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*Corresponding author.

E-mail: 0529carrot@gmail.com



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Regeneration design of mining brownfield based on nature-based solutions

Kangwei Tu^{1,2} , Yilin Niu^{3,4*} and Andras Reith^{5,6}

¹ Marcel Breuer Doctoral School, Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary

² Faculty of Civil Engineering, Architecture and Environment, Hubei University of Technology, Wuhan, China

³ Institute of Landscape Architecture, Urban Planning and Garden Art, Hungarian University of Agriculture and Life Sciences, Budapest, Hungary

⁴ College of Landscape Architecture and Art, Henan Agricultural University, Zhengzhou, China

⁵ Advanced Building and Urban Design Ltd, Budapest, Hungary

⁶ Department of Engineering Studies, Faculty of Engineering and Information Technology, Institute of Smart Technology and Engineering, University of Pécs, Pécs, Hungary

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ABSTRACT

Mining industry once was a strong contributor to the economic development of cities and created economic benefits for human beings, but ecological problems are increasing day by day. This study takes the quarry in Nagykovacs, Hungary as an example, and through comprehensive evaluation of the site, utilizes nature-based solutions to carry out the design practice of seeking new development vitality and opportunities for the brownfield site after mining. Finally, it summarizes the ecological remediation concepts and strategies suitable for mining brownfield sites, and contributes to the reuse of urban land space and the creation of a favourable ecological environment.

KEYWORDS

nature-based solutions, mining brownfield, public health

1. INTRODUCTION

The continuous development and progress of the country's economy and society depend on modern industry. As a result, a number of industrial cities have been born. Industrial cities were initially formed by the agglomeration of resources, population, and technology, and due to the lack of awareness and ability to protect the environment, the production of factories like iron and steel mills, textile and electroplating factories resulted in a large amount of land being contaminated. Therefore industrial cities are the zones with the highest number and concentration of brownfields [1]. The eruption of brownfields in cities seems to be an unavoidable consequence of the historical process of urbanization. However, the withdrawal of enterprises from cities has not solved the problem, and sites that once had significant locational advantages have become abandoned wastelands.

One type of brownfield that is widely distributed and more difficult to deal with in the world is the mining brownfield [2]. The overdevelopment and irrational use of mines has led to serious consequences – once vibrant mines are now barren, leaving only barrenness and devastation. Mining brownfields not only affect the development of the city, but also the ecological environment of the area around the city. Holey mountains, dust pollution, aquifer destruction, geological disasters, and other problems have become the inevitable “aftermath” of mining [3].

Thus, this study applies the combination of ecological remediation tools and Nature-Based solutions (NBs) strategies to the transformation of mining brownfield sites. The transformation will not only improve the surrounding ecological environment, but also optimize the internal spatial pattern of the city, alleviate the pressure on urban land, create a place for people to rest and recreation, and create great social and economic benefits, seeking new development vitality and opportunities for mining brownfield.

2. MATERIAL AND METHOD

The base for this study is located in Nagykovacs, Hungary. Nagykovacs is tucked away in a 340-meter-high valley in the Buda Mountains. It is surrounded by Zsíros, Nagy-Szénás and Kutya Hill in the north, Széna Hill in the west, Nagy-Kopasz Hill in the south, and Remete and Kerek Hill in the east. It is shaped like a large inverted gourd, with a maximum drop of 42.33 (408.13–365.80 m) meters, and a pit area (basin) of 3476.78 square meters. Mining began in the early 1700s and continued until mid to late 20th century, when the government announced its closure. After a long period of mining, the landscape of Homok Hill has been greatly damaged, and half of the southern slope has been cut off, and a huge pit has been formed from west to east (see in Fig. 1).

