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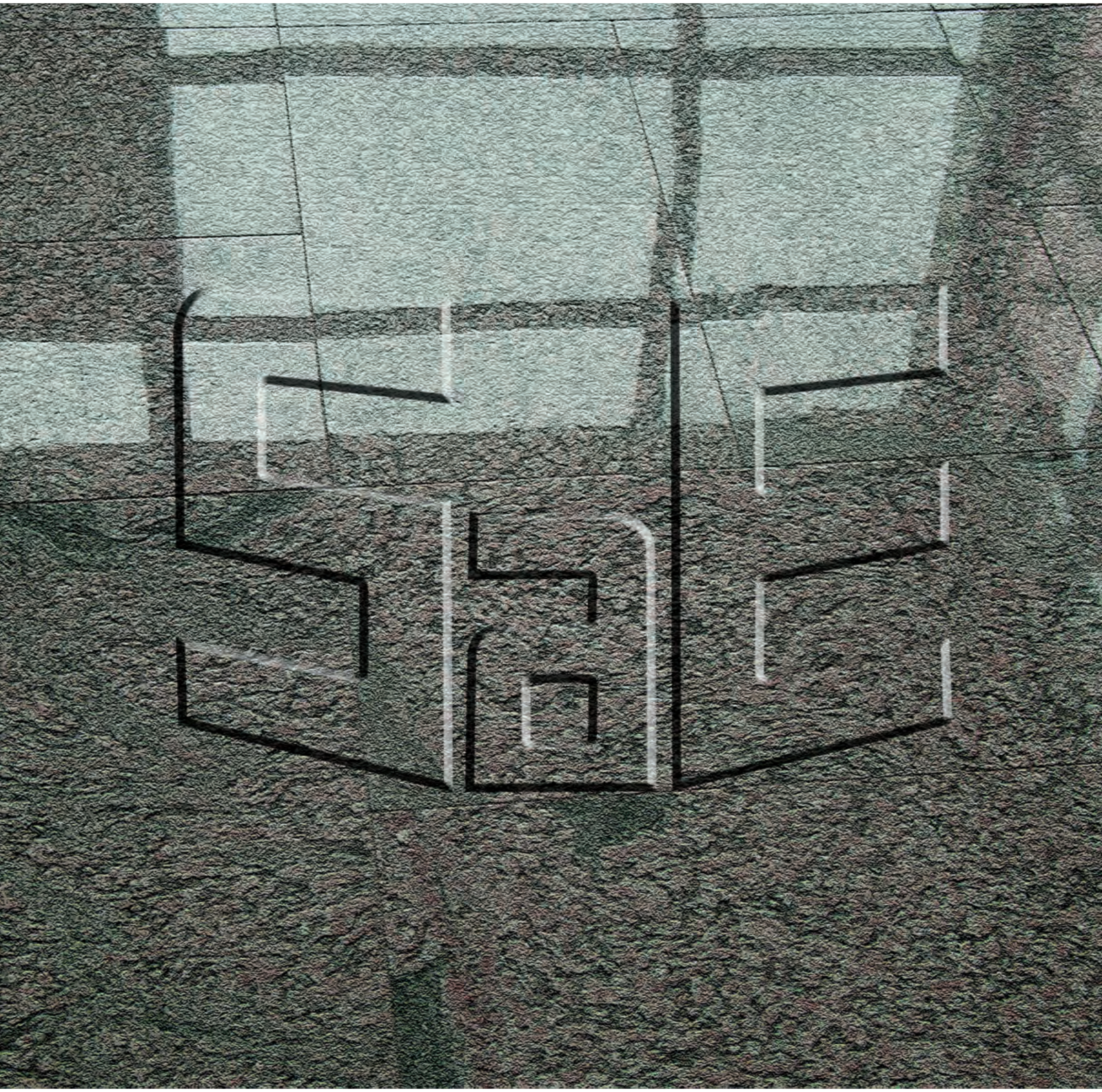

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EFFECT OF THE ADDITION OF CHEMICALLY DEGRADED POLY(ETHYLENE TEREPHTHALATE) ON THE RHEOLOGICAL PROPERTIES OF BITUMEN

WPŁYW DODATKU POLI(TEREFTALANU ETYLENU) PODDANEGO CHEMICZNEJ DEGRADACJI NA WŁAŚCIWOŚCI REOLOGICZNE ASFALTU

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Abstract

The study explores the feasibility of incorporating poly(ethylene terephthalate) (PET) plastomer into processed asphalt through chemical degradation. The depolymerization process involved subjecting the PET plastomer to aminolysis reaction with ethylenediamine. Consequently, the resultant monomer exhibited reduced rigidity and increased machinability. Enhancing its degree of fragmentation facilitated improved homogenization with bitumen. The resulting blend of bitumen and degraded plastomer underwent evaluation for creep resistance in accordance with the Multiple Stress Creep Recovery (MSCR) methodology at a temperature of 64°C. Moreover, fundamental standard tests were conducted, including penetration, softening point, and Fraass breaking point. The incorporation of additional amino groups in the form of degraded PET into the bitumen reduced its susceptibility (Jnr3200 < 0.5 kPa^{-1}) to the creep process and lowered the brittle temperature (approximately –3°C) in comparison to 50/70 neat bitumen. Furthermore, the proposed depolymerization technology for PET and its application to bitumen represents a viable approach for the utilization of PET plastomer.

Keywords: plastomer aminolysis, rheology, recycling, Maxwell model

Streszczenie

W pracy przedstawiono możliwość aplikacji plastomeru poli(tereftalan etylenu) PET do asfaltu przetworzonego poprzez zastosowanie chemicznej degradacji. Proces depolimeryzacji polegał na poddaniu plastomeru PET reakcji aminolizy z wykorzystaniem etylenodiaminy. W efekcie uzyskany monomer uzyskał mniejszą sztywność oraz był łatwy w obróbce mechanicznej. Zwiększenie jego stopnia rozdrobnienia umożliwiło lepszą homogenizację z asfaltem. Uzyskaną mieszaninę asfaltu i zdegradowanego plastomeru poddano ocenie odporności na proces pełzania zgodnie z metodyką MSCR w temperaturze 64°C. Ponadto wykonano podstawowe badania normowe takie jak: penetracja, temperatura mięknienia oraz temperatura Fraassa. Wprowadzenie dodatkowych grup aminowych w postaci zdegradowanego PET do asfaltu zmniejszyło jego podatność (Jnr3200 < 0,5 kPa^{-1}) na proces pełzania oraz temperaturę łamliwości (około –3°C) w porównaniu do asfaltu 50/70. Ponadto zaproponowana technologia depolimeryzacji PET i jego implementacja do asfaltu jest sposobem, który można wykorzystać do utylizacji plastomeru PET.

