Artículo de investigación

The main historical development stages of accessible green roofs in the urban environment

Основные исторические этапы развития эксплуатируемых «зелёных» покрытий в городской среде

Las principales etapas históricas del desarrollo de recubrimientos "verdes" explotados en el entorno urbano

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Abstract

Contemporary accessible green roofs created by architects and landscape designers using special technologies have appeared relatively recently. But the idea of a green rooftop garden is by no means new. In the context of the increasing intensity of the use of urban areas and the resulting shortage of recreational spaces, the use of green roofs is seen as quite promising. In consequence of this fact, it is important to consider the historical retrospective with respect to the emergence and development of accessible green roofs.

Development of green roofs is conditionally divided by the authors into the following historical periods:

- Green roofs in the ancient world;
- Green roofs in the medieval period;
- Green roofs in the modern era;
- Green roofs in contemporary times.

In consequence of the study, the authors analyze the historical experience of the use of accessible green roofs in various countries and in different time periods. The authors consider examples of the accessible green roofs used for the organization of recreational and other functional zones, as well as confirm the urgency of

Аннотация

Современные эксплуатируемые «зелёные» покрытия, создаваемые архитекторами и ландшафтными дизайнерами с применением специальных технологий, появились сравнительно недавно. А вот сама идея «зелёных» покрытий - садов на крышах отнюдь не новая. Ввиду все возрастающей интенсивности использования городских территорий и возникающего в связи с этим дефицита рекреационных пространств применение «зеленых» покрытий видится перспективным. Вследствие этого представляется важным рассмотреть историческую ретроспективу появления и развития «зелёных» покрытий.

Указанное развитие объекта условно разделено авторами на следующие исторические периоды:

- «Зелёные» покрытия в Древнем мире;
- «Зелёные» покрытия в эпоху Средневековья;
- «Зелёные» покрытия в Новое время;
- «Зелёные» покрытия в эпоху Новейшего времени.

В результате исследования проанализирован исторический опыт применения

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application of such green areas in the contemporary city both on buildings' roofs, and over a street and road network, railroad sections, and other urban facilities.

Keywords: Accessible green roofs, rooftop garden, recreation, architecture, urban environment.

эксплуатируемых зелёных покрытий в разных странах и в различные временные периоды. Рассмотрены примеры использования эксплуатируемых покрытий для организации рекреационных и других функциональных зон. Подтверждается актуальность применения таких покрытий в современном городе как на крышах зданий, так и над улично-дорожной сетью, вводами железных дорог и другими городскими объектами.

Ключевые слова: эксплуатируемые «зелёные» покрытия, «зеленые» крыши, эксплуатируемые крыши, рекреация, архитектура, городская среда.

Resumen

Techos verdes accesibles contemporáneos creados por arquitectos y paisajistas que utilizan tecnologías especiales han aparecido relativamente recientemente. Pero la idea de un jardín verde en la azotea no es nueva. En el contexto de la creciente intensidad del uso de áreas urbanas y la consiguiente escasez de espacios recreativos, el uso de techos verdes se considera bastante prometedor. Como consecuencia de este hecho, es importante considerar la retrospectiva histórica con respecto a la aparición y el desarrollo de cubiertas verdes accesibles.
El desarrollo de los techos verdes está dividido condicionalmente por los autores en los siguientes períodos históricos:
- Techos verdes en el mundo antiguo;
- Techos verdes en la época medieval;
- Techos verdes en la era moderna;
- Techos verdes en tiempos contemporáneos.
Como consecuencia del estudio, los autores analizan la experiencia histórica del uso de techos verdes accesibles en varios países y en diferentes períodos de tiempo. Los autores consideran ejemplos de los techos verdes accesibles utilizados para la organización de zonas recreativas y otras zonas funcionales, así como confirman la urgencia de la aplicación de tales áreas verdes en la ciudad contemporánea tanto en los techos de los edificios como en una red de calles y carreteras. secciones de ferrocarril y otras instalaciones urbanas.

Palabras clave: Techos verdes accesibles, jardín en la azotea, recreación, arquitectura, entorno urbano.