The crux of revitalizing mining brownfields hinges on nurturing the self-recovery and self-operation of the ecosystem. Building upon this premise, the design approach should meld natural restoration with artificial remediation. This integration materializes in several ways: honoring natural ecological progression, and strategically planning and remediating mining brownfields in terms of focal points and functionality. Throughout the restoration process, the design has to consider the hydrology, soils, vegetation, microorganisms, fauna, and other relevant factors of the area. Following nature's lead, comprehending its nuances, and curbing excessive artificial intervention are essential to



Fig. 1. Site map (photo by Authors)

site rehabilitation through the application of nature-based solutions. Hence, the primary stages of the study involve:

- Analyzing the current situation of the site including the terrain, ecological, vegetation, traffic conditions and surrounding land use comprehensively;
- In-depth research on the activities and needs of the surrounding population;
- Bridging the gap between needs and challenges, exploring possibilities of using NBs to transform brownfield sites into economically and culturally valuable landscapes.

3. SITE ANALYSIS

3.1. Terrain topography analysis

The internal elevation of the site is between 365.80 and 408.13 m, the internal elevation difference is big, among which the highest point is 408.13 m in the southeast, the lowest point is 365.80 m in the northwest, presenting the overall terrain of northwest low, southeast high. The overall terrain of the site working platform is gentle, the slope is less than 2.28%, and the slope formed by mining is concentrated in 42.51–60.95% (Fig. 2).

3.2. Ecological conditions analysis

The current ecological conditions of the site were analyzed based on site research and data review, and staff consultation. The runoff and evapotranspiration within the site are generally on an upward trend over time, and the flow between the two is constantly shrinking, so it can be deduced that the runoff and evapotranspiration are on an even trend from 2030 to 2050, which will lead to drought on the land within the site. In contrast, the change in flow between drainage and purification is also roughly trending upwards, with precipitation predicted to be greater than drainage during the period 2020–2035. In addition, the mountain is relatively hard as it is dolomitic. As a result of mining and

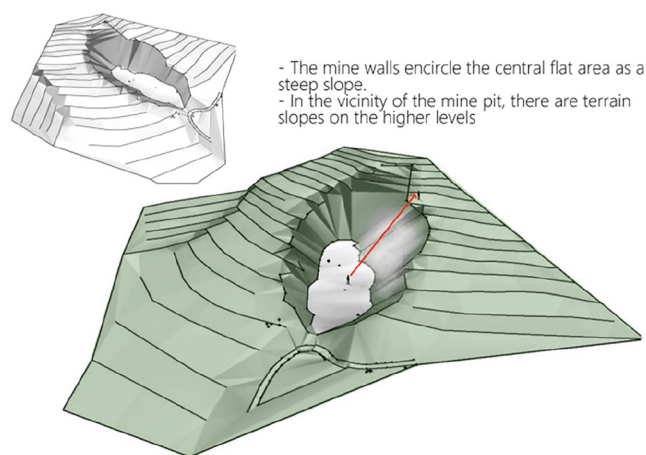


Fig. 2. Terrain topography analysis of the site (plotted by Authors)

weathering, a powdery textural structure has formed on the surface, which has greatly restricted vegetation growth. The range of leaf area and vegetated area will continue to decrease over time. In summary, ecological conditions will continue to deteriorate in the next 20 years, and ecological restoration will be the greatest challenge.

3.3. Vegetation analysis

The site survey indicates that the vegetation in the site is sparse and the overall distribution is uneven. The north-west and southeast corners are relatively densely vegetated, while the central and southwest portions of the site are bare rock (see in Fig. 3). The basin area is sparsely covered with weeds, but there are some original plant groups along the deposit margins: *Populus* sp., *Salix* sp., *Pinus* sp., *Acer* sp., *Betula* sp., *Genista pilosa*. Average trunk diameter 10–20 cm. In general, the existing vegetation type inside the site is relatively single, the vegetation growth conditions are poor, and there is no rich plant level. The first condition for mine rehabilitation is to ensure a good ecological environment, and vegetation planting is a powerful guarantee for creating a good ecological environment [4]. Therefore, the design should fully consider the types of plants and their different purifying effects on the ecological environment.