Słowa kluczowe: aminoliza plastomeru, reologia, recykling, badania asfaltu, model Maxwella

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1. INTRODUCTION

The bituminous binder constitutes a thermoplastic material that emerges as a byproduct during the distillation process of crude oil [1, 2]. The ultimate composition of bituminous binder is predominantly influenced by the origin of the crude oil. Within the climatic conditions of Poland, post-petroleum bitumen manifests in three rheological states: elastic-brittle, viscoelastic, and viscous. The influence of low temperatures renders bitumen susceptible to low-temperature cracking, whereas in its viscous state, it facilitates the development of plastic deformations within mineral and asphalt mixtures during the summer [3]. In recent decades, the most effective approach to augment the viscoelastic state range of bitumen has been the incorporation of polymers into the bitumen phase [4, 5]. The prevalent and efficacious approach involves the modification of bitumen utilizing styrene-butadiene-styrene copolymer (SBS). The notable compatibility of SBS with bitumen, attributed to its analogous solubility with the maltene phase, facilitates the formation of a stable mixture characterized by a cross-linked structure [6, 7]. Currently, the challenge associated with recycling synthetic materials necessitates the exploration of alternative management strategies. Within this framework, plastomer warrant particular consideration. The alteration of bitumen with plastomer necessitates supplementary measures due to the incomplete understanding of their effective integration into the bitumen matrix [8]. Based on an analysis of the literature, it can be inferred that the direct modification of bitumen using plastomer substantially diminishes the stiffness of the bitumen, thereby positively enhancing the rutting resistance of the asphalt mixture (mma) [9]. Nevertheless, this modification results in the degradation of the low-temperature characteristics of the asphalt mixture. Furthermore, the inclusion of a plastomer may compromise the stability of the bitumen-plastomer composite, leading to decreased ductility in the final product [10]. It is noteworthy that the incomplete compatibility between bitumen and plastomer is not the sole challenge faced by researchers during the homogenization process. An additional issue is the optimization of the mixing process, which is influenced by numerous factors [11]. A considerable disparity in the molecular weight, solubility, softening point, and chemical inertness of the plastomer presents a significant challenge to the effective homogenization with bitumen [12, 13]. Moreover, extended mixing duration leads to alterations in the polarity and stiffness of the bitumen as a result of aging. Consequently, the technological modification process warrants careful consideration when homogenizing bitumen and plastomer [14, 15].

This study endeavors to explore a novel approach to modifying PET bitumen. Based on the experiments recorded in the paper [14], the modification procedure involved subjecting PET to depolymerization through an aminolysis reaction. The terephthalamide monomer produced through this process exhibited a reduced molecular weight and incorporated amino groups that enhance adhesion and compatibility with bitumen, thereby contributing to the stabilization of the mixture. Consequently, to achieve a stable bitumen and plastomer mixture, it is imperative to establish not only an optimal mixing technique but also a method for the application of a properly selected and pre-processed plastomer. The literature documents various attempts to modify the plastomer of poly(ethylene terephthalate), commonly referred to as PET, utilizing higher-order amines [16, 17]. Nevertheless, this methodology was primarily directed towards optimizing the recycling process of PET [18, 19]. This research primarily emphasizes the enhancement of the rheological properties of 50/70 neat bitumen, thereby rendering it more suitable for incorporation into asphalt mixtures, while concurrently exploring the potential application of the PET plastomer.

2. MATERIALS AND METHODS

2.1. Bitumen

The primary binder employed during the modification process was 50/70 neat bitumen. The bitumen under examination underwent fundamental rheological testing. The findings of the research, accompanied by the 95% confidence interval for the mean, are illustrated in Table 1.

Table 1. Test results of 50/70 neat bitumen

Feature	Result	Standard
Penetration at 25°C, 0.1 mm	61.8 ±3.4	PN-EN 1426 [20]
Softening point TR&B, °C	49 ±1	PN-EN 1427 [21]
Fraass breaking point, °C	-15.5 ±1.2	PN-EN 12593 [22]
Elongation at 5°C, cm (declared)	2.2 ±0.3	PN EN 14023 [23]
Cohesive energy, J/cm^2	1.7 ±0.5	PN EN 14023
Viscosity at 60°C, Pas	-16.6 ±2.0	ASTM D 4402 [24]
Viscosity at 90°C, Pas	-15 ±1.5	
Viscosity at 135°C, Pas	60	

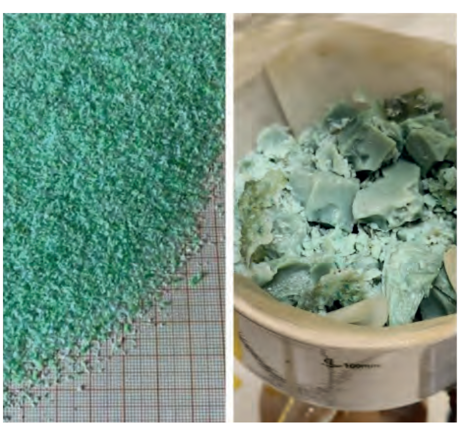
2.2. Poly(ethylene terephthalate) depolymerization process

The modification of road bitumen was conducted utilizing a PET plastomer (polyethylene terephthalate) depolymerized via aminolysis. Ethylenediamine was employed as the amine for conducting the aminolysis reaction. The PET plastomer in question belongs to the category of thermoplastic materials exhibiting a crystalline structure. According to the supplier's specifications, the PET polymer is characterized by a maximum pour point of Tp = 256°C and a glass transition point of up to 75°C. The aminolysis procedure was executed in a reactor fabricated by the author. A continuous nitrogen purge was maintained throughout the aminolysis process. The entire procedure was automated, allowing comprehensive regulation of temperature and mixing speed of the constituents. The maximum particle size of the PET flakes was recorded at 1 mm. This measurement system is illustrated in Figure 1.