Introduction

At all times, the city was functionally saturated space, which for one reason or another, as a rule, is limited in extensive development due to lack of territory. This circumstance led to a reduction in the area of primarily recreational green areas. It seems that the lack of urban areas to meet the recreational needs of citizens can be eliminated through the widespread implementation of accessible green roofs into the structure of the contemporary city. The development of modern construction technologies also contributes to the expansion of the practice in the application of green roofs (Dorozhkina, 2017; Slavin et al., 2018).

The practice of application of flat rooftop gardens is not new at all, and there is a rather long experience of application of such green areas in one construction form or another. Although in Russia green roofs are used rarely in residential and public buildings (Alekseev & Rodionovskaya, 1985; Popov, 2019), their application seems quite promising. For a more comprehensive understanding of the experience and practice of such green areas, it is important to consider the historical retrospective of their appearance in different countries, as well as their evolution.

Prerequisites for the use of green roofs in the ancient world

The first dwellings of prehistoric man, which was essentially a roof-hut made of vegetative matter, i.e. trunks and branches of trees, leaves, grass, and moss, can be attributed to the prototype of the green roof. For many centuries, wooden roofs of houses were covered with reeds, palm branches, straw, while in countries with a harsh climate, the roofs were insulated with a layer of earth with growing grass. The tradition of using a grassy surface in the structure of a wooden house has existed since ancient times in Sweden and Norway. Until now, in these countries, one can find peasant houses with a thick grass cover of a turf layer laid on top of birch bark (Fig. 1).

Figure 1. Grass roofs of wooden houses in Norway

The history of the grass-covered roof is quite old, while the art of creating real gardens on the flat surfaces of buildings and structures has been known for thousands of years.

The famous archaeologist Leonard Burey, during the excavation of the Ur ruins in the ancient Sumerian state in southern Iraq, discovered the remains of trees on the ziggurat towers, indicating that they grew there even in 2113 B.C. (Posobie po ozeleneniyu i blagoustrojstvu ekspluatiruemyh krysh zhilyh i obshchestvennyh zdanij, 2001).

The most daring example in terms of design and excellent landscaping of accessible green roof is the famous Hanging Gardens of Babylon, which are terraced gardens, erected six centuries B.C. Unfortunately, they have not survived to our time, but are considered one of the Wonders of the World (Fig. 2).

Figure 2. The Hanging Gardens of Babylon

According to legend, this masterpiece of architecture was built by Nebuchadnezzar, the powerful king of Babylon, for his beloved wife Amytis. In order that the Princess of Midia should have not missed the green hills of her native land in the stuffy and dusty Babylon, a real Palace was built, consisting of the four tiers covered with vegetation. Hundreds of tons of fertile soil were piled on vast terraces, and trees and bushes brought directly from Midia were planted in it. Hanging Gardens required thousands of liters of water for irrigation, and for this purpose, pipes were hidden in the thickness of the columns, which served to bring water from the Euphrates River to the top terrace by means of special blocks and dippers. For the inhabitants of Babylon, this building was a miracle, a beautiful green oasis in the middle of the desert (Saurova & Torchik, 1990).

Later, along with the culture of the East, the custom of planting flat roofs and balconies by potted plants, shrubs, and fruit trees came to ancient Greece and ancient Rome, where they even celebrated a holiday in honor of Adonis – the God of the beauty of nature. During the excavations of Pompeii and Herculaneum, buried under a layer of ash after the eruption of Mount Vesuvius, the remains of a garden on the roof of the arcade, which surrounded the Villa of the Mysteries in Herculaneum on three sides, were found (Fig. 3a).

