The Concept of Green Industrial Zones

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Abstract. Nowadays, the number of people moving to cities is on the rise, which is creating pressure on urbanization and the expansion of cities. It is necessary to cover not only the increasing space requirements for housing and living space but also the requirements for areas for work, industry, and the overall infrastructure of the city, the so-called gray areas of the city. As a result, greenery is disappearing, and built-up areas are growing. The Slovak Republic and Slovak cities have been copying these global trends in recent decades. The proposed concept described in this paper shows possible solutions to problems due to increasing urbanization and the example of the industrial zone demonstrates ideas that would help create green resilient cities, especially in the context of climate change. The presented paper suggests solutions to these issues on a local scale in the city of Kosice, but it is assumed that their good application on a local scale will result in possible application in the wider context of Central Europe. The main tool of the concept is the transformation of a specific industrial area, which will bring a positive effect not only on the area but also on the city itself.

Keywords: Industrial zones · Nature-based solutions · Transformation · Biodiversity · Resilient cities

1 Introduction

The future of the world's population is urban. According to the World Urbanization Prospects released by the United Nations in 2018, more than half (55%, up from 30% in 1950) of the world's population lives in urban areas and the number is expected to increase, reaching 68% by 2050 [1]. The rapid urbanization process changes the type of land use radically [2]. Due to rapid urbanization and pressure on space, urban areas must provide adequate surroundings for people to live in. It is necessary to cover not only the increasing space requirements for housing and living space but also the requirements for areas for work, industry, and the overall infrastructure of the city, the so-called gray areas of the city. As a result, greenery is disappearing, and built-up areas are growing [3].

Z. Blikharskyy (Ed.): EcoComfort 2022, LNCE 290, pp. 56–66, 2023.
https://doi.org/10.1007/978-3-031-14141-6_6

Another risk for cities in the future is climate change, and buildings are largely responsible for the emission of greenhouse gases [4, 5]. Consequently, in the design of buildings and urban areas is necessary to involve sustainable solutions to reduce both the energy consumption and the pollutant emission of buildings using environment-friendly materials and innovative technological solutions [6, 7]. In this respect, nature-based solutions have significant potential for decreasing the vulnerability and enhancing the resilience of cities in the context of climate change [5]. Green roofs or walls are nature-based solutions that can be implemented in cities to moderate the impact of high temperatures, capture storm water, abate pollution, and act as carbon sinks, while simultaneously enhancing biodiversity [8].

The application of vegetation roofs and walls is encountered more often in the city center on new or retrofitted residential buildings. It is very rarely considered to include a structure with a vegetation layer, in the construction of industrial areas. The greening of industrial zones can create an interesting contrast and thus create a link between nature and industry in cities. At the same time, the structures can be used to cool buildings [9], the surroundings, and to clean the gray water that arises during the operation of the building.

This paper focuses on the concept of the transformation of a selected industrial zone in the city of Kosice, eastern Slovakia, which represents a typical industrial zone that we can find in any Slovak city. Although these areas are part of every city, they are often unaesthetic places without added value. The concept involves the involvement of the zone owner and the university, using nature-based solutions that reflect the needs of the partners involved in order to create a pattern of returning greenery to industrial parts of cities.

2 Methods

2.1 Research Methodology

The uniqueness of this concept lies in the inclusion of the owner and the university in the creation and selection of nature-based solutions for a specific industrial zone in the city of Kosice. Therefore, it was necessary to take into account the demands and requirements of both partners. Subsequently, the incorporation of these solutions is envisaged, in order to monitor the behavior of the constructions with the vegetation layer. This will allow the definition of the most suitable procedures and solutions for the climatic region of Slovakia, resp. central Europe and the possibility of involving the public and raising awareness of structures with vegetation layer. Figure 1 shows the research scheme used in this paper.

2.2 Case Study, City of Kosice

In the first step, a specific industrial zone in the city of Kosice was selected, which includes an administrative building and functional areas. Figure 2 shows the number of industrial zones within the city of Kosice. The zone, that was chosen, is part of a large industrial site located in the city part named Nad jazerom.