Fig. 1. Measuring set for aminolysis reactions

Following the aminolysis process, which is documented in a patent application, the terephthalamide compounds denoted as TRA compound was synthesized. Its integration with asphalt was significantly more efficient compared to the utilization of pure PET [15]. The alteration in the structure of PET and its chemical composition is depicted through the spectroscopic spectrum presented in Figure 2.

a)



b)

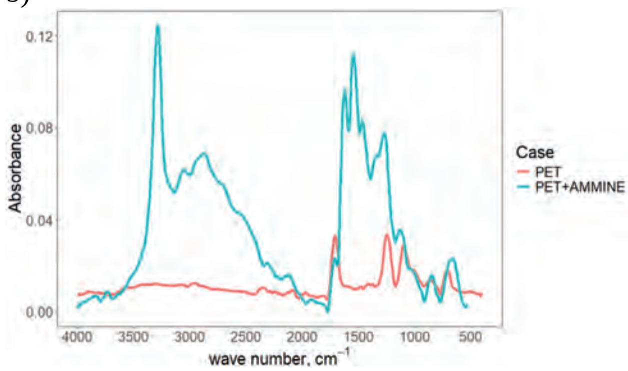


Fig. 2 Polyethylene terephthalate (PET) undergoing the depolymerization process: a) structural composition prior to modification (left) and subsequent to aminolysis (right); b) spectroscopic spectra of unmodified PET and aminolyzed (PET+Ammine) referred to as TRA (terephthalamide)

The initial material manifested a consistency similar to that of soap (Fig. 2a). The shredding process was executed with minimal effort compared to PET, which necessitated substantial energy and a highly efficient mixer for pulverization. Figure 2b illustrates the FT-IR spectrum of the initial PET plastomer and terephthalamide (TRA). It is noteworthy that the distinct spectral peak of the TRA component observed at 1720 cm^{-1}, corresponding to the tensile vibrations of the carbonyl (-C = O) ester group within PET molecules, has substantially diminished. Nevertheless, it should be highlighted that two additional peaks emerged, specifically at 1636 cm^{-1} and 1547 cm^{-1}, which correspond to the characteristic tensile vibrations of the carbonyl (-C = O) and bending vibrations of the N–H of the amide group within the PET additive. Additionally, a novel characteristic peak at 3320 cm^{-1} has appeared, attributed to the tensile vibrations of N–H in the amine group. This was accompanied by a peak for the wave number 2850 cm^{-1}, which can be ascribed to the asymmetric vibrations of the -CH2- groups. According to the observations of other researchers in the [25], [26] this result indicated a successful aminolysis of the PET. Moreover, the FTIR analysis presented herein demonstrated the formation of amide bonds between terephthalic residues and amines involved in the aminolysis reaction. This finding correlates with prior studies, which suggest that the depolymerization of PET in the presence of an excess of amines results in partial, secondary polymerization, manifesting as the formation of a copolymer between terephthalic acid and amines [27]. This phenomenon is posited to exert a favorable influence on the rheological properties of the initial bituminous binder matrix.

2.3. Mixing TRA with bitumen

Bitumen was combined with TRA at a constant rotational speed of the homogenizer mixer set at 3000 rpm for a duration of 60 minutes. The mixing procedure was executed at two different temperature levels: 150°C and 180°C. The proportion of TRA additive utilized was 2% based on the weight of the asphalt. Following the 60-minute mixing procedure, the TRA-modified bitumen was allowed to rest for 15 minutes, while maintaining a temperature of 150°C (irrespective of the main process mixing temperature) alongside a rotational speed of 30 rpm. An initial evaluation of the effectiveness of the TRA mixing process with bitumen was conducted utilizing an epi-fluorescence microscope (Fig. 3).

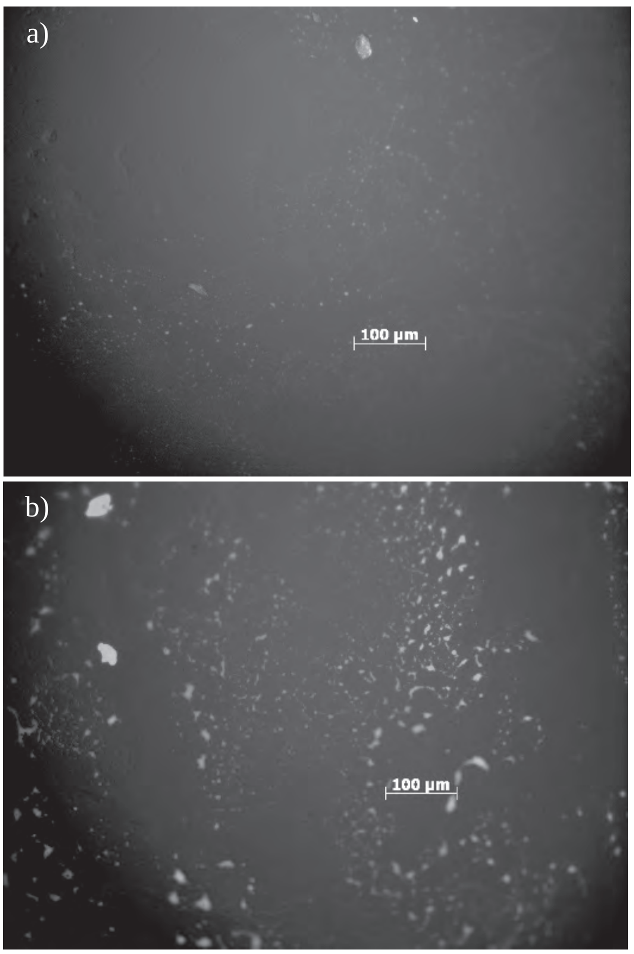


Fig. 3. Dispersion of degraded PET in bitumen phase using an epifluorescence microscope: a) mixing at 150°C; a) mixing at 180°C

Upon analyzing the data depicted in Figure 3, it can be inferred that the mixing temperature significantly influenced the results. When evaluating the TRA dispersion in bitumen across both mixing temperatures, it is important to note that the level of homogenization achieved was high. Specifically, in the sample illustrated in Figure 3b, partial secondary polymerization of TRA in the bitumen was observed, which is projected to enhance the ductility of the bitumen. Conversely, the sample in Figure 3a exhibited a fine-grained nature of TRA dispersion in the bitumen, highlighting an indisputable advantage of utilizing TRA.