Another unusual object of architecture, built in a year of 28 B.C., is the Mausoleum of Augustus in ancient Rome. This was a voluminous and at the same time modest building surrounded by a terrace with columns, looking out onto the roof with trees and evergreen cypresses (Fig. 3b).

a) **b)**

Figure 3. a) The Villa of the Mysteries in Herculaneum; b) Mausoleum of Augustus in ancient Rome

Features of the use of green roofs in the medieval period

With the heyday of culture during the Renaissance, green roofs constructed in the form of hanging gardens which belonged to kings, dukes, and other noble people, were enriched with outlandish plants and became a luxury item. The Renaissance era "transferred" the green roofs to Italy, Germany, and Sweden, were luxury rooftop gardens became especially famous. In Florence, as early as in 1400, exotic plants grew in the rooftop gardens of the Villa Medici, while in Mantua a huge hanging garden was built over the Palace of the Duke of Gonzaga. In 1487, the German Emperor Frederick III built a hanging garden with vineyards, flower beds, and fruit trees in Nuremberg in the southern part of his castle. A little later, in Germany, a two-tier garden was created on the roof of the Palace of Archbishop Johann-Philipp in Passau. The garden was dominated by flower beds, while shrubs and trees were planted in tubs. In 1530, Cardinal Andrea della Valle has built in Rome the Museum in the form of the hanging garden, while Count Marafey has set up a beautiful garden with a large variety of vegetation on the roof of his palace in Verona. Also, a green roof of the Carlsberg Castle in Sweden became known at this time (Titova, 2003).

But the most luxurious creation in the medieval period, in the 16-17th centuries, was an Italian terraced garden on the rocks of the Isola Bella Island surrounded by the waters of Lake Maggiore. The island, named after Isabella d'Adda, the wife of the Milanese aristocrat Carlo Borromeo III, is quite small, it is just 320 meters long and 400 meters wide. Two architects – Francesco Castelli and Angelo Crivelli worked on the creation of the magnificent residence and all the beauty of the terraced gardens. According to their project, the Italian garden was divided into ten terraces, which were decorated with fountains, statues, and niches (Fig. 4). Today, the unusually beautiful island has become a popular destination for tourists, while the garden of Cardinal Borromeo, which contains plants from almost all over the world, serves an example of landscape art of the Late Renaissance (O-p-i.ru, 2019).

Figure 4. Terraced gardens on the Isola Bella Island in Italy

The use of green roofs in the modern era

The beginning of the modern era was marked by great changes in both Russian and world architecture. Green areas, flower beds, and gardens on the roofs started to appear in Russia just in the 17th century. Metropolitan Jonah ordered to create a garden on the second floor of the Rostov Kremlin. The supports of the hanging garden were massive vaults and ceilings, which were covered with lead plates for water resistance. Such gardens were arranged in boyar

estates and estates of the highest clergy. For their beauty and originality, they were called Red.

But the Upper and Lower embankment gardens of the Moscow Kremlin are especially beautiful. The Upper Garden was built in 1623 by the gardener Nazar Ivanov on the vaults of the corner building of the Palace overlooking the Moscow River. It consisted of five consecutive flower arrangements and included an additional terrace on another level. The terrace was surrounded by a stone fence with windows through which one could admire the valley of the Moscow River and the panoramas of Zamoskvorechye. Later, in 1687, a pond with a depth of 1.42 m was built in the Upper Garden, and a water tower with a special mechanism for filling it with water from the river to supply the garden with water was built. This water tower is preserved to this day.

In 1681, at the times of tsar Alexei Mikhailovich, a Lower Garden was arranged, located near the Upper Garden on the slopes of the Kremlin hill at the Tainitsky Gate. Perimeter walls of the garden were decorated with prospective paintings of faux vegetable motifs, written by master Peter Angeles, which visually expanded the space of the garden. Ponds, painted gazebos, fountains, greenhouses for vegetables and flowers were placed in the territory of both Lower Garden and the Upper Garden (O-p-i.ru, 2019).

The hanging gardens of the Moscow Kremlin existed until the end of the 17th century when the construction of a new Kremlin Palace designed by V.I. Bazhenov was undertaken in 1771.

In Moscow, in the 17th century, gardens of boyars V. Golitsyn and A. Ordyn-Nashchekin were no less famous. A distinctive feature of these gardens was a combination of practical benefit with artistic merits. The coolness created by the transparent light shadow of the birches loved in Russia was complemented by the floral aroma, birdsong, and colorful architectural details (Alekseev & Rodionovskaya, 1985).

