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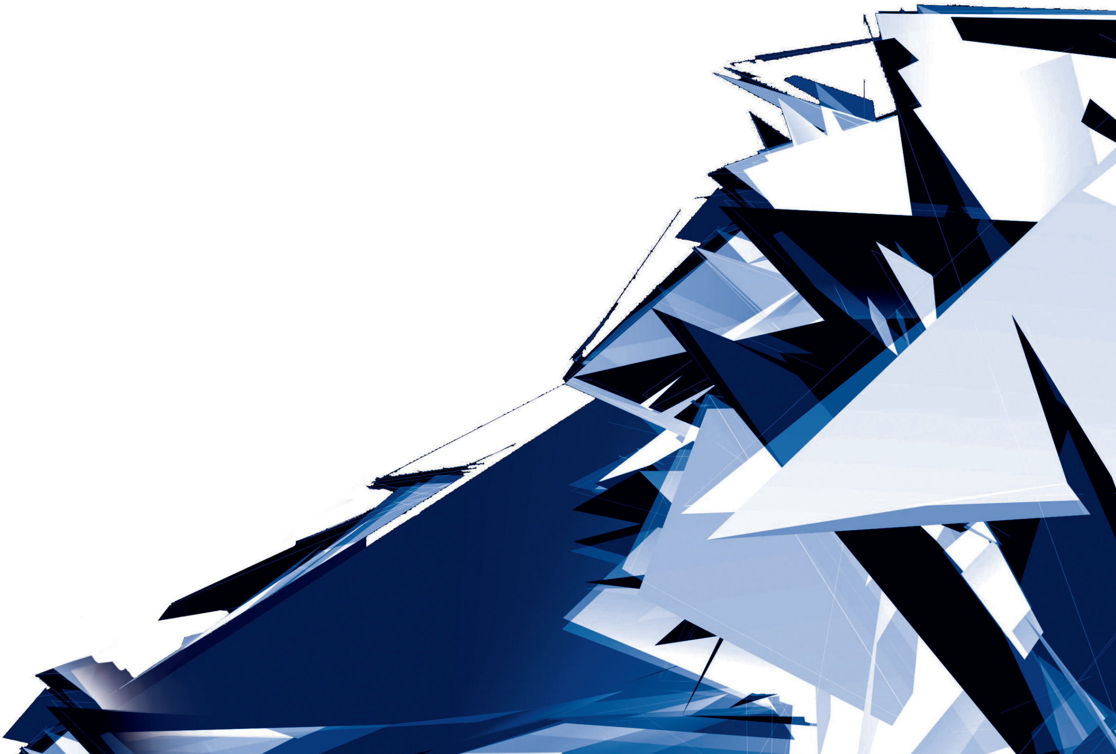

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Guidelines for revitalization of rural areas based on landscape studies

Wytyczne do rewitalizacji obszarów wiejskich na podstawie studiów krajobrazowych

Abstract

The objective of the article is to present the possibility of using landscape studies in the development of guidelines for the revitalization of rural areas. Performing detailed analyses of the cultural and aesthetic values of the landscape has become the basis for formulating the directions for the development of the rural areas located in the vicinity of the town of Drawsko Pomorskie, that previously were part of state collective farms. Landscape studies included the identification and characterization of natural elements and cultural and aesthetic values of the area, based on the landscape audit methodology and commonly applied principles of valorization of cultural landscape. The analyses allowed us to identify areas that, due to a significant decline in the value of the landscape, caused mainly by the location of objects related to the former state farms, require the analysis of the legitimacy of their further protection within the "Pojezierze Drawskie" [hereinafter "Drawsko Lakeland"] Protected Landscape Area. As a result, it was possible to formulate new guidelines for the revitalization of the studied area.

Keywords: landscape research, post State Farm areas, village renewal, landscape audit

Streszczenie

Celem artykułu jest przedstawienie możliwości wykorzystania studiów krajobrazowych w opracowaniu wytycznych do rewitalizacji obszarów wiejskich. Wykonanie szczegółowych analiz wartości kulturowo-estetycznych krajobrazu stało się podstawą dla sformułowania kierunku rozwoju popegeerowskich obszarów wiejskich zlokalizowanych w sąsiedztwie miasta Drawsko Pomorskie. Studia krajobrazowe objęły zidentyfikowanie i scharakteryzowanie elementów przyrodniczych i walorów kulturowo-estetycznych terenu na podstawie metodyki audytu krajobrazowego oraz powszechnie stosowanych zasad waloryzacji krajobrazu kulturowego. Przeprowadzone analizy pozwoliły na wskazanie obszarów, które ze względu na znaczny spadek wartości krajobrazu, spowodowany głównie usytuowaniem na ich terenie obiektów związanych z działalnością byłego PGR, wymagają analizy zasadności ich dalszej ochrony w ramach Obszaru Chronionego Krajobrazu „Pojezierze Drawskie". W rezultacie możliwe było sformułowanie nowych wytycznych dla rewitalizacji badanego terenu.

Słowa kluczowe: studia krajobrazowe, tereny popegeerowskie, rewitalizacja wsi, audyt krajobrazowy

1. Introduction

1.1. Preface

One of the elements of rural renewal processes is the reconstruction of degraded areas and elements of space, which conditions the revitalization of the cultural landscape, defined as a space historically shaped as the result of human activity, containing both products of civilization and natural elements [17, p. 119-120]. Properly carried out identification and valorization of the preserved elements of the cultural landscape aims at indicating the right directions and scope of spatial transformations that can be used to formulate the assumptions of revitalization programs for rural areas.

In a particularly difficult situation, in economic and social terms, are the former state-owned villages, where there are numerous degraded areas located in many cases in the immediate vicinity of both historic buildings, and protected landscape areas. The choice of an appropriate method for assessing and valorizing the landscape is not only a tool conditioning its proper implementation, but also proves to be significant (often due to socioeconomic determinants) for carrying out the processes of renewal and activation of the villages. It therefore has an impact on the future of residents and the development of the areas assessed. However, choosing them may be difficult due to formal or substantive reasons. Difficulties may require the use of a specific method as the client's requirement. On the other hand, despite the large number of methods for assessing and valorizing the landscape, there may be a shortage of comprehensive methods that take various factors into account, and can be used in various forms of landscape. However, the selection of tools and procedures that guarantee a reliable assessment of the landscape proves more significant in the process of its valuation and valorization.

1.2. Objective

The objective of the article is to present the possibility of using landscape studies in the process of village renewal, based on research methodology developed for the needs of expertise of cultural and aesthetic values of the landscape, carried out in the Drawsko Pomorskie municipality, as an example of a considered approach by local self-government bodies to shaping the village space.

2. Landscape study methods for landscape assessment

The landscape is the evidence [3] and the result of human activity, an image of human attitude and relation to space, and an expression of community culture and national property [14, 25, 26]. The beauty contained in the landscape is proof of society's maturity to be its host. For this reason, the cultural landscape is defined as "a space perceived by people, containing natural elements and products of civilization, historically shaped as a result of natural factors and human activities" [22], as well as "the result of the combination of environmental and cultural interactions creating a specific structure, which manifests itself in its regional distinction" [11, 12], evaluated for its adequate protection and harmonious shaping and planning. [17, p. 119, 24].

Landscape is sometimes assessed and valorized (valuing the landscape for different purposes) due to a number of criteria. Among them, one can distinguish: state of preservation, degree of threat, aesthetic and natural values, and frequency of landscape occurrence. In valorization studies, the following scales are used: quantitative, qualitative digital scales (bonitation), continuous and ranking [8].

Many methods of landscape evaluation and valorization have been developed, which can be broadly divided into those based on the assessment of: natural values, aesthetic and scenic values and values for a specific purpose [4].

In the case of natural landscapes and areas of natural value for the assessment of their natural values, single-factor methods are mainly applied, in which the basis for assessment is the occurrence of specific plant communities or animal species in the area, such as the Braun-Blanquet phytosociological method, the avifaunistic method and the MIB method (Mean Individual Biomass of Carabidae) [21].

In relation to cultural landscapes, the methods of landscape assessment based on the analysis of both natural and cultural elements, which is carried out in order to assess aesthetic values and others, e.g. those related to the history and tradition of a given area, apply. Popular methods in this group include: perceptual methods and structural methods based on identification of urban composition elements defined by Lynch [9] and Wejchert [23], and the method of landscape types and elements of landscape interior design according to Bogdanowski [1, 2]. An example here is the Bogdanowski Method [1], which includes two basic stages: designation of architectural and landscape units (due to covering and shaping, and the spatial development of the area) and the valuation of landscape elements within individual units.

Structural methods are used to assess the combination understood as coherence and harmony with the cultural and natural context of individual structural elements of the landscape.

Among the perceptual methods, one should distinguish the method of the Wejchert sensation curve, which is a graphic representation of the observer's emotional feelings regarding space in the timeline. Another perceptive method used to assess the aesthetic values of the landscape is the SBE (Scenic Beauty Estimation), based on the assessment of the beauty of the scenery with a few steps: division of the landscape into units that will be assessed, taking photographs for each unit that will represent its appearance, showing pictures to observers, calculations of observers' ratings [5]. This is a static method, as opposed to dynamic perceptual methods that require real-time analysis (when walking we register feelings, map the terrain and prepare photographic documentation).

The interesting methods of evaluation that attempt to refer to landscape resources in a comprehensive manner are the methods that take into account intangible aspects of cultural heritage [26]. An example here is the *genius loci* [10] analysis of a given area for which the semantic method based on the space concept by Norberg-Schulz, who believed that space is more than a physical structure and as such must be considered more widely, taking into account intangible values [13], was applied. During the analysis, the zones and elements that distinguish them in space are listed for the following criteria: historic, sacred, symbolic, psychological (sensual), social, historical, aesthetic, artistic, landscape, natural, and local/national/universal values.

The Panofski method [15] is the method that organizes and systematizes the information collected, the advantage of which is its comprehensiveness and universality [7]. It is based on three stages of analysis, showing: an automorphic image (based on the analysis of panoramas and view sequences), an exomorphic image (based on the analysis of landscape perception and *genius loci* according to Norberg Schultz), and the endomorphic image (synthesis in the form of conclusions). This method can be a "type of keystone" for the results of individual analyses [16].

3. The practical use of landscape studies for rural renewal – a case study

3.1. Site characteristics

The area covered by the expertise of cultural and aesthetic values of the landscape is located in the rural areas of the West Pomeranian Voivodeship in the Drawsko district. The western border of the area is provincial road No. 173, leading from the town of Drawsko Pomorskie towards the village of Zarańsko, from the north the area is bordered by a dirt road leading from Zarańsko, and to the east towards the village of Darskowo. The eastern border is formed by a dense forest wall and a dirt road leading to the village of Dalewo. The southern boundary is the bed of the Drawa river and a dirt road leading from Dalewa towards Drawsko Pomorskie. The analysed area is located within the "Drawsko Lakeland" Protected Landscape Area (PLA), at its western border (Fig. 1).

The area of the study is mainly used for agricultural purposes (cultivation of cereals, areas of meadows and wastelands), and at its borders there are buildings of the villages of: Dalewo, Gogółczyn and Zarańsko. The eastern part of the village of Zarańsko, which is the former manor farm with a complex of multi-family buildings from the 1970s, is located within the boundaries of the studied area.

3.2. Purpose and types of studies, research procedure and tools

In the research methodology developed for the needs of the expertise of cultural and aesthetic values of the landscape, as carried out in the Drawsko Lakeland municipality, selected elements of the landscape audit methodology were used, as presented in the audit instructions entitled "Identification and assessment of landscapes – methodology and main assumptions" (pol. "Identyfikacja i ocena krajobrazów – metodyka oraz główne założenia") [18], selected for the specificity of the studied area. Due to the fact that it is a small area located in rural areas, where there are no priority landscapes, as defined by the Act of 24 April, 2015 amending certain laws in connection with the enhancement of landscape protection tools, also known as the "landscape

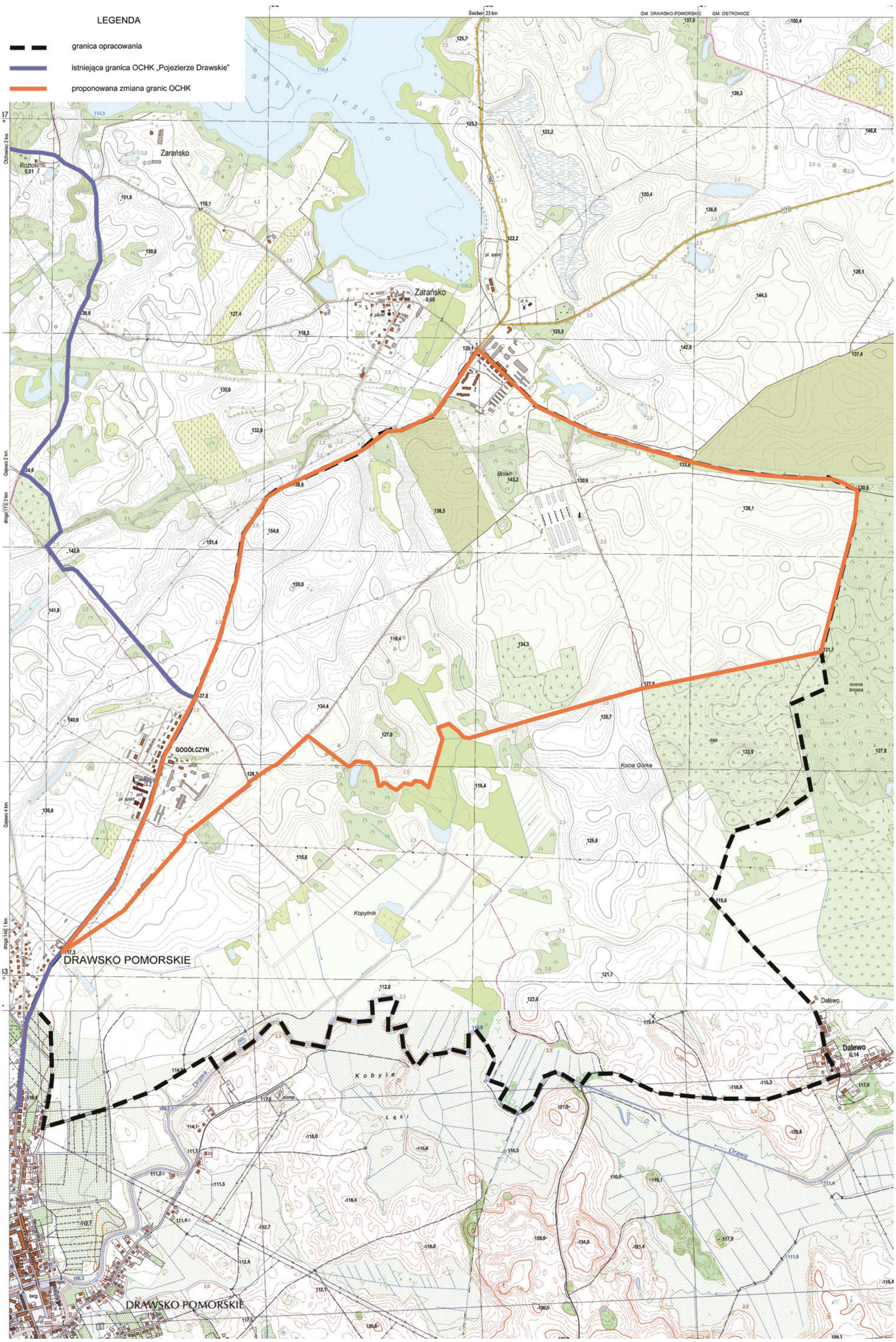

Fig. 1. Site map of the studied area, black line – studied area, blue line – existing border of the "Drawsko Lakeland" PLA, red line – proposed change of borders of the PLA (M. Czałczyńka-Podolska, M. Rzeszotarska-Pałka 2016)

law" [21][1], the indication and development of priority landscape cards has been abandoned. Therefore, the analyses included the preparation of a detailed landscape characteristic, within which its cultural and aesthetic values were identified. In the next stage of the work, identification and assessment of threats to the previously defined cultural and aesthetic values of the area as well as devastation of the landscape occurring in the studied area were performed.

In addition, the site's vista availability was also analysed to verify its potential impact on landscape perception. Characteristic vista panoramas were identified: active and passive exposure venues. Active exhibition venues include panoramas extending from the study area to neighbouring areas, and passive exhibition locations include characteristic insights into the study area from neighbouring areas.

In order to perform the aforementioned analyses, a query was conducted on the source cartographic and descriptive materials [6, 19, 20, 24], as well as field studies. Two local visions of the investigated area were carried out, both in the leafless season for trees and shrubs, as well as in the midst of vegetation season.

3.3. Results of the analyses

3.3.1. Analysis of the scenic accessibility of the area

The site vista analysis was developed to determine the visibility of the area from generally accessible public roads, and as a result, the possibility of its impact on the perception of the landscape. Scenic accessibility from two public roads, which at the same time constitute its boundaries, was examined. These are: a fragment of provincial road No. 173, leading from Drawsko Pomorskie to Zarańsko – the western border of the area and a part of the dirt road leading from Zarańsko towards the east – the northern boundary of the area. Apart from the communication function, these roads also play the role of tourist routes.

As a result of the analysis of vista accessibility, it was found that the area is virtually visually inaccessible from these public roads. The view of the area is obscured by roadside vegetation growing along the dirt road from the north and the terrain along the provincial road – numerous hills with mid-field vegetation, as well as a chestnut alley along this road in the vicinity of Gogółczyn. It was also found that the limited scenic accessibility applies both to summer and winter. The few scenic clearances along the dirt road in the north of the area during the leafless season are practically obscured by terrain – a low embankment running along the dirt road, and the shrub vegetation, which even in its leafless state is so dense that it is an effective view barrier (Fig. 2).

The only two small scenic openings to the area are located at provincial road No. 173 to the north of Gogółczyn. Both openings are characterized by very low visual and aesthetic values due to the linear devastation of the landscape occurring there, in the form of two power lines: high and medium voltage that run through the study area from west to east (Fig. 3).

[1] Priority landscapes are areas that are particularly valuable to the public because of their natural, cultural, historical, architectural, urban, rural or aesthetic-scenic values.

Fig. 2. No vista access to the site, dirt road in the area of Zarańsko, bicycle route (photo by M. Czałczyńka-Podolska, 2016)

Fig. 3. High voltage line – view of the area from road 173 (photo by M. Rzeszotarska-Pałka, 2016)

Analysing the existing scenic values inside the site, it is necessary to name the viewpoint in the form of the so-called Cat Hill [Pol. Kocia Górka], which allows for far-reaching insights into the area in practically every direction, exposing a typical landscape of agricultural crops (Fig. 4). However, it should be noted that this point, although it has unquestionable scenic

Fig. 4. Vista point, the so called Cat Hill (photo by M. Czałczyńska-Podolska, 2016)

qualities, which are not disturbed even by the view of the degraded area of the former state farm, and obscured by the tree planting line, it is not fully available to potential tourists because it is located in privately used agricultural land.

In conclusion, it should be stated that the analysed area is practically inaccessible from public roads and tourist routes, and as such has marginal significance when it comes to influencing landscape perception. Due to this, the manner of development and shaping of the studied area has no direct impact on the tourism and aesthetic potential of tourist and public roads existing in this area.

3.3.2. Identification of the cultural and aesthetic values of the area

The analysis of cultural values of the landscape covered the categories contained in the study "Identyfikacja i ocena krajobrazów" [18], such as: archaeological objects, rural buildings, objects of military and defence architecture, fortified architecture, communication infrastructure, religious objects and complexes, cemeteries, objects of old industrial and craft architecture, objects of court and residential architecture, post-occupancy facilities, objects of tourist and recreational investments, memorials, public facilities, monuments and memorial mounds, preserved traces of property, morphological type of the village, genetic type of the village (according to). The analysis was supplemented with the category of composed greenery, as well as objects entered in the Register of Monuments of the West Pomeranian Voivodeship and the Municipal Register of Monuments of Drawsko Pomorskie and existing tourist routes: walking and cycling.

Within the area of study, several objects were identified in the abovementioned groups, mainly archaeological objects and rural buildings. Among them, only one object was listed – the Evangelical church in the village of Dalewo, currently a branch of the Roman Catholic parish of Saint Stanislaus Kostka (Fig. 5). Numerous archaeological objects identified in the area of study are barely visible in the landscape in the form of small hills. Of the 14 objects of these type: six are settlements, another six – settlement points and traces, and two are burial grounds. The terrains on which archaeological objects are found are generally in the hands of private owners and are concentrated mainly in the vicinity of the existing settlement areas of the villages and the town of Drawsko Pomorskie. Among rural layouts, the villages of Zarańsko, Dalewo and Gogółczyn should be mentioned along with single residential and economic objects entered into the conservation register. The examined site also features composed greenery objects in the form of: a manor park and a chestnut alley located in the village of Gogółczyn.

In the immediate vicinity of the area, several objects with significant cultural values have been identified (in the villages of Zarańsko and Dalewo), which, though located outside its borders, have a strong impact on the landscape. There are also objects entered in the Register of Monuments: the palace park in Dalewo and the manor park in Zarańsko.

The analysis demonstrated that the area has few and only insignificant cultural and aesthetic values, mainly concerning several archaeological objects (hardly visible or completely invisible in the field) and architectural objects in the form of rural and religious buildings, the most valuable of which is the church with a wooden belfry to be found in Dalewo.

Fig. 5. The St. Stanislaus Kostka Church in Dalewo (photo by M. Czałczyńska-Podolska, 2016)

3.3.3. Assessment of threats to cultural and aesthetic values of the area

Among the most important threats related to the identified features of the cultural landscape of the studied area are:

- the decomposition and degradation of residential and park complexes: a mansion in Gogółczyn, which has not been used for many years, the completely blurred composition arrangement of the manor park in Gogółczyn; the manor and court park in Zarańsko – currently unused – have been gradually degenerating for several years;
- the decomposition and demolitions within manor farm complexes: the sole remaining building of the manor farm in Gogółczyn is the octagonal barn – currently unused; the Zarańsko manor complex is gradually becoming devastated – the farm yard layout has been preserved, but there are shortages in farm buildings, the preserved buildings have not been renovated for years and are subject to degradation; the preservation state of the housing colony of the Zarańsko manor farm is very bad – the previously uniform buildings were devalorized by numerous conversions of their facades, replacement of window and door frames, and roofs, and the housing is accompanied by completely depreciated facility buildings in the rear of the yard;

- the neglect of historical rural cemeteries: post-evangelical cemetery in Dalewo with removed tombstones and shortages in the tree stand, poorly legible in the field.

Within the studied area, numerous elements of devastation of the cultural landscape were also found, such as:

- the area of the historical residential colony for employees of the farm in Zarańsko devastated by the introduction in its structure of the multi-family housing complex for employees of state farm in the second half of the twentieth century. The area is subject to surface devastation of cultural and aesthetic values of the rural landscape (Fig. 6);
- devastated area, used in the 2nd half of the 20th century by the state farm for the purpose of poultry farming and silage silos. The area is currently unused, the storage buildings and accompanying others are completely degraded, covered with self-sown plants, shrubbed, and littered. The area constitutes a surface dominant, which is unharmonious in the surrounding landscape, and negatively affects the aesthetic values of the area and the eastern part of the village of Zarańsko (Fig. 7);
- high voltage line running through the analysed area from west to east. Among the gentle hills of the Drawskie Lake District, covered with arable fields, meadows and mid-field trees, the high-voltage line is a linear disharmonial dominant, negatively affecting the aesthetic values of the landscape (Fig. 3);
- the medium voltage line running in the northern part of the studied area constitutes an element of linear disharmony in the landscape with an average negative impact on the aesthetic values of the landscape.

Fig. 6. Zarańsko, area of the former state farm – housing development (photo by M. Rzeszotarska-Pałka, 2016)

Fig. 7. Zarańsko, area of the former state farm – silos (photo by M. Rzeszotarska-Pałka, 2016)

3.4. Use of research results to develop recommendations for the analysed area

On the basis of the expert valuation of the cultural and aesthetic values of the landscape, it should be stated that the existing threats and devastations of the landscape of the site significantly reduce its aesthetic value, and the area of the former State Agricultural Farm in Zarańsko is down to the degraded, requiring urgent revitalization and reclamation activities.

The area subjected to landscape analyses, although located in a significant part within the boundaries of the "Drawsko Lakeland" Protected Landscape Area, does not have significant landscape values. Within its area, there is only one listed monument, and the landscape and aesthetic values of the area are reduced by the identified elements of the devastation of the landscape and the existing threats related to historic buildings. Significant aesthetic and scenic values can be observed only in the southern part of the area, near the picturesque Drawa River and the neighbouring village of Dalewo.

Due to the low cultural and aesthetic values of the area of the study, as well as the occurring devastation and threats to the landscape, it seems reasonable to change the course of the "Drawsko Lakeland" PLA boundaries and exclude the northern part of the area from the PLA. Such a change may bring socioeconomic benefits, opening the possibility of introducing new investments and, as a result, economic recovery of a larger area. It is possible to locate production facilities or tourist services in the northern part of the studied area, in the vicinity of the village of Zarańsko. The landscape transformations connected with this, however, will not be visible from public roads and tourist routes, due to the shape of the terrain and trees. In the "Observation analysis of the site's availability", it was demonstrated that the area is practically invisible from public transport routes and viewpoints, and therefore the location of new cubature objects in this area will not adversely affect the cultural and aesthetic values of the landscape.

In the "Study of conditions and directions of spatial development of the Drawsko Pomorskie municipality" the main directions of development of economic activity in the Drawsko Pomorskie municipality were listed, as follows: "services, primarily related to tourism and leisure, and tourist services" [19, p. 203-205]. The development of production activities is also expected "allowing larger business ventures provided that they apply modern 'green' technologies that spare the natural environment". The authors of the *Study* also stress that "in the areas of former state farms, it is advisable to develop economic activity activating the local unemployed population. Therefore, organizational and economic conditions should be created to stimulate the activity of the local rural environment. Newly emerging economic entities should be adapted to the scale of a given settlement unit". The location of industrial and production facilities is predicted in rural settlements based on the existing economic base of former state farms and other farming cooperatives (SKR). The terms formulated in this way in the *Study* confirm the legitimacy of the location, in the vicinity of the former state farm village of Zarańsko, of production facilities using the former state farm area, currently contributing only to the devastation of the landscape and significantly reducing the aesthetic value of the area. Such a location of production facilities or tourism services may contribute to the development of the village of Zarańsko, the activation of its inhabitants, and in the long term even increase the aesthetic values of the landscape.

4. Final conclusions

Appropriate selection of methods, tools and procedures is the basis for a reliable landscape assessment and should always be connected with their adaptation to the landscape form and the scale of the development. In the analysed case, the use of only the landscape audit methodology (as required by the client) would significantly impoverish the analysis. The omission of such important issues as the accessibility of the site, and the in-depth analysis of the value of resources identified in the area, could have a significant impact on the overall assessment. The combination of various methods (structural, perceptual and other) would appear to be advantageous, especially in the case of cultural landscapes of various forms of development and functions, as well as further work on the landscape audit procedure towards universalism or specifications enabling its application to various forms of landscape.

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The former urban school gardens

Dawne miejskie ogrody szkolne

Abstract

In the studies, the subject of the so-called central school gardens which were founded in interwar Poland was undertaken, thinking about the pupils of all schools in a given city, irrespectively of the level of learning. The character of the gardens was determined by the goal they served, as well as by the user for whom they were founded – they were, first of all, demonstration gardens, based on the model of university botanic gardens. From among the whole group of school gardens which were founded in great quantities at that time, they were distinguished by their relatively large scale, often with access for the wider public and by a "park nature"; therefore, their layout, architectonic details, and partly their plant selection, are not only the reflection of the requirements, being imposed by their didactic function but also a picture of contemporary fashion or standards and rules for the design of gardens and parks.

Keywords: Bydgoszcz, central school gardens, Łowicz, Poznań, Wacław Zaykowski

Streszczenie

W badaniach podjęto temat tzw. centralnych ogrodów szkolnych, które zakładano w Polsce międzywojennej z myślą o uczniach wszystkich, niezależnie od szczebla nauczania, szkół danego miasta. Charakter tych obiektów był zdeterminowany zarówno przez cel, jakiemu służyły, jak i adresata, dla którego je zakładano – były to ogrody przede wszystkim demonstracyjne, wzorowane na uniwersyteckich ogrodach botanicznych. Pośród całej grupy licznie wówczas zakładanych ogrodów szkolnych wyróżniają się stosunkowo dużą skalą, często także dostępnością dla szerszej publiczności oraz „parkowym charakterem" i dlatego w ich rozplanowaniu, detalu architektonicznym, częściowo również w doborach roślinnych – odnajdujemy nie tylko odzwierciedlenie wymogów, jakie narzucała ich dydaktyczna funkcja, ale również obraz ówczesnej mody czy norm oraz zasad projektowania ogrodów i parków.

Słowa kluczowe: Bydgoszcz, centralny ogród szkolny, Łowicz, Poznań, Wacław Zaykowski

1. Introduction

School gardens, a somewhat forgotten type of didactic garden today, were very popular during the interwar period. They were founded in big cities, as well as in small towns and villages. "The central school garden" was, however, a type of school garden strictly linked with the city, and especially with the big city – where many schools with different levels of learning were functioning.

The central gardens were an alternative to the "workplace-related" gardens, that is, created irrespectively of each other, at every school – the alternative being utilized, first, due to a lack of appropriate, undeveloped plots in the direct neighbourhood of big city schools, and due to the distance from school to "living nature" as well as due to saving money. "School gardens in big cities – if they exist – are usually small [...], hence, there has emerged a necessity for creating central gardens in big centres which would have a systematic plant community, with biological and geographic groupings, but consisting of appropriate plants, being selected especially for school purposes" [1, p. 145].

The establishment of didactic gardens for children and school youth resulted from the changes in education system which, from the second half of the 19th century, was based upon explanatory methods of teaching. In the field of teaching natural science, the excursions and field observations played an increasing role. Some of the observations were conducted in the classrooms, utilizing "parapet cultivation", or in school gardens (the children could conduct experiments and acquire basic gardening skills). Forests, meadows and fields were *terra incognita* for children, so organization of lessons in open territory was very important and not easy. In certain cities, some of the lessons on nature were carried out in urban parks; the plants were accompanied by plates with the species name of a given plant (e.g. in Lublin, in the Saski Garden, or in the Urban Park in Grudziądz). In other big cities, the problems of limited access to natural non-urban habitats and the absence of the possibility of creating school gardens at each school were solved in such a way that central gardens were founded, and they were supplementary to nature laboratories, also central, common for many schools. These gardens could combine two basic functions – they were garden repositories, which supplied fresh, live plant material for lessons on nature, performed in the classrooms; and they were simultaneously "demonstration gardens", "living museums" where the pupils could familiarize themselves with the morphology and systematics of the plants and their biology and physiology. The explanatory and scientific (at the same time) nature of the central school gardens made them similar to university botanic gardens in respect of their form and programme; although their structure was simpler and the collection of the plants was more modest, they were adopted to the needs of young people and the financial possibilities of the cities.

2. The aim of the studies

In the present paper, the characteristics of the central school gardens, founded in the interwar period in Poland, are given. On the grounds of the analyses conducted, the most important elements, distinguishing these gardens, as compared to other didactic gardens, are indicated. Based upon the preserved information, the outline of the history of founding such gardens, as well as selected examples, the analysis of their composition is carried out.

3. Definitions

It is difficult to find an *explicite* definition of the "central school garden" in the literature dating back to the interwar period in Poland. More frequently, this term was defined within the classification of the term "school garden" at that time. The "central garden" may be found among demonstration gardens, being defined as a place where "it is possible to show the pupils different plants, which often are absent even in the direct vicinity, and where we may collect plant material for lessons in classroom [...] [such] a garden could be called a small-scale botanic garden" [2, p. 90]. The creation of collective gardens as early as in 1921 was justified by Władysław Szafer, as indicating that "striving at creating a botanic garden at each secondary school separately would not be – obviously – harmful, but it would intrinsically lead to the creation of a small number of average gardens, whereas the real advantage for schools could be provided only by good and not too small botanic gardens" [3, p. 28]. Then, Szafer mentioned that "botanic" gardens, that is, scientific gardens, should serve not only secondary schools but also common schools. In the classification published by Antoniewiczówna central gardens were distinguished as one of four groups of school gardens, next to district gardens, school-adjacent gardens and small flower beds, and were described as collective gardens, being founded for all schools in big cities, demonstration-scientific in nature, often supplemented with a "garden-store place" [4].

