UDC 504:712

Tetyana M. Tkachenko, Ph. D. in Biology, Associate Professor, Doctorate in the Department of Occupational Safety and Environmental Protection
ORCID ID: 0000-0003-2105-5951 ***e-mail:*** *tkachenkoknuba@gmail.com*

Kyiv National University of Construction and Architecture, Kyiv, Ukraine

CREATION OF ENERGY EFFICIENT «GREEN STRUCTURES» IN CONDITIONS OF MODERATE CONTINENTAL CLIMATE

Abstract. *The main aspects of creation of energy-efficient «green structures» in urbocenoses of moderate-continental climate are considered. It was established that problems of exploitation of "green roofs" arise in case of violation of the technology of laying roofing layers and in case of incorrect selection of plant assortment. Technical problems in creating "green roofs" arise when the wrong choice of waterproofing. There should also be a single drainage system, which accommodates all other elements. Failure to observe these conditions may lead to rooting and the development of microorganisms. The assortment of plants on an intensive roof is usually limited to low-growing plants: herbs, shrubs and shrubs. Phenological observations carried out on the intensive roof of the Royal Tower residential complex in Kyiv have shown that with the correct selection of plant assortments and their cultivation technology, plant height can be considerably larger: from 4 to 6 m, which significantly expands the ecological and biological capabilities of intensive green roofs moderately-continental climate. The assortment of species of plants with high adaptive potential of various life forms with a wide variation of height is proposed: from low-growing herbs to trees of 6 m in height: Quercus paludosus multicaulus, Quercus rubra multicaulus, Pinus sylvestris, Acer rubrum, Acer rubrum 'Scanlon', Chenomeles Maulei, Arónia melanocárpa, Berberis thunbergii, Betula pumila, Crataegus laevigata, Vitis amurensis, Parthenocíssus tricuspidáta, Cornus alba, Picea abies, Picea canadensis, Picea pungens, Lonicera alpigena, Lonicera caerulea, Salix caprea, Viburnum opulus, Cotoneaster lucidus, Acer tataricum, Acer ginnala, Elaeagnus argentea, Juniperus horizontalis, Juniperus sabina, Sorbus aucuparia, Ribes aureum, Symphoricarpos albus, Pinus mugo, Spiraea arguta, Spiraea japonica, Thuja occidentalis, Philadelphus coronaries, Mālus sibirica, Malus niedzwetzkyana.*
Key words: *«green structures»; «green roofs»; adaptive potential; assortment of plants; «layered» design.*

Introduction

One of the problems of modern cities is the lack of free territories. The expansion of cities horizontally and vertically inevitably leads to the reduction of green zones, the growth of motor transport communications, and the consolidation of development. As a result, landscape modification, sharp decline in biodiversity, pollution of soil, air and water. Environmental tension in the urban environment has a negative impact on the people's health. Unfortunately, due to the densely built up (especially in the central regions), it is impossible to create a full-fledged recreational zone. A way out of the current situation can be the use of «green construction» – «green roofs», «green slopes», vertical landscaping, eco-parking. The advantages of «green constructions» in the possibility of their use in the already built up territories, as they

do not require additional space, but may be located on already created objects: roofs and facades of buildings, built up slopes. At the same time, they fulfill not only aesthetic, but also economic and ecological functions [1, 2].

Analysis of researches and publications

Nowadays, the energy saving of the roof is achieved not only through the use of building and finishing materials, but also with the help of gardening.

All over the world, roofing gardening is given huge importance, raising this area in the category of the most relevant. In Germany, France, Canada, Japan, the United States, Switzerland, roofing landscaping during construction is mandatory. This direction is becoming relevant in Russia and Belarus.

Already, no one doubts the effectiveness of green roofs in megacities. The positive aspects of roofing gardening (effects of conditioning, noise insulation, sanitary and hygienic, aesthetic) almost completely cover the items of expenditure for their creation [3–9].