The layout of the above-ground gardens in the 17th century was very simple: several paths at right angles with planted flowers (peonies, roses, lilies, and tulips) grown in the areas between the paths, as well as various varieties of apple trees. In winter, the trees were covered with matting and felt to protect them from the cold.

For its time, the Kremlin above-ground gardens in Russia were no less wonder of the world than the famous Hanging Gardens of Semiramis.

Over time, in the 18th century, hanging gardens appeared in St. Petersburg, the north-west capital of Russia. In the period from 1764 to 1769, the architects Y.M. Felten and J.-B. Vallin de la Mothe created the first hanging garden in the Winter Palace, placing it on the stone vaults of the Palace stables at the Small Hermitage (Fig. 5). The garden is surrounded from all sides by the walls of the Palace and resembles an open-air gallery. All the plants, flowering trees, and shrubs have been selected so that the garden is colored with different colors from spring to autumn due to the endless change of flowering and fruiting. The hanging garden of the Small Hermitage still exists, although in the hard years of the siege of Leningrad, as well as the entire Winter Palace, it served a target for Nazi artillery, while the Hermitage staff broke garden beds in it to grow vegetables (O-p-i.ru, 2019).

Figure 5. The Hanging Garden of the Small Hermitage in St. Petersburg

At the end of the 18th century, a similar hanging garden was created by Charles Cameron in the Tsarskoye Selo, a country residence of the Russian tsar (Fig. 6). It was built at the level of the second floor of the Zubov Wing of the Catherine Palace. When building a terrace, waterproofing was made from sheet lead purchased in England and a thick layer of earth was poured for planting garden plants. There were apple trees, lilacs, jasmine, and roses. While tulips, peonies, and daffodils were planted around the bushes (Bessonov, 1988).

Figure 6. The Hanging Garden of Catherine Palace in Tsarskoye Selo

In the second half of the 18th century, when fires raged in Russia, the architect N.A. Lvov drew the attention of homeowners on the grass or turf roofing of wooden buildings, which, along with the flame retardant rammed-earth constructions, protected them from the fire. Even a special treatise published by S.F. Ushakov in 1772 was devoted to the construction of such roofs.

Green rooftop gardens remained for a long time the prerogative of the nobility and rich people, and only in the 19th century, due to the emergence of new building materials and structures, they got massive development.

In 1839, the hanging garden was built in the estate Marfino near Moscow (architect M. Bykovsky), and soon accessible green roofs appeared in Moscow in the Morozov's mansion on Vozdvizhenka street (architect V. Mazyrin) and in Perloff's house on Myasnitskaya street (architect R. Klein). In St. Petersburg, since the late 19th century, hanging gardens began to appear on the roofs of apartment houses: in the house of Zaitseva on Furshtadskaya street (architect M. Bogomolov), in the Orlov's house on Voznesensky Avenue (architect I. Markelov), etc.

"Rationally traditional pitched roofs should be replaced by flat roofs using them for leisure and housework" − claimed in the 18th century a famous scientist and builder Paul Marberger. And half a century later, in the late 60s of the 19th century, the garden was built by the famous Berlin Builder, mason and inventor Carl Rabitz in his house on Invalidenstrasse 66 in Berlin that became a real sensation. His garden consisted of two parts: one part of the roof was used as a place for friendly meetings, while the other was used as a vegetable garden, which was represented by the beds of growing vegetables (pumpkins), herbs (melissa), and flowers (fuchsia, phlox, roses, dahlias, etc.) (Fig. 7) (Posobie po ozeleneniyu i blagoustrojstvu ekspluatiruemyh krysh zhilyh i obshchestvennyh zdanij, 2001).