4. Characteristics of the central school gardens

Two important factors, emphasized in all the sources cited above – the similarity to university gardens and the demonstration characteristic, have affected the high standard of "central gardens" among other didactic gardens; this role resulted in rendering them the appropriate plastic setting and park composition which was consistent with the fashion of that time; they were often designed by known planners of the period. The aesthetic role of school gardens – apart from the educational, social and hygienic roles – was unquestionable in all cases. "The indispensable feature of the school garden, apart from practical distribution of its particular sections, is a special consideration of the aesthetic aspect [...]. The garden must be beautiful and this is a necessary requirement [...] it must also affect (by its architecture) the child's mind, develop a sense of beauty and generate – in the child's soul – the need for harmony and beauty" [5, p. 204].

From among the authors of designs of central gardens, we meet outstanding garden planners such as Edward Ciszkiewicz (garden in Łódź), Stanisław Zadora-Życieński (in Białystok), Wacław Zaykowski (in Łowicz), managers of urban gardens – such as Marian Güntzel (in Bydgoszcz), Władysław Marciniec (in Poznań) and, probably, Paweł Sallmann (in Katowice). Academic professors such as Rudolf Boettner (at the same time, the co-author of the conception of the first part of garden in Jeżyce district in Poznań) or Jan Muszyński (in Vilnius) cooperated with the authors of the abovementioned conception in respect of the selection of the particular sections and plants for emerging gardens. In the project work, the members of the Polish Pedagogical Society of Natural History (PPTP)[1] also participated.

The active involvement of the municipal authorities and district school education offices in the creation of central gardens is a successive feature, distinguishing this type of didactic gardens. The aid consisted not only in financing for the investment but firstly, in leasing the land, support during the stage of the project's development, and later maintenance of the garden. It was just one of the reasons for which urban parks were transformed into central botanic, natural, biological or zoological-botanic gardens. There were just the communal parks where the central gardens were created: in Łódź – in Park Źródliska, in Piotrków Trybunalski – in the southern part of the J. Poniatowski Park and in Białystok – within the limits of the Zwierzyniecki Park. They were also often created in Katowice, Łódź, Warsaw and Vilnius, which was already mentioned in the name of the garden; they were not only gardens which presented flowers but also animals. The discussed school collections became, with the passing of time, the precursor of urban zoological gardens such as for example, in Vilnius and in Warsaw where – during the transfer of the garden to Dobra Street – the city authorities decided to create a separate independent administrative unit which took over the whole so-far existing zoological section of the school garden. Thus, the Warsaw Zoological Garden was created (and has existed until now) [6].

The successive common feature of the central didactic gardens consisted in the fact that they were open to a wide public. They could be attended not only by children and teenagers during lessons on nature, but also by adults. In this last case, small fees were introduced with the aim of covering at least a small part of the expenses borne on the maintenance of plants and animals.

[1] PPTP was founded in 1925 in Warsaw. The Society established the Section of School Gardens; it developed designs for school gardens. The activity of the Society was connected with the foundation of the Central Biological School Garden in Warsaw (situated at 3rd May Avenue) [6]. Probably, the later garden as organized at Dobra Street was also founded on the grounds of the plans developed in the Section of School Gardens, as the site was found all the time under the care of the PPTP. The methodical demonstrations intended for teachers were also organized there [7].

5. History of founding the central school garden during the interwar period

The first attempts at establishing a garden which would serve the pupils of many schools within the borders of the future Second Republic of Poland[2] (known also as interwar Poland) were undertaken as early as at the end of the 19^{th} century in Poznań. In 1898, in the territory of urban plantations – nurseries of trees and decorative shrubs, the so-called "botanic section" was founded; it was a material store place where plants were prepared for conducting some nature classes in people's schools (the lowest degree of school education). As early as 6 years later, this "section" was transferred to a new site in the Jeżyce district and at this location – before World War I – apart from the "storage place", demonstration collections of domestic plants were arranged. In 1925, a school garden was opened there; in the first stage, it was designed by Prof. Rudolf Boettner [9, 10]. The garden in Warsaw was the first demonstration central school garden, founded directly after Poland regained independence. Initially, in 1918, it was situated at the territory, purchased by the City with the aim of building the National Museum and later, when the building of the Museum was commenced (in 1927), it was transferred to a non-developed plot at Dobra Street. In the 1920s, the following central school gardens were also established: Vilnius (1921), Katowice (1923), Łódź (1925), Lwów (1927), Piotrków Trybunalski (1927) and Cieszyn (1928). Further gardens were founded in the thirties – in Białystok (1930), in Bydgoszcz (1930), in Siedlce (before 1933) and in Łowicz (1934).

The territories where – during the interwar period – there were the central school gardens, play various functions today. In Łódź, the former school garden still remains a part of the park, but is not utilized as a didactic part. In Białystok, the territory is utilized for social care purposes: within the limits of the former school garden, a childcare home and home of social care are arranged. In Cieszyn, Katowice, Siedlce, Warsaw and Vilnius, no trace of these gardens remains; their territories were devastated during the Second World War and there were new post-war constructions erected. In Lwów, the former central school garden does not exist today, although the building of the school exists and plays its educational functions. Two objects, situated in the Wielkopolskie district have changed their role and now they fulfil the function of university botanic gardens (The A. Mickiewicz University in Poznań and Kazimierz Wielki University in Bydgoszcz). In Łowicz and Piotrków Trybunalski, during recent years, attempts to restore the splendour of the former school gardens have been undertaken; in the first one, the composition of the garden was reproduced but it is kept as a green urban area; the second one is an urban botanic garden. Neither of these gardens, however, fulfil their primary didactic function; the role of "garden-workshops" was not returned to them; they play the role of a "curiosity" for tourists and inhabitants.

[2] Within the contemporary borders of Poland, there was also another, earlier founded garden which played a role as the Urban Botanic School Garden (established in 1887 in Wrocław). Today, its area lies in the territory of Szczytnicki Park. The garden was rearranged in 1912 during the preparations for The Centennial Exhibition. The pupils could take advantage of the crops of the garden at the site – during excursions, or in their own classes as the plants were brought from the garden to all interested Wroclaw schools 4 times a week, after the previous order [8].

6. Composition

The composition of school gardens was strictly connected with their function, locality and size of the territory. The scientific nature of the garden had the primary role, affecting the spatial layout. From among all the documented former school gardens, which fulfilled the function of collective gardens (central), we may distinguish three basic groups. First there are the demonstration (scientific) gardens which were established based on urban parks and which were managed as institutions being financially and organizationally independent of schools (Łódź, Poznań, Bydgoszcz, Piotrków Trybunalski). The second group consisted of the gardens which, apart from demo sections (plant systematics, biology, medicinal, industrial, economic and decorative plants), also had practical sections – pupils' beds and experimental plots (Cieszyn, Łowicz). The third group contained the garden in Białystok which primarily played a double function – a garden situated at school for children suffering from tuberculosis and a central garden for all Białystok schools; due to this reason, they included demo sections as well as practical parts which supplemented sport areas and areas for children to play.

In all gardens, irrespectively of their classification as mentioned above, the scientific demonstration sections were organized. Depending on the site possibilities (the size of the area), apart from the typical parts, containing collections of thematically arranged plants, found in geometrically determined plots, we could find an arboretum together with community gardens with groups of aquatic and swamp plants and the so-called rockeries, or more generally, collections of the plants from mountain habitats. There were just the arboreta in combination with habitat groups which resembled a park in respect of their composition.

The earliest central school gardens referred distinctly to the naturalistic "calligraphic" trend, a style fashionable in design of parks and gardens at the turn of the 20th century. The application of the groups of aquatic or mountain plants is also characteristic of the contemporary architecture of landscape, however, in this case, the direction of the influence is rather reverse, that is, the first was the interest of botanists in the relationships between the living conditions and organisms living there and then, there were attempts to reproduce the system based on natural communities (phytocoenosis) in university gardens and then, in park composition. The central gardens which were created in the interwar period referred to a modernistic solution in respect of their composition and layout, with their transparent composition and distinct emphasis on main points. Similarly, the equipment of the gardens (pergolas, arbores, basins, retaining ledges and field stairs) corresponded to modernistic aesthetics in respect of form and material. The details of these compositions may be analysed owing to the preserved plans and, first of all, photographs.

According to "modern style", two Wielkopolskie gardens were designed: in Poznań and in Bydgoszcz (based upon Poznań) [11]. In the both cases, the characteristic differentiation was employed, being stressed by stairs and retaining ledges, levels of the particular parts of the garden; all was designed as a simple composition based, first, on a rectangular division of quarters, subject to the main axes. In the preserved photographs, we may see

Fig. 1. Bydgoszcz. View on the entrance to the garden, with rest place and solar clock.
Card dating back to ca. 1940, [19]

all the characteristic parts, elements and architectonic details of both gardens – pergolas and trellis, emphasizing the division of the area into particular functional parts, and the appearance of squares and form of entrance gates (Fig. 1). In the Poznań garden, a vast, oval-shaped section of plants' biology, with a central basin and two squares distributed on the main axis of the garden and arranged in a form of pergola on their peripheries may be recognised as a very characteristic part of the garden.

The garden, established on the grounds of the project of Wacław Zaykowski[3] of 1933 and situated in the peripheral district of Łowicz – Bartkowice, is an interesting and lesser known object.

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[3] **Wacław Zaykowski** (born on 25.09.1875 in Warsaw, died on 16.11.1941 also in Warsaw), from 1923 employed in the Ministry of Religions and Public Education, in the Department of Common Education as a clerk; from 1928 – ministerial counsellor, was the main – and for many years. The only specialist who *develops plans of school territories* [12] Education – gardener-planner, he graduated from the Pomological Institute in Proskau (Prószków near Opole). After studies, he participated in the arrangement of Skaryszewski Park. For 2 years, he was the manager of the botanic garden at the University in Dorpat; 3 years of work in the Ministry of Education in Moscow, one year at the Alfred Frenzl company in Germany. From September 1919 until 1921, he was an inspector in the Ministry of Agriculture and Public Estates (during this period, he took care of the Royal Łazienki Park; from 1 IX until the end of November 1919 as a senior gardener and then, from 1.12.1919 to 7.01.1921, he was the manager of the Royal Łazienki Park and garden at Belvedere. Together with W. Kronenberg and T. Chrząński, he conducted the technical-irrigation office "Plan-Garden". He is the author of *inter alia* a competition project for the territory of the Mory experimental station near Warsaw (1913), implemented the competition project he won for the garden at the K. Szlenkier school in Warsaw (1914), project of the school garden at the E. Orzeszkowa Teacher Seminar in Warsaw (ca. 1920), the project of territory around 7-class common school in Puszcza Mariańska (Mariańska Forest) (1923), Inter-school Nature Garden in Łowicz (1933). According to his projects, there were established: The H. Sienkiewicz

The initiator of its arrangement was Władysław Stanio, the teacher of nature subjects in Łowicz college (teachers' seminar). The garden was arranged in the years 1934–1936. The principal part of the work was performed by the pupils of the seminar, and a part of the plants – according to the requests, dispatched by Stanio, were obtained from the nurseries of the period[4] of decorative plants. The official opening of the garden took place on 7 June 1936 and was a part of the ceremonies celebrating the 800th anniversary of Łowicz [18]. The plot, as received from the town, had an irregular shape and area of ca 1000 m^2. The whole territory was divided into three parts: basic, the greatest one was destined for collections of decorative plants, arranged in a form of vast grass lawns

Fig. 2. Urban Inter-school Natural Garden in Łowicz. Central, decorative part of the garden, 1938, [20, p. 20]

Park in Łowicz (1924) and Vistula Riverside area "Kościuszko plantations" in Warsaw. In 1922, the brothers Zaykowski (Wacław and Stanisław) obtained the first award in the project of Peoples' Park in Łódź. The elements of this park were considered in the project, compiled by W. Rybski, coming from two pieces of work: the project of the Zaykowski brothers and project of E. Ciszkiewicz. In 1928, Zaykowski developed the project for management of the area of the Institute of Physical Education near Bielany. He was a member of the Society for the Support of School Gardens, as established in 1925 [12–16].

4 From among the donors there were included the nurseries of Zamoyski-Estate in Podzamcze, and nurseries conducted by "Koźlakowski and Żaglewski" in Płock, by Freege (Cracow), by Stanisław Przedpełski (Płock), Katriel Eizyk (Kutno), specialising in the production of roses, and by W. Garnuszewski (Warsaw) seed trade company in Hale Mirowskie and Natural Garden in Vilnius. A part of the plants derived from the own plant nursery, established by Władysław Stanio and his pupils at Teachers' Seminar in Łowicz [17].

with flower borders, with groups of shrubs and trees in peripheral parts of arboretum. The first part included also the sectors of medicinal and industrial plants; the composition of the discussed part was based on two concentric circles and perpendicular main axes; in the western part, a rockery was planned; the eastern part was intended for basins for aquatic plants, fish, reptiles and amphibians, and *filicetum* (a collection of ferns). The crossing of the axes was stressed by the flowerbed on the plan of a circle, with a pedestal on which an agave was placed as if it was a flower and solar clock at the same time (Fig. 2). In the demonstration-decorative area, there were also placed cages for small animals: *insectarium*, an aviary for singing birds, and cages for small mammals. The second part of the garden was situated on the northern side in relation to the first one. It was devoted to practical sectors – pupils' beds, nursery and experimental plots and the indispensable gardening material support (seedbeds, coldframes, compost heap, and a store for tools). It was intended for the "summer class", where the pupils could have some of their lessons; due to financial reasons, it was not implemented. The last part, the third in the school garden, was destined for the sector of mass cultivation, that is, the so-called "plant-storage site".

7. Summary

The former school gardens which have scarcely been preserved until today are, first of all, the pre-war central gardens which served the whole society of a given city. The role of these gardens was not limited exclusively to a didactic function; they were objects which, like urban parks, were also used for recreation. There was heed paid to the high aesthetic standard of their composition; they were planned, as a rule, by garden planners in accordance with contemporaneous fashions, and trends in the design of parks and gardens. The implementation of these projects was favourable for them due to the aims imposed for the central school gardens – scientific purposes which among many sectors, established in school gardens, emphasized first of all the sectors of decorative and medicinal plants, systematics and biology of plants and community groups and arboreta, and the fact of frequent widening of the exposition to animals; all this created a very attractive place for the visitors.

Their further existence may be perceived in their high similarity to university gardens as objects which have survived until now, and were those which were easily adapted to academic needs in the post-war reality in the situation where the social interest and the need for their further function existed.

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Identification of the *genius loci* category in the process of recognition of the city landscape design issue

Identyfikacja kategorii *genius loci* w procesie rozpoznawania przedmiotu projektowania krajobrazu miasta

Abstract

City landscape design in the approach presented here is a process that combines the language of contemporary urban design, landscape and the phenomenon that the landscape represents. Using it allows the most important values, meaning and the identity of the space to be recognised, which gives the opportunity to accurately highlight its shortcomings and its potential. The method of city landscape design process presented within includes a distinctive landscape analysis and a system of results synthesis and interpretation. Three aspects have been presented: the general approach to the research process, the role of lighting, and the importance of urban furniture in the design of the city landscape.

Keywords: design, city, landscape, lighting, urban furniture, identity

Streszczenie

Projektowanie krajobrazu miasta w przedstawionym ujęciu jest działaniem odnoszącym się do łączenia języka współczesnej urbanistyki, krajobrazu i fenomenu, jaki krajobraz sobą reprezentuje. Pozwala rozpoznać najważniejsze wartości, znaczenia i tożsamość badanej przestrzeni, przez co daje możliwość dokładnego uwypuklenia jej mankamentów i potencjału. Przedstawiona metoda pokazuje drogę postępowania analitycznego oraz specyficzny sposób syntezy wyników i ich interpretację w procesie projektowym. Przedstawiono tutaj trzy aspekty: ogólne ujęcie procesu badawczego, a także rolę oświetlenia i znaczenie umeblowania w kształtowaniu krajobrazu miasta.

Słowa kluczowe: projektowanie, miasto, krajobraz, światło, meble miejskie, tożsamość

1. Introduction

The city landscape is directly experienced by the individual in a succession of views. Nowadays, urban planning designs fragments of the city structure; however, it is not involved in a comprehensive reception of its undertakings.[1]

The definition presented by Czesław Przybylski says that "designing is first of all an intellectual work, which leads to satisfying the individual's material and spiritual needs" [48]. This definition was expanded in the study by Bohdan Lachert [34], who formulated the intellectual process as a whole in five stages: starting from the intuitional recognition, moving onto the analytical process, then creating an intentional object, completing the object, and ending with an assessment of the work produced in this process. Lachert [34] based the expansion of his conception on the phenomenological model of the architectural work's layered construction proposed by Roman Ingarden [23]. The phenomenological approach proved to be useful, as this trend of thinking allowed less measurable human needs to be taken into consideration in the design of the city landscape.

In the current state of research, the aforementioned concepts are complemented by the *genius loci* phenomenology developed by Christian Norberg-Schulz [45].

Taking into account the fact that the research achievements in Polish landscape architecture in the field of lighting and urban furniture are relatively insignificant, and at the same time they have great importance for the form, function and meaning of the city landscape, these issues will be presented in this article separately.

2. State of research

The notion of designing the city landscape is associated with spatial [61, 27, 77, 7, 60], social [38, 12, 21, 79, 15] and phenomenological [25, 43, 17, 29, 47] aspects[2].

This process assumes that a specific space has its own structure [61, 77, 38], meaning [12, 27, 71, 15] and phenomenon [43, 1980; 17, 47]. At the same time, the city landscape [54, 57] constitutes a metaphor for space and place [38, 17, 29, 47], which is the subject of a design study. It is essential to create a holistic vision of the landscape phenomenon in the design process, as it allows the *genius loci* of a space to be captured. The division of this process into five categories: *things, order, time, light* and *character* allows a complementary analysis of space [43, 28, 29, 53].

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1 Sławomir Gzell, Lectures etc.

2 The emphasis is here laid upon evolution in treatment of landscape in reference to urban layout, where starting from Rome layout authored by Gianbattista Nolli in 1748, through examinations of structure by Camillo Sitte [61] and perception of space by George Kepes, expanded later by Simon Bell [7] or Kazimierz Wejchert [77, 78], or finally the compiled mathematic formulas by Nikos Salingaros [60], to broadening a theme through social issues in sociological-spatial research in humanistic [38] or regulatory schools [21], up to observation of phenomenon of space, among others as a fragment of city landscape in postulates by Jane Jacobs [25], in-depth studies by Christian Norberg-Schulz [43, 44, 45], Jeremi T. Królikowski and Jan Rylke [31], or finally in perceptional remarks by Juhani Pallasmaa [47].

2.1. Lighting

Within the category of *light*, both daytime and nighttime states of space are analysed [45], including natural and artificial lighting as well as the influence of the latter on the image of the space [83]. The properties of natural light and weather conditions cause the reception of space to undergo constant changes [40, 9, 55, 26, 73, 70, 50, 80]. When dealing with the impact of light changeability on architecture, urban planning and landscape architecture, works by K. Lynch [38] G. Cullen [12] K. Wejchert [77] Ch. Norberg-Schulz [45] or P. Zumthor [85] are worth mentioning. The visual features and composition [38, 12, 42, 10, 13, 35, 11, 54], issues of meaning and spatial identity [45, 29, 81], environmental conditions [37, 35, 81] as well as functional and technical aspects [6, 74, 19], ought to be taken into account when dealing with the role of artificial lighting in the city's image at night. Light has the potential to co-create the identity of the urbanised space and to influence its image, for example through introducing new spatial values. Ch. Norberg-Schulz [45] devoted much attention to the value of light in creation of a place. He attributed three types of *light* (which together create the character of place: *romantic, cosmic, classical* light) to three types of the *genius loci* of space [29].

2.2. Urban furniture

The role of urban furniture can be considered in the physiognomic context [1, 2, 76, 72, 84, 52, 75, 4, 12, 49] the social context associated with functioning of the space [25, 14, 20, 79, 41, 18, 3, 22, 17, 39, 67, 58, 68] as well as the phenomenological context related to the emanation of the identity of the place [41, 69, 8, 37, 75, 65, 5, 68].

3. Methodology

3.1. General issues

City landscape design is a process that shows, on the basis of thorough analyses, the condition of a given place [57] and through precise formulation of guidelines – directions and specific solutions to its desired transformations. Designing the city landscape is a process that reveals the condition of a place based on thorough analyses [57]. It also presents specific solutions to a desirable space transformation through the formulation of precise guidelines [27, 59, 15]. The analytical mode of landscape recognition, proceeding in stages, deals with issues related to the structure, meaning and the phenomenon of the place, considered one after another. As a result, the process reveals the values of each of the *genius loci* categories. The analysis of the *Structure*, apart from including the inventory of a space, can be made through the analysis of panoramas [77] or the analysis of values [43, 27, 71, 29]. *Meaning*, being the first interpretation of the structure, may use the analysis of the space in sequential viewing [12, 30] or the perceptual analysis [62]. *Phenomenon* contains an analysis of spatial values and a definition of the place's *genius loci* [45, 43, 29]. The results give a synthesis of a three-stage analysis. They present the project guidelines. The conclusion deriving from the guidelines constitutes the application in the form of a landscape change proposal. The above procedure remains open – one may use in it different partial analyses suitable to the space to be analysed [57].

3.2. Lighting

Considering the issue of lighting, the analysis of elements of the city composition may be indicated in the category of *light* [28], whereby studying its significance and selected spatial values [44, 29]. The method for perceptual analysis of space [62, 63], analysis of curve of impressions by K. Wejchert [77, 78] view morphology analysis by M. Lewin [36]; method for views evaluation [51]; analysis of the space in sequential viewing [30] or the analysis of the city panorama [57] can be useful to compare the spatial layer of urban interiors and their daytime and nighttime views. Lighting masterplans created in order to regulate the lighting of large-scale urban areas do not usually use a uniform method of lighting evaluation [83]. A typology of objects' and interiors' images changes at night, as well as the valorisation method of the visual transformations of the space at night [83] developed by K. Wlazło-Malinowska [83] may be applied in the analysis of night changes of the city.

3.3. Urban furniture

A multi-layered analysis of the cityscape that includes the elements of urban furniture allows a comprehensive understanding of the potential of the designed space [29, 54]. It is equally important to analyse the physiognomic layer, including a perceptual analysis [57], a morphological analysis [36, 66], and a colouristic analysis [33, 66] as well as a functional layer dealing with social issues [24, 39] and the semantics associated with the identity of the place [45, 31, 29].

3.4. City landscape design as a process of the space identity recognition

The analytical part of the project led as part of the classes "City Landscape Design" taught in the course of M.A. studies in the field of Landscape Architecture at the Faculty of Horticulture, Biotechnology and Landscape Architecture at the Warsaw University of Life Sciences is embedded within five categories of *genius loci***.** These methodological foundations are designed to fully analyse and understand the city as landscape; to overcome classical schemes of space analysis; to teach students independence in the choice of preparation of suitable analyses. Students select the methods presented by themselves and adjust the way of conducting their analysis to the characteristics of the project theme and their own sensitivity. The following list of analyses possible to be conducted within the analysis of the *genius loci* constitutes an open list and may be complemented with other procedures relevant to the perspective of the studied area [Fig. 1]:

1. Within the *things* category related to the construction and structure of interiors:

- identification of the structure of public space [57],
- general inventory,
- communication analysis [56],
- inventory of green infrastructure,
- inventory of urban furniture [67], including lighting [83],
- colouristic analysis according to Lancaster's method [33],
- tracking down traces based on the method of *placemaking* [24].

2. Within the *order* category that includes composition issues:
   - analysis of panoramas [56],
   - perceptual analysis by J. Skalski [62],
   - analysis of space in sequential viewing, based on Cullen's theory of sequence viewing [12, 30],
   - morphological analysis by M. Lewin [36],
   - composition analysis [56].
3. Within the *light* category:
   - description of the character of natural light and artificial lighting according to the light category of the *genius loci* analysis [45, 28],
   - analysis of night cityscape including: comparative analysis of space visibility [daytime vs night-time]; comparative analysis of changeability of the objects' and interiors' images at night[3]; comparative analysis of the composition of selected views [daytime vs night-time] and, consequently, results – composition & physiognomic analysis of the space carried out for daytime and night-time [83].
4. Within the *time* category related to social and cosmic time as well as to the rhythms of time [seasonal exploitation, diurnal cycle]:
   - functional analysis of space and objects,
   - studying the flow of users [24],
   - behavioural mapping based on the *placemaking* method [24],
   - counting people and vehicles [24].
5. Within the *character* category related to the spatial values:
   - analysis of spatial values [31],
   - historical analysis – historical and monumental values,
   - individual in-depth interviews – social values [32, 16],
   - informal interview – social values [24, 16],
   - filling in questionnaires or user surveys – social values [16],
   - tracking down traces – social values [24].

The foregoing methods and categories refer directly to the recognition of the structure, meaning and phenomenon, which in turn allow the identity of space to be found in a complementary way [45, 29, 57]. They all refer to the scope of research and its context [45, 38, 12, 3, 7]. At the same time, it is worth mentioning that by interpreting the pattern

[3] Including application of categories of changes of a day's object image at night, developed by K. Wlazło-Malinowska [83], that is *disappearance, reflection, isolation, completion* or *transformation* of the picture of objects by night.

[3, 29, 56, 83] and the *genius loci* categories [29, 43] the form of a place is found [12, 17, 29, 67] in such a way that the description of the identity of a given place is most accurate. Selection of methods depends on the local [urban] or planning scale of study [57]. The analytical process presented here is characterised by openness and flexibility, which makes it possible to select the method depending on the specific characteristics of a studied space as well as the designer's sensitivity and competence. It allows, based on results of respective analyses, design guidelines to be defined in a complementary way, which through an expected accuracy of in-depth field of study should make the designing process easier.

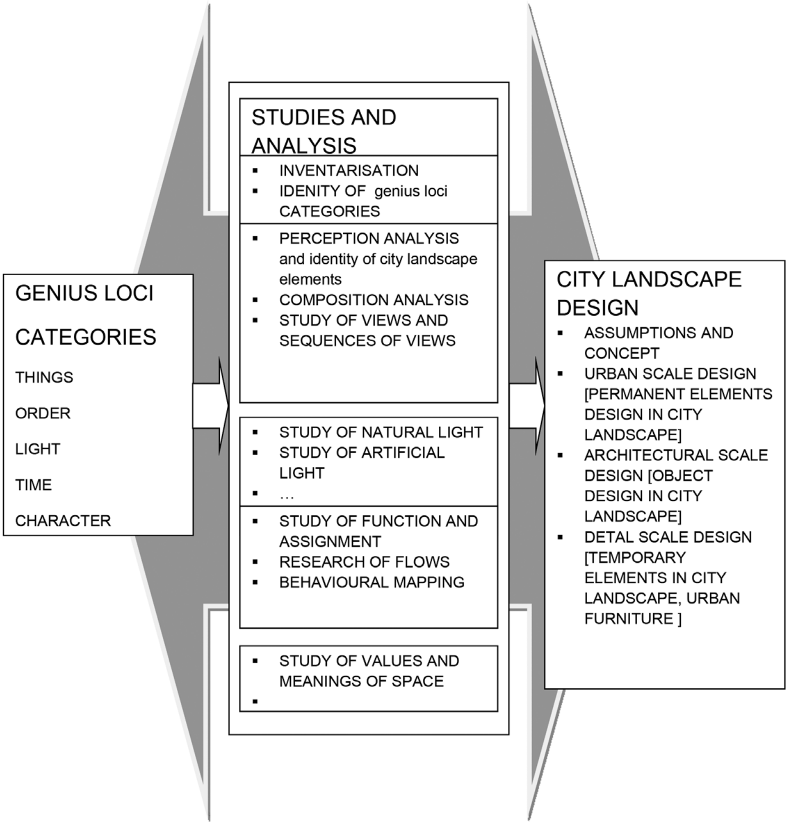

Fig. 1. Open model of city landscape design

4. Summary

City Landscape Design is a process that underlines the meaning of analyses in the diagnosis of space. The open model of design presented in this article refers to the legacy of philosophy, urban planning, landscape architecture, environmental psychology and sociology. It refers as well to interdisciplinary studies of the landscape phenomenon. In the suggested depiction, attention was paid to the importance of light and urban furniture, elements often underestimated, but vital in cityscape design. This research procedure can also be used in universal design, where it can influence the reduction of conflicts by its holistic character expressed in the psychological, social and spiritual dimensions of the *genius loci* categories.

It is, however, worth remembering that in a phenomenological method a close, attentive observation of the landscape and the designer's intuition are both crucial. Distinction, perception and finally identification of the landscape elements linked to specific *genius loci* categories present the significance of this method.

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Urban waterfronts' wilderness as a space of engagement

Dzikie miejskie obszary nad wodą jako przestrzeń zaangażowania

Abstract

The article presents theoretical considerations on the philosophy of designing and protecting wild urban waterfront spaces. Its goal is to examine the sense of these places in terms of their significance for urban and ecological structures, city social life, as well as for individual human beings. The analysis presented here based on the theory of architecture, environmental psychology and aesthetics, leads to two conclusions. First of all, such spaces are important places for city residents to engage in behaviorally and emotionally. Secondly, when it comes to managing wild water areas in cities, it seems to be more important to create places than to implement a specific project. What seems to matter most in creating such places is an emphasis on their familiarity, openness, effective simplicity and harmony in balancing the requirements of water nature and social life.

Keywords: urban wilderness, waterfront, architecture, placemaking, ecology, environmental justice

Streszczenie

W artykule zaprezentowano teoretyczne rozważania na temat filozofii projektowania i ochrony dzikich miejskich terenów nad wodą. Celem niniejszej pracy jest analiza znaczenia takich miejsc pod kątem roli, jaką odgrywają one w strukturach urbanistycznych i ekologicznych, w życiu miasta, a także w życiu poszczególnych ludzi. Zaprezentowana analiza, oparta na teorii architektury, psychologii i estetyki środowiskowej, prowadzi do dwojakich wniosków. Po pierwsze – dzikie miejskie obszary położone nad wodą są dla mieszkańców miasta ważnymi miejscami, w które angażują się behawioralnie i emocjonalnie. Po drugie – jeśli chodzi o gospodarowanie takimi przestrzeniami, ważniejsze od wdrażania określonego projektu, wydaje się być tworzenie miejsc. Najważniejszą zaś rzeczą w tworzeniu takich miejsc jest nacisk na ich swojskość i otwartość aranżacji, efektywną prostotę i harmonię w równoważeniu potrzeb wodnej przyrody i związanego z nim życia społecznego.

Słowa kluczowe: miejska dzika przestrzeń, nabrzeże wodne, architektura, tworzenie miejsca, ekologia, środowiskowa sprawiedliwość

1. Introduction

The city as a result of human activity has become an outpost of civilization and culture, and to some extent this has happened against the logic of nature, which tends towards entropy. Historical urban civilization has long been defined by city walls that separate city life from the savagery of the outside world. However, real, vibrant cities rarely remain the perfect man-made urban structures that we might imagine. The reason for this might be inner forces that inspire uncontrolled growth, with no need for geometry (especially typical of organic medieval structures) to reveal natural human ‘disorder’[1]. Almost every historic city used to have wild enclaves which were beyond the strategies of the city plan or, on the contrary, the plan was based on their very existence. This, for example, was the case of ancient Greek cities, which – besides buildings – also contained open spaces that were used for participatory sporting activities or passive spectator enjoyment; this was not true of their predecessors (Egypt, Mesopotamia) or many successors. The ancient Greek model of life was characterized by “availability of <spare time>” and an atmosphere that encouraged public gatherings [16, p. 18]. And thus Athens’ plan, which oscillated around the space of Panathenaic Way (*dromos*) and Agora, also cultivated and protected important open spaces of other types that were closely related to nature, such as the mystic wild places on the hills of Pnyx that were dedicated to specific urban rituals[2]. In mediaeval England, in city centers which evolved out of rural settlements, there was usually a large open green area that initially served as common ground (pasture for grazing animals), but which was gradually reshaped for urban purposes. Echoes of this traditional landscape can be found in green open spaces in the center of some much more recent Anglo-Saxon[3] towns and housing estates.

