«Green roofs» of Public Buildings to Form a Biosphere Compatible Safe Urban Environment

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Abstract. The article is devoted to the study of the possibility and necessity of "green roofs" on public buildings in the territory of large cities to preserve and replenish depleted part of nature, which was used as a place for a construction site. The basic principles of creating a sustainable city by restoring one of the most important functions of the city – "connection with nature" and natural resource conservation. The experimental method of research and study of "green roofs" from the position of the transformation of the city into a biosphere-compatible one, confirming the theoretical calculations. The retrospective shows the evolution of changes in the composition and design solutions of "green roofs".

1. Introduction and the urgency of the issue

The use of natural resources leads mankind to their serious depletion and even the disappearance of its part [1]. It also applies to green spaces, which are vital for human health and life. [2]. During the evolution the Man intuitively felt the need to restore the green cover of the earth in those places where houses had been arranged. The first mention of green spaces on the roofs were the ziggurats towers in an ancient Sumerian state of Iraq (2113 BC), the mausoleum of Augustus in Rome (28 BC), the Medici Villa with a roof garden (1400), hanging gardens in Nornberg (the middle of the XV century), the Italian garden on the island of Bella (XVII century) and many others. In the middle ages, green roofs spread around the world only on low-rise buildings (Figure 1).

In the second half of the twentieth century green roofs spread in such countries as Germany, Belgium, great Britain, Vietnam, Holland, Spain, Canada, China, Lithuania, Malaysia, Mexico, Poland and many others, and now have achieved significant results (Figure 2).

The international scientific Congress Resolution V "Globalistics-2017: global ecology and sustainable development" stated that "the most important task of ensuring global security is to achieve the biosphere compatibility of man and nature" [3]. In order to form a biosphere-compatible safe urban environment it is necessary to focus on the preservation of all the necessary functions of any city [4]. One of them is the "connection with nature". It is a fundamental function for everyone else (creativity, knowledge, mercy, power, entertainment, and life support). Research of the last three decades has shown that the destruction of the natural environment in the creation and expansion of major cities will lead to the following factors:
Figure 1. Green roofs of houses in the middle ages: a - Sod roofs over wooden houses in Tysfjord, Norway; b - Farm Almen, Norway; c - Carpathian mountains, Romania; d - Germany; e - Faeroe islands; f - New Zealand; g - Iceland; h - Norway; g - Hayman Island, Iceland. (https://kvartira.mirtesen.ru/blog/43396147018/Travyanyie-i-dernovyie-kryishi-

Figure 2. Green roofs of houses in the twentieth century: a - Germany; b - Antwerp, Belgium; c - Office building, London, United Kingdom; d - Hotel, Da Nang, Vietnam; e - Roof garden, Paris, France; f Residential complex "Fusion Park", Amsterdam, Holland (http://www.krovlierussia.ru/rubriki/materialy-i-texnologii/zarubezhnyj-opyt-principy-)
- climate changeability of the earth's shell (ingredient air pollution and occurrence of smog, acid precipitation);
- reducing the amount of oxygen;
- an increasing in the density of dust at ground level;
- acoustic pollution of urban areas (noise levels in large cities have doubled over the past 10 years [5]);
- formation of greenhouse effect, ozone layer destruction in the stratosphere;
- loss of birds in areas with large loss of green cover (loss of biodiversity);
- loss of the most important function of any city – "connection with nature", giving health, positive emotions, physical and mental peace and, ultimately, long-term performance .

In parallel with the ongoing active urbanization and a sharp reduction in the natural area occupied by forests and lawns, there are typical factors of regressive urban development, which are reflected in the reduction of the population and its aging, high mortality, high levels of infectious diseases throughout the year, a decrease in immunity and the emergence of new diseases [6].

In this regard, it is necessary to think about the speedy and full restoration of lost plantations [7-11]. Herbal cover delays in 3-6 times more dust, and the forest-in 10 times [12]. One hectare of lawn can hold about 600 kilos of dust. Herbal cover produces oxygen saturated with ions with a negative charge. This has a beneficial effect on human respiratory system. Only one undersized tree can provide oxygen to three people.