2.4. Rheological Properties Testing

2.4.1. MSCR test

The multi-stress creep recovery (MSCR) test was carried out according to EN 16659 [28] using a dynamic shear rheometer (DSR). It is a measuring system of parallel plates 25 mm in diameter with a gap of 1 mm. The test procedure involves repeatedly applying a load lasting 1 second to an RTFO-aged bitumen sample at constant stress. Each loading is followed by a recovery period of 9 seconds. A single creep-recovery cycle lasting 10 seconds is repeated 10 times at a stress of 0.1 kPa, further increased to 3.2 kPa. The measurement temperature was 50°C, 60°C and 70°C.

2.4.2. Generalised Maxwell model

The tested waste plastomer-modified bitumen underwent a detailed rheological analysis. Its purpose was to describe the strain during creep, using the MSCR test and utilizing the generalised Kelvin-Voigt model (Prony series). The good match of experimental data with this model suggests that the bitumen are within the linear viscoelastic (LVE) limits. The discrepancy in the model's results when compared to the experiment can point to non-linear behaviour τ-γ and provide information about the occurrence of substantial plastic strains. The (shear) relaxation function G is described with the following equation [29, 30] (1):

$$G\left(\psi^t\right) = G_0\left(1+\sum_{i=1}^{n} g_i\left[1-e^{\left(-\lambda_i \psi^t\right)}\right]\right) \qquad (1)$$

where: G_0 – instantaneous compliance, g_i – i-th compliance corresponding to the next Kelvin-Voigt element, λ_i – i-th retardation time, ψ^t – reduced time $\psi^t = \frac{t}{a_\sigma} = \frac{t}{a_\sigma}$, a_σ – shit time factor equaled to 1.

In general equation (1) the shift factor a_σ depends on temperature using nonlinear formula. For case where only one temperature case is used its value is equaled to 1. In the paper, the mastic samples were subjected to pure shearing as part of controlled shear stress. In the analysis, it was assumed that the creep function within the LVE limits will be best represented by a generalised model, consisting of series of parallel Kelvin elements and a single Hooke element. Based on earlier analyses, it was decided that a setup of five Kelvin elements (n = 3) and a single Hooke element is sufficient to correctly describe the bitumen's strain changes. The estimation of the model's parameters required the use of the non-linear least squares method. In order to avoid issues related to the correct determination of the initial values, the MCalibration® program, utilizing an implemented set of solvers, was used for identification of Maxwell model parameters [31]. The model's quality of matching with the experimental data was determined using two qualitative measures, i.e.: the modified determination coefficient R^2 and normalized median absolute deviation NMAD [32].

2.5. FTIR Spectroscopy

Attenuated Total Reflection (ATR) Fourier Transform Infrared (FTIR) allows for determining the the quantitative evaluation of the impact of certain bitumen additives or modifiers by measuring the spectrum of absorption of certain functional groups [33]. In the case of the bitumen sample's testing, some radiation is subject to reflection and some is absorbed by the sample. Taking into consideration the crystal's (diamond's) background, it is possible to obtain the sample's specific spectrum. The ageing effect and the presence of synthetic wax caused a change in the absorption bands' intensity in the analysed spectral range of 1.700÷1.724 cm^{-1} in relation to the reference sample's spectrum. The test results' evaluation featured an analysis of the surface fields of the absorption bands obtained for given bitumens prior to and after foaming. The test was conducted using the FTIR spectrometer from Nicolet iS5, in the spectral range of 7.800÷350 cm^{-1} with the ATR (Attenuated Total Reflectance) attachment. The obtained absorption spectrums were initially corrected by the introduction of a baseline correction and correction characteristic for the ATR attachment.

3. TEST RESULTS

The primary objective of the foundational research was to evaluate TRA modified bitumen in relation to 50/70 neat bitumen. Within the scope of this research, various tests were conducted, including penetration, softening point, and brittleness temperature acc. to Fraass methodology. The findings were subsequently compared with the outcomes of 50/70 neat bitumen (denoted as 50/70 ref), which serves as the base bitumen for the modification. The research findings are visually represented in Figure 4.

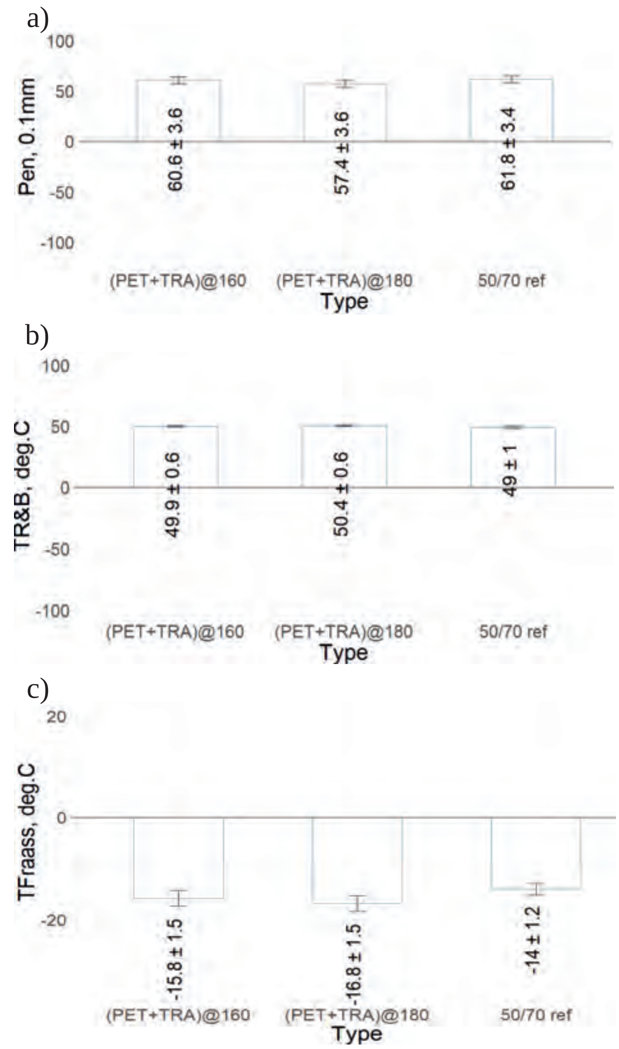


Fig. 4. Basic tests of TRA modified bitumen: a) penetration; b) softening point; c) Fraass temperature

Upon analysis of the test results, no substantial differences were identified in the evaluation of penetration or softening point, with an increase of approximately 1°C, when compared to 50/70 neat bitumen (Fig. 4a-b). Conversely, a notable reduction in the brittleness temperature was recorded, approximately –3°C, at a mixing temperature of 180°C (Fig. 4c). The conventional properties of bitumen did not deliver significant evidence to advocate for the integration of TRA into bitumen. Consequently, additional creep tests for bitumen were conducted in conformity with the MSCR procedure. The outcomes of the evaluation of the parameters Jnr and %ER for

50/70 neat bitumen and its modification with the TRA modifier, mixed at temperatures of 160°C and 180°C, are illustrated in Figure 5.