However, until now, when you build a garden on the roof, a number of problems arise.

The aim of the work is to study and generalize the problems that arise when creating and operating green roofs, as well as finding ways to solve them. We evaluated the general condition of plants after wintering visually on a five-point scale of Tumanov [10]: 5 – the absence of traces of plant death; 4 – slight damage of the tops of the shoots; 3 – 50% of damage, about half of plants die; 2 – 70…80% of damage, death of more than half of plants; 1 – complete destruction, or preservation of individual plants only. In addition, the ability of plants to tolerate unfavorable summer conditions, namely a strong increase in temperature, was determined. The condition of plants in this period was also determined visually on the same scale.

Material, main findings and their analysis

One of the main problems is a high level of humidity. Operated roofs should have increased moisture resistance and as low as possible moisture absorption. This is due to the fact that penetration of water vapor and moisture into the structure of the heater, multiple cycles of "freezing-thawing" ultimately lead to a loss of thermal insulation properties and destruction of the material [11, 12].

The bearing structures of the roof should maintain the weight of the soil layer and the weight of the plants extrapolated in time, other operational loads, usually unevenly distributed over the surface area, and wind loads.

Waterproofing materials can be destroyed under the influence of climatic, chemical and biological factors: temperature changes, aggressive effects of chemicals, microorganisms, destroying effects of the root system of plants. In addition, if in regions with a warm climate, traditional bituminous roofing materials serve long enough, then under conditions of a temperate continental period, the maintenance-free operation of these roofing materials is much shorter. Studies have shown that an ordinary bitumen membrane is able to withstand the roots of plants for no more than six weeks.

To increase the stability of waterproofing, special chemical preparations have been developed – anti root additives, which are introduced into the bitumen-polymer binder in the production process of waterproofing material and evenly distributed

throughout its thickness. They make the membrane completely impermeable to plant roots. Most of the existing bitumen-polymer waterproofing root-resistant materials for green roofs use this method of protection.

There is a variant of roof protection, in which copper foil is applied to the waterproofing membrane. In modern landscaping systems, the waterproofing function is performed by the polymer membrane.

Before installing the landscaping system on the roof of the old building, it is necessary to conduct an examination of the roof. If the roof needs repair, it is necessary to complete it before installing the landscaping system, since, unlike a conventional roof, repairing the multi-layer roofing cake of the green roof, in case of leakage, requires a lot of effort and money.

One of the vulnerabilities of green roofs is the contiguity to vertical surfaces. To avoid leakage in these places, the edge of the waterproofing layer should be raised along the vertical surface. The solution to these problems lies in the strict observance of project requirements. If the requirements are violated, leaks occur, the roof structure is destroyed, the soil and plants rot, and the vegetation layer dries (or freezes).

The problems that arise in the operation of green roofs, in general, come from improper installation or inaccurate calculation of the system load on the rafter and slabs. Some problems may occur if the seeds of trees fly to the roof, so any green roof still needs to be observed and periodically serviced to remove sprouting tree sprouts in their infancy. If seeds of herbaceous plants fall, then the sedum replaces them, because, in fact, it is a weed.

Under the system, the usual roofing cake is completed, which ends with waterproofing. Next comes the root protection film – a special dark film, which prevents the germination of roots in the waterproofing and supporting structures. The quality of the film is checked by the roots of flax. Flax is a plant with the most aggressive roots. In the case of a flat roof, a classic internal drainage system should be provided.

Correct selection of assortment of plants for green roofing is almost 70% of its successful operation. Each type of gardening («intensive» or «extensive») requires a certain range of plants. Plants should not be very heavy, the root system should not be very deep (so as not to damage the waterproofing and other layers of the roof). But the main thing is to take into account the climatic features of the region. Abiotic factors – a powerful load, increasing several times in height. From the correct selection of plants depends on their adaptation and survival.