The gradual disappearance of wild places in cities started in recent centuries. The reasons for this might be twofold: Firstly, the idea of fencing properties initially arose as a result of progress in agriculture around the eighteenth century [20]. Secondly, functional zoning began in the early twentieth century as the first step of the urban planning movement in towns. Roughly from the middle of the twentieth century, urban modernization clearly accelerated and indeed changed the image and the meaning of the traditional city due to the dynamic development of automobile communication and co-related urban sprawl. Entire expanses of green areas disappeared under overpasses, viaducts and local roads. Today, wild places within urban structures are usually waterfronts, industrial wasteland, vast transportation areas (sometimes taken over by nature), and very rarely post-agricultural areas. Truly wild, pristine natural areas in cities – with the exception of sites protected by law (such as nature

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1 I use this word following Sennet’s understanding of this term (Sennet, R., *Uses of Disorder: Personal Identity and City Life,* 1996, also: Sennet, R., *The Craftsman*, 1996).

2 An example of this may be a place reserved for feminine rituals (*tesmoforie*) related with soil, fertility and women’s solidarity. This place was filled with temporary huts and dug-outs dedicated to these rituals only and located very near to the ‘official’, male-only part of Pnyx, which generally was a meeting place of Athen’s citizens (*ecclesia*) [21].

3 This profound idea is visualized and evoked by urban structures of the Royal Crescent in Bath (arch. John Woods, 1767–81), the National Mall in Washington D.C. (urban plan by Pierre L’Enfant i Benjamin Banneker, 1791) or the garden-city principles Welwyn (urban plan by Barry Parker and Raymond Unwin, 1919).

reserves) – are virtually unheard of. Facing ongoing changes in the urban landscape as well as radical changes in the way of life of its inhabitants (a mass exodus from the countryside to the city and then from the city center to the periphery), modern cities are experiencing a crisis of identity and of place attachment [6]. Landscape without signs of the past nor the expression of nature further exacerbate the situation. Contemporary research – particularly in the field of environmental studies (psychology, philosophy) – proves that in our environments we do not need simply an address and a house, but also places which are available for spur-of-the-moment events and meetings. We need a space that offers something more than just a choice of predefined options of behavior (housing, work, recreation) – a space which is not strictly regulated by the oppressive principles of zoning. Paradoxically, we need a space that is not a product of ourselves and of our anthropocentric thinking – a space in which we can feel like "partners of the world or of nature in a larger than usual sense" [25, p. 181] and "feel enlivened to the wide range of our being, one full of surprise, uncertainty and irritation" [25, p. 184]. The need for such places seems to arise directly from human nature; we want not only security and belonging, but also self-realization, knowledge and creation. This can also be interpreted as a cultural retreat from the dominant position of functionalism based on the notion of economic efficiency. Instead, the return of older ideas such as the "good life" originally described by Jane Jacobs (1961) or the coordinated concept of "happiness" (as described recently by Charles Montgomery, 2013) may be observed. These ideas co-create the structure of multidimensional people's needs even though they are frequently difficult to label, see or be drawn in a project. They go far beyond the technical, functional and artistic criteria of a good modern urban project, but they are crucial for the quality of life in cities. Rather than being seen, the qualities of a city which are particularly important for residents might be felt and known, like a sense of community with other residents or with natural elements that are also framed by the city. The presence of wild urban spaces such as waterfronts may satisfy some of these needs.

2. Urban wilderness – mapping the sense of place

Wild natural places play an important role in the urban environment. As spaces for human beings, they are important not only because of what we see (visual aspects) or what we use (functional aspects). Their significance relies on the fact that they provide an evolutionary perspective and an opportunity for more trans-human and ecological being – reminding us of the importance of our symbiotic relation with nature in general, and with other humans and different biological species. Urban wilderness can be read on many levels: as a natural habitat that is important for eco-biological reasons, as a place for people to visit and spend time in, as a cultural space of historical, ideological, social and aesthetic value, and finally as a space of material value which has liberating potential, "where nothing exists and everything is possible"[4].

[4] R. Koolhaas, *The Berlin Wall as Architecture* [18, p. 108].

2.1. Eco-biological importance

Biodiversity, whose size and importance for the world we have just discovered, is increasingly threatened by the activities of human beings[5]. The processes of urbanization also contribute to turning more and more natural spaces into biologically 'dead' areas, not only because of disappearing wild enclaves, which are the natural substrate (*deep beds*) for native species, but also because existing habitats lose their natural connections. Contemporary urban planning and environmental protection strategies require rethinking; protected areas must be reconnected with each other and the overall ecosystem. Since the late 1970s, a new branch of research called *urban ecology* has been developed. Research in this field relates to environmental interactions in cities. A city is understood here as a special kind of ecosystem in which significant roles are played by people and the built environment. A city differs from other more natural environments, mainly because of the intensity of human impact. People are the main actors and builders responsible for the creation of specific human-made structures, but they are also the most important elements of the natural environment in the city [15]. Until recently we have lived with a sense that the formation and existence of cities is only a human matter. The complex issue of biodiversity should make us realize that the urban environment definitely has more players – other species of animals and plants. (Fig. 1, 2).

Nowadays, changes in approaches towards nature are the result of increasing understanding of ecological processes. Unlike in the past, when green city areas served practical needs or were designed to make a city beautiful, nowadays it is more common that natural areas are appreciated just for what they are. Ecology has gained priority over aesthetic values. We understand much better now that the landscape evolves from and is dependent on natural resources: "it is these interconnected systems of land, air and water, vegetation and wildlife which have dynamic qualities that differentiate cultural landscapes from other cultural resources such as historic structures" [5, p. 2]. An example of a place-based urban ecological analysis was given by researchers from the University of Washington; their study of park development in Seattle over the 20th century is a practical insight into changing environmental and cultural priorities. While studying the implementation of John C. Olmsted's long-term plan from 1903 over the course of the 20th century, Dooling, Simon and Yocom (2006) observed and described the processes of change. They focused on the relationship between patterns of park development and shifting political, economic and cultural conditions and so highlighted four different periods of park planning in Seattle [12]. Starting from the first period (up to 1915), which was characterized by a romantic concept of nature as civilizing, humanizing and healing the city with its scenic beauty, there then came a period of urban challenges (up to the late 1960s), and later a period of progressive participatory planning, (up to the mid-1980s), ending with a period called "pocket park in a global city". The last period in Seattle's history of parks was when the

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5 Because of the current very high level of extinctions (approximately one per million existing species each year), scientists say "we have now entered <<the sixth great extinction event>> the fifth having occurred sixty-five million years ago, when dinosaurs and many other organisms went extinct. That event resulted from natural causes, perhaps including a giant asteroid striking the Earth; this one we are causing" [7].

Wildlife Habitat Management Plan was established to protect critical areas against development and treat "wildlife as an integral part of the city" [8]. New parks and green areas have recently been developed (such as the Olympic Sculpture Park[6]), thus creatively producing a symbiosis between human culture and domestic nature (Fig. 3, 4).

Fig. 1, 2. Complex issue of biodiversity as perceived in urban wilderness
Waterfront of Lake Drwęckie in Ostróda (Northern Poland), 2016 (1); community art in Oakland (California, USA), 2014 (2) (photos by author)

Fig. 3, 4. Symbiosis between human culture and domestic nature: Olympic Sculpture Park in Seattle (WA, USA), 2014 (photos by author)

2.2. Social and cultural significance of urban wilderness

Urban wilderness, especially water wilderness, is essential for us. Not only does it create patches of sustainable, biodiverse landscapes that provide a healthy environment for various species including people, but it is also a necessary landscape for testing and developing our sociobiological habits. Like any other animals, people perceive their environment to look

[6] Olympic Sculpture Park was designed by Weiss/Manfredi/ Architecture/Landscape/Urbanism (international competition – 2001) in cooperation with Seattle Art Museum; it is a rehabilitation of a post-industrial area dedicated to staging the history of the site's redevelopments and prospects, exhibiting art in an open outdoor gallery, and promoting the wildlife and domestic species in the city center.

for opportunities and to avoid danger. Our landscape preferences are derived from survival behavior, which is a product of evolution. A natural landscape which offers a multitude of individual qualities is a good "participatory landscape" that encourages quite a different mode of experience. Such a landscape "develops a spatial continuity with a person" in which one is no longer "a disinterested spectator" and the appeal of the landscape is "not exclusively visual" [4, p. 88]. It offers a greater opportunity for participation and enjoyment; in "a no man's land, children and adults may leave their marks without guilt, nature will erase them" [17, p. 83]. It is also a place for experimenting and discovering the limits of safety. To explain this phenomenon, some authors use 'prospect-refuge' theory, which links certain types of landscapes with the attribution of symbolic values such as 'prospect', 'refuge' and 'hazard'. People climb trees, hike and walk on the edge of waterfront – by doing so they practice an adaptive behavior that "leads to fascination with hazard symbols" [2, p. 32]. The prospect-refuge theory may be understood on multiple levels of cultural reading. It obviously, in a sense, explains human behavior, but it also explains the human aesthetic response to the landscape.

Landscape preference studies by environmental psychologists (Kaplan & Kaplan, 1981) state that the most preferred landscapes are those with elements of 'mystery' and 'involvement'. Involvement refers to the desire "to figure out, to learn, to be stimulated" [11, p. 47], while mystery refers to "surprise or novelty" – it embodies "the temptation to follow the path <just a little farther>" [11, p. 50]. In landscapes that stress 'prospect' rather than 'refuge', "more information is promised than is actually revealed" [8, p. 66]; they evoke people's fascination with the idea of nature as wilderness, which goes back to Rousseau's symbolic concept of 'wildness'. In the past, this idea was a driver of the romantic movement versus the instruments of civilization[7]. For many people, the city has become a wrong place to be, not a habitat, but rather a waiting-room where one expects to leave "for the land where [...] human beings truly belong" [14, p. 201]. Unlike architectural space, natural space is spacious and "horizontal" and is consonant with our body time – "a rhythm akin to the natural processes of the physiology of the human organism" [14, p. 202].

Natural wilderness is also praised for its political and social neutrality; it does not serve any commercial purposes. Hence, it becomes an important tool in competing for space and resources. Introducing nature to the city or preserving it is a democratic move – it not only improves living conditions in a densely populated modern city, but also becomes a statement of political and economic freedom. Some authors associate nature with the feminist symbolism of 'mother earth' or 'motherland', as opposed to the structured, architectural 'fatherland'. From this point of view, the natural environment is symbolically associated with nurturance and tranquility, whereas built environments are associated with the social dominance structure of a nation [9]. Nature is also seen as a space of individual recovery and protection against dominative aggression and control. It offers generously what is limited in urban space: a sense of freedom and an opportunity to react to urban stress. What is really important and has to be emphasized here is that everyone needs direct contact with nature and that "people's reaction

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7 In American culture the idea of "wilderness" is usually closely related to the idea of Zion in Wilderness, which can be traced back to the times of the early American Puritans (from the end of the 17th century); for them, going West meant simply leaving the cities, which were the embodiment of "vulgar necessities and as interruptions in the natural flow of persons in nature" [14].

to nature is an example of non-economic need" [11, p. 54]. People even value "common instances of nature" and their uniqueness, and at the same time they sometimes do not at all value "non-natural elements" in a landscape [11].

2.3. The architectural dimension of wild space within the city

We need to reintroduce natural elements into our built environment, but we need to do it in a contemporary way. This requires refreshing our approach to urban and architectural design mostly in terms of control, visual dominance and the anthropic principle of modernity. We understand now that a landscape is "a <lifeworld> rather than a scene to view or a projection of cultural meaning" [19, p. 4]. It cannot be civilized in a battle against nature; neither it can be kept unmodified by humans, because we live in it. There is no way now to go back to the 18th century utopian and pastoral visions that forced people to live in a 'natural' costume, whereas the landscape itself was highly controlled for the pleasure of a very few to admire the scenic view.

Some help in grasping the problem comes from the theory of architecture and art. In his theoretical study of architectural form, Żórawski (1962) analyzed the perceptive conflict in man-made forms shaped according to human aesthetic preferences and built in natural landscapes. As Żórawski wrote, "landscape touched by the human hand loses its original character"; it happens because we tend from free forms (*formy swobodne*) towards cohesive ones (*formy spoiste*). Paradoxically, as he observed, "we are attracted by natural forms which do not bear any marks of human activity" [27, p. 153]. This contradiction is accented by many other authors. Alexander (1977) developed this problem in *A Pattern Language.* He noticed that for people who lack "a total view of the ecology of the land" it is most natural to build "in the best possible place", which is the place where the landscape, greenery and the view is the most beautiful [1, p. 509]. But this is in striking contrast to what we want to achieve, because in doing so we destroy the existing beauty of the place. Another issue theorized by Alexander is 'a lifeworld'. Talking about landscaping, he assumes that gardens which are "formal and artificial[8] (...) have none of the quality which brings a garden to life – the quality of wilderness" [1, p. 802]; "a garden growing wild is healthier, more capable of stable growth (...), can be left alone (...) and for people too, a garden growing wild creates a more profound experience (...) the gardener is in the position of a good doctor, watching nature take its course, occasionally taking action..." [1, p. 803]. Taking these into consideration, the architect should also work like a doctor, treating "the site and its building as a single living eco-system" and leaving areas "that are most precious, beautiful, comfortable and healthy as they are" [1, p. 511].

Enjoying the beauty and ecology of nature requires "an incomplete landscape – that is an open space that has not been designed in every detail and that is not perfectly maintained" [17, p. 82]. Such a landscape of unstructured aesthetics allows and encourages people's activity and involvement. It enables a multiplication of ways of using the existing – natural or man-made – space. The resulting place is a stage of a triangulation process and improvisational practices

[8] The opening passage of the chapter is: "Many gardens are formal and artificial. The flower beds are trimmed like table cloths or painted designs. The lawns are clipped like perfect plastic fur. The paths are clean, like new polished asphalt. The furniture is new and clean, fresh from a department store" [1, p. 802].

of users who might be not only human beings but also other species living in an urban ecosystem (Fig. 5, 6). A landscape has to be vast and open enough so as not to suffocate these activities. In this sense, as stated by Welsch, "the old maxim of <less is more> could still have a point" [25, p. 188].

Fig. 5. Willamette River waterfront in downtown Portland as inhabited by wild gooses (Oregon, USA), 2014 (photo by author)

Fig. 6. The Point at Elk Rock Garden above Willamette River's bank in Portland (Oregon, USA), 2014 (photo by author)

3. The *riverlution*[9] idea

3.1. "Everywhere in the world the best place to live is by the river"[10]

Urban wilderness as pristine natural environment frequently exists amidst urban structures as water and waterfront areas. Certainly, there are places and towns that are more blessed by nature with beautiful rivers and varied waterfronts or are built as a semi-natural island like Venice. Being in Venice, it is easy to understand that what attracts people to the place now is the unique relation between urban aspiration and the totality of the water nature that overwhelms the city. However, these breathtaking landscape conditions are both an environmental challenge to assume and the result of very sensitive and patient human activity over the centuries to balance the benefits of the place with its sustainability. During the last two centuries of urban modernization, rapid and senseless development in many places has irreversibly destroyed natural relations between towns and their water resources. River networks, which were once crucial for industry as well as for inhabitants, were frequently the starting point for many towns. It was so, for example, in the urban history of Łódź – the biggest new 19th-century industrial city and the heart of the Polish textile industry. When the city was founded in 1820, the authorities took into consideration what Stanisław Staszic[11] had written about the site, that it was a place "with innumerable springs" [32]. However, when the town began to develop, the natural water resources began to shrink because of increasing

9 The term 'riverlution' is borrowed from the manifesto of the Human Access Project [28].

10 Translation of the title of an interview with a developer of *River Angel* housing in Wrocław [34].

11 Stanisław Staszic (1755-1826) – a leading figure in the Polish Enlightenment and pioneer of Polish geology.

water consumption and the reduction of forest areas and biologically active areas generally. Łódka, the biggest river in Łódź, was the initial axis of urban development but had almost disappeared from the city at the beginning of the 20th century in a narrow concrete storm-water drain. Similarly, other rivers have disappeared from the landscape of many other towns[12] as a result of unreasonable planning decisions or insensitive competition for space.

Sometimes, instead, the attraction of a waterfront becomes oppressive for nature. This might result in expanding building areas over waterfronts and rearranging them to simply make economic use of them. Today, thanks to technical progress it is possible to build almost anything we want and wherever we want – it is only a question of cost. Waterfronts seem to be hugely popular locations[13] for development, no matter whether they are natural or artificially created[14]. Therefore, in some cities there are attempts to uncover rivers and their waterfronts and to do so even at the price of removing the existing overbuilt structures. This happened in Seoul, where the project of uncovering the river Cheonggyecheon – once buried to support a new elevated highway – was executed in 2005: the former transportation space was turned into open linear park space on both sides of the uncovered stream (project by SeoAhn Total Landscape) [31]. This famous and successful project has inspired many others all around the world.

People are increasingly interested in the waterfront areas in cities. It has become obvious to almost everyone that these areas should be protected as open green areas and that they may constitute the main attraction and pride of the city. Moreover, the main value of these areas is based on their ecological importance as green corridors, connecting wildlife habitats amidst the urban structure and improving environmental conditions within the city. Even the unimpressive (in terms of physical size) uncovered Łódka river valley in Łódź – sometimes hardly visible in the urban structure – now forms the axis of a "local ecosystem" [23, p. 50]. It includes not only parks and rearranged green patches, but also wild or even derelict natural elements that are useless as spatial structures but are of great potential for developing the local wildlife ecosystem.

3.2. Socio-cultural cultivation of urban wilderness

Place attachment[15] is strongly linked – positively or negatively – with pro-environmental behavior. Positive affective bonds with one's place should be associated with activities to protect that place. For some people this might also mean "putting the interest of the place

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12 In Cracow, one of the rivers that has disappeared in a tunnel is Młynówka Królewska, once an important river for the local water-mill industry outside the city and the axis of development of neighboring villages. Nowadays it can only be traced in the urban structure of the city as an open-to-the-public strip of greenery, a linear park called – the same as the hidden river – *Młynówka Królewska.*

13 "The housing condominium is situated [according to the design] right at the waterfront and thus apartments will have splendid views and an environment enabling relaxation. This will improve the quality of life of the inhabitants. [*River Angels*] is one of the best locations in town with massive potential for the future" (extract from an interview with Ron Ben Shahar from Angel Poland Group (developer)/"Na całym świecie najlepiej mieszka się nad rzeką" [34].

14 An example of new massive development situated around the waterfront of an artificial lake (in a post-military and post-industrial area of the former airport) is Aspern Smart City in Vienna, currently under construction.

15 *Place attachment* is a psychological term signifying the set of positive affective bonds or associations between individuals, groups, communities, and their daily life settings [6].

before their self-interest" [6, p. 156]. Many studies have shown that people are more open to pro-environmental behavior in the context of protected natural areas and recreational settings. Natural, fresh and clean surroundings might be a "prompt" [26] to pay more attention to the problem of the environment. It is also important that natural, open spaces close to water are frequently the most valued places that are often remembered in detail as people's *personscapes*. These "personally sacred places" have predictable origins – "most are from childhood; most are outdoors in nature". They express "our growth and identity" [10, p. 194]. One of the studies undertaken by Hester in Manteo (North Carolina, 1985) was to identify the "essence" and "sacred structure" of a place. The places most valued by inhabitants of Manteo were – not surprisingly – the places and areas encircling the local bay. For most communities, a "sacred structure" signifies a center of community life that is frequently associated with a sequence of ritual behaviors that celebrate place attachment. A "sacred structure" should primarily inform about what to protect and what not to do rather than impose dominant formalist trends and their architecture over existing structures. Sometimes to make a place it is enough to show interest and promote activities and public engagement with the place. Performative pro-community and pro-ecological events such as Water Critical Mass (*Wodna Masa Krytyczna*) on the Vistula River in Cracow or the Big Float on the Willamette River in Portland (Oregon) are examples of this. These actions are intended to inspire an attitude change and public interest in rivers to improve the water quality and the environment quality in general. According to its organizers, the Big Float project "serves the dual purpose of fundraising and giving Portlanders a fun day on the river"[16]. Its mission is to change the way the city "interacts with the river that runs through it" and to "envision a day when Portlanders can interact with a clean, swimmer-friendly version of the Willamette [..] to heal the link between people and waterway" [28].

3.3. Wild vs ordered

Nature can be allowed to assert itself or it can be tightly controlled. In the urban environment, nature is unavoidably superimposed by some cultural meaning, no matter whether it is left uncultivated or is the object of economic consumption and architectural rearrangement. The water environment in a city is an illustrative example of a "new cultural landscape" which is not "new from scratch" but which demonstrates how change "adds new layers to an already layered composition" [19, p. 2]. The decision to redesign the natural landscape in a city entails responsibility mainly for the decision makers. The choice between leaving an area uncultivated and taking it into tightly controlled possession and rearranging it as a housing, commercial or recreation area is not the only choice. There is always a range of possibilities of what can be done with a wild urban waterfront. To name just a few, instead of taking the space under control, it may be more reasonable to take it under protection and cultivation. Similarly, instead of the immediate profits of extensive functional use of the area,

[16] Human Access Project (HAP) is an organization responsible for Big Float and other actions promoting the Willamette River in Portland [28].

it may be more profitable to preserve this enclave as a natural reserve of the city and a space of relief (a "free space amidst the hyper design of the rest" [25, p. 187]) that will increase the value of surrounding buildings and developments.

To answer the question, "wild versus ordered?", it is necessary to listen to the place itself to gain knowledge *of* the place rather than *about* the place. It requires time and mindfulness to understand its daily life patterns and to determine its real needs, issues and problems. As studying places indicates, the lack of a functional label does not necessarily mean the lack of use; less design may sometimes encourage more satisfying activities. This is very clear when analyzing the city life on both sides of the Vistula River in Warsaw. The right bank of the Vistula – in places almost wild, with spacious sandy beaches – is full of people on warm summer days. It has become an increasingly popular place to be – it is amenable for users and encourages various types of spontaneous activities. The left bank, freshly rearranged (arch. RS Architektura Krajobrazu, 2015) as new concrete embankment with a type of stand-like stairs to observe the water and the other side of the city, serves different needs and co-creates Warsaw's more metropolitan side. Both sides are practically complementary and seem to be in dialogue with each other. In contrast to the more open, unstructured space on the right side that encourages more unpredictable behavior, the activities on the left bank seem easier to anticipate. Warsaw's residents accepted the first stage of changes on the left bank "with reserve"; as an architectural journalist commented, "the built section of wharf is designed more for urban aesthetes majestically parading along the promenade than for amateurs of informal riverside recreation"[17].

4. Creating a place not a design

4.1. Key traits for protecting and sharing

Waterfronts, especially urban waterfronts where the land meets the ocean, lake or river, are unique and definite resources that are based on the individual relationship between the urban structure and water. In 1981, The Waterfront Center, a non-profit educational organization, was formed to help in defining urban waterfronts as dynamic *places* to create the best opportunity for community enhancement and enrichment. As this organization claims, its main goal is to assist communities and professions in "making the wisest and best long-term uses of waterfront resources for maximum public benefit" [30]. It also manages the international awards program "Excellence on the Waterfront" (since 1987), which recognizes the best projects and visionary plans. For this they created a set of judging criteria to assess the quality of architectural projects (1. sensitivity of the design to the water; 2. quality and harmony of the design), community (3. civic contribution) and environmental care (4. environmental values), as well as cultural enrichment (5.) and technical problems (6. degree of difficulty). The criteria given by TWC, in a sense, respond to the problem of protecting and sharing

[17] Commentary to the design by Grzegorz Stiasny [24].

these places. Considering the value of the project, it is clear that what matters most is not a specific form but its correspondence with a particular site, its nature and people's behavioral patterns. The important value of a design is to make public use of water resources, to provide physical, not only visual, access to and along the waterfront – to let people enjoy the water environment. A project should fit into the surroundings – be they natural or man-made – and should grasp the problem of human scale. Considering its social background, a good project should help its community's economy and boost civic pride. It should be a sustainable project in the sense that it is economically viable over the long run and cares about environmental values. A good project should contribute to the local culture and enrich the place. And, finally, its value may also be measured by the difficulties it has to overcome, be they natural, political or economic.

Bearing in mind the human dimensions of architecture and planning, in particular planning so-called public common spaces, one should not forget about environmental justice[18]– a key concept for sharing limited goods. Justice as understood here involves: 1. spatial distribution (of attractions and environmental risks); 2. legislative procedures; and 3. the decision-making process (via participation) and democratic, open access to information. The environmental justice movement (not only in U.S.) has forced an attitude change to public spaces and their functions [13] – it really does influence projects with the idea of public accessibility all over the world. Let us take the example of the Human Access Project – a public initiative in Portland. It organizes not only Big Float but also some micro-projects to inspire local engagement with waterfront places and the creation of various "pocket beaches" in the city center to let people freely access the river. One of the pocket beaches realized by HAP is called "Poetry at the Beach". It is a really tiny place located underneath a bridge with a patch of sandy beach. The most important part of it seems to be a pathway leading from the main waterfront boardwalk straight to the river. The sides of this pathway are made up of big stones on which one might sit to rest and observe the river or just stop and *read* them as the stones are covered with short poems written by children from the local elementary school. All the poems written here are inspired by the river and nature and they grasp a specific moment in space and time. Like the one written by Makenzie (8th Grade): "Walk down the pathway/Towards the center of all life /Rushing body of magic/Forever flowing to the sea" (Fig. 7–8).

4.2. Conclusions

Wild or ordered urban waterfronts are important elements of cities' new cultural landscapes. As such they constitute "an important part of the quality of life for people everywhere", "a key element of individual and social well-being" and – as is stated in the European Landscape Convention – this is why "their protection, management and planning entail rights and responsibilities for everyone"[19]. Because they are made of nature, architecture and city life, taking care of such places is a complex, multidimensional

[18] Environmental justice (esp. in U.S.) is the term referring to equal treatment of people of different races, nationalities and income in terms on environmental decision making [28].

[19] *European Landscape Convention. Preamble.*

responsibility that has to be shared between many people and professions. This is especially true when we assume that we want to take care of the place instead of taking control. A waterfront environment requires nature protection (land and water) because it is a landscape evolved from and dependent on natural resources and is a wildlife habitat. As a man-made architectural structure, it requires technical maintenance and management as well as strategies for the future. As a place for people, it requires understanding of what it means to people. To do so – to truly understand the place – one has to avoid exclusive assumptions and "to learn from poverty", from people that "rely on the informal economy" and who are "intimately tied to the place without choice" [10, p. 200]. For the designer it means the necessity of combining science and experience: his or her own experience with the place as well as the experience and knowledge of local experts. "Learning from poverty" is also a way to achieve more ecological and locally intelligent solutions.

Redesigning existing natural patches of waterfront land is a risky job that almost always involves conflicts that are usually caused by unbalanced distribution of resources and power between global players and local actors, but they are also about the aim of waterfront redesigning: is it to produce a space of production, consumption or a lived space? The existing oppositions are also solid evidence that the places in question are of special importance to people, and thus dealing with these places requires accommodation of conflicts as well as cooperation. The attitude which is expected here involves an open mind and time to work out and adopt more organic, *slow* and community-based design methods. Using such methods should prevent designers from aiming at formal design that contradicts not only the nature of the site but also the human content of architecture. What seems to be the most important lesson here it is to focus on creating a place not a design. The conclusions of this lesson might be revolutionary for the philosophy of design; it is about not only inviting the public to engage in the design process via participatory projects and for designers to be involved with the complexity of the place, but it is about the idea that sometimes it is simply better to leave things as they are than to implement projects. To put it more accurately, in the case of such projects the emphasis on culture and architecture should not destroy the nature of the place and forget about the true nature of humans.

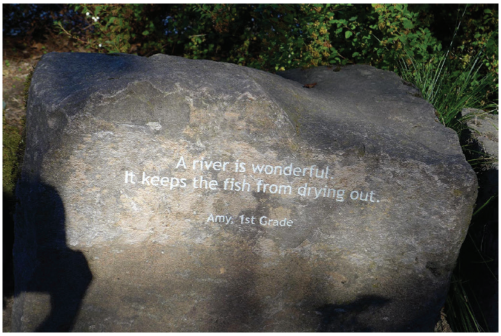

Fig. 7–8. *Poetry at The Beach* – a micro-project realized by HAP in Portland, 2014 (photo by author): one of the stones with a short poem (7) and the wild pocket beach at the end of the path (8)

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Methods of commemorating liquidated cemeteries and former cemetery areas as an expression of remembrance, relief, and respect for a *sacred* place

Sposoby upamiętniania zlikwidowanych cmentarzy i terenów pocmentarnych jako wyraz pamięci, zadośćuczynienia i poszanowania *sacrum* miejsca

Abstract

Old German cemeteries which have been devastated and liquidated, are a disgraceful reminder of the 1970s and 1980s. They are particularly numerous in cities and villages in Western and Northern Poland. Though they constitute a historically exceptional relic of those places and people, only a few have been memorialized. The paper presents a review of exemplary forms of commemorating liquidated cemeteries, as symbolic sights in the landscape with a specific historical, cultural, and social significance.

Keywords: *sacrum* in the landscape, forms of commemoration, former cemetery areas

Streszczenie

Niechlubnym świadectwem okresu lat 70 i 80 XX w. są dziś zniszczone i zlikwidowane tak zwane cmentarze poniemieckie, których wielką liczbę można odnaleźć w miastach i wsiach głównie obszaru zachodniej i północnej Polski. Pomimo, że stanowią one wyjątkowe świadectwo historii miejsca i ludzi, istnienie tylko nielicznych zostało upamiętnione. Referat prezentuje przegląd przykładowych form upamiętniania zlikwidowanych cmentarzy, jako symbolicznych znaków w krajobrazie o szczególnym znaczeniu historycznym, kulturowym i społecznym.

Słowa kluczowe: *sacrum* w krajobrazie, formy upamiętniania, tereny pocmentarne

1. Introduction

In all cultures, a cemetery is a specific place, perceived multi-dimensionally, and from many aspects. It is a sacred place with diverse symbolism, an evidence of the community history of a given culture and time. Since a cemetery combines the past and the future, it is also a place of broadly understood individual and collective memory. There are, however, situations when cemeteries are closed, or even removed. The causes can be legal, historical, social, spatial, economic, or cultural. Closing a cemetery for new burials can be the beginning of its slow devastation. In time, a place valuable in terms of individual memory, without people who remember and care for it, may be forgotten. When cemeteries are liquidated, the only way to protect the cultural and religious significance of such places is collective memory. For it to last, however, it is important to properly mark the place, to remind people of its previous character and history.

2. Aim and methods

The subject of the study are various methods of commemorating former cemeteries. Examples from Szczecin, Wrocław, Gdańsk, and Świnoujście, namely from Western and Northern Poland, where, mostly for historical reasons, a large number of the so-called former German cemeteries remain, were analyzed. In the paper, six different implementations were characterized. In addition, Szczecin lapidaria were discussed, and memorial plaques placed on former cemetery areas were discussed collectively. This text is not devoted to analyzing the causes which lead to the closure and removal of cemeteries, but will focus on the methods of commemorating former burial sites. Also, the publication does not aim to determine the ideal spatial development form of a site of memory, but is a review of the forms applied, together with the author's commentary on the applied solutions in the Discussion part. The purpose of the paper is to demonstrate that the activities to commemorate cemeteries are conducted independently in different cities, have diverse character, and many implementations emerged particularly in the first decade of the 21st century.

3. The methods of commemorating former burial sites

Cemeteries are a space where the sacred meets the profane. The worldly aspect of a necropolis not only results from its function as a burial place, but also as a place of meetings, walks, traffic routes, as well as green areas. The sacred aspect of cemeteries shows itself in that they are a place where rites, beliefs, and religious practices take place. They are deeply symbolic, and have huge cultural significance. They are sites of silence, remembrance of the dead, they bring deep reflections about the essence of human life and death, which also makes them universally sacred.