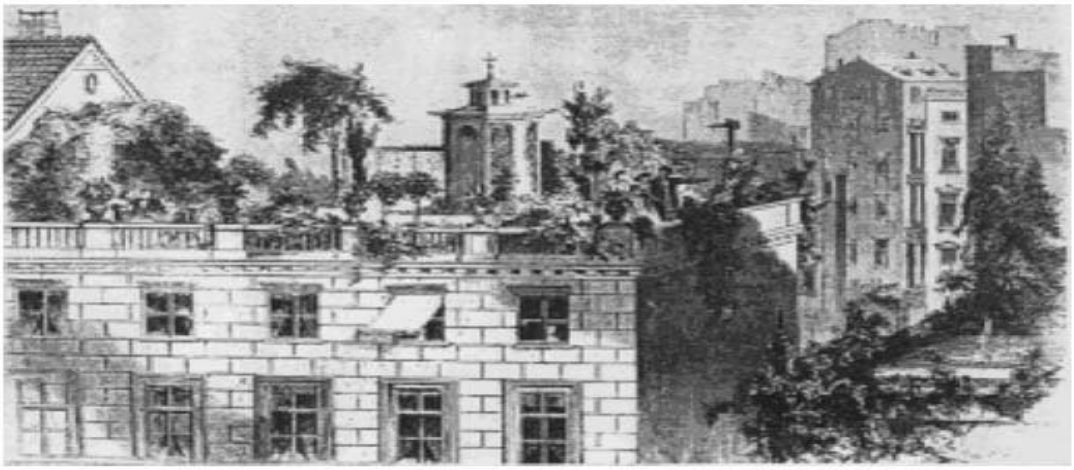


Figure 7. Naturdächer von vulkanischem Cement (Natural roofs of volcanic Cement) of Carl Rabitz

Believing in the success of his creation and the prospects of building rooftop gardens, in 1867 Carl Rabitz presented his project called Naturdächer von vulkanischem Cement at the world exhibition in Paris.

After the exhibition, the Leipzig newspapers have published rave reviews: "...This design is not much more expensive than a roof covered with tar paper or roofing and is much cheaper than brick, slate, and iron roofs... The roofs, which previously were used only by cats and only had the grey color will be replaced with lawns, will create extra space for relaxing and socializing between people... We're waiting for the architects to start using this decoration of homes in the construction. There is no doubt that the soaring gardens will find practical application in modern and future construction" (O-p-i.ru, 2019).

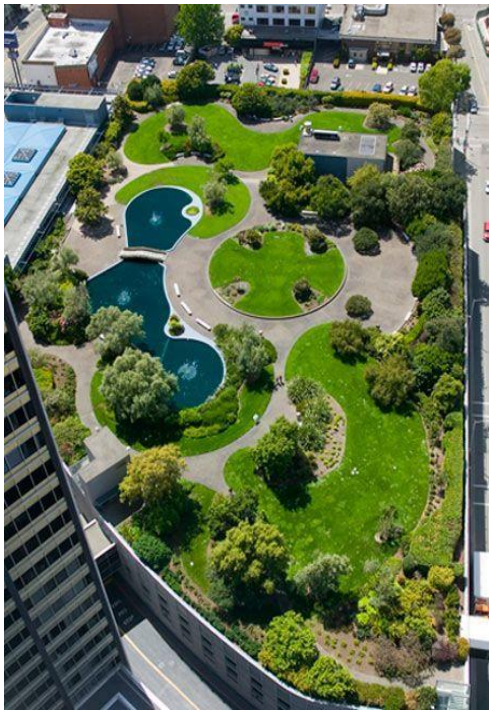
An integral component of the living environment − accessible green roofs in contemporary times.

At the beginning of the 20th century, accessible green roofs became again of increased great interest. The theoretical works and architectural projects of Le Corbusier and Frank Lloyd Wright made a huge contribution to their development. Le Corbusier formulated "five starting points of modern architecture", two of which were related to the accessible roofs for green spaces; these were supporting pillars and flat roof terraces. "Before – writes the architect – the house was beaten into the ground... The concrete gives us individual supports. Now the house is in the air, high above the ground, under the house is a garden, and on the roof of the house is also a garden." The first principle is the ability to use the free space under the building, not occupied by structures. The second principle is the ability to increase the area of the house due to the accessible roof area. It is the second principle that modern architects adhere to, while Le Corbusier himself implemented many projects based on this principle – from small villas to large residential complexes (Residential Unit in Marseille, a single residential complex in Reza Nantes), which have accessible green roofs (Le Corbusier, 1970).