In the temperate continental climate, when creating an «intensive roof», you can successfully use quince *Chenomeles Maulei*, *Arónia melanocárpa*, *Berberis thunbergii*, *Betula pumila, Crataegus laevigata, Vitis amurensis, Parthenocíssus tricuspidáta, Cornus alba, Picea abies, Picea canadensis, Picea pungens, Lonicera alpigena, Lonicera caerulea, Salix caprea, Viburnum opulus, Cotoneaster lucidus, Acer tataricum, Acer ginnala, Elaeagnus argentea, Juniperus horizontalis, Juniperus sabina, Sorbus aucuparia, Ribes aureum, Symphoricarpos albus, Pinus mugo, Spiraea arguta, Spiraea japonica, Thuja occidentalis, Philadelphus coronaries, Mālus sibirica, Malus niedzwetzkyana* [13].

The creation of gardens on green roofs has a great success. Creating a garden design, you can choose as a traditional geometric scheme, and create something like a flower border, with the inclusion of useful vegetable plants in it. Geometric schemes are simple, but very effective. The classical variant is a composition in a circle or in a square divided into sectors. It can be deployed both on the plane and in

elevated beds. On such beds the soil warms up faster and moisture does not stagnate. To ensure that the beds do not lose shape, they are framed with walls of various materials – wood, metal or brick. Many vegetable cultures are really beautiful. Leaf salads, beets, onions, effectively look and neatly tied tomato bushes look great. In its own way, powerful plants of squash and pumpkin are attractive, the main thing is to place all this correctly on the site. The design of the garden will be especially impressive if you select plants that are contrasting in color, shape and texture. For example, you can create a beautiful pattern, alternating the bushes of green and reddish salad or beets. As a soloist usually take large expressive plants, for example, ornamental cabbage. Her elegant, with a pink middle of a head, decorate any garden, and their coloring will become brighter every day until the late autumn.

We have studied the adaptation of plant species in a multi-storey residential building.

a

b

Fig. a, b – Intensive green roof of the residential complex Royal Tower, Kiev, 2016

Table – The observation of plant phenotype in Kiev

№ in order	Name	Height, m	Mark	Damage level, %
1	*Quercus paludosus multicaulus*	5	4	slight damage to the tips of shoots with complete restoration
2.	*Quercus rubra multicaulus*	6	4	slight damage to the tips of shoots with complete restoration
3.	*Malus multicaulus*	3	4	slight damage to the tips of shoots with complete restoration
4.	*Carpinus*	3,5	4	slight damage to the tips of shoots with complete restoration
5.	*Pinus sylvestris*	6,0	4	slight damage to the tips of shoots with complete restoration
6.	*Amelanchier lamarckii*	3,5	4	slight damage to the tips of shoots with complete restoration
7.	*Amelanchier lamarckii*	4,0	4	slight damage to the tips of shoots with complete restoration
8.	*Ácer platanoides 'Globosum'*	4,5	4	slight damage to the tips of shoots with complete restoration
9.	*Acer rubrum*	5,0	4	slight damage to the tips of shoots with complete restoration
10.	*Acer rubrum 'Scanlon'.*	6,0	4	slight damage to the tips of shoots with complete restoration
11.	*Ligustrum vulgare'Globosum'*	1,10	4	slight damage to the tips of shoots with complete restoration
12.	*Thuja occidentalis 'Smaragd'*	3,0	4	slight damage to the tips of shoots with complete restoration
13.	*Thuja occidentalis Brabant*	2,5	4	slight damage to the tips of shoots with complete restoration
14.	*Spiraea japonica Golden Princess*	0,40	4	slight damage to the tips of shoots with complete restoration
15.	*Spiraea japonica Goldflame*	0,40	4	slight damage to the tips of shoots with complete restoration
16.	*Spiraea japonica 'Little Princess'*	0,30	4	slight damage to the tips of shoots with complete restoration
17.	*Berberis thunbergii*	0,25	4	slight damage to the tips of shoots with complete restoration
18.	*Berberis thunbergii*	0,60	4	slight damage to the tips of shoots with complete restoration
19.	*Euónymus alátus*	1,50	4	slight damage to the tips of shoots with complete restoration
20.	*Hydrangea arborescens 'Annabelle'*	0,80	4	slight damage to the tips of shoots with complete restoration
21.	*Pinus mugo 'Pumilio'*	1,0	4	slight damage to the tips of shoots with complete restoration
22.	*Pinus mugo 'Pumilio'*	0,8	4	slight damage to the tips of shoots with complete restoration
23.	*Azalea rubra*	0,5	4	slight damage to the tips of shoots with complete restoration
24.	*Thuja occidentalis 'Danica'*	0,6	4	slight damage to the tips of shoots with complete restoration
25.	*Hydrangea anomala 'Petiolaris'*	1,5	4	slight damage to the tips of shoots with complete restoration
26.	*Parthenocíssus tricuspidáta*	1,0	4	slight damage to the tips of shoots with complete restoration
27.	*Physocarpus opulifolius 'Luteus'*	0,8	4	slight damage to the tips of shoots with complete restoration