The notion of a post-cemetery area does not have an official definition. According to the long-term research and experience of the author, it is a space, which, for different reasons, has lost its former burial function, and its landscape has changed enough to make it difficult to recognize and identify as a cemetery. This could be a formally liquidated cemetery, or a cemetery, which, having been abandoned and neglected, has suffered significant devastation. Usually, such areas are completely stripped of tombstones, and signs of the graves. In other cases, scarce surface grave and cemetery elements can survive. Such an area can be re-used e.g. as a park, and in such a case it is often referred to as a post-cemetery park [9, p. 15-16]. It is worth noting that within the boundaries of towns, the number of historical cemeteries is very often quite significant. For instance, in Gdańsk, there are more than ten historical cemeteries, in Szczecin there are 91 in total [9, p. 9], but in Wrocław there are as many as 120 [3, p. 11]. After 1945, the authorities of the PRL were liquidating cemeteries on a large scale, associating them with the German past of the towns. For instance, between 1960-1970 in Wrocław, it was decided to liquidate 45 pre-war cemeteries [3, p. 312]. It was a time of their mass removal, but it should be remembered that cemeteries were also closed and liquidated before that, and the causes could be diverse. It is worth remembering that since the second half of the 18th century, regulations appeared in Western European countries prohibiting the burial of dead in churches and within city walls, and orders were made to remove old cemeteries adjacent to churches, and to transfer them outside cities [3, p. 312; 18, p. 66; 1, p. 505; 5, p. 78]. For instance, according to statistical data from 1926, in the city of Wrocław and in its nearest vicinity, there were 41 cemeteries, of which 17 were already closed [3, p. 314]. Current conservation practice holds that historical cemeteries should not be closed, and definitely not liquidated. However, if they have already been liquidated, the optimal solution is to preserve them as areas of greenery with proper commemoration of the site. Regardless of its status of preservation, a former cemetery area should be a place of remembrance, which should attract people's attention and encourage them to think about the past. In general, the basic form of commemorating the area is with monuments, but these can also be monumental planning schemes, which combine the compositions of sculptural and architectonic elements, and give the space its commemorative function. Such facilities form common spaces and build social identity [4, p. 7-8,10,14]. Therefore, for the memory to last, a visual symbol is necessary, being a medium of remembrance. For the sacred to survive, human awareness is needed and the memory must be preserved. Not commemorating former cemetery areas results in the people buried there being forgotten. Therefore, the phenomenon of "weathering of the sacred" can be observed [8, p. 209-211], which, according to the author, means the gradual deterioration of the sacred aspect as a result of the fading of individual and collective memory about the site's history, its significance, and the people buried there. The examples discussed below, show how old burial sites are commemorated at present.

3.1. The cemetery of non-existent cemeteries in Gdańsk, Poland

It is a symbolic monument planning scheme to commemorate Gdańsk cemeteries of different denominations, devastated after World War II, mainly in the 1970s. As early as 1998, the Authorities of the City of Gdańsk decided to commemorate Gdańsk's former cemeteries by erecting a monument in the square of the Corpus Christi Church [19]. The structure was established in the post-cemetery park at 3 Maja Street, in the area of the former Evangelical Corpus Christi cemetery, which was active in the years of 1815-1956. The designers were Hanna Klementowska and Jacek Krenz, and the opening ceremony took place in 2002 [12]. The monument planning scheme was supposed to resemble a temple with a symbolic altar (Fig. 1). Access to the area is through a metal gateway with a decorative tree symbol, and the whole area is surrounded by a fence. The gate, together with the fence, emphasizes the separation of this space, just like a cemetery is a separate space, where there is always a clear border between the sacred inside and the profane surrounding. The main material for the planning scheme is stone, together with low and high vegetation. There are no colorful bedding displays, and evergreen plants dominate, which adds gravity to the site. The main axis runs along a stony alley with a row of trees, it directs one's gaze to a stone altar located at the end. It was built from 38 surviving tombstones and stone crosses from the 18th, 19th, and 20th centuries that were transferred from different liquidated cemeteries in Gdańsk. Human remains found during the construction of the monument are placed under the main slab, in the central part of the symbolic cemetery [6]. Some of the tombstones are cracked and mounted loosely, which may symbolize brutal treatment of the graves, the dead, and commemorates their monuments during the liquidation of the cemeteries. On the dark stone altar, the following sign is placed, "... TO THOSE WHO HAVE NO NAMES", highlighting the fact that, as a result of the liquidation of the cemeteries, the buried lost the right to survive as individual memories. The altar slab, just like the alley that leads to it, has ground lighting. With the geometry of the elements, the composition creates a formal and sublime atmosphere. It is also enhanced by small fields suggesting cemetery quarters with plants, stone columns obliquely cut at the top, and cracked along the whole length, and stone benches resembling a sarcophagus. Cemetery gravestones are also placed in these quarters. At present, the planning scheme is a place of ecumenical meetings, it is also often visited on All Saints Day.

Fig. 1. Cemetery of former cemeteries in Gdańsk (photo by A. Pilarczyk)

3.2. Monuments commemorating former cemeteries in Gdańsk, Poland

In 2005 the Authorities of the City of Gdańsk decided to commemorate the sites of the liquidated Gdańsk cemeteries. With the implementation of the scheme, between 2006–2009, 17 stone slabs were erected [7]. Each slab has a description in three languages: Polish, Latin, and German, and includes the old name of a cemetery, the time of its operation, and its approximate plan (Fig. 2). The form of a vertical slab is very simple, its shape suggests a gravestone on a stone base. The material is dark granite. The form and the material are the same for each cemetery. On a horizontal base, it is written that the monument was funded by the city, as well as the year of its erection. At the very top of the plate, the symbols of the city of Gdańsk are placed (a crown, and two Greek crosses below them). On the slabs, there are no other symbols or markings related to the denomination or cemetery imagery.

Fig. 2. Monuments commemorating non-existent cemeteries in post-cemetery parks in Gdańsk (photo by A. Pilarczyk)

3.3. Gdańsk cemeteries lapidarium, Poland

The lapidarium (Fig. 3) was opened in 2006 in the Academic Park at the Gdańsk Technical University, at the place where between 1893–1956, St. Nicolas Catholic Cemetery and Royal Chapel were located. The planning scheme was designed by Joanna Tucka and has an area of 0.45 hectares. A place was created to collect and secure headstones and other stone elements from old Gdańsk cemeteries of different denominations. In total, more than ten objects have been gathered here from the 18th, 19th and 20th centuries. In the middle, a cenotaph has been erected made of an erratic boulder with a sign reading 'Gdańsk' according to the oldest version of the word from 997 [15]. The boulder is on a platform, and around it, a spiral was created where granite cuboids are placed with the digits from X to XI; they symbolize 11 centuries of the city's existence. The composition is completed by low shrubs. Historical cemetery stone elements are placed in rows on the lawn in the lapidarium square and along the park alley.

Fig. 3. The Gdansk lapidarium in the Academic Park in Gdańsk (photo by A. Pilarczyk)

3.4. Remembrance site in Świnoujście, Poland

In Świnoujście, Fryderyk Chopin city park was established between 1975 and 1976. It was established at the site, where from 1771 to the 1950s an Evangelical-Lutheran cemetery was active. In 2010, a competition for the concept of revitalizing the Park was announced under the headline: "Integrated Downtown Project – Chopin St. Park Reconstruction". A project from the Bronisz Land Design Studio prepared by Artur Bronisz, Alicia Jasińska, Joanna Antosik and Anna Miszczyńska, won first place in the competition and was consequently implemented. The Park was opened in 2013 [13, p. 247-248]. Within the project, a place commemorating the cemetery was built (Fig. 4). The composition consists of three cuboids oriented horizontally in one line, these are white horizontal plates. Each wall has an opening filled with a sign; a Latin cross symbolizing the Christian faith, a circle with the Luther Rose – the sign of Protestant Reformation, or the star of David – the symbol of Judaism. Next to it, a vertical granite slab is erected, with a description in Polish and German reading "IN MEMORY OF PREVIOUS RESIDENTS OF ŚWINOUJŚCIE. IN THIS PLACE FROM 1771 TO THE 1950s, RESIDENTS OF ŚWINOUJŚCIE WERE INTERRED. THE REMAINS OF THE DECEASED, EXHUMED DURING THE INVESTMENT PROJECT, HAVE BEEN TRANSFERRED AND BURIED IN THE MUNICIPAL CEMETERY. RESIDENTS OF ŚWINOUJŚCIE AD 2013". Given the park's size, the remembrance site is small, and the number of elements or the size of the symbols are not very visible. An integral part of the remembrance site is the so-called light clearing, namely an open space with irregularly arranged points of light (Fig. 5).

Fig. 4. Remembrance site in Fryderyk Chopin City Park in Świnoujście (photo by A. Pilarczyk)

Fig. 5. The visualization of the remembrance site in Świnoujście; the so-called light clearing can be seen in the background (http://www.a-ronet.pl/index.php?mod=nagroda&n_id=2118)

3.5. Common remembrance memorial in Wrocław, Poland

In 2005 a competition for the construction of a monument commemorating the residents of Wrocław buried on the already liquidated cemeteries took place. The monument (Fig. 6) was unveiled in 2008, and its designers were Tomasz Tomaszewski, Alojzy Gryt, and Czesław Wesołowski. The structure was erected in what is now known as Grabiszyński Park, at the site of the former crematorium at the former Grabiszyński III cemetery, active from 1916 to the 1950s–1960s. [21]. The monument can be accessed through a paved alley, at the beginning of which is a concrete entry gate with a Latin sign reading "MONUMENTUM MEMORIAE COMMUNIS" at the top, meaning "Common remembrance memorial". The monument is in the form of a high wall with a length of 60 m, and a height of 4–5 m and composed of 32 granite fragments, upon which old gravestones are mounted. The four parts of the monument symbolize Catholic, Evangelical, municipal, and Jewish cemeteries. Within the monument's composition, the Christian cross and the Jewish menorah – a seven-branched candlestick, one of the oldest and best known symbols used in Jewish religious art, appear. On one horizontal plate, there is a list of all the cemeteries liquidated after 1945 in Wrocław. On one of the vertical plates, there is a sign in Polish and German, reading "IN MEMORY OF PREVIOUS RESIDENTS OF OUR CITY, WHO WERE BURIED IN THE LIQUIDATED CEMETERIES – PEOPLE OF WROCŁAW". Additionally, on the horizontal granite plates, the following sign is placed "A CEMETERY CAN BE DEMOLISHED – BUT NEVER THE MEMORY" in Polish and German. The memorial is illuminated.

Fig. 6. Common Remembrance Memorial in Grabiszyński Park in Wrocław (photo by A. Pilarczyk)

3.6. Remembrance site at the Central Cemetery in Szczecin

The Central Cemetery, opened in 1901, is currently the largest cemetery in Poland. In 1994, a commemorative boulder (Fig. 7) was placed in an old quarter of the city with a sign in German, "ZUM GEDENKEN AN DIE TOTEN DER STADT STETTIN", or "In memory of the deceased people of Szczecin". It was funded by former residents of Szczecin and by the remaining German minority. In 2001 next to the boulder, a tall wooden cross was erected. Nearby, there are pre-war grave monuments. Religious celebrations take place at this site. [17, p. 149-150]. It is a relatively modest form of commemoration, particularly taking into account the size of the cemetery and its pre-war excellence.

Fig. 7. The Szczecin remembrance site at the Central Cemetery in Szczecin (photo by A. Pilarczyk)

Fig. 8. The lapidarium at the Central Cemetery in Szczecin (photo by A. Pilarczyk)

3.7. The lapidarium at the Central Cemetery in Szczecin

A specific remembrance feature is cemetery lapidaria. In Szczecin, the largest and most valuable one is the lapidarium at the Central Cemetery (Fig. 8), opened in 2007 in the area of the former urn grove. Taking into account the guidelines of the Provincial Monuments Conservation Officer, a project was initiated to recreate the old spatial arrangement, to preserve and, partially to reconstruct the elements of landscape architecture, greenery, and headstone arrangement. The designers are Joanna Wojtecka, Marzena Jaroszek, and Krzysztof Gołębiecki. This place is not accidental, since in this part of the cemetery, numerous old tombstones and other original elements have survived. Some historical headstones were erected in situ. Other ones, removed from different places of the large cemetery, were also placed here; their original location cannot be determined anymore. In this way, a diversified and interesting collection of tombstones was created, surrounded by aesthetically arranged greenery [16, p. 336-338]. A historical path runs through the lapidarium, which was established at the Central Cemetery in 2010, making this spot easier to reach and see.

3.8. Other lapidaria in Szczecin

As in the case of Gdańsk, Wrocław, or other places in Western Poland, a large number of old German cemeteries in Szczecin were also destroyed after World War II. At present, the oldest and most visible signs of their existence are alleys with impressively mature trees [11]. Meanwhile, only a small number of gravestones have been preserved, depending on the site. Single tombstones were often moved from former cemetery areas to one site, to create small lapidaria (Fig. 9, 10). Such actions were not always in agreement with the conservation authorities. They were often initiated and executed by local communities. The reason was often the desire to clean up a cemetery area, and the need to collect abandoned, usually turned over pre-war headstones. Such places are the destination of accidentally found tombstones from different places outside the areas of the old cemeteries. Currently, one place where such items end up is the lapidarium at the Central Cemetery.

Fig. 9. The lapidarium created in the 1990s at the post-cemetery park in Sąsiedzka St. in Szczecin (photo by A. Pilarczyk)

Fig. 10. The lapidarium from 2007 at the former Evangelical cemetery in Ostowa St. in Szczecin (photo by A. Pilarczyk)

3.9. Other forms of commemorating old burial sites in Szczecin

Analyzing former cemetery areas in Szczecin, it may be stated that, only in a few post-cemetery parks, has any information appeared about the graveyard past of the site. An example may be Albert Wilimsky Park at Krzemienna St. in Szczecin – an old Evangelical cemetery liquidated in 1976. This area has been converted into a park and in 2008 a brick and mortar column was erected here with a plaque containing the Park's name and information in Polish and German stating that this is a post-cemetery park (Fig. 11). Another example is an informative plaque located at the entrance to the area of the former military cemetery; today, it is Friedrich Ackermann Square (Fig. 12).

Fig. 11. A plaque giving information about the cemetery past of Albert Wilimsky Park in Krzemienna St. in Szczecin (photo by A. Pilarczyk)

Fig. 12. The old military cemetery at Mikołaja Kopernika St. in Szczecin with a plaque giving information about the past of this site (photo by A. Pilarczyk)

4. Discussion

To mark the sites of historical cemeteries is an expression of respect for the burial sites, and of the need to preserve them in the collective memory. The majority of the projects characterized above were created at the beginning of the 21st century and it can be assumed that they will keep on emerging, since, as mentioned above, there are hundreds or perhaps thousands of forgotten cemeteries in various cities and villages of Poland. The activities described relate to "foreign" cemeteries; that is, those belonging to other nationalities and cultures. Despite this fact, numerous initiatives have appeared to commemorate these sites, coming both from City Authorities, and from local communities. The examples discussed above demonstrate the social need to commemorate the burial sites of former, mainly German, residents, and to protect the surviving gravestones and grave monuments.

The commemoration forms described differ significantly, therefore it is not easy to compare them. What connects these examples is the willingness to celebrate and to preserve the memory of these sites and people. This shows itself, amongst others, by the use of lasting construction materials, such as stone. These are boulders, granite blocks, stone slabs, columns, stone sett. Apart from the practical aspect, stone has vital cultural and symbolic meaning. This symbolic meaning results mostly from the high resistance of stone to the destructive operation of time. In the cult of the dead, stone has been used since the dawn of time, therefore it is of great cultural importance. Old stone grave elements are of particularly high value, they are symbols of the dead, a sign of a site's history, monuments, cultural artifacts, artistic or artisan creations. For this reason, lapidaria spontaneously turn into remembrance sites (Szczecin 3.7., 3.8.), and in the designed cemetery commemoration areas, tombstones are gathered, from one or many different cemeteries (Wroclaw 3.5., Gdańsk 3.1. and 3.3.).

Designing commemorative facilities has an extremely long tradition. In the case of a former cemetery, what should be commemorated is obviously not only the fact of its existence, but also the people buried there, which is not the same thing. The fact that the site is to honor the memory of the deceased, is highlighted in Gdańsk (3.1.), in Wrocław (3.5.), in Szczecin (3.6.), and in Świnoujście (3.4.). Memorial plaques giving information about the cemeteries, but not about the people buried there are found in Gdańsk (3.2.), and in Szczecin (3.9.).

The remembrance sites require proper imagery. Since symbols are carriers of meanings, they help us to understand the notions and content that are difficult to describe, and make them comprehensible [2, p. 5]. The content layer is particularly significant for remembrance sites. The above projects include symbols related to religions or denominations - the cross, the Luther rose, the star of David, the Menorah, an altar, a temple. These are also symbols referring to the cult of the dead, the eternity, the division of the sacred from the profane, passage from the world of the living to the world of the dead, from the material zone to the spiritual zone. These symbols are, for instance, a gate, a passage, a wall, a border (Gdańsk 3.1, Wroclaw 3.5.), a route (Gdańsk 3.1, Wroclaw 3.5.), water (Szczecin 3.7.), light (Świnoujście 3.4, Gdańsk 3.1.), a spiral (Gdańsk 3.3). Meanwhile, the use of plant symbols and plant compositions is less common, or completely avoided in the adopted solutions. Only evergreen plants are visible (Gdańsk 3.1., 3.3., Szczecin 3.7.), which are justifiably associated with immortality. In addition, trees and shrubs create the atmosphere of sadness and reflection, appropriate for this type of site. Therefore, greater attention should be paid to creating proper plant arrangement in places that commemorate old cemeteries, since the symbolism of plants growing in burial sites has a very old tradition. For instance, cypress trees that symbolize sadness, death and mourning have been commonly planted in Mediterranean cemeteries since ancient times. In Poland and in some European countries, where this tree does not grow, thujas or black poplar of the Italian variety were planted; its column-like appearance resembles a cypress tree [2, p. 57]. In addition, trees with hanging treetops, which resemble "weeping", are becoming popular in cemeteries. Also, far back in ancient times, death was associated with flowers such as hyacinth, narcissus, rose, anemone, violet, poppy [20, p. 141-144]. Plants traditionally growing in cemeteries include: ivy, box, periwinkle, laurel, holly, and coniferous trees and shrubs of different species. Despite the devastation of many cemeteries, to this day, one of the most characteristic surviving elements of old cemeteries in Szczecin is their vegetation [11]. Studies and observations of the condition of historical cemeteries show that alleys of trees were planted as well as species including yew, ivy, periwinkle, or lilies of the valley.

The landscape of remembrance, which old cemeteries and former cemetery areas are, should be managed with particular focus on the dignity of these sites. Taking into account, however, the number of liquidated cemeteries, their differing areas and statuses of preservation, it is difficult to expect that each former cemetery could be fully converted into a commemorative site. For large post-cemetery planning schemes with few surviving historical and composition elements, a better solution is to appoint a small section of the space a zone for remembrance and reflection. In this way, the funds raised for this purpose can be used more effectively. Also, it is easier to preserve a section of the site in proper condition, since preserving the former cemetery areas is also a form of commemoration. The rest of the site can be arranged more neutrally and be used as green leisure area. An example of this type of solution is the Common Remembrance Memorial in Wrocław (3.5). In the case of old cemeteries where a certain number of historical headstones remain and the composition and vegetation arrangement have been preserved, a memorial park or a lapidarium park can be created. Such a place will be both a remembrance site, and a post-cemetery park, combining remembrance, historical, and leisure functions. The characteristic elements of the composition, which keep the sites' identity, should be highlighted. Examples of this type can be found in Szczecin in the post-cemetery parks in Władysława Nehringa St. [10] and Ostrowska St., not discussed in this paper.

In the context of commemorating the old cemeteries, competitions for designing such places are worth emphasizing. Competitions are a good opportunity to obtain relatively best design with appropriate solutions, and to achieve a good final effect. Due to the nature of these places, their symbolic and cultural meaning, their designers should be characterized by sensitivity and the ability to properly integrate different artistic means and to shape proper imagery. Commemorative elements should be characterized by high aesthetic and artistic value (adequate form). It should also be emphasized that remembrance sites are also places of meetings and leisure, that is why it is necessary to properly equip them in terms of their intended function. The commemorative facilities and spaces should attract, and stay in one's memory, hence the need to personalize their creation as a whole, and to create relevant cultural, historical, and social memory media [14].

5. Conclusions

Some of the commemorative facilities discussed were established in the 1990s, but the most numerous projects date back to the first decade of the 21st century. The initiative to create sites that commemorate old cemeteries and people buried there in Poland have come from both local authorities as well as other communities, social groups, or individual persons. The creation of such places is opposite to the process of collective oblivion. This demonstrates the need to build social identity and a sense of unity by sharing the same space and being equal in death. It is also a form of apology and redemption. The attitude towards historical cemeteries, especially to the "foreign" ones, shows the level of culture and sensitivity of contemporary society. Therefore, the formation of such remembrance places and commemorative facilities demonstrates positive social changes.

The remembrance sites for old cemeteries and the deceased can vary, these include great monuments, monumental planning schemes, properly arranged spaces, lapidaria, but also small commemoration plaques. The commemoration places mentioned in this paper have specific symbolism related to the religion, denomination, and the theme of death and passing. However, the author believes that this symbolism should be richer, more diversified, and universal. The use of symbols, archetypes, allegories is important for cultural heritage; for this reason they should be invoked, so they can be familiarized with, understood, and utilized. Thus, it is important that the content layer be expanded, which would contribute to the development of the audience's sensitivity and cultural awareness. For this purpose, it is necessary to carefully select the material, and to not forget about vegetation. Plants not only help to properly shape the mood of a place, they can also be used symbolically. When shaping remembrance sites for old cemeteries, it is highly desirable to use a plant which is traditionally planted at cemeteries. This raises the cultural, historical, and aesthetic value of the place. This is even more the case when adapting areas of old cemeteries for parks; besides the elements typical for cemeteries (spatial arrangement, landscape architecture elements, tombstones etc.), plants typical for cemeteries should also be left there.

To create remembrance sites for old cemeteries and people buried there is by all means both desirable and justified. Their presence can promote individual and social cultural development, shape the identity, the system of values, or deepen the awareness, and thus it comprehensively enriches us. The process of their creation should be supported both materially and spiritually.

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The influence of horizontal land cover structure changes over the valley Odra river landscape in the Wrocław area

Wpływ zmian poziomej struktury pokrycia terenu na krajobraz doliny Odry w rejonie Wrocławia

Abstract

This article concerns the subject of landscape changes based on dynamic changes in horizontal land cover over 20 years (1995–2015). The research area is the Odra valley in Wrocław and its surroundings, which is divided into architectural-landscape units and land structure changes using photointerpretative retrospective analysis. Based on this analysis, a characteristic changeability index was specified, which shows the percentage value of changes in each unit. These changes have direct influences on the visual perception of each landscape.

Keywords: Odra valley, land cover changes, landscape, architectural-landscape units, photointerpretative retrospective analysis, the city of Wroclaw

Streszczenie

Artykuł podejmuje temat przemian krajobrazowych na podstawie dynamicznych zmian w poziomej strukturze pokrycia terenu w okresie 20 lat (1995–2015). Obszarem, który poddany został badaniu jest dolina Odry we Wrocławiu i okolice miasta. Wykonano badania dotyczące podziału obszaru na jednostki architektoniczno-krajobrazowe oraz określenia przemian struktury terenu za pomocą fotointerpretacyjnej analizy retrospektywnej. Na podstawie tej analizy określono wskaźniki zmienności cech, które przedstawiają wartość procentową przemian w każdej jednostce. Zmiany te mają bezpośredni wpływ na odbiór wizualny krajobrazu danego miejsca.

Słowa kluczowe: dolina Odry, zmiany pokrycia terenu, krajobraz, jednostki architektoniczno-krajobrazowe, fotointerpretacyjna analiza retrospektywna, Wrocław

1. Introduction

In the preamble of the European Landscape Convention, we read that one of the motives behind the creation of this document is their concern "to achieve sustainable development based on a balanced and harmonious relationship between social needs, economic activity and the environment" [20]. The concerns that the creators of the ECC write about, cover many aspects. One of them is the landscape, or "the area perceived by people whose character is the result of the action and interaction of natural and/or human factors" [20]. It follows that the landscape will always be influenced by both anthropogenic and natural factors that will shape it according to human intentions and legal regulations, but also according to the forces of nature. Thus, the landscape subject to all kinds of changes is a dynamic image that changes over time. In turn, this fact raises the research question: where is the boundary between voluntary shaping of the landscape and its protection, taking into account the principle of sustainable development? In the sense that sustainable development "is socio-economic development in which the process of integrating political, economic and social activities takes place, preserving the natural balance and durability of basic natural processes, in order to guarantee the ability to meet the basic needs of individual communities or citizens of both modern generations as well as future generations" [22].

It is extremely difficult to define the boundary of anthropogenic activities for the landscape based on this principle, because it requires a number of analyses from the border of many different fields of science. Considerations on this subject were undertaken by, among others, Bogdanowski, who made one of the first attempts to organize the concepts related to the landscape, its typology, the division of landscape into architectural-landscape units, and landscape interiors. As a precursor, he highlighted the principles of composition and planning, which he based on an analysis of the factors of many aspects: social, economic, political, natural and historical-cultural [1, 2]. The thoughts of Prof. Bogdanowski in reference to landscape interiors were continued by both Böhm [3] and Patoczka [9, 10]. An important role in this topic was also played by Chmielewski, who widely developed many threads concerning landscape issues. He drew attention to the issue of landscape changes over time based on the analysis of land cover structure, both in function and form [4–6, 8, 12–14].

2. Purpose, materials and methods

The article attempts to draw attention to the pace of change in the horizontal structure of land cover, which has a direct impact on landscape physiognomy. For this purpose, cartographic research was carried out based on methods of architectural and landscape units as well as photointerpretive retrospective analysis. The Odra river valley in the Wrocław region was selected for the research due to the diversity of the landscape in the middle part of the valley. The boundaries of the valley from the east and west side were adopted in accordance with the border of the Odra valley. The area is designated in accordance with the floodplains of the Odra, and thus corresponds to the natural surface of the river flood, i.e. the surface of the natural zone of influence by the high water levels of the Odra [16]. The northern boundary of the study area is the administrative border of the city of Wrocław, while the southern border runs through Nature 2000 protected areas (administratively, the southern boundary is crossed by two Communes: Czernica and Siechnice). The area to be analyzed includes both an anthropogenically transformed area (the city center of Wrocław) and an extremely natural area – Nature 2000 protection areas (Widawa Valley, Pilczycki Forest and Grądy in the Odra Valley). The entire area under study has a total area of about 202 km^2.

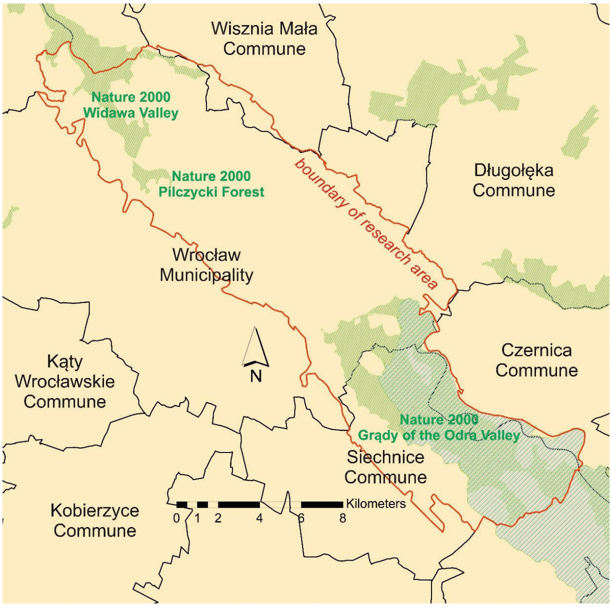

Fig. 1. The research area border

In order to conduct proper analyses, cartographic materials from the Central Geodetic and Cartographic Documentation Center (Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej) in Warsaw, the Provincial Center for Geodetic and Cartographic Documentation (Wojewódzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej) in Wrocław, and the Regional Water Management Board (Regionalny Zarząd Gospodarki Wodnej) in Wrocław were used. The materials of the Map Archives of Western Poland (Archiwum Map Zachodniej Polski) were also used. The first stage of the research concerned the division of the study area into architectural-landscape units. According to Bogdanowski, this division should be made by designating similar forms of landforms and land cover together by imposing graphically designated areas on each other. It is also important to take into account historical data. [1, 2, 8, 4]. Taking the above into account, the study used the current orthophotomap (2015) and Messtischblatt topographic maps from 1937–1944, to determine spatial layouts, as well as the numerical terrain model and hydrographic map, to determine the relief. The division into units was made on a scale of 1: 50000 using the ArcGIS program.

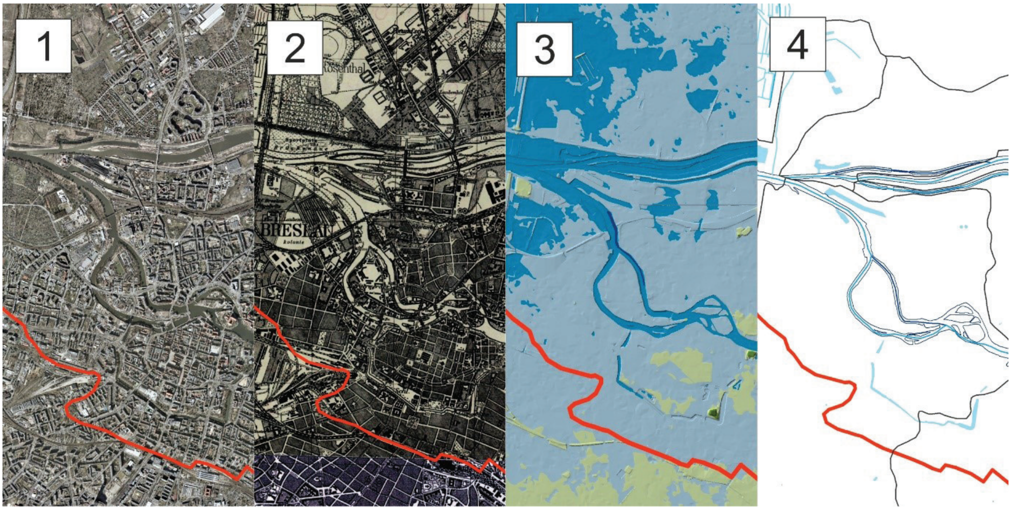

Fig. 2. The fragments of catographical materials used to create the architectural-landscape units: 1 – actual ortophotomap, 2 – Messtischblatt, 3 – numerical terrain model, 4 – hydrographical map (source: CODGiK and Archiwum Map Zachodniej Polski)

The aim of the second stage of the research was to carry out a retrospective photointerpretative analysis [4–6, 12–14], which was made for designated architectural and landscape units using a 20 year period (1995–2015). The following sources were used for the analysis: orthophotomap (2004 and 2015) and aerial photographs (1995), which were calibrated to the same PL-1992 plane coordinate system (the reference system used to create the Topographic Data Base) [19]. The study was conducted on a scale of 1:10 000 using the ArcGIS program. The result of the retrospective photointerpretative analysis was to show the variability of the land cover data using the Characteristic Changeability Index [4].

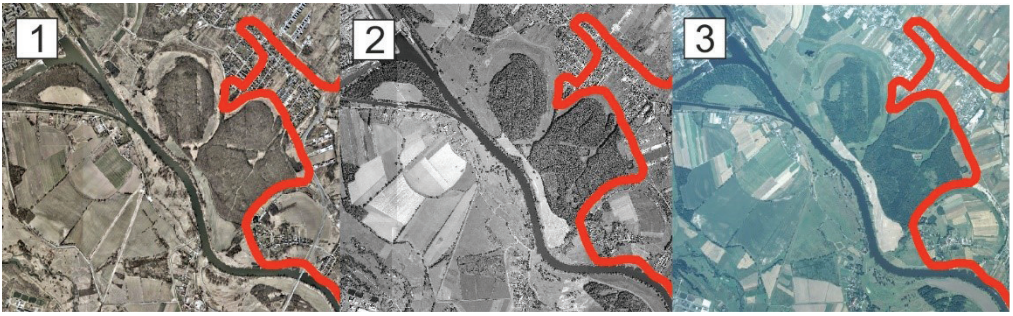

Fig. 3. 1 – 2015 ortophotomap, 2 – 2004 ortopfotomap, 3 – 1995 aerial photography (source: CODGiK)

3. Results

The choice of architectural-landscape units was dictated by the benefits of selecting such units, such as the internal landscape uniformity of units, the possibility of obtaining a "natural" image within a unit (comparable to the natural spatial unit) and is considered the best form of land division in landscape analysis [11, 4]. On this basis, a graphic division of the study area into units according to the criteria adopted for each map was made. For the numerical terrain model, the borders were designated based upon estimated differences in height, for the hydrographic map division lines for microcatchments were adopted, historical spatial layouts were recognized for historical topographic maps, and contemporary spatial systems for orthophotomaps. In the following step, the chosen boundaries were imposed and the boundaries of architectural-landscape units were selected according to the principle of choosing the most overlapping lines. Fifteen architectural and landscape units have been distinguished using this method.