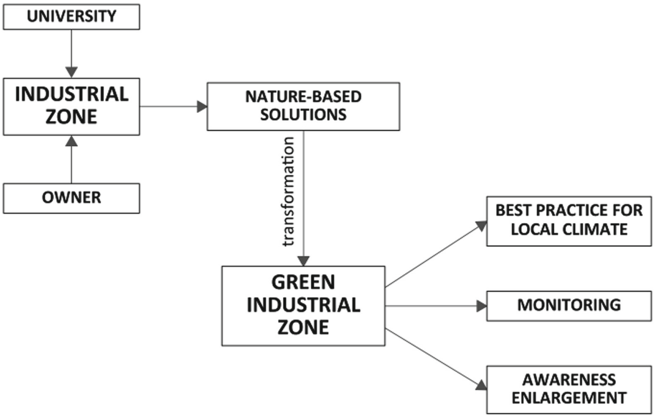

Fig. 1. Research scheme.

Fig. 2. Area indicator of the number of industrial areas within the city of Kosice and examples of industrial parts.

As mentioned, the existing industrial zone includes an office building. It is a four-story building built as a two-way prefabricated skeleton with reinforced concrete prefabricated ceiling panels and infill masonry. Before the implementation of the proposed modifications, a static assessment was prepared to determine the load-bearing capacity of the structures.

Figure 3 shows the current state of the zone, where it can be seen that the zone is formed mainly by impermeable surfaces such as asphalt and concrete. Currently, permeable areas make up only 14% of the total area.

Fig. 3. Current state of the selected industrial zone.

2.3 Nature-Based Solutions

Industrial zones in Slovakia have to meet the functional requirements that are placed on these areas. So, in these areas are mostly used impermeable but durable materials such as asphalt, concrete, and steel. Therefore, in the context of climate change and the lack of permeable (natural surface - vegetation, water bodies), these areas are increasingly struggling with overheating and the so-called heat island. The aim is to increase the resilience of the zone and the city, aesthetic value, and biodiversity while maintaining the functionality of the space. Based on this, the creation of a structure with a vegetation layer (e.g. green roofs/walls) is chosen as the main tool.

Multiple societal challenges can be addressed simultaneously through Nature-Based Solutions as increasing human well-being; urban regeneration; enhancing coastal resilience; multi-functional watershed management and ecosystem restoration; increasing sustainable use of matter and energy; developing the insurance value of ecosystems and increasing carbon sequestration. In this case, the implementation of constructions with a vegetation layer highly promotes biodiversity, social cohesion, health, climate, sustainable water management, and green jobs [8].

3 Results

The concept of the transformation of the industrial zone in the city of Kosice aims to create different types of structures with a vegetation layer and thus capture the maximum amount of rainwater. Priority is given to the direct accumulation of rainwater by building structures with a vegetation layer through the implementation of vegetation roofs and shelters. Excess water from vegetation segments and water from non-absorbent surfaces will be treated and subsequently accumulated by infiltration blocks within the zone area.

Transformations of building structures are proposed after a thorough analysis of technical limits, economic parameters, and environmental impacts. Thanks to the transformation, about 1,025 m^2 of vegetation roofs or shelters will be built. According to the vision (Fig. 4 and 5), the application of green solutions will increase the share of vegetation areas in the area of interest from the original 14% to 41%.

As mentioned, industrial zones have to meet demanding functional requirements, so it is not possible to remove asphalt surfaces. At the same time, these areas are in good technical condition and their removal and replacement do not represent a major economic or environmental benefit. Rainwater from asphalt roads and parking areas will be collected, cleaned of oil substances, and accumulated directly in the area of interest using infiltration blocks. Part of the parking area is covered with vegetation shelters. The proposed shelters protect the vehicles from adverse weather conditions, but above all prevent the interiors of the vehicles from overheating in the summer. The areas of vegetation shelters in car parks and emergency material storage reduce the non-absorbent asphalt area from the original 3308 m^2 to 2765 m^2 and turn it into a functional water retention element. The added value of vegetation shelters is the protection of motor vehicles against the increasing manifestations of climate change and weather extremes, such as hail.