Conclusions

Analysis of roofing gardening technology has shown that the success of the operation of the entire roofing structure depends on the quality of the waterproofing, the drainage layer and the proper laying of all layers. Difficulties with the operation of the "green roof" are associated with a violation of the technology of laying layers and improper selection of the range of plants.

The analysis of the phenological observations of the state of plants in the conditions of the temperate continental climate of Ukraine showed that all types of life forms of plants can flourish in multi-storey buildings: grasses, shrubs, semishrubs, trees. In this case trees with a height of 4 to 6 m showed a high adaptive potential. All plants came from the winter period with an index of 4 points, which indicates the preservation of decorativeness and vitality. The analyzed range of plants can be considered as promising for roofing gardening in the conditions of the temperate continental climate of Ukraine.

REFERENCES (TRANSLATED AND TRANSLITERATED)

1. Tehnoekologija: navch.posib. dlja vyshh. navch. zakl. / V.M. Udod, V.V. Trofimovich, O.S. Voloshkina, O.M. Trofymchuk. – Kyi'v: KNUBA, ITGIP NANU, 2007. – 195 s. (in Ukrainian)
2. Landshaftna ekologija: navch. posibnyk / A.Je. Kuskov, T.M. Tkachenko. – Makii'vka, Donec'k: vyd-vo Noulidzh, 2009. – 165 s. (in Ukrainian)
3. Tkachenko T.N. Vozmozhnost' sozdanija jenergojeffektivnyh jekologicheski chistyh zelenyh tehnologij v uslovijah Ukrainy // Stroitel'stvo, materialovedenie, mashinostroenie: sb. nauchn. trudov. Serija: «Sozdanie vysokotehnologicheskih jekokompleksov v Ukraine na osnove koncepcii sbalansirovannogo (ustojchivogo) razvitija, Vyp.81, GVUZ «Pridneprovskaja gosudarstvennaja akademija stroitel'stva i arhitektury». – Dnepropetrovsk, 2015. – S. 256–260. (in Russian)
4. Grant, G., L. Engleback, B. Nicholson, D. Gedge, M. Frith, and P. Harvey. 2003. (in English)
5. Brenneisen, S. 2003. The Benefits of Biodiversity from Green Roofs Key Design Consequences. In Proc. Greening Rooftops for Sustainable Communities: Chicago 2003.
6. Sutton R.K. Green Roof Ecosystems. – Cham: Springer, 2015. – 447 p.
7. Izumi C. Mori. Biomarkers of green roof vegetation: anthocyanin and chlorophyll as stress marker pigments for plant stresses of roof environments / C. Mori Izumi, S. Utsugi, S. Tanakamaru, A. Tani, T. Enomoto, M. Katsuhara // J. Environ. Eng. Manage., 19(1), 21-27 (2009)
8. Peck Steven W. Report on benefits, barriers and opportunities for green roof and vertical garden technology diffusion / Steven W. Peck, Callaghan C., M. E. Kuhn, B. Bass – Canada Mortgage and Housing Corporation, 1999. – 77 p.
9. Minke whales, G. und Witter, G.; Haeuser mit Gruenem Pelz, Ein Handbuch zur Hausbegruenung; Verlag Dieter Fricke GmbH, Frankfurt, 1982.
10. Metody opredelenija morozostojkosti rastenij. / Pod red. Tumanova I.I. – M.: «Nauka», 1967. – 88 s. (in Russian)
11. Nojferta P., Nefa L. Proektirovanie i stroitel's'vo. Dom, kvartira, sad. – M.: Arhitektura-S, 2005. – 255 s. (in Russian)
12. Ljusev V.K. Posobie po ozeleneniju i blagoustrojstvu jekspluatiruemyh krysh zhilyh i obshhestvennyh zdanij, podzemnyh i polupodzemnyh garazhej, ob#ektov grazhdanskoj oborony i drugih sooruzhenij. – M.: Strojizdat, 2008. – 110 s. (in Russian)