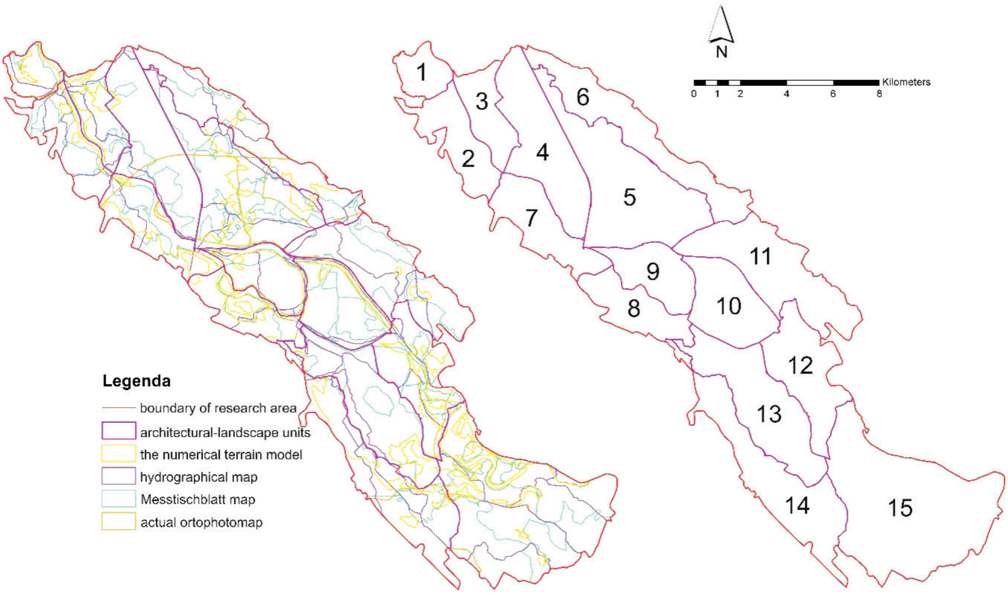

Fig. 4. The border analysis: the numerical terrain model, hydrographical map, Messtischblatt map and actual ortophotomap and the map of architectural-landscape units

Due to the extensive research area, selected land cover forms were analyzed, which are of key importance for landscape analyses in the river valley: surface waters, high greenery, building areas, road and rail transport. The system of watercourses is a characteristic element of the river valley area, hence the decision to choose surface water as an important function of land cover in the research area. Another element is the areas covered with high greenery, and thus all kinds of tree stands (forest complexes, linear systems of trees, groups of trees or single trees). Trees in the landscape are a component of the walls of landscape interiors [1–3, 9, 10]. The number of trees translates into the density of the walls of the landscape interior and influences the assessment of the interior – hence the quantitative analysis of land cover in this form is important for the visual reception of the landscape. In addition, areas covered with a high level of greenery also have a positive impact on the aesthetics of the anthropogenic landscape [17]. A similar situation applies to buildings, which is also a component of the walls of the landscape interior and affects the visual reception of the landscape in the given interior. The last studied form of land cover is road and rail communication. Roads and railways affect the fragmentation of the natural environment and make it difficult to migrate biotic matter in ecological corridors (such as river valleys, among others), which translates into the division of the analyzed landscape and the fragmentation of landscape interiors.

The criteria for the division of selected land cover forms was developed on the basis of the "Technical guidelines for the topographic database" [18] and the study "Cartographic modeling in the suitability tests of areas for afforestation" [15]. Coverage with selected forms is shaped into surface, linear and point objects.

Table 1. The division criteria of the chosen land cover forms

	COVERING	HIGH LEVEL OF GREENERY	SURFACE WATERS	BUILDING AREAS	ROAD TRANSPORT AND RAIL TRANSPORT
1	SURFACE	▸ green areas with an area> 500 m² (with a width of over 10 m and a length of more than 500 m)	▸ watercourses with an average water table width of over 5 m ▸ water reservoirs (natural and artificial) in the area > 100 m²	▸ single construction objects with an area of up to 200 m² ▸ building groups with an area of over 200 m²	▸ not classified
2	LINEAR	▸ bands and rows of trees up to 10 m wide (distance between trees < than 10 m) and lengths from 50 m	▸ watercourses with an average water table width of up to 5 m ▸ longitudinal water reservoirs (eg oxbow lakes) with an average width of 5 m and a length > 50 m	▸ not classified	▸ road lanes within multi-lane roads, one-way roads, paths, tram tracks, railway tracks up to 5 m wide
3	POINT	▸ single trees and groups of trees up to 200 m² (0,02 ha)	▸ water reservoirs (natural and artificial) in the area < 100 m²	▸ not classified	▸ not classified

In order to determine the total area of all studied forms of land cover, the surface and linear objects were given surface forms. These objects were transformed into surface forms using ArcGIS tools: "feature to polygon" for point objects and "buffer" for linear objects. From these procedures, a surface image was created for all forms of land cover. A photointerpretative retrospective analysis spanning 20 years was carried out for three particular years: 1995, 2004 and 2015, as illustrated in the following maps.

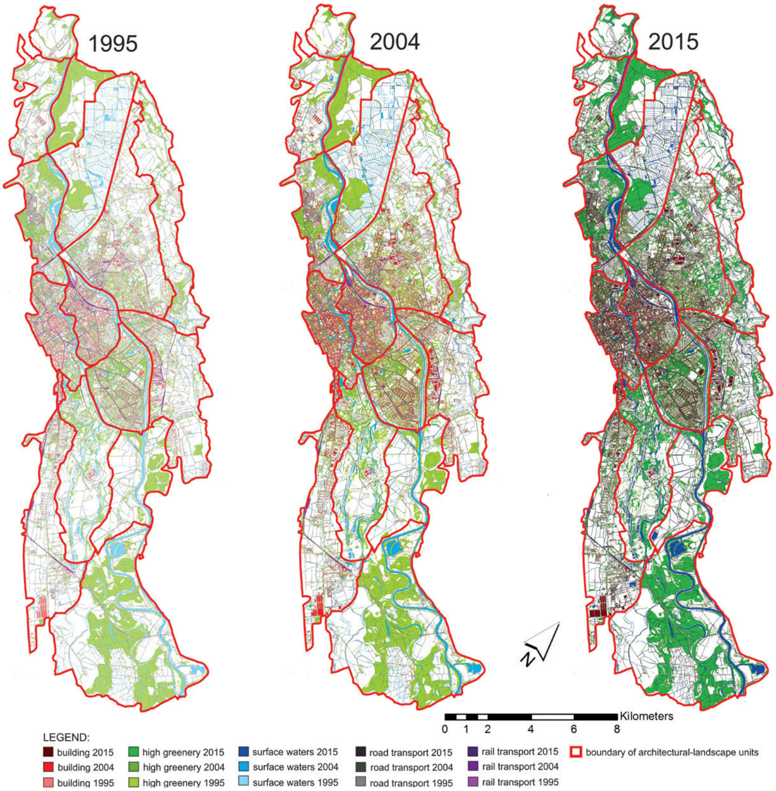

Fig. 5. The photointerpretative retrospective analysis made in 2015, 2004 and 1995 (all research areas)

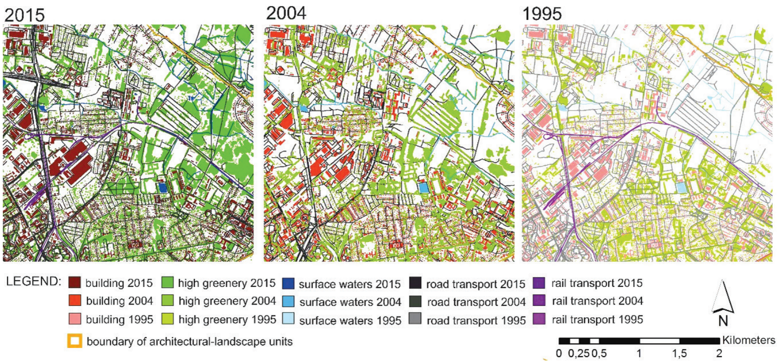

Fig. 6. The photointerpretative retrospective analysis made in 2015, 2004 and 1995 (a part of the research area)

Using the formula for the Characteristic Changeability Index [4] tabulated data on the percentage share of each land cover in all architectural- landscape units is shown.

Table 2. The percentage share in the chosen land cover forms and the characteristic changeability index (CCI) for all architectural-landscape units

A–L UNIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HIGH GREENERY [%]															
1995	15,92	16,27	56,44	13,63	16,07	16,77	35,42	23,4	18,7	36,58	14,66	22,22	19,15	9,7	37,73
2004	15,85	14,78	58,87	13,87	20,01	14,51	31,57	22,19	18,35	34,37	13,11	22,02	22,01	9,71	37
2015	22,17	23,48	61,21	16,55	23,66	19,14	32,3	17,89	15,52	35,66	18,46	25,47	28,66	13,03	37,97
CCI	28,19	30,71	7,79	17,64	32,08	12,38	–9,66	–30,80	–20,49	–2,58	20,59	12,76	33,18	25,56	0,63
SURFACE WATERS [%]															
1995	4,61	7,64	1,45	12,37	2,13	4,28	13,26	8,63	8,23	6,03	2,66	7,85	10,4	2,74	9,22
2004	5,39	8,17	1,59	10,27	2,1	4,57	13,42	9	8,61	5,92	2,74	7,78	10,63	2,87	9,57
2015	6,36	9,09	2,9	12,34	2,39	5,33	14,61	9,1	9,56	6,17	3,22	8,93	11,36	3,13	10,38
CCI	27,52	15,95	50,00	–0,24	10,88	19,70	9,24	5,16	13,91	2,27	17,39	12,09	8,45	12,46	11,18
BUILDING AREAS [%]															
1995	0,41	2,09	0,05	0,59	6,52	0,83	3,7	18,03	17,21	7,93	5,15	0,3	0,64	5,41	0,2
2004	0,39	2,32	0,05	0,57	7	1,04	3,73	18,9	17,44	8,11	5,93	0,28	0,69	6,04	0,22
2015	0,51	2,65	0,05	0,82	7,62	1,19	4	19,83	17,82	8,56	6,93	0,29	0,69	7,68	0,29
CCI	19,61	21,13	0,00	28,05	14,44	30,25	7,50	9,08	3,42	7,36	25,69	–3,45	7,25	29,56	31,03
ROAD TRANSPORT [%]															
1995	6,78	9,23	7,17	7,28	15,64	8,36	20,42	26,65	26,67	26,06	13,13	6,66	8,17	12,15	6,51
2004	5,74	10,42	7,43	7,1	16,01	8,82	20,97	26,74	25,81	25,73	13,65	7,09	8,24	12,63	6,4
2015	8,22	10,35	7,52	8,35	17,28	9,06	21,51	26,76	25,25	25,7	13,98	8,68	8,16	13,34	6,27
CCI	17,52	10,82	4,65	12,81	9,49	7,73	5,07	0,41	–5,62	–1,40	6,08	23,27	–0,12	8,92	–3,83
RAIL TRANSPORT [%]															
1995	0	0	0	0,42	1,27	0,17	1,19	2,68	5,43	0,87	1,71	0,05	0,03	2,49	0,16
2004	0	0	0	0,42	1,26	0,17	1,19	2,68	5,43	0,87	1,71	0,05	0,03	2,49	0,16
2015	0	0	0	0,42	1,26	0,17	1,66	2,7	5,46	0,87	1,71	0,05	0,03	2,56	0,16
CCI	0,00	0,00	0,00	0,00	–0,79	0,00	28,31	0,74	0,55	0,00	0,00	0,00	0,00	2,73	0,00

The percentage share of the variability of a given feature is shown in the bar graph. On the basis of the results of the variability of a given land cover form, conclusions were formulated in each of the architectural-landscape units.

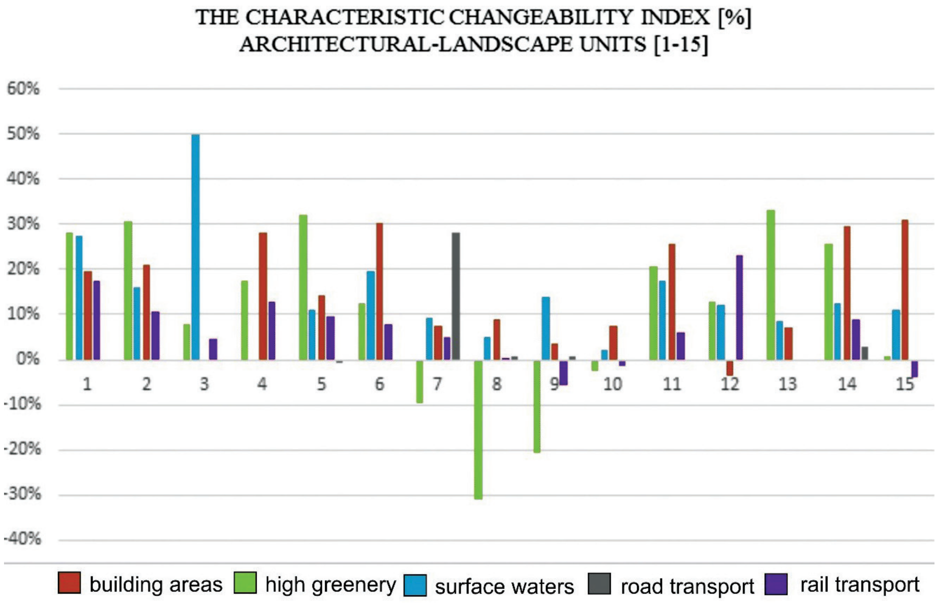

Fig. 7. The characteristic changeability index

The characteristic changeability index clearly showed that the dynamics of changes in individual forms of land cover within 20 years is significant. Most of the surveyed land cover forms showed an upward trend, which means that over time, the analyzed land cover forms grew in each of the architectural-landscape units. Only in units 7, 8, 9 and 10 can downward trends be seen, which is associated with the stronger anthropogenic impact on the cultural landscape of these units. Reading the data from the graph, it can also be seen that in each unit (except unit 15, where most of the area is protected – Nature 2000) there are changes in the level of greenery. The more natural the landscape and the smaller the impact of anthropogenic activities, the greater is the growth of areas covered by greenery, greenbelts or groups of trees. On the other hand, the more cultural and anthropogenic the unit was, the greater the decrease in greenery (this is especially visible in the very center of Wrocław in units 8 and 9). It is also interesting to note that in most units there is an increase in the amount of surface water. This applies to waters flowing in the I, II and III order watercourses (along with drainage ditches), as well as stagnant waters in natural and artificial reservoirs. The study area lies in the Odra valley, so the main riverbed flows along the center of the area. The changing shape of the Odra coastline can be observed, especially in areas that are considered most natural. In addition, new artificial reservoirs appear in the form of ponds and small water reservoirs in private properties near detached family houses. Hence the significant increase in the amount of water. The exception is unit 4, where there are extensive drainage fields that maintain their form as a system of drainage ditches. In this space, a slight decrease in surface water is observed, which is related to periodic droughts in the system of drainage ditches. The characteristic changeability index showed that only unit 3 lacked noticeable changes in the number of built-up areas within the unit (this is the area where a high level of green cover is the dominant form of land cover). The remaining units show the dynamics of the change, which in most cases shows building development in each unit. The exception is unit 12, in which a slight decrease is noticeable, which may be due to the fact that according to the Local Development Plan, this area (Opatowice) is a designated area for polders of the Odra river as well as having a rather inconvenient transport connection to the center of Wrocław, which is an obstacle to the development of the settlement. We also read from the chart that there are slight fluctuations in the increments and losses of areas related to road transport throughout the study area. Units 9, 10, 13 and 15 show declines, while in the rest of the units there is an increase in road transport. The largest increase is visible in unit 12, which results from the previously mentioned shortage of appropriate transport infrastructure. Expansion of roads in this place may cause an increase in the number of buildings in the future, at the expense of other forms of land cover. The first three units do not have rail transport within their area, while in the rest of the units the occurrence of this form of land cover is noticeable. The number of railway lines in most units has not changed (in 7 of the units this area has been constant over the last 20 years). The high variability of this feature can only be seen in unit 7, which was dictated by the construction of the stadium for EURO 2012 in Wrocław, the expansion of the Kozanów and Pilczyce housing estates and the development of railway infrastructure in this area of the city (railway and tram transport).

4. Discussion of the results

Changes in the horizontal land cover structure are inevitable. However, each transformation of the smallest section of space has a direct impact on the appearance of the landscape, which translates into the visual reception of the place. If such significant increments and losses of land cover forms can be seen in just 20 years, what will the landscape look like after 50 or 100 years? The current rate of change would indicate a drastic transformation of the landscape. Most of the changes in the studied area of the Odra River valley are of an anthropogenic nature, which is the result of inapt planning decisions and numerous investments. This is evidenced by, for example, statistics showing the number of construction projects in Wrocław in proportion to investment in urban green areas. In the ranking of 152 investments, we can find only 6 which concern the revitalization of the Odra areas (implemented as part of the long-term Program for the Odra 2006), expansion of recreational areas within the city's limits or the construction of a new cemetery. Investments concerning the reconstruction of roads and existing buildings with residential and utility functions as well as new road, residential and service investments dominate [21]. We can also see the transformation of the landscape in suburban areas near Wrocław, where the spatial policy of communes affects the development of built-up areas even at the expense of protected areas [7].

The presented research results allow the formulation of general guidelines for the entire area where changes in land cover occurred.

1) High level of greenery:
   - protection of green areas with high natural and landscape value spaces,
   - limiting the possibility of tree felling in highly urbanized areas,
   - introduction of new green spaces in areas that have been heavily anthropogenically transformed (biologically active areas).
2) Surface waters:
   - protection and maintenance of irrigation fields,
   - protection of surface waters with high natural and landscape value,
   - applying the principles of sustainable development when creating new artificial reservoirs.
3) Buildings:
   - limiting the possibility of introducing new construction projects in highly urbanized areas,
   - limiting the possibility of building in valuable natural areas,
   - applying the principles of sustainable development while expanding Wrocław and neighboring towns and villages.
4) Road transport:
   - prudent road planning based on the principles of sustainable development,
   - limiting the possibility of extending road communication to valuable natural areas.
5) Rail transport:
   - prudent planning of railway routes based on the principles of sustainable development.

5. Final remarks

In accordance with the principle of sustainable development, the shaping of space should take into account human needs, but with respect for the laws of nature. Only then will it be a guarantee for present and future generations, so that they have a chance to live in a harmoniously formed space in which the proportion of natural areas balances with areas that have been strongly anthropogenically influenced. Therefore, it is important to create parametric standards of possible anthropogenic actions and protective measures that would be the basis for creating planning documentation. In order to objectively set such standards, it is necessary to introduce a system of monitoring changes in the landscape and to determine the type of landscape and character of a given place. Based on the rate of landscape change, it is recommended that this kind of analysis should take place at least once every 5 years. The research methods used can apply to the entire country of Poland irrespective of the extent of anthropological changes (environmental, environmental-cultural and cultural).

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The flexural capacity of laminated veneer lumber beams strengthened with AFRP and GFRP sheets

Nośność na zginanie belek z forniru klejonego warstwowo wzmocnionych matami AFRP i GFRP

Abstract
This paper presents the results of preliminary tests focused on the strengthening of laminated veneer lumber (LVL) beams with aramid fibre-reinforced polymer (AFRP) and glass fibre-reinforced polymer (GFRP) sheets. Edgewise bending tests were performed on elements throught 4-point loading. The following two types of strengthening arrangements were investigated: sheets bonded to the bottom face along the entire length of the element, and a U-shaped half-wrapped type of reinforcement. The reinforcement ratios of the beams strengthened with GFRP sheets were 0.3% and 1.0% for the first and second strengthening arrangements, respectively; for the beams strengthened with AFRP sheets, these ratios were 0.2% and 0.64%, respectively. The experimental data revealed an increase in both the bending strength and the stiffness in bending of the strengthened elements. The failure mode was dependent upon the type of the strengthening configuration.

Keywords: LVL, fabrics, timber structures, aramid fibres, glass fibres, strengthening

Streszczenie
W artykule przedstawione zostały rezultaty badań belek z forniru klejonego warstwowo wzmocnionych tkaninami zbrojonymi włóknem aramidowym (AFRP) i szklanym (GFRP). Badania przeprowadzono na próbkach w układzie krawędziowym poddanych 4-punktowemu zginaniu. W badaniach wstępnych przyjęto dwie konfiguracje wzmocnienia: maty przyklejone do dolnej powierzchni elementów na całej długości i tzw. zbrojenie typu U doprowadzone do połowy wysokości przekroju poprzecznego. Stopień zbrojenia elementów wynosił 0.3% i 1.0% dla elementów zbrojonych matami GFRP oraz 0.2% i 0.64% dla belek zbrojonych matami aramidowymi. Wyniki badań wykazały wzrost wytrzymałości na zginanie i sztywności przy zginaniu. Postać zniszczenia zależna była od przyjętej konfiguracji wzmocnienia.

Słowa kluczowe: LVL, tkaniny, konstrukcje drewniane, włókna aramidowe, włókna szklane, wzmacnianie

1. Introduction

The mechanical properties of a wood depends upon the location of the analysed point (heterogeneity) and the orientation of the analysed sample relatively to the direction of the woodgrain [8]. Increasing the bending strength of the cross section by reinforcing the tensile zone using composite strips or sheets has been the subject of many scientific publications. This solution enables the utilisation of the compressive strength of the wooden structure in order to obtain greater ductility of the beams when subjected to bending forces. The first papers regarding the use of glass sheets in this way emerged in the 1960s [21]. Nowadays, a configuration is usually used in which the reinforcement is bonded between two lower lamellas or glued from the bottom of the element [7, 22]. In order to increase efficiency, traditional passive reinforcement of the structure can be replaced by active reinforcement, the key advantage of which is introducing the initial upward camber of the element [6].

Flexural reinforcement with pultruded FRP rods bonded in pre-cut grooves along the longitudinal axis of the beam is a well-known solution. Composite elements obtained in this way, in spite of slight interference in the original cross section, enable the reinforcement to be hidden inside the element's perimeter without increasing it; it also ensures that the adhesive layer is partially covered thus protecting it against external influences. Attempts to strengthen elements with the use of GFRP rods are presented in [5, 14, 23]. Phenomena relating to specific issues of this concept, such as anchoring reinforcement inserts, have also been the subject of research [1, 11, 16].

Unlike glued wood, the application of composite reinforcement for solid beams is related to repairing local damage [10] or restoring and improving the mechanical properties of utilised elements [4, 9] rather than obtaining new structural members. These tests were performed both for reinforcement in the passive state [11] and for prestressed elements [15].

In addition to composites reinforced with only one type of fibre, hybrids – a combination of at least two types of fibres – have also been used as the reinforcement of wooden structures [2, 3].

2. Materials and methodology

2.1. Laminated veneer lumber

The subjects of the experimental research were laminated veneer lumber beams with a cross section dimension of 45 × 100 mm and a length of 1,700 mm. Each beam consisted of 15 layers of 3-mm-thick veneer – wood fibres in every lamella were oriented in the longitudinal direction. Prior to the application of FRP sheets, the surface was ground and the edges were chamfered. Selected mechanical properties of the LVL beams are presented in Table 1.

Table 1. Selected parameters of the laminated veneer lumber beams [17]

Parameter	Edgewise properties
bending strength [N/mm^2]	44
shear strength [N/mm^2]	4.6
modulus of elasticity – E [N/mm^2]	14000
shear modulus – G [N/mm^2]	600
density [kg/m^3]	480

2.2. Composite fabrics

In the test, sheets reinforced with glass fibres (S&P G-Sheet E 90/10 B) and aramid fibres (S&P A-Sheet 120) were used as the reinforcement of LVL beams. The glass sheet is a bidirectional fabric with 90% of the fibres set along the main direction of the material and 10% in the transversal direction. The aramid sheet is a unidirectional fabric. Selected properties of used fabrics are presented in Table 2.

Table 2. Selected parameters of composite sheets [18, 19]

Parameter	Aramid sheets S&P A-Sheet 120 [290 g/m^2]	Glass sheets S&P G-Sheet E 90/10 B
modulus of elasticity [kN/mm^2]	≥ 120	≥ 73
tensile strength [N/mm^2]	≥ 2 900	≥ 3400
fibre weight [g/m^2]	290	800
weight per unit area of sheet [g/m^2]	320	880
density [g/cm^3]	1.45	2.60
elongation at failure [%]	2.5	4.5
design thickness [mm]	0.200	0.308

2.3. Adhesive

The reinforcement was bonded to the external faces of the elements by means of S&P Resin 55 HP epoxy resin. The hardener and epoxy resin was mixed with a low speed drill at the proportion of two to one by weight [20]. The prepared mixture was applied on the LVL beam surface and was also used to saturate sheet fabrics.

2.4. Methodology

The subject of the experimental tests were laminated veneer lumber beams strengthened with aramid and glass fabrics. The purpose of the research was analysis of the influence of the reinforcement on the behaviour of bending beams under static load. The scope of the research included preparing the following series of test elements:

- LVL series – reference beams;
- LVLA series – laminated veneer lumber beams strengthened with one layer of aramid sheet applied to the bottom face of the beam (reinforcement ratio 0.2%);
- LVLAU series – LVL beams strengthened with an aramid sheet bonded to both sides and the bottom face of the specimen (reinforcement ratio 0.64%);
- LVLG series – laminated veneer lumber beams strengthened with one layer of glass sheet applied to the bottom face of the beam (reinforcement ratio 0.3%);
- LVLGU series – beams strengthened with a glass sheet bonded to the soffit and both sides of the specimen – U type reinforcement (reinforcement ratio 1%).

The static tests were conducted in the Laboratory for the Strength of Materials of Kielce University of Technology in accordance with reports [15, 16]. The 4-point bending tests were performed using an MTS-322 universal hydraulic machine. The loading rate was set to 7 mm/min. The static scheme setup is illustrated in Fig. 1.

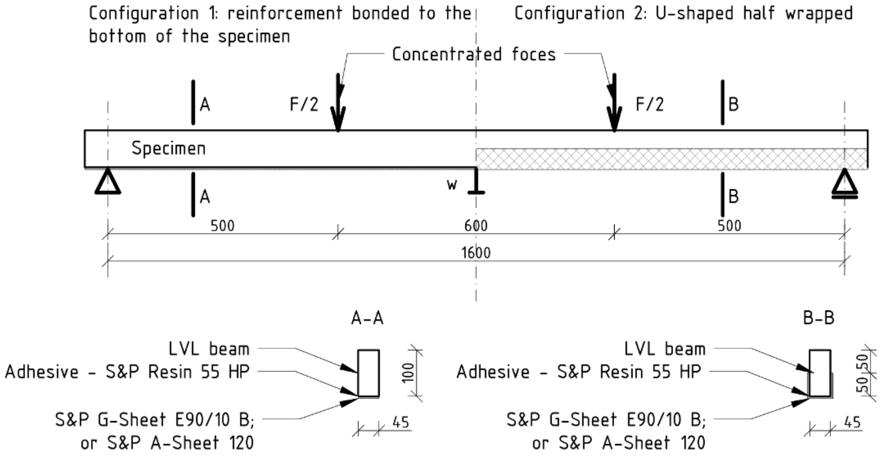

Fig. 1. Static scheme setup

The loading force, test time, actuator displacement and deflection in the centre of the beam were continuously measured during the tests. After the bending tests, the failure modes were recorded. In the next step, values of the bending strength and the global modulus of elasticity in bending were estimated on the basis of experimental data. The bending strength was determined from the following equation according to standard [12]:

$$f_m = \frac{3Fa}{bh^2} \tag{1}$$

where:

- a – distance between loading position and the nearest support axis [mm],
- F – loading force [N],
- b – width of the cross section [mm],
- h – height of cross section [mm].

In the next step, the determined values of bending strength from formula (1) were corrected to the reference width of the laminated veneer lumber elements (300 mm) by multiplying with the correction factor determined from the following equation given in standard [13]:

$$k_{m,corr} = \left(\frac{b}{300}\right)^s \tag{2}$$

where:

- s – shape parameter determined from the expression: $s = 2v - 0.05$,
- v – coefficient of variation of the test results (0.15).

Global modulus of elasticity in bending was determined from the following expression [12]:

$$E_{m,g} = \frac{3al^2 - 4a^3}{2bh^3\left(2\frac{w_2 - w_1}{F_2 - F_1} - \frac{6a}{5Gbh}\right)} \tag{3}$$

where:

- $F_2 - F_1$ – increment of load in the range 0.1 – 0.4 of maximum load [N],
- $w_2 - w_1$ – increment of deformation corresponding to the increment of load $F_2 - F_1$ mm,
- G – shear modulus (value adopted in accordance with the manufacturer data as 600 MPa).

3. Test results

3.1. Test results for the reference beams

Figure 2 shows the relationship between the loading force and the mid-span deflection for the reference elements. The behaviour is typical of unstrengthened beam-like specimens. The bending strength is limited by the tension strength of the elements.

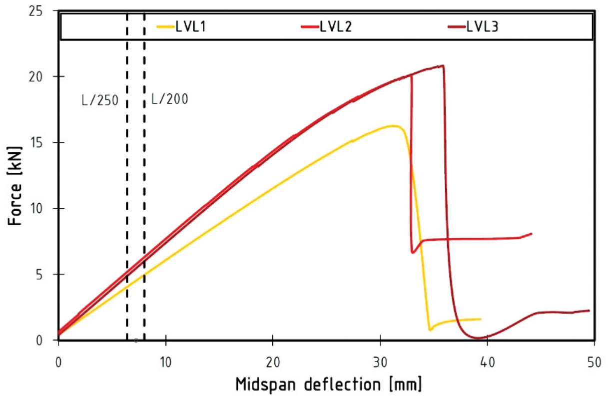

Fig. 2. Force-deflection curves for the reference beams

Figure 3 shows failure modes of the unstrengthened laminated veneer lumber beams. The crack occurred in the pure bending zone between the loading points (Fig. 3). The failure was caused by exceeding the tensile strength.

Fig. 3. Failure modes of reference beams

Table 3 provides the basic information concerning the results of the 4-point bending test for the reference elements including failure load, deflection at the point of failure load, time at which the loading force was reached as well as other identified parameters. In a similar manner, the results for the strengthened elements are presented.

Table 3. Test results for reference beams

Specimen	Failure load [kN]	Deflection [mm]	Time to failure [s]	Bending strength [MPa]	Modulus of elasticity [GPa]
LVL1	15.64	28.73	215	52.15 (39.62*)	11.20
LVL2	20.14	32.86	250	67.14 (51.01*)	14.09
LVL3	20.83	35.86	269	69.44 (52.76*)	14.08
* Values corrected to the reference height					

3.2. Test results for the beams strengthened with glass sheets

The LVLG series is characterised by large disproportions in maximum loading force and behaviour during tests. The U-shaped reinforcement caused a significant increase in the the time taken to reach ultimate failure. After reaching the maximum bending strength, the force decreased several times (Fig. 4) before the bending test was ended.

Beams strengthened with the glass fabric sheet bonded to the bottom surface of the elements failed due to the loss of tensile strength of the LVL beam. The failure mode was initiated by fracture above the composite layer in the pure bending zone. The rupture of the fabric sheet or delamination was not recorded in this series. In the case of the LVLGU series, the failure was caused by exceeding the compressive strength of the LVL between the axis of the loading points. For these specimens, the crack was initiated at the top face of the elements. The crack then propagated in a downward direction causing rupture of the glass fabric and splitting of the veneer layers. The rupture of the fabric sheets occurred locally (Fig. 5).