Fig. 4. Current state of the selected industrial zone: front view.

The result of the transformation is to maintain the functionality and requirements that are necessary for this type of zone, but suitable tools will increase the aesthetic value of the area and its overall sustainability. Some of the proposed changes to the selected area would be visible immediately upon entering the plot and should evoke a pleasant feeling. Consequently, in order not to realize that a person is in a gray area of the city, the transformation of terraces and roofs into vegetation should create a more optically friendly environment for work and at the same time a space for relaxation and regeneration.

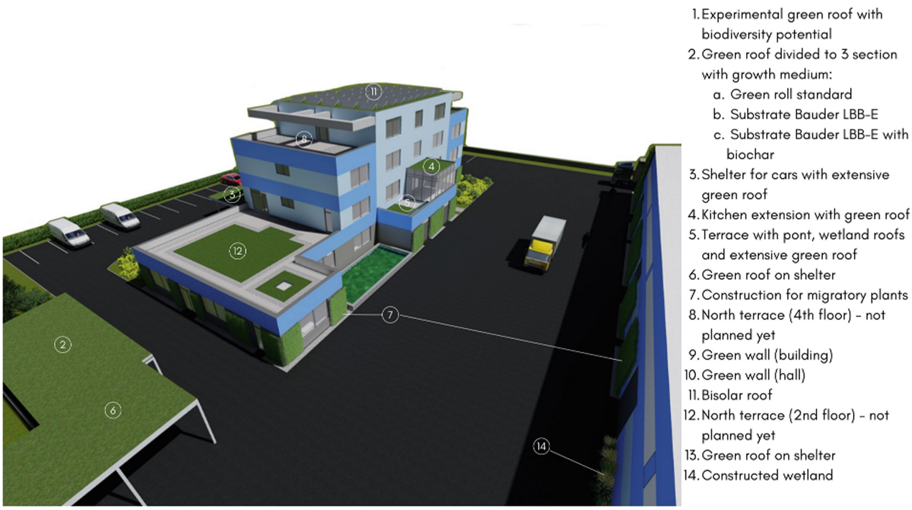

Fig. 5. Current state of the selected industrial zone: back view.

Various types of vegetation structures have been designed within the area, such as vegetation roofs with different substrate heights, extensive green roofs, green walls, vegetation roof in symbiosis with photovoltaics, wetland roofs, and others (Fig. 4 and 5). Thanks to the use of different types of vegetation roofs and walls on different structures with different orientations to the cardinal system, it is possible to demonstrate their behavior in given climatic conditions during the whole year. In the design and realization of the concept of transformation, the inclusion of the university and the creation of a research project are considered. The implementation of a structure with a vegetation layer is designed as experimental with continuous recording of selected physical parameters in different layers of the structure.

Long-term in situ measurements of the behavior of the test segments of vegetation roofs are realized as two circuits according to the scheme in Fig. 6. The first circuit measures and records with a minute step the relevant climatic parameters, which are temperature and relative humidity, atmospheric pressure, wind speed and direction, solar radiation intensity, amount, and intensity of atmospheric precipitation in the locality of Košice, Nad jazerom. The second circuit measures and records selected quantities in the layers of the test roof segments in one minute using built-in sensors.

The measured data from both measuring circuits are stored in cloud storage, and accessible in real-time for further analysis. The online interface - visualization of measurements provides a clear control of measurements and a clear display of measured quantities within the experiment.

The application of various vegetation roofs and walls brings certain benefits to the building but also to the environment, such as air purification, increased biodiversity, and rainwater retention, which relieves public sewerage, and rainwater remains part of the water cycle, resulting in cooling of the surrounding. As it is planned to monitor selected physical parameters in various layers of the structure and, at the same time, outdoor climatic conditions, these structures will be innovative experimental in situ laboratories.

The aim of the project is the application of different types of structures with different types of vegetation, which will guarantee a high variability of the measured results and will also increase biodiversity and environmental resilience.