According to remote sensing data [13] the area of green space in Moscow has decreased by 1.5% over the last decade. At the same time, the indicator of the Central part of the city is only 16%, it means the lowest of all administrative districts of Moscow.

To restore the balance of the city with nature it is necessary to pay special attention to the possibility of using huge areas of roofs of public buildings occupying about 21% of the entire territory of the city in Moscow, which is evident from the comparison of the 1996 master plan of the city and the increase in these areas every 15 years by 5% according to the Moscow development plan until 2025 [14].

The intensification of urban spaces use for new construction sites and reconstruction of existing ones makes us think about the new format in the environmental construction of large cities.

For the implementation of the principle of the city transformation in biospherically one requires the creation of normative documents based on knowledge and research.

In 1990 the British system BREEAM (Building Research Establishment Environmental Assessment Method) was introduced, and in 1998 the American rating system LEED appeared, which are the world standards for measuring projects of energy efficient, environmentally friendly and sustainable buildings for the transition of the construction industry to the design, construction and operation of such buildings. World Green Building Council was established in 2002 and the Russian Green Building Council (RuGBC) has been entered in operation since 2009.

2. Materials and methods

For research and confirmation of necessary relevance of "green roofs" creation the experimental installation is created on the example of buildings of public appointment with the area of roofs more than 500 m². It helps to define comparative efficiency of a roof with green plantings in relation to traditional (by the example of comparison of experimental results and theoretical calculations of three types of multilayered systems of "green roof") (comparison of heat resistance of the investigated roofs).

The comparative calculation has been made for the complex of buildings roof in Tula (figures 3-6). The proposed project coating has a total heat transfer resistance equal to 4.62 m²K / W. The greening of the coating in accordance with the three presented options will lead to an increase of this value by 22%, 8% and 6% respectively.
Figure 3. The original roof. $R_0 = 4.62 \text{ m}^2\cdot\text{K}/\text{W}$

Figure 4. Greening №1. $R_1 = 5.62 \text{ m}^2\cdot\text{K}/\text{W}$
1. Anti-root film
2. Protective Mat
3. Floradrain 40
4. System filter
5. Substrate

Figure 5. Greening №2. $R_2 = 4.90 \text{ m}^2\cdot\text{K}/\text{W}$
1. Anti-root film
2. Protective Mat
3. Floricet 75 – 2 layers
4. System filter
5. Substrate

Figure 6. Greening №3. $R_3 = 5.62 \text{ m}^2\cdot\text{K}/\text{W}$
1. Anti-root film
2. Protective Mat
3. Floradrain 25
4. System filter
5. Substrate

3. Conclusions

Installation of additional layers for the creation and effective operation of the “green roof” leads to the following results:
- air quality improves: 150 m$^2$ of grass roof provides annual oxygen demand for 100 people [15];
- temperature conditions in major cities are improving [16];
- stormwater runoff is cleaned and rationally used [17] in urban areas: a 40 cm thick layer of soil covered with grass holds up to 20% of atmospheric precipitation;
- the noise and dust level is reduced (from 2 to 10 dB) [18];
- restoration of biodiversity of urban birds is created;
- additional exploited areas are created: they can be places of rest for the population;
- appearance of buildings and urban development improves;
- an opportunity to save on heating and air conditioning appears:

the possibility of reducing the insulation layer in Russian cities depending on the average annual temperature of 3% in the cities with temperate continental climate (temperature in winter not lower than -30 °C, and in summer no higher than +30 °C, for example, Voronezh) and continental climate (temperature in winter not lower than -25 °C, in summer no higher than +25 °C) up to 6-7% in areas with temperate continental climate (for example, Moscow);
- service life of waterproofing is extended;
- investment attractiveness of construction is increased.

Comparative analysis of heat transfer resistance calculations is made for the same model in 18 cities of Russia with different climatic conditions. It is concluded that green roofs are most effective in high latitudes climate than in mid ones [19], where the thickness reduction of the insulation is more than 7%.

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