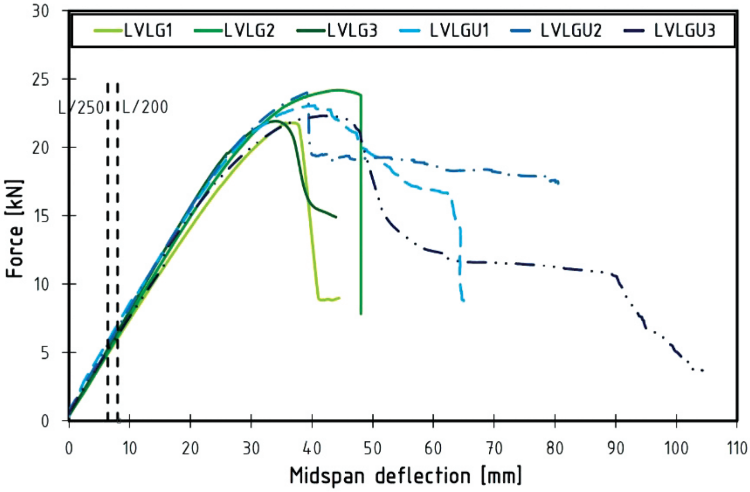

Fig. 4. Force-time curves for the beams strengthened with glass sheets

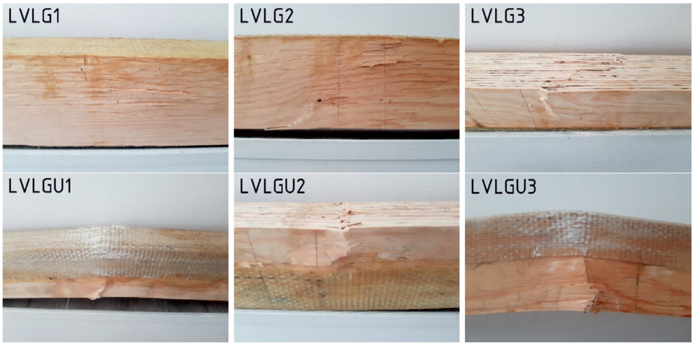

Fig. 5. Failure modes of specimens strengthened with glass sheets

Table 4. Test results for the beams strengthened with S&P G-Sheet glass sheets

Specimen	Failure load [kN]	Deflection [mm]	Time to failure [s]	Bending strength [MPa]	Modulus of elasticity [GPa]
LVLG1	21.80	35.66	263.7	72.66 (55.21*)	13.89
LVLG2	24.17	44.36	329.0	80.58 (61.23*)	15.10
LVLG3	21.92	34.14	252.9	73.07 (55.52*)	15.58
LVLGU1	23.05	40.48	320.0	76.83 (58.38*)	15.18
LVLGU2	23.99	39.18	299.9	79.98 (60.77*)	15.37
LVLGU3	22.31	41.96	319.5	74.38 (56.52*)	13.73

* Values corrected to the reference height

3.3. Test results for the beams strengthened with aramid sheets

Elements in the LVLA series behave in a similar manner as the reference elements under static load. The load versus deflection curves have a linear shape. For the U-shaped reinforcement, more ductile behaviour was observed for the visible plastic part of the load versus the deflection curves (Fig. 6).

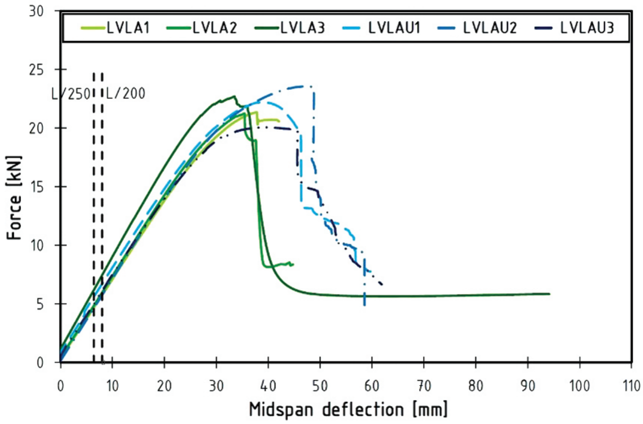

Fig. 6. Force-deflection curves for the beams strengthened with aramid sheets

Failure of the specimens of the LVLA series was caused by exceeding the load-carrying capacity in the tensile zone where the maximum bending moment occurred. Rupture of the aramid fibres was followed by the fracture of the laminated veneer lumber. Fracture propagated from the initiation point along the longitudinal axis of the beam. The exception is the LVLA1 beam for which the failure was caused by torsion of the element with a visible local indentation in the axis of the loading point. For the LVLAU series, failure of the elements was caused by exceeding the compressive strength of the engineering wood product as well as by the rupture of the AFRP sheet in a similar mode to the LVLGU series (Fig. 7).

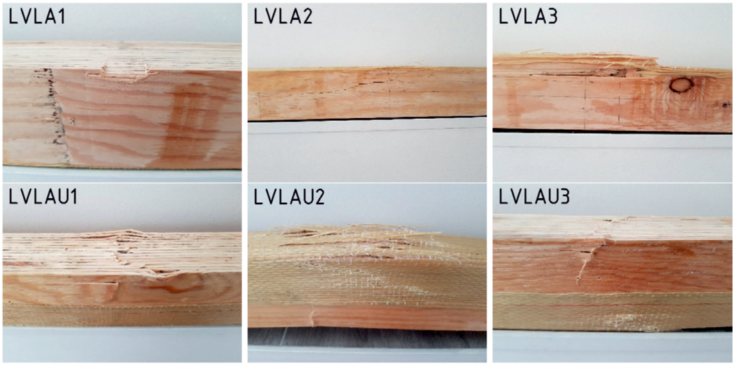

Fig. 7. Failure modes of specimens strengthened with aramid sheets

Table 5. Test results for the beams strengthened with S&P A-Sheet 120 aramid sheets

Specimen	Failure load [kN]	Deflection [mm]	Time to failure [s]	Bending strength [MPa]	Modulus of elasticity [GPa]
LVLA1	21.35	37.82	313.4	71.18 (54.08*)	13.58
LVLA2	21.28	35.46	259.4	70.92 (53.89*)	14.08
LVLA3	22.70	33.54	259.3	75.68 (57.50*)	16.05
LVLAU1	22.18	37.99	289.3	73.92 (56.17*)	14.66
LVLAU2	23.55	47.26	357.8	78.51 (59.66*)	14.21
LVLAU3	20.06	39.63	303.4	66.87 (50.81*)	13.73
* Values corrected to the reference height					

3.4. Statistical analysis

Table 6 presents the results of the statistical analysis of the experimental tests data. In the group of elements strengthened with GFRP sheets, the average increase in bending strength was 20% for the reinforcement bonded to the bottom face and 22% for the U-shaped reinforcement. For the AFRP sheets, these values were 15 and 16%, respectively. The insignificant increase in bending stiffness for both analysed sheet types was recorded. Variation of the test results for the strengthened elements was lower in comparison to the reference elements.

Table 6. Statistical analysis of the test results

Series	Bending strength [MPa]			Modulus of elasticity in bending [GPa]		
	Arithmetic mean	Standard deviation	Coefficient of variation	Arithmetic mean	Standard deviation	Coefficient of variation
LVL	62.91 (47.80*)	7.67	0.12	13.12	1.17	0.10
LVLA	72.60 (55.16*) (+15%)	2.18	0.03	14.57 (+7%)	0.32	0.06
LVLAU	73.10 (55.54*) (+16%)	4.79	0.06	14.20 (+10%)	0.90	0.02
LVLG	75.44 (57.32*) (+20%)	3.64	0.05	14.86 (+12%)	0.60	0.04
LVLGU	77.06 (58.55*) (+22%)	2.29	0.03	13.56 14.76 (+12%)	0.62	0.04
* Values corrected to the reference height						

4. Summary

The paper presents the results of the preliminary test of the laminated veneer lumber beams strengthened with composite fabrics. Aramid and glass sheets were used as reinforcement. Analysis of the static work of the specimens revealed the following:

- There was an increase in the bending strength of the strengthened elements in comparison to the reference beams; the average increase was 20% and 22% for the GFRP sheets, and 15% and 16% for the AFRP sheets for the fabrics bonded to the bottom face and the U-shaped reinforcement, respectively.
- The flexural stiffness of the strengthened specimens increased slightly for both configurations, regardless to the type of fibres used.
- In the case of the beams strengthened with the U-shaped reinforcement, the failure was due to the loss of the compressive strength of the LVL.

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Assessing the dynamic response of a steel pipeline to a strong vertical mining tremor using the multiple support response spectrum method

Ocena odpowiedzi dynamicznej naziemnego gazociągu na pionowy wstrząs górniczy z wykorzystaniem metody wielopodporowego spektrum odpowiedzi

Abstract

This paper presents an analysis of the dynamic response of an overground steel pipeline during a strong mining shock. The analysis was conducted using various calculation methods- a time history (THA), a response spectrum (RSA) and a multiple support response spectrum analysis (MSRS). For the THA and MSRS methods, non-uniform effects of ground excitation were taken into account. During the analyses, the bending moment was calculated. On the basis of obtained results, it can be noted that the non-uniform effects had a significant impact on the dynamic behaviour of the pipeline and it was indicated that the MSRS method led to more accurate estimation than the RSA.

Keywords: non-uniform excitations, multiple support response spectrum

Streszczenie

W artykule przedstawiona została analiza odpowiedzi dynamicznej gazociągu na rzeczywisty wstrząs górniczy. W obliczeniach zastosowano metodę całkowania równań ruchu (THA), spektrum odpowiedzi (RSA) oraz wielopodporowego spektrum odpowiedzi (MSRS). W metodzie THA i MSRS uwzględnione zostały efekty związane z nierównomiernością wymuszenia kinematycznego. W trakcie analizy obliczono momenty zginające w konstrukcji, na których podstawie zauważono, że nierównomierne wymuszenie ma wyraźny wpływ na wartość odpowiedzi dynamicznej.

Słowa kluczowe: nierównomierne wymuszenie, wielopodporowe spectrum odpowiedzi

1. Introduction

Seismic and the human-induced vibrations are examples of common dynamic loads that have an influence on structures. The most hazardous dynamic loads in the case of the stability and strength of structural elements are seismic shocks. In some regions of the world, seismic activity is low and does not constitute a threat to buildings. However, in these regions, other sources of dynamic load may occur, such as mining shocks, which have an impact on buildings which is similar to that of seismic load. Mining shocks can represent excitation energy close to that of seismic shocks. There are many studies that prove that mining tremors may cause damage or cracking to structural elements [5, 12].

The influence of mining shock to a structure strongly depends on the energy of the shock, the maximum acceleration and also the foundations. All of these parameters can be taken into account during the dynamic analysis of structures under mining shock. To determine the maximum dynamic response of a given object, many different methods of analysis are used. Common dynamic methods applied in research are time history analysis (THA) and response spectrum analysis (RSA). THA is based on the integration of the equation of motion in each time step. This method determines the full range of engineering parameters such as displacement, strain and stress at any point in time. The second methods, RSA, only allows the maximum value of a given parameter to be estimated.

Both of these methods correctly describe the behaviour of the structure under uniform excitation. Unfortunately, a uniform model of excitation (a model assuming a constant value of excitation in each structural support) may be inappropriate for some types of objects. The dynamic response for multiple support structures such as bridges or pipelines strongly depends on non-uniform effects appearing during the passage of mining shock. Non-uniformity can be taken into account using THA. In this procedure, the effect connected with the non-infinity wave velocity (wave passage effect) and the attenuation effect (decreasing amplitude along the direction of the wave propagation) can be counted. The effects related to ground conditions like site or coherence effect cannot be implemented in THA without data from field measurements. In this case, the THA method is suggested for use in the region of homogenous ground condition. The method that takes into account all of the non-uniform effects is the random vibration approach [6, 10, 13]; this method was developed on the basis of the SMART 1 array experiment in Taiwan. The results obtained during the experimental observation enabled formulation of a stochastic, spatial seismic ground-motion model. The random vibration approach allows consideration of not only the wave passage effect, but also the additional phenomena connected with local soil conditions and loss of coherency between supports. This approach is very useful in case of a lack of measurement results. The stochastic parameters used in this method enable prediction of the effects related to the ground wave passage. However, there is no possibility to implement the non-uniformity effects in RSA. In the case of the non-uniform excitation model, RSA lead to an underestimation of the maximum dynamic response of the structure [4, 8]. In some studies regarding non-uniform seismic excitation, the multiple support response spectrum (MSRS) method is used. The MSRS method is based on RSA but also takes non-uniformity into account. The authors indicated that the method allows an accurate estimation of the maximum level of dynamic response of the structure under non-uniform seismic shock [9, 11]. It is noteworthy that there has been no research using the MSRS method to calculate dynamic response under mining tremors.

In this paper, an analysis of the dynamic response of a steel pipeline under mining shock is presented. The calculation of the dynamic response is determined using the THA, RSA and MSRS methods of dynamic analysis. The chosen methods correspond with and are a continuation of the authors' field of research. The aims of the analysis are to compare the results obtained for each method and determine the usefulness of the MSRS method in the case of mining shock analysis.

2. The theoretical basis of the multiple support response spectrum method

The multiple support response spectrum method was used to determine the dynamic response of the pipeline under non-uniform mining excitation. As mentioned in section 1, the MSRS method allows the non-uniformity of the excitation to be taken into account. In this method, typical effects connected to non-uniform mining shock can be taken into consideration. These effects are: the wave passage effect (associated with non-infinity wave velocity), the site effect (different foundation conditions), the attenuation effect (decrease of amplitude with increasing distance) and the incoherence effect (changes in the frequency spectrum of excitation). The results of the MSRS analysis strongly depend on the accuracy of the implemented non-uniformity parameters of kinematic excitation. During the calculation, the maximum structural displacement can be obtained. The maximum value of nodal displacement z can be determined by following Eq. (1).

$$\mathbf{z}_{\mathbf{max}} = (\mathbf{b}^{\mathbf{T}} \cdot \mathbf{l}_{\mathbf{uu}} \cdot \mathbf{b} + \mathbf{b}^{\mathbf{T}} \cdot \mathbf{l}_{\mathbf{uz}} \cdot \mathbf{\Phi}_{\mathbf{BD}} + \mathbf{\Phi}^{\mathbf{T}}_{\mathbf{BD}} \cdot \mathbf{l}_{\mathbf{zz}} \cdot \mathbf{\Phi}_{\mathbf{BD}} + \mathbf{\Phi}^{\mathbf{T}}_{\mathbf{BD}} \cdot \mathbf{l}_{\mathbf{zu}} \cdot \mathbf{b})^{0.5} \quad (1)$$

Where $\mathbf{l}_{\mathbf{uu}}$, $\mathbf{l}_{\mathbf{uz}}$, $\mathbf{l}_{\mathbf{zz}}$ are the correlation matrix between the displacements of the supports; the displacement at the support and modal displacement, and the modal displacements, respectively. Matrix **b**, describes the response of the system to the ground motion occurring at a single support. Matrix **b** is based on the value of the displacement of the structure for unit ground motion and the maximum ground displacement in supports. Matrix $\mathbf{\Phi}_{\mathbf{BD}}$ represents the response of the system in the simple mode to the spectrum curve relating to a single support. The $\mathbf{\Phi}_{\mathbf{BD}}$ matrix consists of three components: the vector of the mode shape of the structure, the displacement response spectrum function for the ground motion at the support and the modal shape coefficient (which is well-known from the classical response spectrum theory).

The MSRS method was developed by Der Kiureghian and Neuenhofer [3]. The method comes from random vibration analysis and is based on the classical equation of motion with the influence of ground motion (Eq. (2)).

$$\mathbf{M}\cdot\ddot{\boldsymbol{x}}+\mathbf{C}\cdot\dot{\mathbf{x}}+\mathbf{K}\cdot\boldsymbol{x}=-\mathbf{M}\cdot\ddot{\boldsymbol{x}}_g \tag{2}$$

where:

MCK	–	mass, damping, stiffness matrix of the structure;
x	–	total displacement of the structure's node;
$\boldsymbol{x}_g$	–	displacement of the ground (support).

In general, the total displacement of a structure's node can be presented as the sum of the pseudo-static and dynamic components. The pseudo-static displacement depends on both ground motion and structural stiffness. The dynamic component depends on the modal characteristics of the structures and also on the power spectral density of the excitation forces.

The utility of the response spectrum analysis causes this method to lead to a conservative estimation of the dynamic response of an object. In the case of spectral analysis, the maximum value of structural displacement is required; therefore, certain conditions are needed. The main conditions are that the value of the displacement of the structure supports is equals to the maximum ground displacement in this location (u_{kmax}). The another conditions is that the response spectrum function (D_{ki}) represents the maximum response of the mode during excitation. Following this, the formula representing the structural displacement can be presented as follows (Eq. (3)):

$$z(t)=\sum a_k\cdot u_{k\max}+\sum b_{ki}\cdot D_{ki} \tag{3}$$

Due to the fact that the maximum peak of ground accelerations appeared in different places at different times, the maximum displacements of structural elements also appeared at different times. As a consequence, the peak response of the structure can be estimated through the application of the complete quadratic combination (CQC) rules (Eq. (4)). Finally, the maximum response of a structure subjected to the ground motion excitation can be expressed by the following formula (Eq. (5)):

$$z_{\max}=\sqrt{\sum z(t)_i^2+\sum\sum\rho_{ij}\cdot z(t)_i\cdot z(t)_j} \tag{4}$$

$$z_{\max}^2=\sum\sum a_k\cdot a_l\cdot u_k\cdot u_l+2\cdot\sum\sum a_k\cdot b_{i,j}\cdot\rho_{ukSki}\cdot u_k\cdot D_i+\sum\sum\sum\sum b_{kl}\cdot b_{ij}\cdot D_k\cdot D_l \tag{5}$$

Equation (5) can also be represented using the integral version. The simplification of the notation leads to the final formula presented in Eq. (1).

3. Numerical model of the steel pipeline

In this paper, the dynamic response was calculated for an overground pipeline. The analysed pipeline consisted of a single, uncovered steel pipe. The diameter of the pipe was 60 cm and the thickness was 1.35 cm. The total length of the pipeline was 105 m (7 spans of 15 m). The length of the structure enabled it to represent the behaviour of a real length of pipeline. Supports are located at 15 m intervals along the length of the pipeline.

To evaluate the dynamic response of the chosen pipeline to a mining shock, a numerical model had to be created. The model was created in the ANSYS software application [1]. Because of the pipeline dimensions, a simple beam model was used in the analysis. The pipeline was represented as a multi-span continuous beam (Fig. 1).

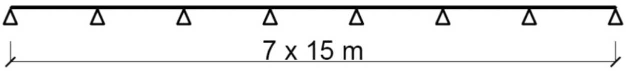

Fig. 1. Physical model of the pipeline

In the numerical model, the pinned supports and the rigid ground conditions were taken into account. This assumptions deflect on the real construction on the pipeline supports. To avoid excessive deformation of the structure, the supports of real pipeline are equipped with special bearings or sliders which allow easier displacements. The reduction of deformation leads to less stress level of structure. The pinned supports used in the numerical model limit the possibility of displacements. This caused a structural stiffness increasing and finally, may leads to the increasing the inertial forces in structure. Summarise, using the non-displaceable, pinned supports conduct to safer (overestimated) results. It also can be noticed, that this approach of modelling were effectively used in the same thematic works [10].

The finite element mesh density was chosen on the basis of the convergence of the modal analysis. Linear material characteristics and linear beam finite elements were used for the response spectrum analysis.

4. Kinematic excitation – mining shock

To calculate the dynamic response of the pipeline, data relating to an actual mining shock was applied. The mining shock in question was recorded in the Upper Silesian Coal Basin (USCB). The shock was registered as an acceleration of the ground and the displacement of the ground was determined on this basis. The value of the acceleration of the shock was scaled up to the maximum PGA appearing in the region of the USCB. During the dynamic analysis (in the case of THA analysis), the shock was applied to the numerical model as a time history of the displacement of the structural supports. Only the vertical direction of shock was considered. The vertical component of acceleration and the displacement of the mining tremor are presented in Fig. 2.

The peak value of the displacement of the shock was 2.5 mm. The dominant frequency of the shock was in the range of 3–4 Hz and this value does not coincide with the natural frequency of the pipeline.

In case of the THA, two kinds of the ground excitation model were used – uniform and non-uniform. In the uniform model of excitation, the supports of the structure repeat the same movements simultaneously. This model is a representation of infinity wave velocity. A wave velocity of 500 m/s was used in the case of the non-uniform excitation model.

Additionally, attenuation effects were taken into account. In this model, each pipeline support repeats the same moves as the previous support but to a weaker degree and with an appropriate time lag.

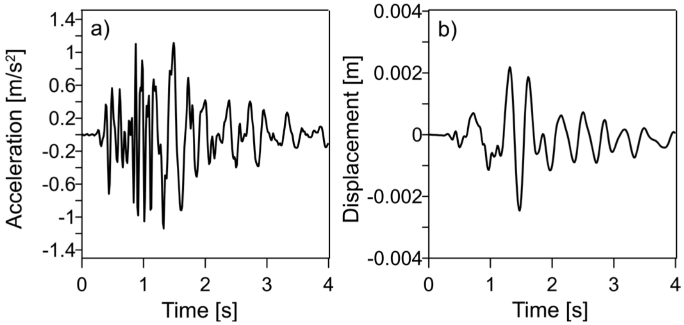

Fig. 2. A time history of the vertical component of (a) acceleration and (b) displacement of the mining shock

The other calculation methods applied in this investigation (RSA and MSRS) concern the estimation of the dynamic response of the structure under mining shock. In the case of the dynamic analysis of the structure to the mining shock, the main difficulty is the application of the appropriate kinematic excitation. The analysis may be based on shocks stored in database (historical shocks); however, the obtained results concern only the specific excitation that has been input. To define the dynamic response of the object to any mining tremors which may appear in a given zone (e.g. in the USCB) spectral curves should be used. The standard spectral curves determined for the specific region enable representation of the behaviour of ground motion during possible mining tremors. By contrast, RSA and MSRS analyses (for which spectral curves are used) are much faster than THA.

In this paper, the standard acceleration spectral curve of the vertical component of the USCB region was used [2]. During the calculation, a maximum ground acceleration of 1.1 m/s^2 was used. In the case of RSA, the spectral curve presented in Fig. 3 (denoted by the black line) was taken into account. In the MSRS method, the spectral curve needed to be modified. The spectral curves applied to the structural supports differ from each other. The differences between the values of the spectral curves are caused by the non-infinity wave velocity and the distance between the supports. The modification of the spectral curves is created by multiplying the spectral value by the coherency function. In this analysis, the simple coherency function was used [7]. The used function took into account both the distance between the supports (d) and the wave velocity of 500 m/s (v). The function is represented by Eq. (6).

$$coh(\omega,d)=e^{-\frac{d\cdot\omega}{2\cdot\pi\cdot v}} \tag{6}$$

In the numerical model, the original spectral curve (see Fig. 3 – black line) was added to the first support. The spectral curves applied to the other supports were modified by the coherency function. In Fig. 3, an example of the used spectral curves are presented; the curves for the first support (black line), fourth support (grey line) and last/eighth support (dashed line) are shown.

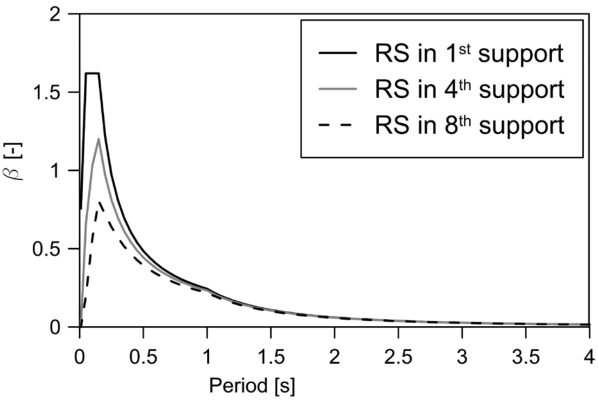

Fig. 3. Example spectral functions used in RS and MSRS analyses [2]

5. Results of the analysis

The dynamic response of the overground pipeline under mining shock excitation was calculated using the THA, RSA and MSRS methods. In each kind of analysis, the Rayleigh model of damping was used. The parameters of the damping model ($\alpha = 2.67$ and $\beta = 0.01$) were determined on the basis of the first and second natural frequency of the pipeline ($f_1 = 7.26$ Hz and $f_2 = 8.77$ Hz).

During the calculations, the bending moments at some specyfic points were determined. The results for five points are presented in this paper. Three of the chosen points (P1-P3) were located under the second, third and fourth supports and the other two points (P4-P5) were situated in the middle of the third and fourth spans. The location of these points is presented in Fig. 4.

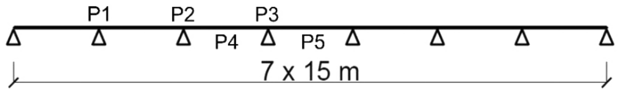

Fig. 4. The location of points chosen for analysis

The results obtained for the uniform and non-uniform THA are presented as a time history of the bending moment in mining excitation. The values of bending moment are presented in Figs. 5 and 6 by the black and grey lines for the uniform and non-uniform excitation models, respectively. The estimated values of bending moment from the RS and MSRS analyses are marked as solid lines in Figs. 5 and 6. Dashed lines for RSA and solid lines for MSRS indicate the maximum values of bending moment for the chosen finite elements.

At the beginning of the response analysis, the results obtained for the points located under the supports are presented. In Fig. 5, the bending moments at points P1 (Fig. 5a), P2 (Fig. 5b) and P3 (Fig. 5c) calculated by the THA, RSA and MSRS methods are collated. The results for each calculation method are indicated by the line styles as described above.

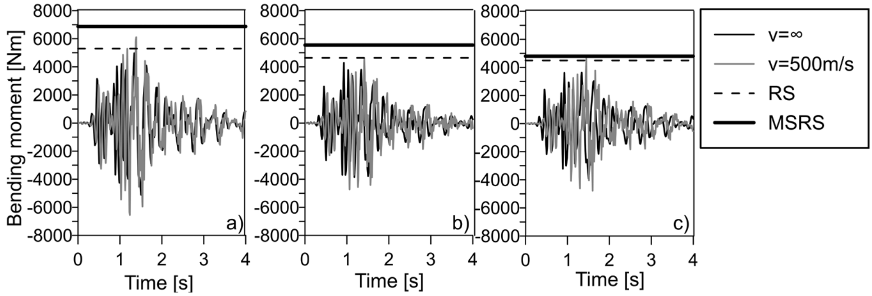

Fig. 5. Time history of bending moments at points (a) P1, (b) P2 and (c) P3

On the basis of Fig. 5, it can be seen that the bending moment strongly depends on the wave velocity. The influence of the wave velocity on the value of the bending moment can be clearly observed in THA. The bending moments obtained during THA in the case of non-uniform excitation are greater than the moments for uniform ground motion. For the uniform excitation model, the maximum value of the bending moment at point P1 reaches around 5 kNm, whereas for the non-uniform case, it is over 6.5 kNm. The difference is significant and equates to 25%. A similar dependence can be observed at the other points (P2 and P3). The peak value of bending moments determined for the uniform and non-uniform ground-motion model at point P2 differs by 10–20%, and at point P3 it is as high as around 30%. It is noteworthy that the maximum value of bending moment at each point appears between one and two seconds of excitation time (at the time when the mining excitation reaches the highest level). It is important to note the fact that the maximum peak of bending moment appears at different times in the case of uniform and non-uniform excitation. The maximum duration of time between the occurrence of extreme values of moment is observed for point P3. This delay is caused by the non-infinity velocity of the mining shock wave and the long distance between the supports.

Another part of the analysis concerns the estimation of the dynamic response using response spectrum methods. During this analysis, the maximum value of bending moment for each point was calculated. Comparing the results obtained during THA and RSA, it can be seen that the RSA leads to a safe estimation only in the uniform excitation case. In case of the uniform model of excitation, for all points (P1-P3), the value of bending moment obtained from RSA is higher than the maximum peak moment from THA. The difference between the exact (THA) and the estimated solution (RSA) reach around 150 Nm, 200 Nm and 590 Nm for points P1, P2 and P3, respectively. Based on this, it can be claimed that the safety stock is 5–15%.

The results presented in Fig. 5 indicate that RSA leads to an underestimation of the bending moment level if the non-uniformity effects are taken into account. The maximum bending moments calculated using THA including non-uniform effects are greater than the acquired through RSA. This phenomenon is clearly seen in Fig. 5. The line represents the results of the non-uniform THA is crosses by the line denoting the level of the bending moment obtained from RSA. The maximum difference is observed for point P1 and reaches over 1000 Nm. For points P2 and P3, the differentials between results are not particularly high, but it also cannot be treated as a correct estimation of dynamic response. In the case of non-uniform mining excitation, a more accurate estimation can be obtained by using the MSRS method. As is the case with THA, the MSRS method takes non-uniformity effects, such as wave velocity or the distance between the structural supports, into account. The comparison of the results obtained using the THA, RSA and MSRS methods indicate that the MSRS analysis leads to accurate estimation of structural response. The bending moments calculated using the MSRS method are greater than the moments obtained from RSA and THA. This can be observed for each analysed point. For example, for point P1, the maximum value of the bending moment obtained from THA is 6.5 kNm, whereas the moment received during the MSRS method reaches almost 6.9 kNm. For the other points, the differences are 0.7 kNm for point P2, and 0.1 kNm for point P3.

The complete results relating to the dynamic response of the pipeline during a mining shock for another two points of the structure were taken into considered. The solutions for the points located in the middle of the spans are presented in Fig. 6.

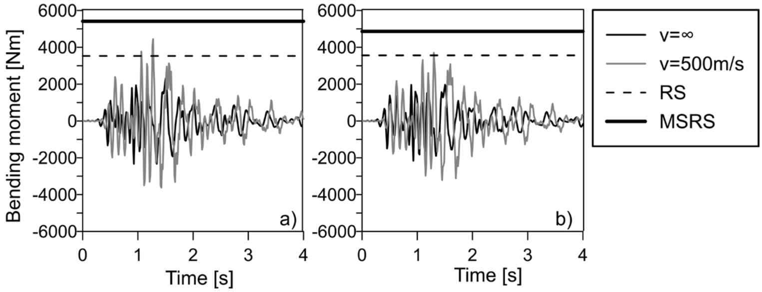

Fig. 6. Time history of bending moments at points (a) P4 and (b) P5

The results for points P4 and P5 are presented in Figs. 6(a) and 6(b), respectively. The comparison of the results obtained from the different types of analysis indicate a similar dependence for points P1-P3. The main observation is that non-uniformity effects have a strong influence on the value of bending moment. The maximum bending moment obtained from THA relating to the uniform excitation model reaches 2,300 Nm for point P4 and 2,100 Nm for point P5. In the case of THA taking into account the non-uniform effects, the results are much greater. The peak bending moment for point P4 is 4,400 Nm and for point P5, it is 3,700 Nm; this is approximately 80% more than the results from the analysis that disregards the non-uniformity. For points P1-P3, the maximum bending moments appear between one and two seconds of excitation time. The lag between the peak values of moment is also clearly visible. For points P4 and P5, a response analysis was also conducted. The bending moment obtained during RSA reaches around 3,500 Nm for both points. Additionally for both points P4 and P5, the values of moment estimated by RSA are greater than the results from THA without non-uniform effects. As with points P1-P3, RSA yields a reliable estimation of the dynamic response for points P4 and P5 in the case of uniform excitation, but simultaneously underestimates the response when the non-uniform effects are taken into account. The underestimate derived from the RSA reaches around 900 Nm for point P4 and 200 Nm for point P5. The influence of the non-infinity wave velocity is correctly represented by the MSRS method. The results obtained from the MSRS method are greater than from RSA; the difference reaches over 1000 Nm. On the basis of Fig. 6, it can also be observed that the MSRS analysis yields a higher value of bending moment than the THA (with non-uniform effects included). In the case of the MSRS method, the safety stock in points P4 and P5 reaches 20–30%.