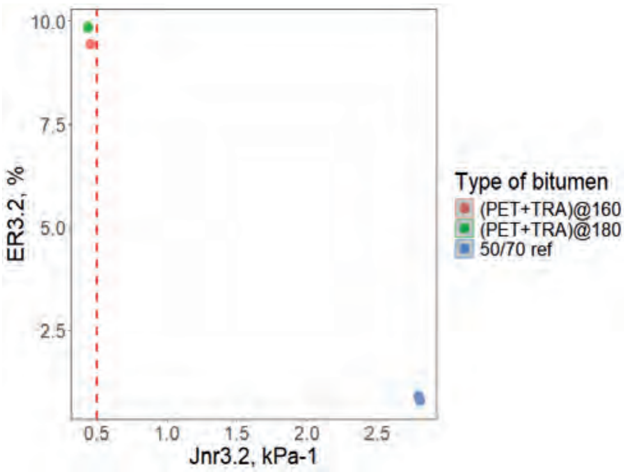


Fig. 5. MSCR test results

As indicated in Figure 5, the outcome of the irreversible component of the Jnr susceptibility was observed to be less than 0.5 kPa^{-1} (red line), which implies that the 50/70+TRA bitumen is suitable for the production of mineral and bitumen mixtures designed for heavy traffic. According to the standards set by AASHTO M 332 and AASHTO T 350, such bitumen can be classified for application in extremely heavy traffic conditions (exceeding 30 million axles (ESAL) and vehicle parking speeds of less than 20 km/h), similar to SBS-modified bitumen. In contrast, the irreversible compliance value of 50/70 neat bitumen, when compared to 50/70+TRA, was five times greater, measuring less than 2.5 kPa^{-1}. It is noteworthy that the elastic recurrence value %ER also experienced a substantial increase, with levels fluctuating around 10%, whereas conventional 50/70 neat bitumen did not attain a value exceeding 1%. This phenomenon can be attributed to the incorporation of robust amine bonds by the addition of TRA to the bitumen, which enhanced the cohesion of the asphalt at elevated temperatures, while also marginally reducing the temperature according to Fraass breaking point temperature. To estimate the magnitude of the rheological effects accompanying the deformation of the tested bitumen, particularly those containing TRA, a simulation of the deformation trajectory over time, derived from the MSCR study, was conducted and described by calibrating the parameters of the generalized Maxwell model. The results of the parameter identification for the physical Maxwell model of bitumen incorporating TRA are presented in Figure 6.

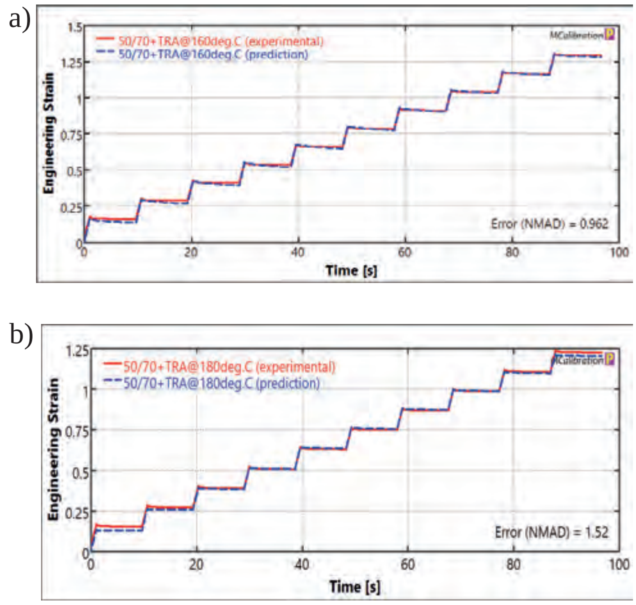


Fig. 6. Identification of the Maxwell model parameters for the deformation in time based on the MSCR test: a) 50/70+TRA at 160°C; b) 50/70+TRA at 180°C

A summary of the parameters of the generalized Maxwell model for the three elements of the Prony series is presented in Table 2.

Table 2. Generalised Maxwell model parameters

Parameter	50/70+TRA at 160°C	50/70+TRA at 180°C	50/70 referenced
G_0, MPa	1.15	1.96	0.1
g_1	0.41	0.29	0.37
t_1, s	3.3e-5	0.024	0.001
g_2	0.49	0.27	0.39
t_2, s	0.03	2.7e-6	0.002
g_3	0.0004	0.0002	0.26
t_3, s	9.9	0.0008	0.013
R^2 NMAD, %	0.97 0.96	0.96 1.52	0.86 7.6

In evaluating the outcomes of parameter identification for the generalized Maxwell model (refer to Fig. 2), it is pertinent to observe that the relaxation time for 50/70 neat bitumen, when TRA is incorporated, is decuple in comparison to 50/70 neat bitumen. This implies that the deformation rate will be definitely faster for 50/70 bitumen relative to TRA-modified 50/70 neat bitumen. Consequently, the inclusion of the TRA compound favorably mitigates the acceleration of deformation during the rutting process of asphalt mixtures (mma) subjected to vehicular traffic. Additionally, the instantaneous shear modulus, G_o, in modified bitumen exceeds that of

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50/70 neat bitumen by over 20-fold. This denotes that a substantial initial stiffness can be anticipated within the minor deformation spectrum, impacting both the formability of mma and the energy dissipation rate attributable to rheological phenomena. The integration of bitumen with TRA results in a novel composite material characterized by enhanced stiffness at elevated operating temperatures and diminished sensitivity to loading durations compared to 50/70 neat bitumen. Moreover, the modified bitumen exhibits a reduced brittle temperature, suggesting retention of a flexibility reserve at lower temperatures. This outcome is presumably attributable to the superior compatibility of TRA with bitumen and the noted secondary polymerization occurring in the degraded PET in bitumen phase. Hence, this approach presents itself as a viable alternative for recycling PET, acknowledged for its complexity in processing and chemical inertia. Future research endeavors will concentrate on the evaluation of alternative amines and the refinement of the TRA and bitumen amalgamation process.