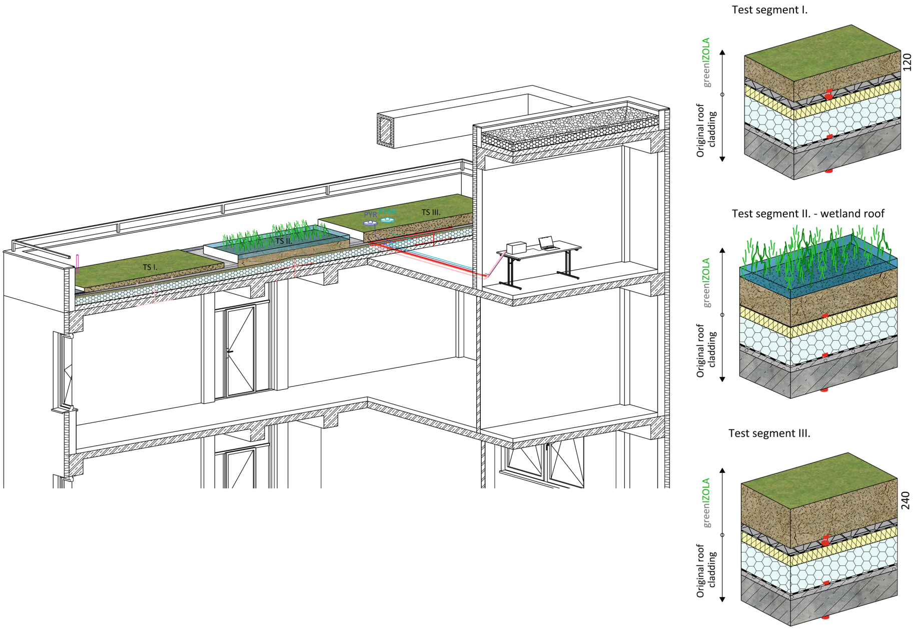

Fig. 6. Experimental vegetation roof construction with different types of compositions.

Industrial zones are primarily intended for work, production, storage, and business, but these localities have no aesthetic value and form a kind of gray zones of the city with unattractive buildings, asphalt, and concrete surfaces. Although these areas are functional zones of the city, it is necessary to realize that people work in these areas and therefore spend a significant number of hours a day in them. The environment in which people work has a great impact on their mental and physical health and overall well-being. It is known that people look for greenery and a natural environment to relax when they are exposed to stress. When transforming a gray building into green, it is not possible to bypass its internal environment. People spend long hours in this area. Work breaks can be used to stay in the roof garden, but the indoor environment must also have a positive effect on them. This can be achieved by interventions following the biophilic design and by the application of natural elements in the indoor environment (see Fig. 7) [10–13]. Creating a more pleasant environment for work in combination with indoor climate [14–18] and energy saving [19–21] will not only have a positive impact on the mental health of employees but also on their efficiency.

The connection of the concept with the university will also bring popularization of this topic among the general population as well as the scientific field, thanks to the quantification and verification of the achieved results. The solved area would work as a source of information for both the professionals and the public as evidence of the impact of vegetation on positive changes in the environment. At the same time, it would point out the diversity of options for the selection of structures with a vegetation layer and the method of their construction. The project also includes the creation of a training camp for the public in order to point out the benefits as well as the obstacles of green construction. It should be noted that there is no universal design that meets all the requirements, so the diversity of construction types and multiple designs would help meet the needs of the wider public and help expand the concept of green construction in architecture. The achieved results of experimental me-amusements would lead to the specification of suitable constructions with a vegetation layer for the climatic conditions of Central Europe.

Fig. 7. The design of the interior of the research and presentation center is in harmony with the concept of biophilic design.

The transformation of the selected industrial zone is divided into several steps:

1. Finding a suitable object for reshaping – object found, and the owner of the building and land agrees with the planned changes.
2. Creation of a plan and design of modifications and changes – architectural design – use of extensive, intensive, wetland roofs, vegetation walls, and pulling plants.
3. Gradual implementation of changes – stage I – experimental roof, vegetation roof over existing shelter divided into 3 parts, car shelter with vegetation roof.
4. Promotion of the made changes, creation of a detached workplace for research and development of the field.
5. The next step in the implementation of the changes – stage II – an extension of the kitchenette with an extensive vegetation roof, the creation of a wetland roof on the western terrace, and a vegetation roof over other existing shelters.
6. The next step of changes – stage III – implementation of the network structure at the perimeter of the façade at the level of the first above-ground floor for pulling greenery, the construction of vegetation walls on the building and hall.
7. Stage IV – replacement of photovoltaic panels on the roof and implementation of an extensive vegetation roof – design of the biosolar roof.