3.4. Surrounding land and traffic analysis

The site is highly accessible, with the northern part of the site adjacent to a city road, only 850 m from the city center, and the southern part of the site backed by a large forest (Buda Landscape Reserve, National Ecological Network Core Area, Cave Surface Reserve), which is inlaid with two hiking trails that provide a natural connection to the future development of the site. Superior natural resources make it a destination to get close to nature and return to idyllic life. However, the internal flow of the site is not sufficiently smooth and cannot accommodate a large parking demand.

3.5. Summary of the site

- Mining is prone to geological disasters such as mud-slides and landslides. And the project is adjacent to residential living areas, which is a potential safety hazard;



Fig. 3. Vegetation analysis of the site (plotted and photo by Authors)

- The long period of mining has caused damage to the soil, exposing a large amount of bare rock on the site, leaving almost half of the land without grass, and the ecosystem is in dire need of restoration;
- Land sitting idle is a waste of resources; however the presence of a gently sloping topographical structure in the vicinity of the mine and its privileged location between the city and the forest gives it great potential to provide urban dwellers with access to nature and space for recreational outdoor activities in the future.

4. REPAIR SCHEME

NBs have gained attention as a rapidly evolving theory in the field of ecological restoration and planning [5]. At the turn of the century, the World Bank and International Union for Conservation of Nature and Natural Resources (IUCN) first introduced the concept of NBs, which specifically refers to an action to conserve, sustainably manage, and restore ecosystems. It advocates relying on the forces of nature and ecosystem-based approaches to provide human well-being and biodiversity benefits while addressing environmental challenges like climate change, diminishing environmental resilience, and ecosystem decline [6]. The core concepts and guidelines of NBs are highly compatible with the main theme of this project. Taking into account the local conditions discussed in the previous section, the key to the next retrofit design is how to respect the unique topography of the site, fully utilize the existing natural advantages, and bridge the gap between the challenges of ecological degradation and the public's need to be close to nature. Strengthening the participation of all stakeholders in the construction, and promoting the formation of a multi-investment, common governance and shared operation and maintenance model.

Based on the scenery of the forest reserve in the southern part of the site and the ecology of mine re-greening, and with the theme of protecting and displaying geological relics, the site will be transformed into a mine (geological) park integrating 'mining culture, sightseeing, outdoor sports, leisure and fun', integrating the common demands of multi-interest groups. Ecological restoration is the basic goal - from industrial and mining heritage to urban park, a series of spatial elements need to be dealt with. Not only to retain part of the original geomorphology (exposed cliffs for example), to retain the site characteristics and memories of the quarry, but also to restore the vegetation in key areas to create an ecological landscape. The human-centered design is the core value - the mine park is intended to be a public park open to all citizens, which can meet the needs of multiple outdoor activities and become a fast track from the city to nature, enhancing the health and well-being of local residents. The key elements of the restoration design include,

- Level the land and build a protective green space as a buffer to maintain a safe distance from residential areas;

- Plant a large number of climbing and ground cover vegetation to help vegetation recovery and soil restoration;
- Utilizing the cultural heritage of the quarry to carry out a new type of renovation, shaping public buildings and spaces with a sense of place. It also introduces ecology into the urban environment and advocates a healthy lifestyle through direct contact with nature.

In terms of the overall functional layout, the northern part of the site adjacent to the city road is leveled as a transition area between the quarry and the residential area, and is mainly used as a transportation hub. The flat part of the mine shaft in the center is used as a picnic and resting area where the pedestrian flow is concentrated, and low intensity outdoor activities and children's play areas are sporadically distributed. Facing the forest in the north, the terrain rises gradually, so the amphitheater is situated according to the topography, and a viewing platform facing the nature reserve is formed at the northern high point, which is extended horizontally to connect with the hiking trails. On the west side, the gently sloping terrain is fully utilized to create spaces for extreme sports, slides and other special features (see Fig. 4). The following are a few key nodes to show how NBs is developed in the base.