6. Conclusions

In this paper, the dynamic response of an overground pipeline to mining shock was calculated. Based on the results obtained from a variety of dynamic analysis types, some final conclusions can be formulated.

The conducted analysis indicated that the non-uniform effects of wave passage strongly influence the dynamic response of an object. This phenomenon is especially observed for long structures. Neglecting some non-uniformity effects, such as non-infinity wave velocity or the decreasing of amplitude, leads to incorrected results. The dynamic response of the structure may be up to 80% lower than the response calculated when considering the non-uniform effects.

The comparison of results from the time history analysis and the response spectrum analysis shows that the spectrum method allows estimation of the solution in the case of the uniform excitation model only. The estimation of the results guarantees a safe level of dynamic response derived from the uniform ground-motion model. The analysis also indicated that the response spectrum analysis leads to the underestimation of the solution in the case of non-uniform excitation. The results for response spectrum analysis were lower than the results predicted for the time history analysis in which the non-uniform model of kinematic excitation was included.

To represent the behaviour of the structure under non-uniform kinematic excitation, the multiple support response spectrum method can be used. The MSRS method permits estimation of the maximum level of the bending moment in the structure when taking into account the non-uniformity effects. In each of the analysed points, the MSRS method provided more conservative results. Thus, in contrast to RSA, the MSRS method may be used in the estimation of the dynamic response of a long structure subjected to the non-uniform modelling of mining shocks.

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The generating new individuals of the population in the parametric identification of the induction motor problem with the use of the genetic algorithm

Tworzenie nowych osobników populacji w problemie parametrycznej identyfikacji silnika indukcyjnego z użyciem algorytmu genetycznego

Abstract

This paper presents the problem of the identifying parameters for use in mathematical models of induction motors with the use of a genetic algorithm (GA). The effect of arithmetical crossover and the generation of new populations on identification results is analysed. The identified parameters of the model were determined as a result of the minimisation of the performance index defined as the mean-square error of stator current and angular velocity. The experiments were performed for the low power induction motor. The steady-state genetic algorithm with regard to convergence and accuracy of the identification process and calculation time is analysed.

Keywords: identification, mathematical model, induction motor, genetic algorithm, crossover

Streszczenie

W artykule przedstawiono problem identyfikacji parametrów modeli matematycznych silników indukcyjnych z zastosowaniem algorytmu genetycznego (AG). Analizowano wpływ krzyżowania arytmetycznego i generowania potomków na wyniki identyfikacji. Identyfikowane parametry modelu wyznaczono w rezultacie minimalizacji wskaźnika jakości zdefiniowanego jako błąd średniokwadratowy prądu stojana i prędkości kątowej. Badania eksperymentalne przeprowadzono dla silnika indukcyjnego małej mocy. Algorytm genetyczny z częściową wymianą populacji analizowano ze względu na zbieżność i dokładność procesu identyfikacji i czas obliczeń numerycznych.

Słowa kluczowe: identyfikacja, model matematyczny, silnik indukcyjny, algorytm genetyczny, krzyżowanie

1. Introduction

Induction motors that are powered by voltage inverters are typically operated under variable load and power conditions, which affect the physical parameters of the motors and consequently, change their static and dynamic properties. These factors influence the transient and steady state of the motors and therefore the values determined in the process of identifying the parameters for the mathematical model [3, 14, 20].

Parametric identification methods of the induction motor mathematical model can be broadly divided into on-line and off-line strategies. Methods for off-line identification include classical static optimisation methods (such as Nelder-Mead's method and Box's method) and artificial intelligence (AI) methods (i.e. genetic/evolutionary/hybrid algorithms or artificial neural networks) [15, 18, 20]. The efficiency of AI methods make them increasingly popular both in technology and other fields; numerous examples are given in papers [2–11, 13]. AI methods are employed primarily when other methods do not offer a correct solution to a problem.

The parametric identification of induction motor is a very difficult problem and therefore the use of classical (numerical) optimisation methods is limited as the solutions of the mathematical model are unstable during the process. The local minimum of the performance index is determined, usually when the number of the identified parameters is large. It is then advisable to change the initial conditions or use another identification method, for example, a genetic algorithm that enables a high quality of the process for any starting conditions [17, 20].

The genetic algorithms (GAs) work on the population of individuals through the random choice of a sufficient number of representatives, the chance of determining the local minimum is smaller than in the case of classical methods [16, 20]. However, genetic algorithms demand more numerical calculations and the identification process is therefore time consuming [20].

Despite the abovementioned, attention should be paid to the structure of genetic algorithms with regard to such factors as representation of individuals, crossover, mutation, selection and the set of control parameters such as population size, probabilities of crossover, mutation and stop criterion [16]. Because its efficiency and effectiveness depends on it. It is reasonable to modify the genetic algorithm with regard to, for example, selection modifications, crossover and mutation operators, elitist model introduction or the generation of new individuals [1, 4, 19, 21].

This paper attempts to substantially modify the genetic algorithm by controlling the crossover operator and generation of new individuals. The influence of the proposed genetic algorithm modifications on the identification results is analysed. A genetic algorithm based on floating point representation, tournament selection with steady-state, arithmetical crossover and uniform mutation is used. The experimental investigations are performed for an induction motor powered from voltage inverter.

In this work, a mathematical model of an induction motor in the rotating references frame, orientated according to the stator voltage vector was used. The parameters of the mathematical model of an induction motor were determined as a result of the minimisation of the performance index with the use of a genetic algorithm.

2. Formulation of the identification of the induction motor mathematical model

The model that takes into account the dynamics of the electromagnetic state and the dynamics of angular velocity is a complex system of nonlinear differential equations. Motor equations are presented in a rectangular coordinate system. It is common to use mathematical models of the motor formulated in the coordinates rotating in accordance with the stator voltage vector and in the stationary coordinate system [15, 16, 20].

The mathematical model of the induction motor in the reference frame *d-q*, orientated according to the voltage vector, has the following form [15]:

$$
\begin{aligned}
&\frac{\mathrm{d}}{\mathrm{d}t}\phi_d(t)=\phi_q(t)\omega_s(t)-R_sI_d(t)+v(t)\\
&\frac{\mathrm{d}}{\mathrm{d}t}\phi_q(t)=-\phi_d(t)\omega_s(t)-R_sI_q(t)\\
&\frac{\mathrm{d}}{\mathrm{d}t}I_d(t)=a_1\phi_d(t)+a_3\phi_q(t)\omega_e(t)-a_2I_d(t)+\\
&\qquad\qquad +I_q(t)\omega_s(t)-I_q(t)\omega_e(t)+a_3v(t)\\
&\frac{\mathrm{d}}{\mathrm{d}t}I_q(t)=-a_3\phi_d(t)\omega_e(t)+a_1\phi_q(t)-I_d(t)\omega_s(t)+\\
&\qquad\qquad +I_d(t)\omega_e(t)-a_2I_q(t)\\
&\frac{\mathrm{d}}{\mathrm{d}t}\omega_e(t)=\frac{3p^2}{2J}\left(\phi_d(t)I_q(t)-\phi_q(t)I_d(t)\right)-\frac{P}{J}M_o(t)
\end{aligned}
\tag{1}
$$

and:

$$
\begin{aligned}
&a_1=\frac{R_r}{\sigma L_sL_r},\ a_2=\frac{R_s}{\sigma L_s}+\frac{R_r}{\sigma L_r},\ a_3=\frac{1}{\sigma L_s}\\
&\sigma=\frac{L_sL_r-L_m^2}{L_sL_r}
\end{aligned}
\tag{2}
$$

where:

- I_d, I_q – components of stator current vector in the rotating *d-q* reference frame,
- ϕ_d, ϕ_q – components of stator flux vector,
- L_s – inductance of stator,
- L_r – inductance of rotor,
- R_s – resistance of stator,
- R_r – resistance of rotor,

L_m – stator-rotor mutual inductance,
ω_e – electrical angular velocity and $\omega_e = p\omega$,
p – number of pole pairs,
ω_s – angular stator frequency,
J – inertia moment of motor and load,
M_o – load torque,
$\mathbf{v}$ – module of stator voltage vector.

The schematic of the mathematical model of the induction motor with input and output signals is presented in Fig. 1. Input signals include the synchronous angular frequency ω_s and the amplitude $\mathbf{v}$ of stator voltage vector; the output signals are angular velocity ω and amplitude I of stator current vector [18].

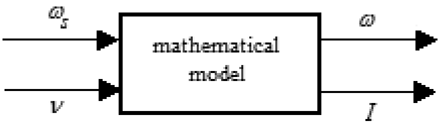

Fig. 1. Schematic of the mathematical model of the induction motor with input and output signals

The selection of the performance index has a significant influence on the identification process results [18]. The identification of the mathematical model of the induction motor is more accurate if the performance index includes more than one component. If the performance index includes only one component, such as the stator current or angular velocity, the time responses of the selected quantity is consistent, but those of the quantities not included in the index may not overlap.

The parameter values of the mathematical model of the induction motor were determined as a result of the mean-square error minimisation of stator current I and angular velocity ω. The following identification performance index was assumed [16, 18]:

$$Q = \frac{K}{N}\sum_{i=1}^{N}\left(I(i)-\hat{I}(i)\right)^2 + \frac{1}{N}\sum_{i=1}^{N}\left(\omega(i)-\hat{\omega}(i)\right)^2 \tag{3}$$

where:

K – the weight coefficient experimentally determined in [16] in order to maintain the compromise between the mean-square error of stator current I and mean-square error of angular velocity ω,
N – the number of measurements,
^ – the solution of the motor mathematical model,
I – the amplitude of the stator current vector.

This paper presents the minimisation of the performance index with the use of a genetic algorithm with steady-state. The author applied selected genetic/evolutionary algorithms to the identification problems. The papers [16–18] present important directions for further analysis of the effectiveness and efficiency of these algorithms.

This paper discusses the influence of arithmetical crossover and the generation of new individuals and populations on the results of the identification process, such as the identified parameters and the time necessary for calculations. The steady-state genetic algorithm based on a floating point representation is used because this representation can be used even when the number of identified parameters is large. Every population is subject to genetic transformations such as the modified tournament selection, an arithmetical crossover and a uniform mutation. The arithmetical crossover is as follows [12]:

$$\begin{aligned} \boldsymbol{x}_1' &= a\boldsymbol{x}_1 + (1-a)\boldsymbol{x}_2 \\ \boldsymbol{x}_2' &= a\boldsymbol{x}_2 + (1-a)\boldsymbol{x}_1 \end{aligned} \tag{4}$$

where:

$\boldsymbol{x}_1, \boldsymbol{x}_2$ – parents,
$\boldsymbol{x}_1', \boldsymbol{x}_2'$ – new individuals after crossover,
a – crossover parameter $a \in [0, 1]$, selected experimentally to obtain the best possible course of the genetic process.

The procedure for generating successive GA populations is implemented in such a way that in the current iteration of the algorithm, only one or two individuals of the previous population are exchanged. This is conditional on the modification of the crossover operator, where, depending on the approach applied, the number of descendants is changed. Depending on the value of the arithmetic crossover parameter *a*, either one descendant that replaces the worst individual in the population or two descendants who replace their parents are created. Due to the small number of individuals exchanged, the algorithm requires a larger number of iterations because the concept of iteration is not identical to iteration, in which all or most of the population is exchanged.

Figure 2 presents the schematic of the mathematical model of the induction motor identification with the use of a genetic algorithm.

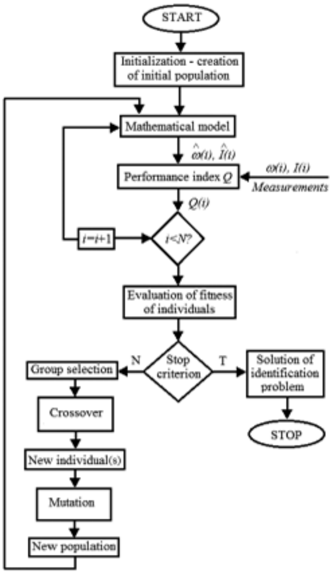

Fig. 2. Schematic of induction motor parametric identification with the use of steady-state genetic algorithm

3. Results of the parametric identification process

The identification of the mathematical model of the induction motor is based on the minimisation of the performance index with the use of a steady-state genetic algorithm. During the identification process, mathematical model parameters, such as: a_1, a_2, a_3, R_s, R_r and J were determined. The following values of mathematical model parameters were accepted in computer simulations: $a_1 = 521.4$, $a_2 = 280.1$, $a_3 = 54.2$, $R_s = 2.95\ \Omega$, $R_r = 2.47\ \Omega$ and $J = 0.04$ kgm^2. The steady-state genetic algorithm was analysed with regard to convergence and accuracy of the identification process and the time of numerical calculations.

The genetic algorithms have a stochastic character, so every start of the identification procedure gives slightly different results. Thus, in experiments or simulations of identification, the average result is given. The influence of both arithmetical crossover and the generation of new individuals on the results of the simulation of the identification process with the use of a genetic algorithm is presented in Table 1. The values of identified parameters, the values of the performance index and the time of process are given as average results. In the tables, '*a*' stands for the parameter of arithmetic crossover.

Table 1. The effect of arithmetical crossover and the generation of new individuals on the results of simulation of identification with the use of a steady-state genetic algorithm

a	Average values							
	Identified parameters						Performance index Q	Time [s]
	a_1	a_2	a_3	R_s	R_r	J		
0	526.32	283.32	57.14	3.23	2.70	0.041	0.058	566
0.3	525.54	284.98	57.33	3.03	2.63	0.041	0.023	498
0.5	522.81	281.62	55.61	2.99	2.56	0.040	0.001	425
Random	526.22	282.65	57.99	3.12	2.68	0.041	0.035	502
1	527.84	283.65	58.02	3.25	2.72	0.041	0.052	560

The results of experimental identification of the mathematical model of the induction motor with the use of a steady-state genetic algorithm are shown in Table 2. The effect of the arithmetical crossover and the generation of new individuals on the identification results and calculation time is also analysed. The convergence of time responses of motor angular velocity and current with the mathematical model is assessed by multidimensional correlation factors R_ω and R_I.

The results of simulations and experiments show that the value of crossover parameter *a* considerably influences both the values of the identified parameters and the time durating of the process. The parameter of arithmetical crossover $a = 0.5$ ensured the most accurate results (due to the values of identified parameters and the time of the process), whereas the least accurate results were obtained for operator of crossover values $a = 0$ and $a = 1$. The application of $a = 0.3$ and *a*-random may, in some cases, yield comparable results. The value of crossover parameter *a* also affects the number of created descendants and the creation of a new population. For $a = 0.5$, only one new individual replacing the worst individual in the population is created. For $a = 0$ and $a = 1$, two new individuals that are generally the same as their parents are created; thus, mutation plays an important role when a new population is entered.

Table 2. The influence of arithmetical crossover and the generation of a new population on the results of experimental identification with the use of a steady-state genetic algorithm

a	Average values									
	Identified parameters						Performance index Q	R_w	R_I	Time [s]
	a_1	a_2	a_3	R_s	R_r	J				
0	537.18	289.53	59.32	3.56	2.89	0.044	48.432	0.998	0.991	621
0.3	527.35	285.32	58.40	3.39	2.36	0.039	44.976	1.000	0.991	533
0.5	525.54	282.12	56.28	3.34	2.46	0.041	39.081	1.000	0.993	485
Random	519.83	286.08	59.22	2.88	2.66	0.043	45.532	0.999	0.991	562
1	535.21	290.35	59.00	3.46	2.87	0.044	48.987	0.998	0.991	630

In Fig. 3, time responses of the induction motor obtained in the experimental identification process with the use of the genetic algorithm are compared to those of its mathematical model. It can be seen that a very strong convergence between motor time responses and the time responses of its mathematical model was obtained.

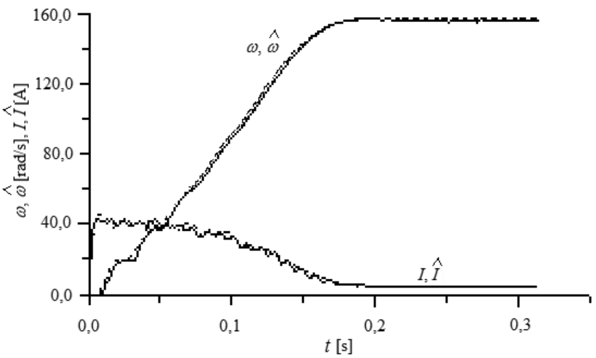

Fig. 3. Comparison of time responses of induction motor (solid line) and its mathematical model (dashed line) in the identification process with the use of the genetic algorithm (the identified parameters: a_1, a_2, a_3, R_s, R_r, J)

4. Conclusions

The paper has presented the parametric identification of a mathematical model of an induction motor with the use of a steady-state genetic algorithm. The effect of arithmetical crossover and the generation of new populations on the identification results has been analysed.

On the basis of simulation and experimental investigations, it has been confirmed that the adopted parameter of arithmetical crossover significantly affects the genetic process. It is claimed that the proposed crossover (parameter of arithmetical crossover $a = 0.5$) in which only one new individual replacing the worst individual is created allows us to get the most accurate identification results considering the value of the identified parameters and the time of the process. Assuming that the value of $a = 0$ or $a = 1$, where two descendants, almost identical to their parents whom they replace in the population, the least accurate results are obtained. In these cases, the operation of mutation has a decisive influence on the solution. The random value of a or at the level of 0.3 makes it possible to statistically achieve a good convergence between motor time responses and the time responses of its mathematical model; however, the identification process takes longer than that for which the parameter $a = 0.5$.

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THE METHOD OF CENTRALISED DISTRIBUTION OF ELECTRONIC EDUCATIONAL RESOURCES IN ACADEMIC E-LEARNING

Metoda scentralizowanej dystrybucji elektronicznych zasobów edukacyjnych przez e-learning akademicki

Abstract

In this article, a method of centralised distribution of university e-learning electronic educational resources is proposed. E-learning is seen as a complex organisational hierarchy. The method applied in this article is based on n structured analysis of the problems and objectives of the system. The method considers electronic educational resources for e-learning. The advantages of the proposed method include the timely completion of multi-session e-learning and the availability of a reserve of electronic educational resources.

Keywords: e-learning, electronic educational resources, hierarchical structure

Streszczenie

W niniejszym artykule zaproponowano metodę scentralizowanej dystrybucji elektronicznych zasobów edukacyjnych akademickiego e-learningu. E-learning jest postrzegany jako złożona hierarchia organizacyjna. Metoda zastosowana w tym artykule opiera się na analizie struktury problemów i celów systemu. Metoda uwzględnia elektroniczne zasoby edukacyjne dla e-learningu. Zaletami proponowanej metody są między innymi terminowe ukończenie wielosesyjnego e-learningu i dostępność względnej rezerwy elektronicznych zasobów edukacyjnych.

Słowa kluczowe: e-learning, elektroniczne zasoby edukacyjne, struktura hierarchiczna

1. Introduction

Electronic educational resources (EERs) and open educational resources (OERs) in particular are becoming more and more popular in the modern university [12]. There is a trend for the transition of university e-learning support systems to hyper-convergent platforms. This significantly reduces maintenance costs.

E-learning on the hyper-convergent platform can be considered as a complex organisational hierarchical system. In scientific development, much attention is paid to the research of properties of hierarchical systems and their functional processes [1, 2]. In these operations, it is shown that the process of framing decisions in different complex organisational hierarchical systems has some important features. These features should be considered in the case of creation of appropriate systems. The problem arises of determining the corresponding singularities. The most effective way to solve this problem is to model the functioning processes [3–5]. The organisational system is considered as a mathematical object. Research on such an object is best performed by investigating its properties. Therefore, it is necessary to develop mathematical models of the functioning of e-learning within the framework of the system approach. On the basis of this model, it is possible to offer a method for the distribution of system resources. This method has to consider the features of the hyper-convergent platform, in other words, it needs to provide centralised distribution.

The purpose of this article is to present the development of a method of centralised distribution of electronic educational resources in university e-learning.

2. Analysis of existing approaches

The systems that have a hierarchical structure are researched into [1, 2]. In [3], the approach to the description of the modelled system is proposed. Here, the organisational system is perceived as a set of interacting elements. The nature of this interaction depends on the objects or tasks the system needs to perform. It is assumed that the set of elements is fixed. The level of description of such systems is determined by the degree of detail of the processes under consideration.

In [4], the possibility of the interaction of the elements of the system with each other is considered. Information channels of communication between elements are analysed. The type of channel is associated with the type of information. The general list of information channels is determined by the level of the system description. Each problem is treated as a system transformation operator.

In [5], it was shown that the structure of the system can be interpreted as the state of the system at a particular point in time. In hierarchical systems, all states are hierarchies. The definition of a complete hierarchical system is proposed.

In [6–9], the main problems that arise in the modelling of complex organisational hierarchical systems are shown; these are:

- identification of systems and specification of model components and selecting a method for determining a parameter model,

- classification of organisational systems,
- the choice of the subsystem and its communication operations,
- the study of structures within the framework of one system under study.

In [10, 11], the basis of the model is the structure of the goals and objectives of the complex organisational hierarchical system. The system is represented by the GX graph tree [5]:

$$G_X = (\overline{X}, R) \tag{1}$$

where

$\overline{X} = \left(X^0, \overline{X}^1, ..., \overline{X}^{m-1} \right)$ – a cortege consisting of a set of controls of various ranks,

X^0 – the main governing body,

$\overline{X}^i = (X_1^i, X_2^i, ..., X_{\ell_i}^i), 0 \le I \le m-1$ – set of controls of various 'i-th' ranks,

$R = \left\{ r_{j\nu}^i \right\}$; $0 \le i \le m-2$; $1 \le j \le li$; $1 \le \nu \le li+1$ – communication subordination between government bodies,

i – the rank of the control 'j', from which the link leaves,

ν – the number of the vertex $(i+1)$-th rank into which the connection enters.

We use this approach to construct a graph model of the functioning of the academic e-learning on a hyper-convergent platform.

3. Graph model of e-learning

We will deliver in compliance to a graph GX isomorphic to it graph $G_C(\overline{C}, H)$, when $\overline{C}$ – the set of the purposes; $H = \left\{ h_{j\nu}^i \right\}$ – set of graph edges. In the process of achieving the main object of the system, C0 external disturbances arise. They are of a mostly situational, non-stochastic character. Before governing bodies $(m-1)$-th rank $\left\{ X^{\nu_{m-1}} \right\}$, $1 \le \nu_{m-1} \le \ell_{m-1}$, there is a set of the purposes and tasks. They lead to omission of the appropriate objects $\left\{ C^{\nu_{m-1}} \right\}$.

We will consider a set of the purposes and tasks facing governing bodies $\left\{ X^{\nu_{m-1}} \right\}$. We will present this set in the form of a graphs set $G_{C_0}^{m-1} = \left\{ G_{C_0}^{\nu_{m-1}} \right\}$ purposes and tasks of system (Fig. 1):

$$G_{C_0}^{\nu_{m-1}} = \left(\overline{C}_0^{\nu_{m-1}}, h \right) \tag{2}$$

where:

$\overline{C}_0^{\nu_{m-1}} = \left(C_0^{\nu_{m-1,0}}, \overline{C}_0^{\nu_{m-1,1}}, ..., \overline{C}_0^{\nu_{m-1,n-1}} \right)$ – cortege, consisting of a number of operational management objectives for different ranks,

$C_0^{\nu_{m-1,0}}$ – the main objective of operational management ν-th governing body $(m-1)$-th ranks,

$\overline{C}_0^{\nu_{m-1},f} = \left(C_0^{\nu_{m-1},f,1},...,C_0^{\nu_{m-1},f,\ell_f}\right)$; $0 \le f \le n-1$; f – the rank identifier in the graph $G_{C_0}^{\nu_{m-1}}$,

l_f – number of objects f-th ranks,

$h = \left\{h_{jg}^{f}\right\}$, $0 \le f \le n-2$; $1 \le j \le l_f$; $1 \le g \le l_f + 1$ – set of the graph edges.

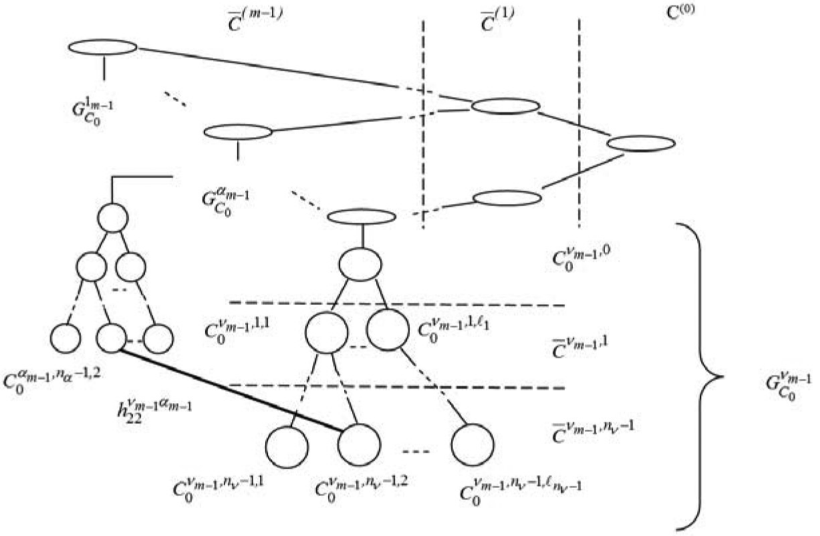

Fig. 1. Graph of the purposes and tasks

Peaks in the graph $G_{C_0}^{\nu_{m-1}}$ connect edges $h_{j\Theta}^{f^{\nu_{m-1}}Z^{\alpha_{m-1}}}$, when $0 \le f \le n(\nu) - 1$; $0 \le Z \le n(\alpha) - 1$; $1 \le j \le l_f$; $1 \le \Theta \le l_Z$, with one or several peaks in the graph $G_{C_0}^{\alpha_{m-1}}$; $\alpha \ne \nu$; $0 \le \alpha, \nu \le \ell_Z$ (Fig. 2).

Edge $h_{j\Theta}^{f^{\nu_{m-1}}Z^{\alpha_{m-1}}}$ defines two subgraphs: $G\left(X^{\nu_{m-1}}\right)$ and $G\left(X^{\alpha_{m-1}}\right)$.

In this way, a graph of coordinating objects and tasks can be constructed:

$$G_{CK} = (\overline{C}_K, S_K) \tag{3}$$

where:

$\overline{C}_K = (\overline{C}_K^0, \overline{C}_K^1, ..., \overline{C}_K^{m-2})$ – the vector consisting of a set of the coordinating objects of governing bodies of different ranks,

$\overline{C}_K^0 = \left(C_{K1}^0, C_{K2}^0, ..., C_{K\ell_0}^0\right)$ – set of the coordinating purposes of governing body X_0 in graph G_X,

$\overline{C}_K^{ij} = \left(C_{K1}^{ij}, C_{K2}^{ij}, ..., C_{K\ell_t}^{ij}\right)$ $1 \le j \le l_i$; $0 \le I \le m-2$; $1 \le t \le l_t$ – set l_t the coordinating control objects X_j^i

$$S_K = S_K^T \cup S_K^{TA}, \quad S_K^T \cap S_K^{TA} = \varnothing \tag{4}$$

where:

$S_K^T = \left\{ S_{k\omega_{\tau\gamma}\nu}^{Tt_{ij}} \right\}$, $1 \le t, \omega \le l_t$; $0 \le i, \tau \le m - 2$; $1 \le j \le l_i$; $1 \le \gamma \le l_\tau$; $1 \le \nu \le l_m - 1$ – set of the non-oriented relations between *t*-th and ω-th the coordinating purposes, O.

$S_K^{TA} = \left\{ S_{k\omega_{\tau\gamma}\nu}^{TAt_{ij}} \right\}$ – set of the oriented (transitive and antisymmetric) relations between the appropriate coordinating objects.

The creation of the coordinating object C_{Kt}^{ij} communications $h_{j\Theta}^{f^{\nu_{m-1}} Z^{\alpha_{m-1}}}$ in the graph $G_{C_0}^{\nu_{m-1}}$ is performed as follows: in the graph G_X, the governing body decides on the smallest value of a rank i, with which organs α and ν rank (m – 1) are transitively connected by the relations $R = \left\{ r_{j\nu}^i \right\}$.

Let $\overline{C}_0^{\nu_{m-1}}$ – quantity of the resources selected for the achievement of the operational management ν-th goals. Governing body X_j^i is transitively connected to ν relations $R = \left\{ r_{j\nu}^i \right\}$.

These relations define tasks $\overline{C}_\Pi$ on the redistribution of resources between governing bodies with indexes ν and α $(1 \le \nu, \alpha \le \ell_{m-1}, \nu \ne \alpha)$ $(m - 1)$-th rank.

We will construct the graph of the purposes and tasks of operational redistribution of resources:

$$G_{C\Pi} = (\overline{C}_\Pi, S_\Pi), \tag{5}$$

where:

$\overline{C}_\Pi = (\overline{C}_\Pi^0, \overline{C}_\Pi^1, ..., \overline{C}_\Pi^{m-2})$ – the tuple purposes set; $\overline{C}_\Pi^0 = (C_{\Pi 1}^0, C_{\Pi 2}^1, ..., C_{\Pi \ell_t}^{m-2})$, $1 \le t \le lt$ – the tuple purposes set for X^0.

For governing bodies X_j^i:

$$\overline{C}_\Pi^{ij} = \left(C_{\Pi 1}^{ij}, C_{\Pi 2}^{ij}, ..., C_{\Pi \ell_t}^{ij} \right); \quad S_\Pi = S_\Pi^T \cup S_\Pi^{TA}, \quad S_\Pi^T \cap S_\Pi^{TA} = \varnothing \tag{6}$$

where:

$S_\Pi^T = \left\{ S_{\Pi\omega_{\tau\gamma}\nu}^{Tt_{ij}} \right\}$, $1 \le t, \omega \le l_t$; $0 \le i, \tau \le m - 2$; $1 \le j \le l_i$; $1 \le \gamma \le l_\tau$; $1 \le \nu \le l_m - 1$ – set of. They provide the decision tasks of operational management $\nu_m - 1$. $S_\Pi^{TA} = \left\{ S_{\Pi\omega_{\tau\gamma}\nu}^{TA_{ij}} \right\}$ – the ratio *s*.

We will call elements with indexes ν and α $(1 \le \nu_{m-1}, \alpha \le \ell_{m-1})$ $(m - 1)$-th rank, which have isomorphic graphs $G_{C_0}^{\nu_{m-1}}$ and $G_{C_0}^{\alpha_{m-1}}$.

On the set $\overline{X}^{m-1} = \left\{ X^{\nu_{m-1}} \right\}$, $1 \le \nu \le \ell_{m-1}$, we will set partition $\left\{ U_1, U_2, ..., U_{\ell_y} \right\}$ set $\overline{X}^{m-1}$ on types ($y = \overline{1, \ell_y}$ – set of types of governing bodies (m – 1)-th rank).

Thus, it is enough to define:

- graphs of the objects and tasks of operational management of each of type of governing bodies $(m - 1)$-th rank,
- set of edges $h = \left\{ h_{j\Theta}^{f^{\nu_{m-1}} Z^{\alpha_{m-1}}} \right\}$ between the vertices $X^{\alpha_{m-1}}$ and $X^{\nu_{m-1}}$,

- set of pointers $d=\left\{d_{fj}^{\nu_{m-1}\alpha_{m-1}}\right\}$ – displays:

$$F_{\Pi}:d\rightarrow\overline{C}_{\Pi};\quad F_{K}:h\rightarrow\overline{C}_{K}. \tag{7}$$

The structure *W* defined by a tuple

$$M=\left\langle G_{X},G_{C_0}^{m-1},G_{CK},G_{C\Pi},F_{\Pi},F_{K}\right\rangle. \tag{8}$$

It is a union of substructures $W=\bigcup_{\nu=1}^{\ell_{m-1}}W_{\nu}$.