13. Tkachenko T.N. Al'ternativnye vidy promyshlennogo ozelenenija / Tkachenko T.N., Savenkova S.V. // Naukovo-tehnichne ta organizacijno-ekonomichne spryjattja reform u budivnyctvi i zhytlovo-komunal'nomu gospodarstvi: tez. III mizhnar. konf. (12.04-13.04.2012) / Makii'vka, Donbas'ka nacional'na akademija budivnyctva i arhitektury. – 2012. – Ch.I. – S. 211–214. (in Ukrainian)

REFERENCES

1. Техноекологія: навч.посіб. для вищ. навч. закл. / В.М. Удод, В.В. Трофімовіч, О.С. Волошкіна, О.М. Трофимчук. – Київ: КНУБА, ІТГІП НАНУ, 2007. – 195 с.
2. Ландшафтна екологія: навч. посібник / А.Є. Кусков, Т.М. Ткаченко. – Макіївка, Донецьк: вид-во Ноулідж, 2009. – 165 с.
3. Ткаченко Т.Н. Возможность создания энергоэффективных экологически чистых зеленых технологий в условиях Украины // Строительство, материаловедение, машиностроение: сб. научн. трудов. Серия: «Создание высокотехнологических экокомплексов в Украине на основе концепции сбалансированного (устойчивого) развития, Вып.81, ГВУЗ «Приднепровская государственная академия строительства и архитектуры». – Днепропетровск, 2015. – С. 256–260.
4. Grant, G., L. Engleback, B. Nicholson, D. Gedge, M. Frith, and P. Harvey. 2003.
5. Brenneisen, S. 2003. The Benefits of Biodiversity from Green Roofs Key Design Consequences. In Proc. Greening Rooftops for Sustainable Communities: Chicago 2003.
6. Sutton R.K. Green Roof Ecosystems. – Cham: Springer, 2015. – 447 p.
7. Izumi C. Mori. Biomarkers of green roof vegetation: anthocyanin and chlorophyll as stress marker pigments for plant stresses of roof environments / C. Mori Izumi, S. Utsugi, S. Tanakamaru, A. Tani, T. Enomoto, M. Katsuhara // J. Environ. Eng. Manage., 19(1), 21-27 (2009)
8. Peck Steven W. Report on benefits, barriers and opportunities for green roof and vertical garden technology diffusion / Steven W. Peck, Callaghan C., M. E. Kuhn, B. Bass – Canada Mortgage and Housing Corporation, 1999. – 77 p.
9. Minke whales, G. und Witter, G.; Haeuser mit Gruenem Pelz, Ein Handbuch zur Hausbegruenung; Verlag Dieter Fricke GmbH, Frankfurt, 1982.
10. Методы определения морозостойкости растений. / Под ред. Туманова И.И. – М.: «Наука», 1967. – 88 с.
11. Нойферта П., Нефа Л. Проектирование и строительсьво. Дом, квартира, сад. – М.: Архитектура-С, 2005. – 255 с.
12. Люсев В.К. Пособие по озеленению и благоустройству эксплуатируемых крыш жилых и общественных зданий, подземных и полуподземных гаражей, объектов гражданской обороны и других сооружений. – М.: Стройиздат, 2008. – 110 с.
13. Ткаченко Т.Н. Альтернативные виды промышленного озеленения / Ткаченко Т.Н., Савенкова С.В. // Науково-технічне та організаційно-економічне сприяття реформ у будівництві і житлово-комунальному господарстві: тез. ІІІ міжнар. конф. (12.04-13.04.2012) / Макіївка, Донбаська національна академія будівництва і архітектури. – 2012. – Ч.І. – С. 211–214.