4.1. Road design

Walking into the site, visitors will find vegetation growing out of the broken stone cracks, echoing with the cold stone walls, revealing the marvelous tenacity of the natural texture. In the face of this “scar” formed by the rough mining, the landscape design tries to explore the carrying method of ecological restoration and urban repair in the park on the basis of preserving the industrial geomorphology of the quarry.

Based on the concept of NBs and prioritizing the symbiotic relationship between people, site and nature, the main access road connecting the activity site and the hiking trail is designed as a trestle, which on the one hand minimizes further damage to the geological structure, and on the other hand, through the design of the height difference of the

trestle bridge, it can skillfully connect the touring trail located at the bottom of the pit to the sightseeing trail located at the mid-level of the mountain, as well as the hiking trail on the top of the mountain. In this way, from the visitor center, one crosses the skateboard park and climbs up the slope along the zigzag trestle to reach the viewing platform with a wide view. On the northwest side, the Mining Wilderness Scavenger Hunt provides an alternative access point, where people can try the cable bridge and then walk along the cliff face to the observation tower in the dense forest (Fig. 5).

The structural system of the trestle is divided into two kinds: the watchtower is the main anti-tilting member, and the reinforced concrete beam-column system is chosen. The observation platform adopts a steel truss structure system without web rods in order to expand the landscape view of the 20 m overhanging space. In terms of material selection, local terrazzo with anti-aging treatment is used for the outdoor platform. This ensures stability and durability while responding to the natural appearance of the quarry in terms of texture.

4.2. Vegetation restoration

In this project, the internationally recognized Sustainable SITES Initiative Version2 (SITES v2) was used as the process manual for ecological restoration [7]. Firstly, the original



Fig. 4. Remediation plan of the site (plotted by Authors)

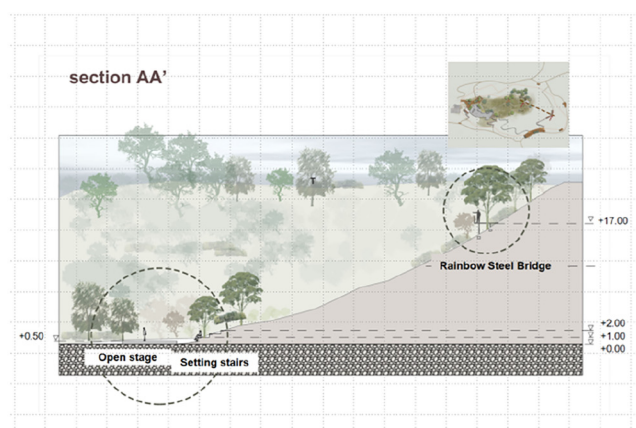


Fig. 5. Park trestle design (plotted by Authors)

woody debris, seeds, and log piles were preserved, and native plants were used to enhance plant diversity, restore grasslands, and create wildlife corridors to connect the mine pit to the southern forest. The ecological environment of mining brownfields is harsh, with poor and acidic soils, so the selection of native plants has an irreplaceable role in the restoration of site habitats. They are not only resistant and highly adaptable to the site, but are also more amenable to management. Therefore, in the central part of the mine, especially in the area where the exposed rock wall is concentrated, a large number of native hanging plants and climbing plants are planted in the form of planting holes and planting grooves. While preserving the original topography, the slope stability is increased, the ecological self-healing ability is improved, and the vegetation is restored as soon as possible to create a characteristic natural landscape by utilizing the special topography of the quarry.

In the middle of the site, where the terrain is low and flat, the planting of lawn ground covers with purifying effects, like *Polemonium dolomiticum*, *Scabiosa columbaria*, or *Corydalis dolomitica*, will effectively remove metal substances from the air and increase the oxygen content. In addition, the planting of mixed forests will keep the ecosystem healthy and stable, and maintain the virtuous cycle of the habitat [8]. Wooden strips modeled after railroad tracks pass through the lawn, echoing the historical memory of the quarry, and adding a sense of sequence to the landscape, while at the same time clarifying the space for activities and delineating areas suitable for family gatherings, picnics, and children's play (Fig. 6).