Having inspired by the ideas of Le Corbusier, other famous architects began to implement similar projects in many countries. In 1914, the German architect Walter Gropius has built in Cologne office building with a restaurant and a rooftop garden, while in the United States, at the same time, no less famous American architect Frank Lloyd Wright has designed in Chicago a large restaurant with accessible green roof. In 1938, the architect Ralph Hancock developed one of the largest (0.6 hectares) in Europe garden complex called Derry and Toms on the roof of a six-storey house on Kensington High Street in London. (Fig. 8a). In 1956-1957, the British architect Geoffrey Alan Jellicoe created an unrivaled water garden on the roof of a department store in Guildford, the Sky Garden, as the architect called it. The garden included vegetation, recreation areas, and fountains hovered over the city business center at an altitude of more than 30 meters (Fig. 8b).

a)

b)



c)

Figure 8. a) Derry and Toms Garden complex on the roof of a six-storey building in London; b) Water garden on the roof of a department store in Guildford; c) The rooftop garden of the Kaiser Center five-storey garage in Auckland

In the late 50s of the 20th century, landscape architect Theodore Osmundson (USA) designed one of the largest gardens (12,000 m2) on the roof of the five-storey garage of the Kaiser Center in Oakland, which was distinguished by the abundance of greenery, flowers, and herbs, and free contour of the water basin that create the illusion of a picturesque park (Fig. 8c).

Later, Osmundson said about rooftop gardens:

"The rooftop garden, especially located above ground level, is like a tranquil island in an urban jungle. A sense of isolation from the traffic, noise, dust, and total disarray typical of a downtown street appears in most rooftop gardens above ground level. This is one of their main properties, which is rarely achievable in a city park at ground level. One of the significant qualities of almost all above-ground rooftop gardens is their silence. Street noise bounces off the walls of buildings and bypasses the roof level. In addition, a distant view of the surroundings of the garden can give the feeling of being in the suburbs. One of the most common responses of those visiting a rooftop garden for the first time is a pleasant surprise that there is such a quiet natural place in a busy city…"

In the context of Russia, in the early 20th century, accessible green roofs have become a kind of fashion in Moscow. Perhaps, the impetus for this was given by an article written by the famous journalist I. Vasilevsky, who returned in 1911 from Leipzig. He wrote that the roofs of many buildings in Germany "give what the mass of the urban population does not have □ clean air, sun, light, and warmth... The rooftop garden on one of the big houses in Leipzig has a size that gives the owner even strawberries, raspberries, cauliflower, and undersized fruit" (Restaurant-keeper, 1911, 14, p. 4) (O-p-i.ru, 2019).

In 1912, the owner of the restaurant on Dorogomilovskaya street created rooftop garden on the roof of his house for restaurant visitors, while in 1913, a more substantial garden with grottos and fountains was designed on the cafe roof on Kalyaev street. The roofs of the houses, at that time the highest in Moscow, began to be used as viewing decks (for example, the roof of the Izvestia Publishing House on Pushkin square, 1927). One striking example is the first ten-storey building in Moscow built in Bolshoy Gnezdnikovsky lane and designed by the architect E.R. Niernsee. The flat roof was surrounded by parapets in the form of arches,

along which tubs with bushes and containers with flowers were placed. In 1930, the garden was supplemented by café, Roof summer cinema, and a playground, where the boys played football in the summer. And in 1977, the roof of the Niernsee house became known to every Soviet TV viewer – here the events of the "Office Romance" movie were unfolded (Fig. 9).

Figure 9. Film frame of the Office Romance movie: the very same roof of the building in the Big Gnezdnikovsky lane in Moscow

In the 20s, accessible green roofs have become an integral component in the organization of the living environment, which was given a theoretical justification by Soviet constructivists (Vesnin and Golosov brothers, I. Leonidov, M. Ginzburg, A. Kuznetsov, N. Milyutin, etc.). In 1923, the accessible green roof of an eight-storey house on Spiridonovka street was adapted for children's playgrounds, protected by metal grids, where flowers and low shrubs were planted in vases and boxes, as well as plants potted in tubs placed outdoors in the summertime. In 1926, according to the project of M. Ginzburg, a huge solarium and a garden with flowering rose bushes were installed on the roof of a new residential building on Malaya Bronnaya Street. Later, a similar roof-solarium was built on a six-storey building on Khavskaya street.

