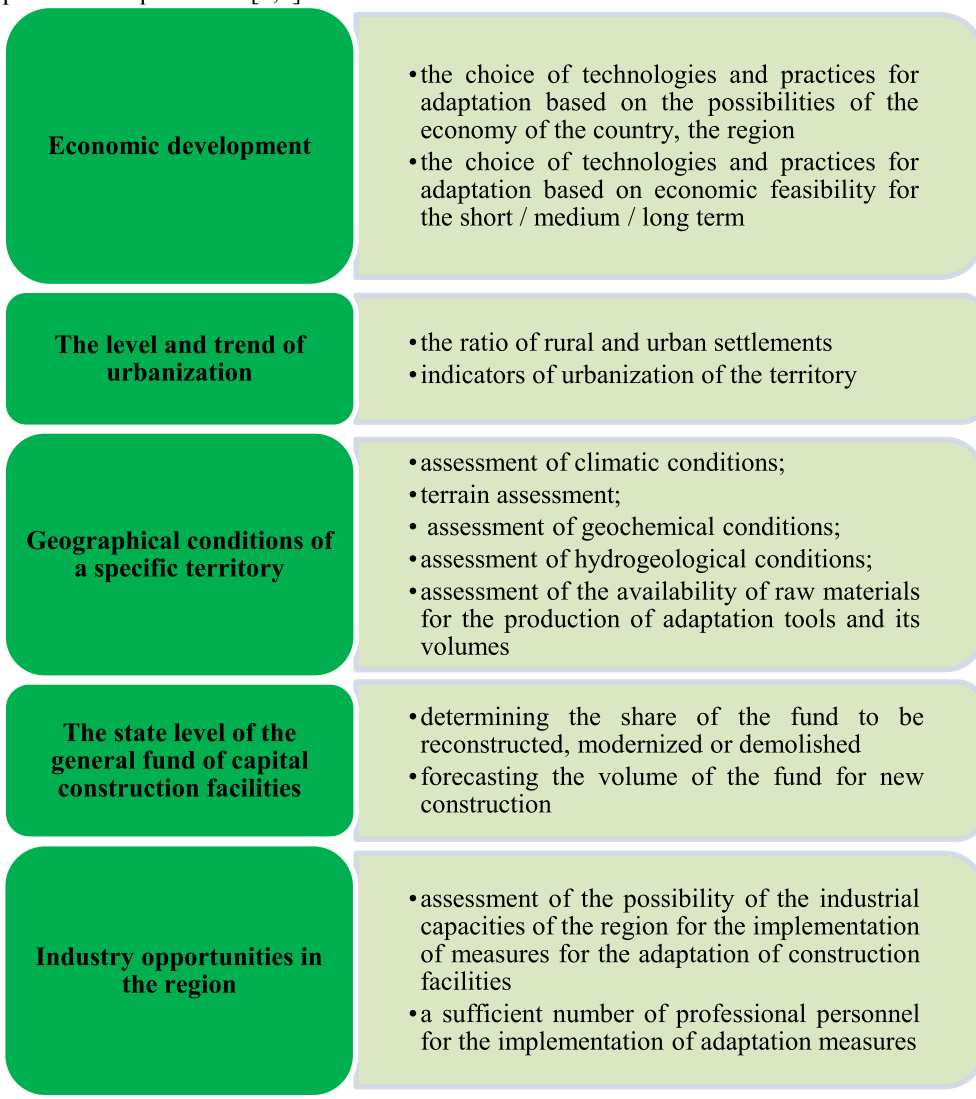

Fig.1. List of conditions to be assessed for implementation of adaptation and mitigation measures to mitigate the effects of climate change on construction sites.

Based on it, when implementing adaptation and motivation measures, it is necessary to organize a decision-making system for a comparative analysis of all possible typologies and practices for mitigating the effects of climate change. This will facilitate the work of the national technology needs assessment team in determining priorities for technologies relevant to a particular region [8,9].

3 Results

Considering the impact of climate change on the life cycle, we note that in Russia climatologists identify 4 consequences of climate change that directly affect the life cycle of construction projects (Figure 2). And at every stage of the life cycle of capital construction facilities, climate risk management involves the implementation of its own characteristic set of organizational and technological measures.