4.3. Terrain utilization

In the terrain design, this project strives to minimize the intervention on the site and to preserve the characteristics of the original landscape. This not only reduces the waste of materials, but also maximizes the ecology of the site to maintain its own cycle of succession. While protecting the ecological environment, it also creates a landscape with a historical heritage.



Fig. 6. The lawn in the middle of the park (plotted by Authors)

For sites with difference in elevation, various landscape treatments including long steps, landscaped lawns, outdoor stands, and grass slopes for retaining walls are used to create a landscape space with diverse heights, distinct levels, and morphology. Rock gardens are designed on gently sloping areas that hug the mountain. The use of different shapes of raw rock (dolomite) from the mountain for display, together with drought-tolerant plants, adds to the ornamental value of the site and provides a scientific perspective on mining.

The Extreme Paradise located at the entrance of the park was originally a place where waste materials were piled up in a quarry, and the original vegetation had been completely destroyed. On the basis of restoring the ecological reinforcement of the hillside, making full use of the undulating and changing height difference of the current situation, the climbing, skateboarding, trampoline and other activity facilities are combined together to form a characteristic activity place of the mine (Fig. 7). There will also be a “five senses” outdoor children's adventure center, in which zip lines will be introduced along one side of the gentle slope. Balanced slopes, sound gardens, and light and shadow forests are designed to encourage children to go back to the basics, to see the forest, to hear nature, to touch the earth, to kiss the soil, and to explore and play with their senses. These activities are situated in a jumble of heights and contrasted by the mountains behind, ultimately completing the overall repair of the quarry's sunken form.

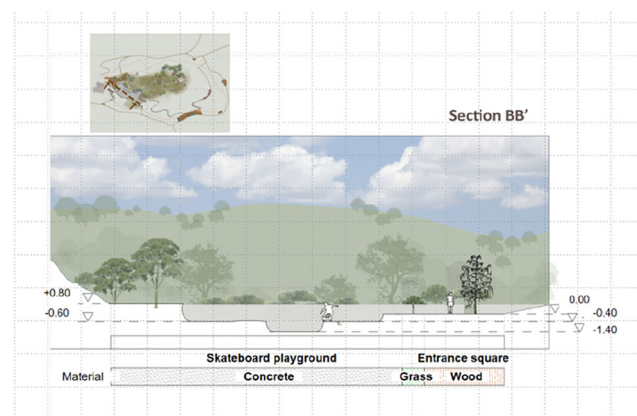


Fig. 7. Terrain design using height difference (plotted by Authors)

5. CONCLUSIONS

With the transformation of industry on an international scale, the solution to the problem of brownfield sites is imminent. The nature-based solutions provide a brand new perspective to minimize site intervention while making full use of the current resource conditions, achieving a win-win situation of ecological remediation and landscape enhancement.

This article firstly analyzes the formation and background of mining brownfields, clarifying the significance of ecological restoration. Secondly, a comprehensive investigation and analysis of the subject of this study, Nagykovacs, were conducted, extracting the main technical means of design intervention using NBs. These provide reference for similar projects, and the experiences that can be drawn upon include:

In terms of ecological restoration, the main design method is based on the “rewilding” design concept, while fully implementing the principle of “design according to local conditions,” minimizing excessive intervention in the internal environment of the site, and maximizing the use of the site’s original terrain, vegetation, and natural materials.

Regarding plant configuration, a variety of native plants are used, with an emphasis on the design of plant layers, particularly the introduction of climbing and wall-hanging plants, which can effectively promote soil balance and moisture conservation, thereby improving the ecological environment.

In terms of artistic expression, the original industrial relics and buildings on-site should be reused in an artistic form, which can be designed as major public facilities to showcase mining culture to people, enhancing the resonance with the memories.

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