8. Stage V – the transformation of the remaining terraces and the creation of an artificial wetland near the storage hall.
9. Promotion of new changes and summarizing of the benefits of application structures with vegetation layer in grey zones - raising awareness of changes and their impacts on buildings, surroundings, and people.

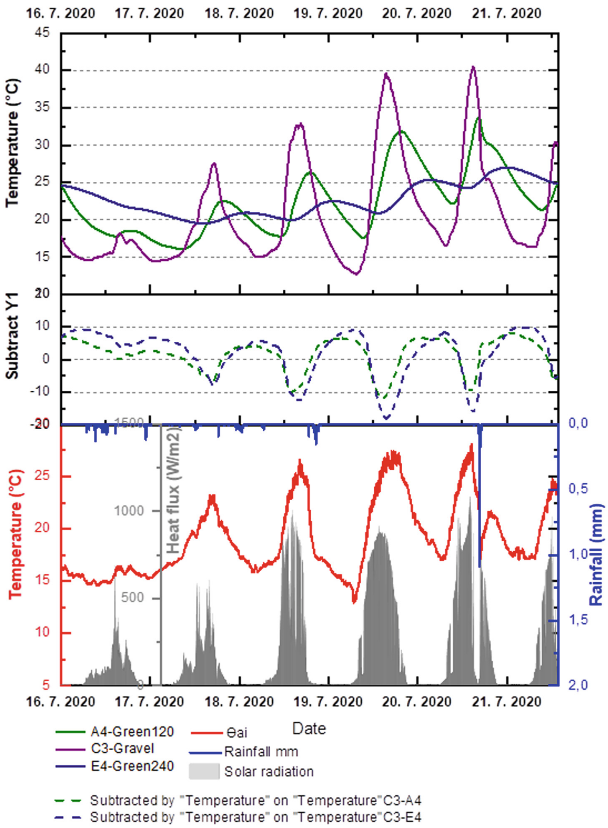

Fig. 8. Experimental vegetation roofs and comparison of the measured data.

The stage of preparations and architectural design for the implementation of green roofs on a specific existing building in the industrial zone in the town of Kosice is currently completed. The first experimental roofs with different heights of substrate were realized, at the same time sensors for measuring the temperature in different layers and a weather station were installed. Figure 8 shows measured data from three different roof segments (substrate height 120 mm, 240 mm, and gravel layer segment) during the summer. Selected physical parameters are measured in different layers of roof plastic.

4 Conclusions

Well-designed industrial zones in terms of sustainability, aesthetics, and inclusion are very rare in Slovakia. The presented example of transformation is therefore an exceptional concept, which can represent a positive example and thus help to improve conditions in the city, but also creates a precondition for sustainable and aesthetic transformation of industrial zones within the climatic conditions of Central Europe. Linking the private sector (owner of the selected zone) with the university will not only improve the aesthetics of the industrial area and its sustainability in the context of climate change but also involve a wider circle of other potential investors and contractors. The impact of vegetation on the building and its surroundings might be quantified by people's response to such a change, reduction of energy demands for cooling and heating, reduction of rainwater runoff, an increase of biodiversity in the area, and cooling of the surroundings, etc. The concept of a green industrial zone creates a strong and sustainable foundation and example for building resilient cities in the present and future.

Acknowledgments. The authors are grateful for the support of the Ministry for Education of the Slovak Republic with VEGA 1/0217/19 "Research of Hybrid Blue and Green Infrastructure as Active Elements of a Sponge City", a project run by the Slovak Research and Development Agency APVV-18-0360 "Active hybrid infrastructure towards to a sponge city".

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