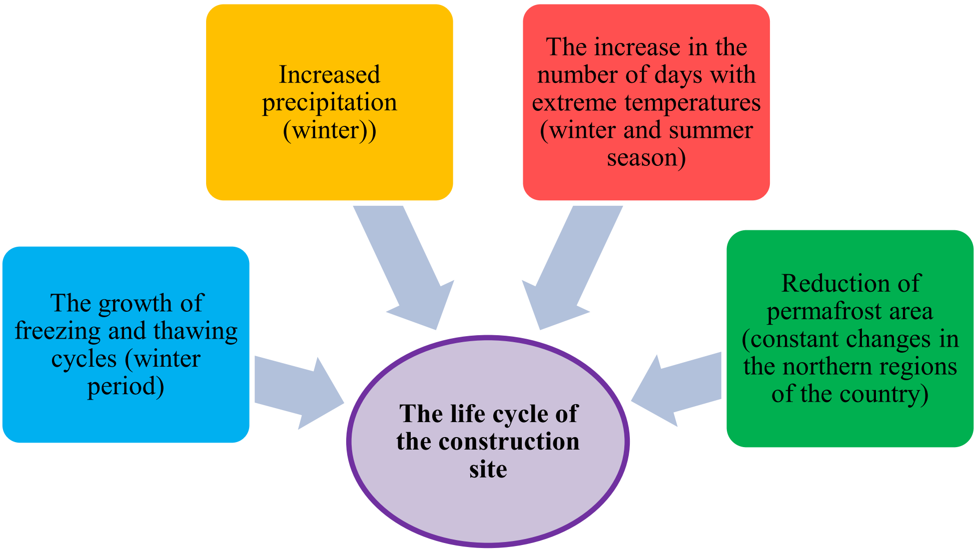

Fig.2. The consequences of climate change affecting the life cycle of a capital construction facility, typical for the territory of Russia.

A special feature of the pre-project stage of the life cycle is that it determines the direct negative effects of climate change characteristic of the selected construction area and climate zone. Consequently, the reliability and accuracy of the results of determining these influences will affect the adaptation of the future object at subsequent stages of the life cycle. At this stage, specialized climatologists are involved in collecting information and forming a database on climate change, its dynamics and development prospects. The collected information is then used to select design solutions and determine the amount of capital investments to adapt the planned capital construction project to implementation [10].

4 Discussion

At the design stage, various solutions and technologies are selected to minimize the specific impact of the weather phenomenon. So, in conditions of increasing freeze-thaw cycles and the increase in precipitation in the winter season, the logical solution is to select the least hygroscopic materials and a high brand of frost resistance in contact with the external environment. This will increase the service life of building materials and reduce operating costs and preserve the architectural appearance of the future building or structure.

The reduction in the area and volume of permafrost in the northern regions of the country, combined with the increase in precipitation in winter, can lead to the increase in the groundwater level to undesirable levels. In this regard, it is necessary to design the waterproofing of foundations and calculate subsidence for the future, even if at the time of design and construction the groundwater level is at acceptable levels. In addition, it will also be necessary to calculate the load-bearing capacity of the roof, taking into account the increase in the amount of snow and liquid precipitation in winter [11].

Due to the increase in the number of days with extreme temperatures, both in winter and in summer, it is important to provide an individual heating and air conditioning system for the building, design it in accordance with the requirements of construction, sanitary norms and rules to ensure the required level of comfort, taking into account energy saving. Automation of heating and air conditioning systems is aimed at organizing the operation of systems depending on the outdoor temperature to create an optimal temperature regime inside premises with permanent or temporary long-term stay of people. In addition, it is necessary to introduce multilayer enclosing structures with the use of highly efficient energy-saving insulation materials in their composition.

With the increase in the number of days with extreme temperatures, it is necessary to optimally orient the capital construction object to the cardinal directions and design translucent structures taking into account changes in the zenith position of the Sun in winter and summer. This will create conditions when in winter the sun's rays will enter the room through light openings, and in the summer season they will be excluded [12].

As a result of the increasing frequency of weather events due to climate change, many technological solutions should be designed with a long-term bias in accordance with the planned service life.

The situation associated with the increase in the number of temperature fluctuations above and below zero, as well as the increase in days with extreme temperatures during construction work requires the use of concrete heating technologies during transportation to preserve the quality of the delivered products and perform concrete work in winter.

The increase in precipitation combined with the above-mentioned weather events will require planning the transportation of materials and work taking into account the weather forecast to eliminate downtime. Also, in conditions of precipitation growth, it is important to use closed sites for long-term storage of building materials, as well as equipment of workplaces with temporary roof structures with a large slope to exclude the sticking of wet snow. It will keep the workplace dry and eliminate heavy loads on the temporary roof due to wet snow [13].

Also, the reduction in the area and volume of frozen soils, combined with the increase in precipitation, can lead to the increase in the groundwater level at the construction site, including creating a threat of flooding of the pit, as a result of which it is necessary to install temporary storm sewer networks and drainage wells on the construction site along its perimeter and along temporary roads.

To ensure the comfort of the working personnel involved in the construction site, it is preferable to place temporary buildings in the shade when construction work is carried out in a hot climate, as well as use temporary buildings with multilayer enclosing structures [14].

The adaptation of a capital construction facility to climatic changes at the stage of its operation is characterized mainly by organizational and technological measures. In conditions of the increase in precipitation in winter, the increase in freeze-thaw cycles, as well as reduction in the area and volume of permafrost in the northern regions, it is necessary to organize monitoring of the groundwater level during the entire service life of a building or structure, monitoring violations of the strength and physical properties of structural elements of a construction object and the device with subsequent operation of drainage wells and stormwater sewers on the territory. In situations where outdoor temperatures have reached unfavorable values, it is important to optimize the operation of heating and air conditioning systems to ensure the required level of comfort while maintaining or reducing energy consumption [15,16].

5 Conclusions

Thus, it is especially important to develop and carry out measures to adapt the construction site to climatic conditions, to introduce technologies to mitigate climate risk in the most appropriate and cost-effective way at the initial stages of the life cycle of the construction object, when the object itself exists virtually. In this case, additional budget and time costs will not be required to change the design documentation, as well as to stop its operation and change the technological processes occurring in the construction site at the operational stage.

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