Text of the article was accepted by Editorial Team 25.01.2018

Т.М. Ткаченко

СТВОРЕННЯ ЕНЕРГОЕФЕКТИВНИХ «ЗЕЛЕНИХ КОНСТРУКЦІЙ» В УМОВАХ ПОМІРНО-КОНТИНЕНТАЛЬНОГО КЛІМАТУ

Анотація. Розглянуто основні аспекти створення енергоефективних «зелених конструкцій» в урбоценозах помірно-континентального клімату. Встановлено, що проблеми експлуатації «зелених покрівель» виникають при порушенні технології укладання покрівельних шарів і при неправильному підборі асортименту рослин. Технічні проблеми у створенні «зелених покрівель» виникають при неправильному

виборі гідроізоляції. Також повинна бути єдина дренажна система, на якій розміщуються всі інші елементи. При недотриманні даних умов можливе протікання покрівлі та розвиток мікроорганізмів. Асортимент рослин на інтенсивній покрівлі зазвичай обмежується низькорослими рослинами: травами, напівчагарниками і чагарниками. Фенологічні спостереження, проведені на інтенсивній покрівлі житлового комплексу Royal Tower у Києві, показали, що при правильному підборі асортименту рослин і технології їх вирощування висота рослин може бути значно більшою: від 4 до 6 м, що істотно розширює еколого-біологічні можливості інтенсивних зелених покрівель помірно-континентального клімату. Запропоновано асортимент видів рослин з високим адаптаційним потенціалом різних життєвих форм з широкою висотою варіювання: від низькорослих трав до дерев 6 м висотою: *Quercus paludosus multicaulus, Quercus rubra multicaulus, Pinus sylvestris, Acer rubrum, Acer rubrum 'Scanlon', Chenomeles Maulei, Arónia melanocárpa, Berberis thunbergii, Betula pumila, Crataegus laevigata, Vitis amurensis, Parthenocíssus tricuspidáta, Cornus alba, Picea abies, Picea canadensis, Picea pungens, Lonicera alpigena, Lonicera caerulea, Salix caprea, Viburnum opulus, Cotoneaster lucidus, Acer tataricum, Acer ginnala, Elaeagnus argentea, Juniperus horizontalis, Juniperus sabina, Sorbus aucuparia, Ribes aureum, Symphoricarpos albus, Pinus mugo, Spiraea arguta, Spiraea japonica, Thuja occidentalis, Philadelphus coronaries, Mālus sibirica, Malus niedzwetzkyana.*

Ключові слова: «зелені конструкції»; «зелені покрівлі»; адаптаційний потенціал; асортимент рослин; «пошарова» конструкція.

Автор (науковий ступінь, вчене звання, посада):

Ткаченко Тетяна Миколаївна
кандидат біологічних наук, доцент, докторант кафедри охорони праці та навколишнього середовища
Київський національний університет будівництва та архітектури
Адреса робоча: 03037 Україна, м. Київ, вул. Максима Кривоноса, 6, кімн. 217
ORCID ID: 0000-0003-2105-5951 ***e-mail:*** *tkachenkoknuba@gmail.com*