4. CONCLUSIONS

On the basis of the research performed and the analysis of the results, the following conclusions were formulated:

- The aminolysis process of the PET plastomer led to the formation of terephthalamide with reduced mechanical strength, thereby enhancing its processability and subsequently improving the efficiency of the bitumen homogenization process with TRA.
- The modification of 50/70 neat bitumen via the incorporation of TRA resulted in a decrease in Fraass breaking point temperature by roughly –3°C, whereas the softening point demonstrated an increment of approximately +1°C in comparison to the conventional 50/70 bitumen.
- The incorporation of TRA into 50/70 neat bitumen resulted in a fivefold reduction in irreversible susceptibility compared to 50/70 neat bitumen, bringing it to below 0.5 kPa^{-1}. Conversely, the elastic recovery value in bitumen 50/70+TRA, as determined by MSCR, increased by approximately tenfold compared to 50/70 neat bitumen.
- The presence of TRA in bitumen resulted in a tenfold reduction in the relaxation rate of bitumen and an approximate twentyfold enhancement in stiffness relative to 50/70 neat bitumen. This modification is anticipated to beneficially influence the reduction of MMA deformation rate under high operational temperature conditions when TRA is utilized.

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APPLICATION OF BIM SYSTEMS IN INTELLIGENT DESIGN – PROCESS AND COST

ZASTOSOWANIE SYSTEMÓW BIM W INTELIGENTNYM PROJEKTOWANIU – OPTYMALIZACJA PROCESÓW I KOSZTÓW

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Abstract

The article analyzes the application of BIM (Building Information Modeling) systems in intelligent design, focusing on process and cost optimization in construction. The authors discuss the benefits of implementing BIM throughout the entire life cycle of a building, from the pre-design phase to operation. BIM enables rapid concept analysis, supports interdisciplinary collaboration, streamlines cost estimation, and improves construction management. During the operational phase, BIM supports efficient facility management through real-time data collection and updates. The authors emphasize that the future of construction lies in integrating BIM with technologies such as IoT, artificial intelligence, and augmented reality. Despite the low level of BIM adoption in Polish companies, the trend of digitalization in construction is inevitable, and firms effectively implementing these technologies will gain a competitive advantage.

Keywords: BIM, design, optimization, costs, automation

Streszczenie

Artykuł analizuje zastosowanie systemów BIM (Building Information Modeling) w inteligentnym projektowaniu, koncentrując się na optymalizacji procesów i kosztów w budownictwie. Autorzy omawiają korzyści płynące z wdrożenia BIM w całym cyklu życia obiektu budowlanego, od fazy przedprojektowej po eksploatację. BIM umożliwia szybką analizę koncepcji, wspiera współpracę międzybranżową, usprawnia kosztorysowanie i zarządzanie budową. W fazie eksploatacji BIM wspiera efektywne zarządzanie obiektem poprzez gromadzenie i aktualizację danych w czasie rzeczywistym. Autorzy podkreślają, że przyszłość budownictwa leży w integracji BIM z technologiami takimi jak IoT, sztuczna inteligencja i rozszerzona rzeczywistość. Mimo niskiego stopnia wdrożenia BIM w polskich firmach trend digitalizacji budownictwa jest nieunikniony, a firmy skutecznie implementujące te technologie zyskają przewagę konkurencyjną.

Słowa kluczowe: bim, projektowanie, optymalizacja, koszty, automatyzacja

1. INTRODUCTION

BIM (Building Information Modeling) technology is revolutionizing contemporary architectural design, offering a range of benefits for the entire construction process. From generating comprehensive technical documentation to automatic updates across all project views, BIM is a powerful tool supporting designers' work. In the dynamic world of architecture, where design decisions are subject to constant changes, and every part of the building requires careful consideration in terms of functionality and aesthetics, BIM systems prove invaluable. BIM is a universal tool used in various phases of the investment process, and the BIM concept itself assumes the possibility of using it throughout the entire life cycle of a building. The construction process is schematically shown in Figure 1.

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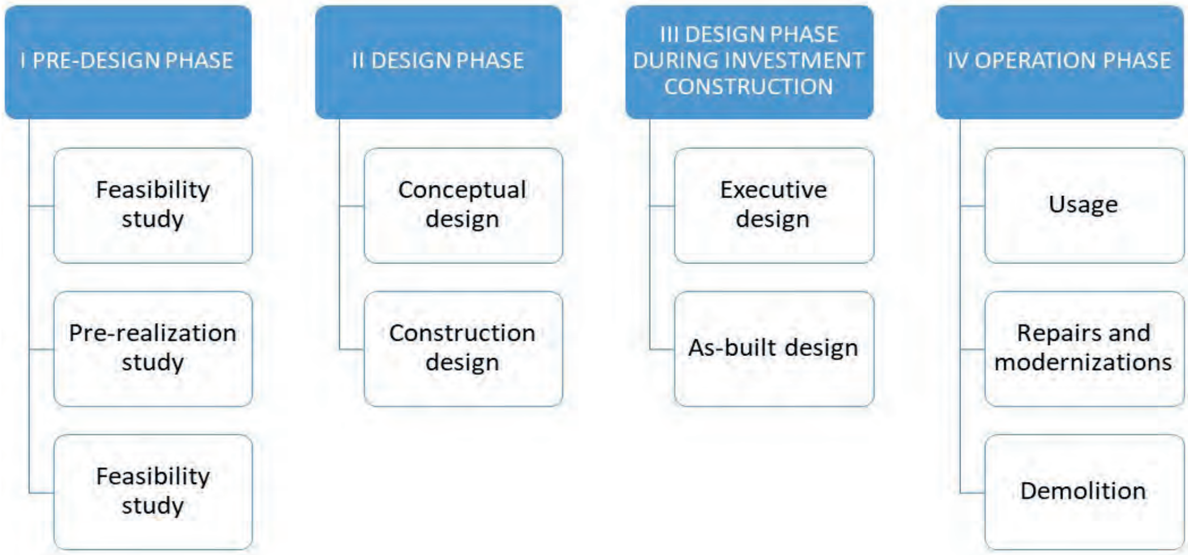

Fig. 1. Phases of the construction investment process with division into individual stages (source: [1])

The purpose of such a division is primarily to optimize the management of the investment process, among others by reducing costs, reducing investment implementation time, as well as minimizing the risk of inefficient use of resources [2]. BIM can be applied for various purposes in each of the distinguished stages, which is shown in the article.