Unfortunately, the Great Patriotic War has made adjustments to the development of the architecture of accessible green roofs and stopped the creation of rooftop gardens for many years. In the 60s and 70s, the design and construction of green roofs were carried out occasionally. But architects still managed to build several buildings with green roofs in post-war times. So, in 1976, in Minsk, an apartment house was built (architect G. Sysoyev, and engineer N. Cusco), consisting of two blocks of 14 and 16 floors, where on the roof of the first block, a two-tiered garden with a staircase was designed. Various trees, shrubs, and flowers were planted in concrete vases and containers, placed on both terraces. Thus, the entire garden was perceived from below as the architectural completion of the building. For several years, this green oasis was used to carry out studies on the characteristics of the microclimate, which showed its sufficient comfort and allowed drawing a conclusion about the feasibility of using accessible green roofs in urban development to meet the recreational needs of residents (Zelenaya krovlya, 2012; Soskov, 1983; Anikin & Sysoev, 1978; Zabaluyeva, 2017).

Figure 10. Example of the design of tunnel gallery over a city street and the creation of pedestrian boulevard on its upper covering (North Chertanovo, Moscow)

The overall architectural and spatial structure of the urban areas of the experimental microdistrict of North Chertanovo, located in the Southern Administrative District of Moscow near the Bitsevsky Forest Park, at the intersection of Balaklava avenue and Chertanovskaya street, allowed incorporating the accessible green roof into the urban environment. The residential area has a high architectural and urban development potential due to the components of the landscape, such as the natural height difference (about 30 m) which allowed the architects to implement effective zoning of space and interconnection within the residential neighborhood, designed for 20 thousand inhabitants with a total area of 77 hectares, combined with the attractiveness of border green areas (Fig. 10).

The upper tier is reserved entirely for pedestrians and cyclists, while under it, in the lower tier, semi-underground sections of streets and driveways for traffic are laid. Also in underground space, over the entire area of the residential district, except engineering and operational facilities of all types, underground garages with total capacity of about three thousand cars, as well as warehouses and utility spaces of the serving enterprises are designed. The garbage collection system is also located in the underground space and is designed using an innovative for its time network of pneumatic pipes and garbage chutes, connecting the houses with the compressor station of garbage disposal. The garbage disposal station itself is located on the south-west border of the residential area and is hidden by greenery.

Similarly, the natural height difference of the landscape was taken into account when constructing buildings and structures. Thus, fan-shaped houses were erected on the upper terrace, while public commercial institutions are situated on the lower terrace. The natural boundary between these two zones within the residential area is the parade promenade, under which a semi-underground tunnel gallery, which serves main engineering and transport artery of the residential area, is laid. The one-way traffic is counterclockwise. The height of the tunnel in the light is 3.8 m.

Figure 11. Moscow International House of Music

In 1999, in Moscow, on a roof of the Botanical Garden of Moscow State University a garden was created, where now research of various types of plants is carried out to optimize their selection for gardening of house roofs. For example, linden, rowan, thuja, juniper, and ornamental shrubs were chosen for the garden of Moscow International House of Music (2003), where greenhouse and exotic plants grow, while outdoor plants are grown on the roof. This object has become one of the most successful solutions among the new rooftop gardens in Moscow (Fig. 11) (Posobie po ozeleneniyu i blagoustrojstvu ekspluatiruemyh krysh zhilyh i obshchestvennyh zdanij, 2001).

Conclusion

Thus, having considered the green roofs in different historical periods, one can conclude that they were used in both the ancient world and the middle ages, as well as in the modern era and nowadays. Almost always, such green roofs were created and used as additional recreational spaces, both private and public. These facilities were not used widely in cities until the late 20th, early 21st centuries, and were occasional and exceptional in nature.

It seems that currently, green rooftop gardens are becoming of particular relevance primarily for the creation of green recreational spaces in a high-density urban environment characterized by a shortage of territory. The use of such green areas is promising both on the roofs of buildings and over the street and road network, railroad sections, and other urban facilities.

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