4. Method of electronic educational resource allocation

We decompose each graph from the set $G_{C_0}^{m-1}$. To this end, we construct a family of embedded partitions:

$$K=\left\langle K^{1},...,K^{n-2}\right\rangle \tag{9}$$

on graphs $\left\{G_{C_0}^{\nu_{m-1}}\right\}$:

$$K^{f}=\left\langle K_{1}^{f},...,K_{\ell_{f}^{'}}^{f}\right\rangle \tag{10}$$

and:

$$\bigcup_{j=1}^{\ell_{f}^{'}}K_{j}^{f}=G_{C_0}^{\nu_{m-1}},K_{j}^{f}\cap K_{\rho}^{f}=\varnothing,\quad j\neq\rho,\ \ 1\leq f\leq n-2,\ \ 1\leq\ell_{f}^{'}\leq\ell_{f}.$$

For every element K_{j}^{f} right: $K_{j}^{f}=K_{1}^{f+1}\cup...\cup K_{\ell_{f+1}}^{f+1}$.

The partition is carried out as follows. In the graph $G_{C_{0,f}}^{\nu_{m-1}}$ ($C_{0,f}^{\nu_{m-1,j}}$ – root $G_{C_{0,f}}^{\nu_{m-1}}$) select subgraphs with peaks $\left\{C_{0,f+1}^{\nu_{m-1}}\right\}$. These are related by relations $K=\left\langle K^{1},...,K^{n-2}\right\rangle$ c $\left\{h_{jg}^{f}\right\}$.

Thus, the partition $K=\left\langle K^{1},...,K^{n-2}\right\rangle$ defines a set of independent relations $\left\{h_{jg}^{f}\right\}$ of subgraphs on the graph $G_{C_0}^{\nu_{m-1}}$.

We represent them in the form:

$$G_{C_0}^{\nu_{m-1}}=\bigcup_{\beta^{\nu}=1}^{U}G_{C_0,\beta^{\nu}}^{\nu_{m-1}}. \tag{11}$$

We will set external influences as:

$$\overline{\alpha}:\left\{G_{C_0}^{\nu_{m-1}}\right\}\rightarrow\left\{G_{C_0}^{\nu_{m-1}*}\right\} \tag{12}$$

where:

$\left\{G_{C_0}^{\nu_{m-1}*}\right\}$ – set of the subgraphs, objects and tasks of operational management subject to external influence.

Let

$$\bar{\beta}:\left\{G_{C_0}^{\nu_{m-1}*}\right\}\xrightarrow{K}\left\{G_{C_0,\beta^\nu}^{\nu_{m-1}*}\right\}. \tag{13}$$

We will define a set of subgraphs of the objects of operational management:

$$\left\{G_{C_0}^{\nu_{m-1}**}\right\}\subset\bigcup_{\beta^\nu=1}^{U}G_{C_0,\beta^\nu}^{\nu_{m-1}*}\cup\left(\bigcup_{\beta^\nu=1}^{U}G_{C_0,\beta^\nu}^{\nu_{m-1}}\cap\left\{\left\{G_{C_0,\beta^1}^{1,m-1}\right\}\times\ldots\times\left\{G_{C_0\beta^\ell}^{\ell,m-1}\right\}\right\}\right). \tag{14}$$

The structure allocation of resource.

$$S_{pr_\nu}=\left(G_{C_0}^{\nu_{m-1}}=\left\{G_{C_0K}^{\nu_{m-1}}\right\}\cup\left\{G_{C_0B}^{\nu_{m-1}**}\right\}\cup\left\{G_{C_0H}^{\nu_{m-1}**}\right\},R^S\right) \tag{15}$$

Peaks in S_{pr} – subgraphs $\left\{G_{C_0B}^{\nu_{m-1}**}\right\}$ aren't to each peak from $\left\{G_{C_0H}^{\nu_{m-1}**}\right\}$, the vector of required resources is defined:

$$e_B=\left(e_B^1,e_B^2,\ldots e_B^{\ell_B}\right) \tag{16}$$

R^S– set of arcs from $\left\{G_{C_0K}^{\nu_{m-1}}\right\}$, $\left\{G_{C_0B}^{\nu_{m-1}**}\right\}$ in $\left\{G_{C_0H}^{\nu_{m-1}**}\right\}$. These are defined on the elements of the set $\left\{G_{C_0H}^{\nu_{m-1}**}\right\}$.

Each arc has an incident vector of resources:

$$e_B=\left(e_B^1,e_B^2,\ldots e_B^{\ell_B}\right) \tag{17}$$

and simultaneously:

$$\sum_{a\in\ell_a}e_{D_a}=e_{B_C} \tag{18}$$

Thus, on a set $\left\{G_{C_0}^{\nu_{m-1}}\right\}$ it is possible to define a set of structures S_{pr}, setting different R^S. Each of the structures $\left\{S_{pr}^{\nu_{m-2}}\right\}$ determines the distribution of resources between the direct descendants of governing body ν_{m-2}.

5. Analysis of results

For the assessment of the efficiency of the proposed method of electronic educational resource distribution, two criteria have been chosen, namely the timely completion of multisession e-learning and the existence of a relative reserve of electronic educational resources. Calculations were performed with use of the developed functioning model of e-learning in V.N. Karazin Kharkiv National University (Ukraine). each of multi-session was planned to be selected classes lasting 80 minutes.

Schedules of dependences of values of indicators for these criteria are shown in Figs. 2, 3. Apparently from the results of modelling, the method proposed in this article is more effective than the standard method, especially with regard to increases in parallel educational processes.

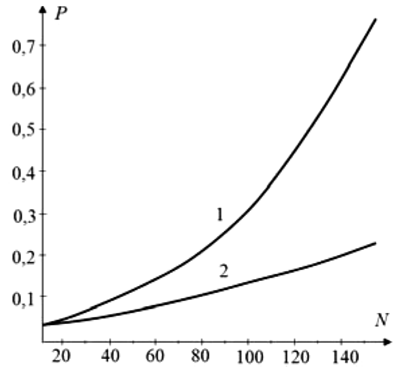

Fig. 2. Dependence of probability of timely completion of a multisession e-learning (P) from the number of parallel educational processes (N): 1 – standard distribution method of electronic educational resources, 2 – the proposed central distribution method of electronic educational resources

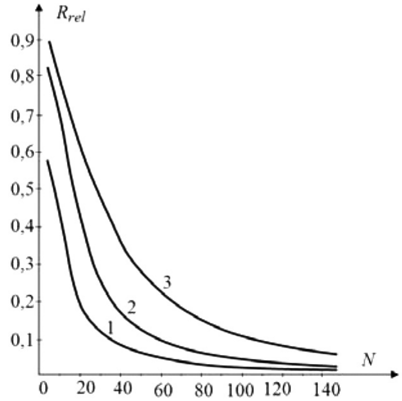

Fig. 3. Dependence of reserve of electronic educational resources (R_{rel}) from the number of parallel educational processes (N) during the session and selecting the distribution method of electronic educational resources: 1 – standard; 2 – combined; 3 – proposed

6. Conclusion and recommendations for further research

In this article, a method for the centralised distribution of electronic educational resources of academic e-learning is proposed. In this method, e-learning is considered as a difficult organisational hierarchical system. The method is based on an analysis of the structure of the given object and the purpose of the system.

In the method described in the article, the electronic educational resources for e-learning are distributed using a centralised distribution method. In further investigations, we'll plan to include hyper-convergent features of the basic system of support.

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Finite element analysis of reinforced concrete elements subjected to torsion

Analiza skręcania elementów żelbetowych metodą elementów skończonych

Abstract

This paper presents FEM techniques used for modelling concrete elements subjected to torsion. It compares the results from a 3D numerical analysis and a numerical homogenization method analysis. Finally, the results are compared to the reported experimental data.

Keywords: beam, torsion, homogenisation, FEM

Streszczenie

W artykule przedstawiono sposoby modelowania skręcanych elementów żelbetowych za pomocą Metody Elementów Skończonych. Zaprezentowano porównanie wyników otrzymanych w trójwymiarowej analizie numerycznej oraz w analizie numerycznej bazującej na teorii homogenizacji. Wyniki zestawiono z wynikami eksperymentalnymi znanymi z literatury.

Słowa kluczowe: belka, skręcanie, homogenizacja, MES

1. Introduction

In a basic case, reinforced concrete structures are subjected simultaneously to axial forces (N), shear forces (V), bending moments (M) and twisting moments (T). In engineering practice most of these states can be analysed independently, or by taking into account the effect of a secondary value on the principal value, such as considering the effect of shearing in bending analyses, or in an interactive manner, as is the case in analysing eccentrically compressed sections or in analysing the combined effect of torsion and compression or the effect of torsion and shear on the cross-section capacity. In common practice a maximum of two internal forces are considered in such analyses.

In the design of sections subjected to combined bending and torsion, the strength analysis is carried out separately for bending and torsion, as if the cross-section was subjected to pure bending or pure torsion at one time. The procedures prescribed by the standards do not address the combined effect of bending and torsion and assign the effect of bending to the longitudinal reinforcement and the effect of torsion to the transverse reinforcement on exclusive basis.

Although very practical, this approach, which separates the bending and torsion effects does not represent the actual behaviour of beam elements in reinforced concrete structures. This concerns, in particular, the outermost beams, such as spandrel beams in column-and-slab structures for which the torsional moment has a considerable effect.

Experimental studies of elements subjected to combined bending and torsion showed that with an increasing share of the bending moment in relation to the torsional moment, bending starts to govern the behaviour of the reinforced concrete element under loading. Bending has a predominant effect not only on the strength and deflections but also on the stress and strain state of the element. The situation is not so clear in the case of increasing the share of torsion and, as a result, it is common practice to design additional reinforcement to resist the entire torsion with no participation of the designed bending reinforcement.

However, before examining the interaction of two or more internal forces, it is important to investigate the behaviour of a section subjected to pure torsion so as to eliminate misrepresentation of results due to the effect of bending.

The following part of this paper presents a numerical approach to the problem of pure torsion using non-linear models of concrete (Concrete Plastic Damage and Menétrey plasticity model with softening behaviour). The results obtained in this way are compared with the experimental data and with the provisions of the relevant standards.

2. Numerical analysis

Two numerical modelling approaches are compared in this paper. The behaviour of the reinforced concrete beam subjected to torsion in the experimental study whose results are reported in [3] is represented in each case. The original dimensions were given in Imperial units. They have been converted to SI and rounded. The rounding takes into account the average dimensions of all elements subjected to the experimental test and does not affect the results of numerical calculations.

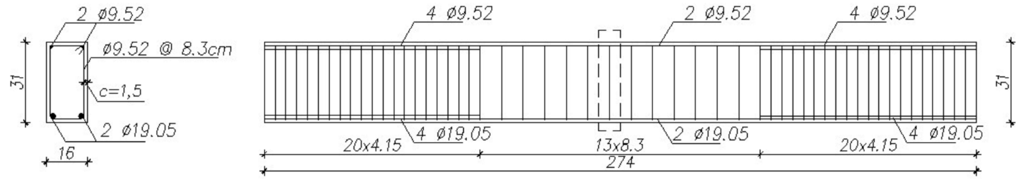

Fig. 1. Schematic representation of beam No. B11 – longitudinal and transverse sections

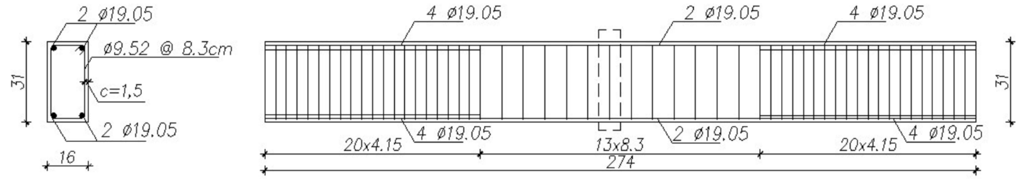

Fig. 2. Schematic representation of beam No. B21 – longitudinal and transverse sections

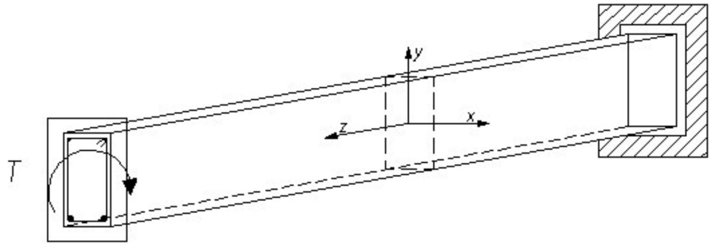

Fig. 3. Boundary conditions

In the first approach, a numerical model is created to represent all the geometric parameters of the beam under analysis, including the boundary conditions and torsion is applied by force control, i.e. the application of a pair of forces. In the second approach, the model is created for a section of a beam subjected to torque without restraint, i.e. with the warping free boundary conditions, and the effect of torsion is obtained by deformation-controlled action.

The ZSoil®.PC v2018 software was used in the analysis, with the Concrete Plastic Damage constitutive model described in [5] and, for comparison, the Menétrey plasticity model with softening behaviour given in [4].

The first approach seems the obvious choice and is available to any user of advanced FEM-based programs. On the other hand, for obvious reasons it is also non-economical due to the labour-intensive preparation of data and time-consuming calculations and processing of results.

In the second approach, representation of the beam behaviour is limited to the middle portion where the torsional moment is constant. The analysed portion of the beam has a length equal to the distance between the stirrups and includes a centrally located stirrup. Periodic boundary conditions are imposed on the cross-sectional surfaces to enforce the same nodal displacement in the *x*, *y* and z directions. Moreover, six independent boundary conditions are imposed in the analysed beam section to constrain translation and rotation. The torsion effect is obtained by applying a macro-strain field in *x*-*y* and *x*-*z* directions.

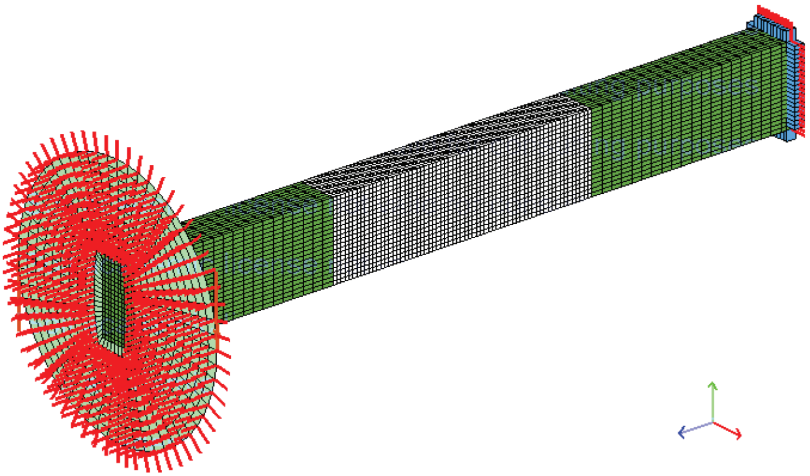

Fig. 4. 3D model of beam in ZSoil

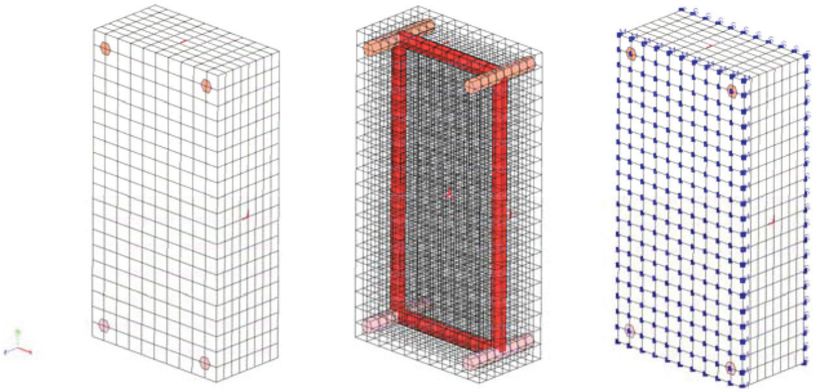

Fig. 5. Beam model obtained with the homogenisation approach – a continuum model, system of bars, periodic boundary conditions

The boundary conditions no longer play a role in this approach and the computation time is reduced.

In numerical analyses of objects, as in the first approach, considerable perturbations can occur at the shear zones due to stress concentrations. In order to avoid their dominating effect a number of measures must be implemented, including, without limitation, use of different material properties or different material models. In the analysed case, the measures used at supports include application of an elastic constitutive model for concrete, an increased amount of longitudinal reinforcement, and smaller distances between stirrups (as described in [3]). However, perturbations were still found at the joint between continuous elements made of Elastic and Concrete Plastic Damage materials, waning away no sooner than about the beam midspan. Application of load was yet another challenge. Thus, in order to avoid the concentrated load effect the load was applied through a membrane. The natural consequence of this approach is the long time required for creating the model and for carrying out the calculations.

The second approach is based on homogenisation theory. Similarly to the homogenisation theory described in [6], it considers a 3D element that is loaded, in the general case, with all the six internal force components $\boldsymbol{\Sigma}=\left\{N,M_x,M_y,M_z,Q_x=0,Q_y=0\right\}^T$, (i.e. longitudinal force, two bending moment components, torsional moment and two transverse force components) generating generalised strains (macro-strains) that describe the kinematics $\mathbf{E}=\left\{E_0,K_x,K_y,\Phi_z,\Gamma_x,\Gamma_y\right\}^T$. In the analysed case, in which the analysed element is subjected solely to pure torsion, the vector of strain control macro-strains $\mathbf{E}$ takes the form $\mathbf{E}=\left\{0,0,0,\Phi_z,0,0\right\}^T$. In the analysed linear element a repeatable 3D unit (periodic cell) is distinguished of finite length which in the numerical solution stage does not go to zero at the boundary, which differentiates the current solution from the cross sectional analysis of the beam presented in [7].

The total strain field comprises two parts: macro-strains used for deformation-controlled action and strains caused by perturbation of the displacement field $\mathbf{u}^p(\mathbf{x})$ on which the periodic boundary conditions are imposed.

$$\boldsymbol{\varepsilon}(\mathbf{x})=\boldsymbol{\varepsilon}^E(\mathbf{x})+\boldsymbol{\varepsilon}^p(\mathbf{x})=\mathbf{L}_E(\mathbf{x})\mathbf{E}+B\mathbf{u}^p(\mathbf{x}), \tag{1}$$

$$\mathbf{u}(\mathbf{x})=\mathbf{u}^E(\mathbf{x})+\mathbf{u}^p(\mathbf{x})=\mathbf{C}_E(\mathbf{x})\mathbf{E}+\mathbf{u}^p(\mathbf{x}). \tag{2}$$

where:

$$\boldsymbol{\varepsilon}^E=\begin{Bmatrix}\varepsilon_{xx}^E\\ \varepsilon_{yy}^E\\ \gamma_{xy}^E\\ \varepsilon_{zz}^E\\ \gamma_{xz}^E\\ \gamma_{yz}^E\end{Bmatrix}=\begin{bmatrix}0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\1&y&-x&0&0&0\\0&0&0&-y&1&0\\0&0&0&x&0&1\end{bmatrix}\cdot\begin{Bmatrix}0\\0\\0\\\Phi_z\\0\\0\end{Bmatrix}=\mathbf{L}_E(\mathbf{x})\mathbf{E}, \tag{3}$$

$$\mathbf{u}^E=\begin{bmatrix}0&0&\frac{1}{2}z^2&-yz&z&0\\0&-\frac{1}{2}z^2&0&xz&0&z\\z&yz&-xz&0&0&0\end{bmatrix}\cdot\begin{Bmatrix}0\\0\\0\\\Phi_z\\0\\0\end{Bmatrix}=\mathbf{C}_\mathbf{E}(\mathbf{x})\mathbf{E} \tag{4}$$

and B is the differential operator matrix obtained from the Cauchy-Riemann equations.

This approach is a particular case of application of the method described in [6].

In the considered case of pure torsion $\gamma_{xz}{}^{E} = -y\varphi_z$ and $\gamma_{yz}{}^{E} = x\varphi_z$.

In this method, the numerical analysis considers a completely consistent 3D stress/ strain state for which geometric and constitutive equations hold at any point. Control over the cross-sectional values is maintained. This approach enables cross-sectional analysis without the need to consider the effects of concentrated forces or boundary conditions.

It is sufficiently general to be applied to the analysis of any cross-sectional shape with longitudinal and transverse reinforcement if needed. Moreover, any constitutive model can be used to describe the mechanical behaviour of materials. Prestress and the effect of non-uniform strains caused by shrinkage or thermal effects can be introduced depending on the needs and capabilities of the constitutive model.

The three-dimensional approach with fully three-dimensional analysis of the strain and stress fields enables the use of realistic and sophisticated material models, such as those which describe damage at the micro-structure level, softening or plasticity. In such models one must not leave out certain components of the strain or stress field as is the case in the so-called engineer's methods based on elastic behaviour of the material used due to their simplicity and universality. Moreover, they must not be used for modelling the behaviour of structures composed of one-dimensional (1D) linear elements. In more advanced constitutive models, different couplings between the strain and stress field components can be observed, increasing the accuracy of representation of the actual behaviour of the analysed structure.

The above approach can be used with any FEM program that enables defining initial (imposed) strains and is provided with the periodic boundary conditions option.

3. Standard procedures

The standard procedures contained in Eurocode 2 [8] require a torsion check for reinforced concrete members when the structure's stability is defined by the torsional resistance of its members. However, as mentioned, there are no guidelines on including the interaction of bending with torsion and in when torsion results from the strain compatibility conditions (as in statically indeterminate structures) the provisions are limited to recommending the use of reinforcement for the crack width control (minimum longitudinal reinforcement, transverse reinforcement and additional bars over the beam height).

All the design procedures are based on the relationships in thin-walled box sections in which equilibrium is satisfied by closed shear flow. Since reinforced concrete members have, as a rule, a solid cross-section, in the design they are represented by thin-walled components.

As far as the torsional resistance of concrete members is concerned, EC-2 [8] distinguishes the torsional resistance identified with the torsional cracking moment $T_{Rd.c}$ limited by the stresses generated in the wall that exceed the tensile strength of the concrete $\tau_{t.i} = f_{ctd}$ and the torsional moment resistance $T_{Rd.\max}$ defined by the diagonal compression failure. This value depends on the freely chosen value of angle θ. Similarly to shear, the important parameter is *cot*θ which in Poland can take any value in the range between 1 and 2 (1 and 2.5 in Europe).

This gives 100% difference of capacity between the limit values. However, in most cases it is governed by the $T_{Rd.c}$ capacity. The required quantity of additional steel is determined from the condition of equilibrium of vertical forces in the section wall where the sum of forces caused by torsion and forces caused by the action of transverse forces is equal to the capacity of stirrups.

$$\frac{T_{Ed}}{2A_k} \cdot h_k + \alpha_v \cdot V_{Ed} = \frac{A_{swt} \cdot f_{yd}}{s} \cdot h_k \cdot cot\ \theta \tag{5}$$

where α_v – factor depending on the number of stirrup legs ($\alpha_v = 0.5$ and $\alpha_v = 0.25$ for two and four-legged stirrups respectively). The amount of reinforcing steel determined in this way depends directly on the value of $cot\theta$.

The following two interaction requirements are used to check the capacity of a section subjected to torsion:

$$\frac{T_{Ed}}{T_{Rd.\max}} + \frac{V_{Ed}}{V_{Rd.\max}} \leq 1 \tag{6}$$

$$\frac{T_{Ed}}{T_{Rd.c}} + \frac{V_{Ed}}{V_{Rd.c}} \leq 1 \tag{7}$$

which take into account the combined action of shear force and torsional moment.

In the case of more complex cross-sections, in particular if they are sensitive to deplanation, the standards prescribe strut-and-tie or beam-truss modelling.

The behaviour of a section subjected to pure torsion and in response to interaction taking into account all the relevant factors might be of interest in this context.

As shown, the standard procedures present a very simplified description of the problem and do not allow more complicated cases to be taken into account.

4. Comparison with the experimental data

In this section the results obtained from numerical modelling of the homogenized model with macro-strain control are compared with the experimental data obtained by McMullen and Warwaruk [3] for solid cross-sections subjected to torsion. The comparative analysis has been carried out for beams No. B11 and No. B21.

The strength of concrete, according to [3] was measured on 15 × 30 cm cylindrical specimens.

The graphs show the relationship between the unit torsion angle and torsional moment for a full-length beam model with force-controlled action and beam modelled on the basis of homogenization assumptions. In both cases, the Concrete Plastic Damage model was chosen, the parameters of which are given below.

Table 1. Material data of beams B11 and B21 based on [3]

Beam	f_{cm} [MPa]	f_{ctm} [MPa]	Bottom reinforcement		Top reinforcement		Transverse reinforcement	
			A_s [cm²]	f_y [MPa]	A_s [cm²]	f_y [MPa]	A_s [cm²]	f_y [MPa]
B11	35.78	3.41	5.70	323.4	1.42	365.4	1.42	379.2
B21	39.64	2.87	5.70	323.4	5.70	323.4	1.42	370.2

Table 2. Parameters for the Concrete Plastic Damage model of material

Parameter	B11	B21	Description
Compressive/ tensile strength			
f_c	27.78 MPa	31.64 MPa	f_{cm} – 8 MPa, according to EC-2
f_t	1.80 MPa	1.9 MPa	$f_{ctk0.05}$
E	22.5 GPa	22.5 GPa	taking into account the type of aggregate
ν	0.2	0.2	
f_{co}/f_c	0.4	0.4	initial uniaxial compressive strength
f_{cbo}/f_{co}	1.16	1.16	initial biaxial compressive strength
Damage in compression			
$\sigma_{c,D}/f_c$	0.95	0.95	activation stress level
$\bar{\bar{\sigma}}_c/f_c$	1	1	ref. stress level for damage
D_c	0.55	0.55	damage at ref. stress level
G_c	3.33 kN/m	3.33 kN/m	fracture energy
Damage in tension			
$\tilde{\sigma}_t/f_t$	0.5	0.5	ref. stress level for damage
$\tilde{D}_t$	0.5	0.5	damage at ref. stress level
G_t	0.066 kN/m	0.066 kN/m	fracture energy
s_0	0.2	0.2	stiffness recovery factor
Dilatancy			
type	variable	variable	
α_{po}	0.35	0.35	tensile dilatancy parameter
α_p	0.35	0.35	dilatancy parameter (compr.)
$\underline{\sigma}_{c.dil}/f_c$	0.95	0.95	activation stress level (compr.)
α_d	2	2	appex smoothing parameter

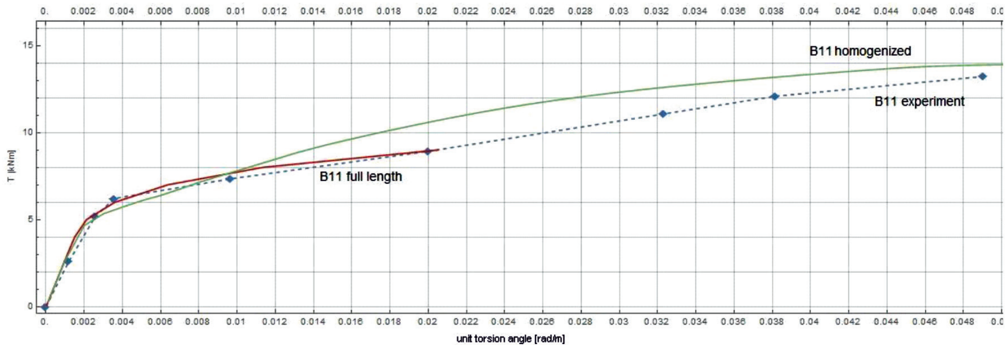

Fig. 6. Torsional moment – unit torsion angle relationship for beam No. B11

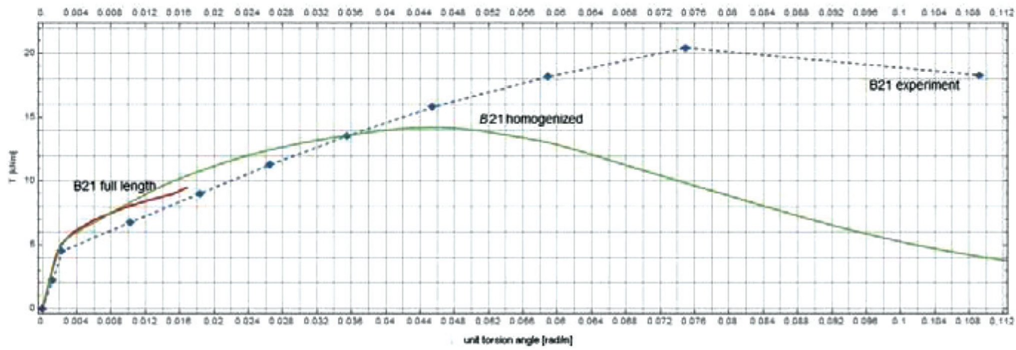

Fig. 7. Torsional moment – unit torsion angle relationship for beam No. B21

The graph shows the relationship between the unit torsion angle and torsional moment for beam in the homogenization approach with reinforcement and for plain concrete cross-section. Also in this case, the Concrete Plastic Damage model was used with the parameters given above.

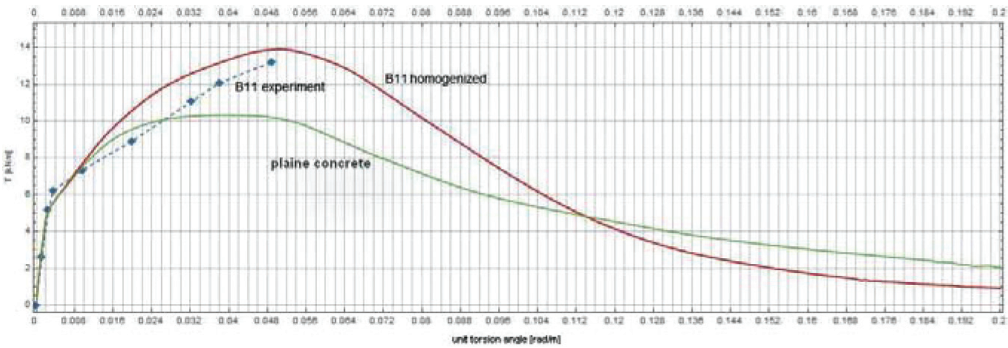

Fig. 8. Torsional moment – unit torsion angle relationship for beam No. B11 with reinforcement and for plain concrete cross-section

Moreover, the beam behaviour is presented in the homogenisation approach for elastic plastic material with softening behaviour (M-W) for w_r = 0.001 m and dilatancy angle of $\Psi_c = 7$

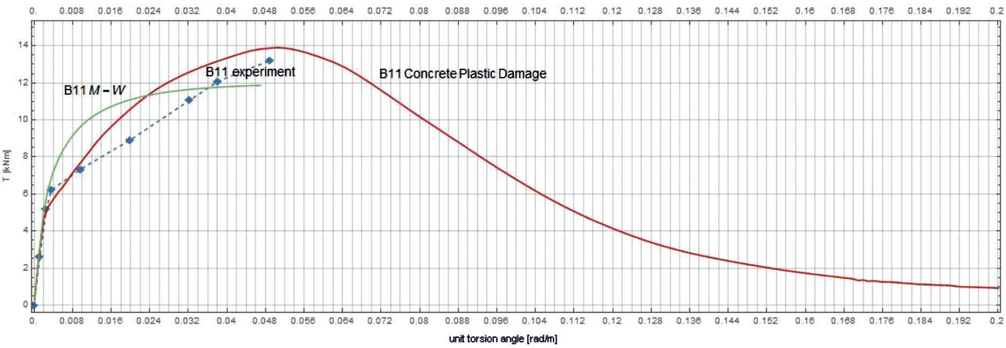

Fig. 9. Torsional moment – unit torsion angle relationship for beam No. B11 for Concrete Plastic Damage and M-W material models

5. Final conclusions

It has been demonstrated that numerical analyses can be limited to analysing a section of a linear element with a user-defined periodic boundary condition imposed on its walls. This approach significantly reduces the calculation time. Moreover, it enables the use of a simple deformation-controlled procedure. The results obtained in this way exhibit a satisfactory consistency with the experimental data.

Note is made of the problem of selecting a material model for the continuum. While more accurate results in the pre-failure stress-strain state of cross-sections can be obtained with complex descriptions of the concrete, these require determination of numerous parameters, not always discernible in the straightforward, engineer's approaches.

Agreement of the results of numerical simulation with the experimental data obtained in simple loading cases gives grounds for further research on the behaviour of beams subjected to combined loading.

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