In turn, the authors in [3] write about many dimensions of BIM (4D improved time management, 5D costs, 6D energy analysis, 7D facility management, 8D investment security). The authors emphasize that there is no single BIM application covering all these dimensions, but many different software specializing in various stages of building creation and life.

Collaboration between designers, contractors, investors, and other participants in the construction process is crucial for the success of any construction project and gains a new dimension thanks to BIM. This technology enables effective communication at various stages of the project, from traditional meetings in architectural offices, through multi-disciplinary online meetings, to quick exchange of information via emails, text messages, or phone calls. In this article, the authors will indicate how the application of BIM systems affects the optimization of design processes and cost reduction, opening new possibilities in intelligent design. Research conducted in [4] confirmed that the degree of BIM technology application in Polish construction companies is still not satisfactory, and its pace of development largely depends on the requirements set by public contracting authorities and private investors. Therefore, it is important to indicate the possibilities of using BIM in design and construction companies and the subsequent implementation of these solutions.

Next, the authors will show the possibilities of applying BIM in subsequent phases of the construction investment process.

2. PRE-DESIGN PHASE

Conceptual massing and site context modeling open up a range of possibilities for us. By utilizing tools for creating conceptual masses of the surroundings and the designed building, we can assess the degree of site shading, which allows us to refine the form of our structure. These analyses also enable optimal space utilization, determining the proportions between the built-up area and the building's foreground. Figure 2 shows a compilation of apartment areas for an example building mass along with sunlight and shading analysis.

Preliminary analyses are performed in programs for modeling the general form of the building, such as Formit or SketchUp, with the ability to add a location with specific geographic coordinates. This approach also supports the analysis of the building's total area, usable floor area, and built-up area, allowing for the assessment of building coefficients relative to the plot. Guidelines for proportions are determined by Development Conditions or Local Spatial Development Plans.

When starting the design process, an architect tries to understand the context of the place: existing building heights, building line, the need to create semi-public or semi-private spaces for clients and new users. They consider how the new structure will affect the surroundings and what aspects can enhance the location's prestige. When designing the form and

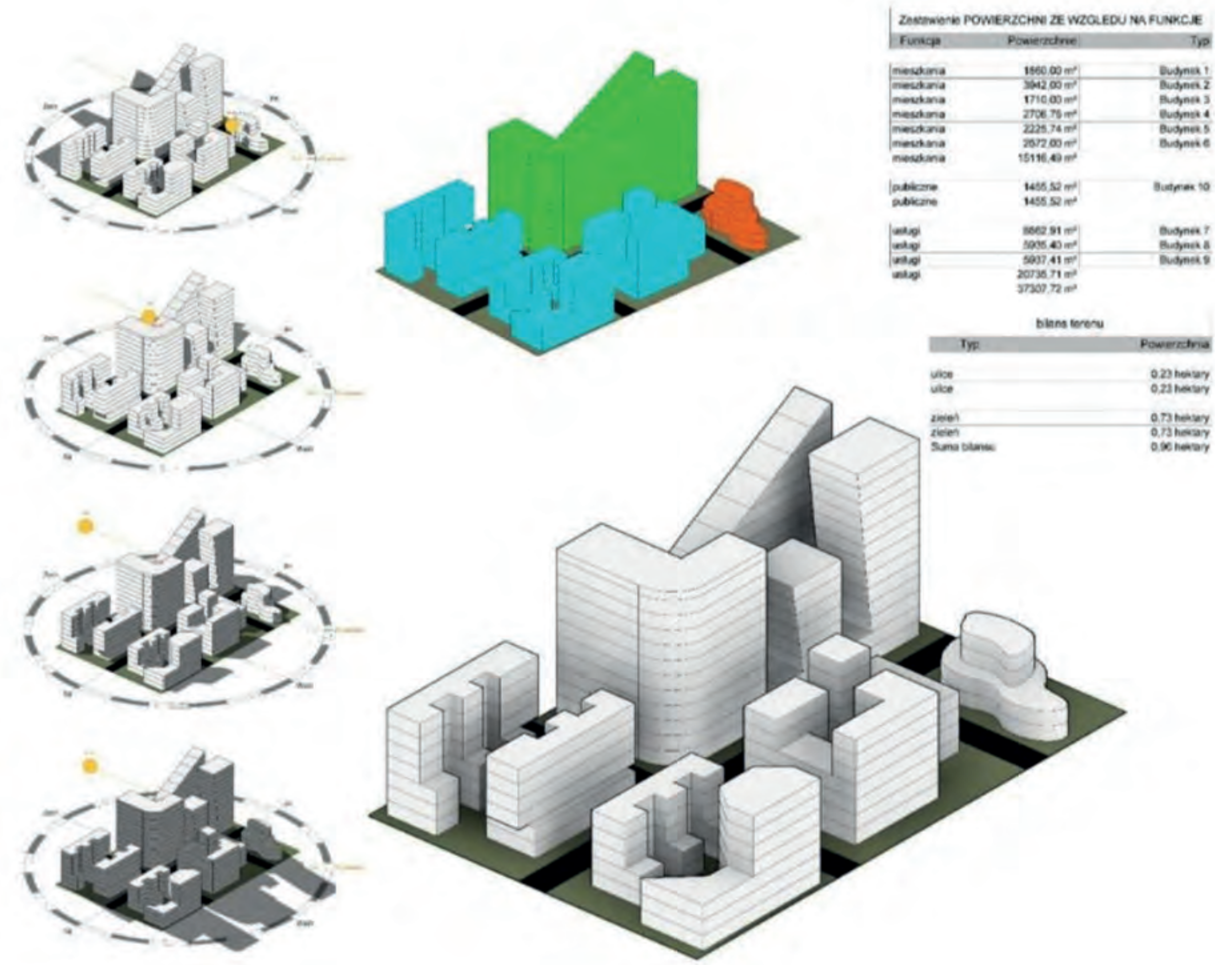

Fig. 2. Compilation of apartment areas for an example building mass with sunlight and shading analysis

layout, it's important to remember that you're not just creating a building with its physical elements, but also a new space that can attract investors.

3D printing is often used in the process of designing the building layout. A previously prepared master model serves to define the context. Then, building masses of various shapes, close to the desired final effect, are printed. Such models can be modeled in 3D programs, exported to .stl files, and printed in appropriate scales for presentation at meetings. Discussions over a physical model accelerate the decision-making process because humans are accustomed to making spatial decisions by directly experiencing space. A monitor and flat screen are only a representation of space, often distorted compared to reality after construction.

The ideal of intelligent design could involve an architect creating cardboard models that are automatically transformed into 3D models and analyzed for ergonomics and finances. Such an approach would combine the intuitiveness of working with physical material with advanced digital analysis.

3. DESIGN PHASE

BIM models in various disciplines serve diverse functions. We distinguish between architectural, structural, MEP (Mechanical, Electrical, and Plumbing) models, and others adapted to the specifics and needs of a given project. These are created by designers in close interdisciplinary collaboration.

Initially, the model is usually created in an architectural office and shared with other disciplines for further collaboration. The aim is to ensure linear progress of changes with the participation of all involved parties. It is crucial to provide a platform for exchanging project information, such as CDE (Common Data Environment) or BCF (BIM Collaboration Format).

Architectural models enable the analysis of key parameters such as the building's usable area, plot coverage ratio, or the number and size of apartments.

Structural models are primarily used for engineering calculations. Consisting of beams, columns, walls, and slabs, they are analyzed in terms of geometry and shape. The results of these analyses allow for optimization and possible redesign of undersized elements, ensuring the optimality of the structure in terms of dimensions at every point.

MEP models (ventilation, air conditioning, water and sewage, electrical) inside and outside the building serve two main purposes. Firstly, they enable internal calculations such as pressure drops or selection of profiles and duct sizes. Secondly, they allow for external clash detection between disciplines. It is important that the MEP model is integrated with architectural and structural models, creating a federated, comprehensive building model.

BIM supports a holistic approach to design, where the building is treated as a whole rather than a collection of separate systems. It helps solve design problems that extend beyond individual disciplines.

The vision of intelligent design assumes a system where the designer inputs data, which is then automatically analyzed by advanced algorithms, generating conclusions and calculations. The designer's role evolves towards verification and acceptance of these results and further refining of parameters for generating results, leading to a more efficient and precise design process. An example of such actions can be the automation of apartment schedules (Fig. 3).

Algorithmization, which can be performed using the Dynamo application, helps in many such activities. There are many programming languages that allow for creating applications. Dynamo is one of the programs supporting modeling and creating various schedules in Revit. It can be described as an environment for designing new tools within Revit using block diagrams. Importantly, using Dynamo doesn't require advanced programming skills, although basic knowledge in this area is helpful. With such tools, you can create block diagrams that interact with each other, and the only limitation is the user's imagination. Using a few input data, we can control extensive urban planning assumptions or modify the layout of rooms in a building.

One of the interesting examples of Dynamo application is the creation of parametric building objects. The article shows the general principle of operation using the example of designing a cubic building. Initially, you need to enter a few key values such as: number of floors, floor height, degree of mass rotation, or total building height. By modifying these data, we can generate different variants of the building. We can then analyze each version in terms of total area, usable area (PUM), and estimated implementation costs, and even the attractiveness

Zestawienie pomieszczeń

Mieszkanie	Numer	Nazwa	Powierzchnia
Część wspólna	1	Korytarz	57 m²
Część wspólna	50	Klatka schodowa	23 m²
			80 m²
M2.1	2	Przedpokój	5 m²
M2.1	3	Salon z kuchnią	17 m²
M2.1	4	Sypialnia	8 m²
M2.1	5	Łazienka	5 m²
M2.1	126	Balkon	26 m²
			61 m²
M2.2	6	Przedpokój	5 m²
M2.2	7	Salon z kuchnią	17 m²
M2.2	8	Sypialnia	8 m²
M2.2	9	Łazienka	5 m²
M2.2	116	Balkon	26 m²
			61 m²
M2.3	10	Przedpokój	5 m²
M2.3	11	Salon z kuchnią	17 m²
M2.3	12	Sypialnia	8 m²
M2.3	13	Łazienka	5 m²
M2.3	118	Balkon	9 m²
			44 m²
M2.4	14	Przedpokój	12 m²
M2.4	15	Salon z kuchnią	19 m²
M2.4	16	Sypialnia 1	15 m²
M2.4	17	Sypialnia 2	13 m²
M2.4	18	Garderoba	5 m²
M2.4	19	Łazienka	5 m²
M2.4	119	Balkon	22 m²
			93 m²
M2.5	20	Przedpokój	5 m²
M2.5	21	Salon z kuchnią	17 m²
M2.5	22	Sypialnia	8 m²
M2.5	23	Łazienka	5 m²
M2.5	117	Balkon	12 m²
			47 m²
M2.6	24	Przedpokój	5 m²
M2.6	25	Salon z kuchnią	17 m²
M2.6	26	Sypialnia	8 m²
M2.6	27	Łazienka	5 m²
M2.6	123	Balkon	6 m²
			41 m²
M2.7	28	Przedpokój	5 m²
M2.7	29	Salon z kuchnią	17 m²
M2.7	30	Sypialnia	8 m²
M2.7	31	Łazienka	5 m²
M2.7	121	Balkon	12 m²
			47 m²
M2.8	32	Przedpokój	12 m²
M2.8	33	Salon z kuchnią	19 m²
M2.8	34	Sypialnia 1	15 m²
M2.8	35	Sypialnia 2	13 m²
M2.8	36	Garderoba	5 m²
M2.8	37	Łazienka	5 m²
M2.8	120	Balkon	22 m²
			93 m²
M2.9	38	Przedpokój	5 m²
M2.9	39	Salon z kuchnią	17 m²
M2.9	40	Sypialnia	8 m²
M2.9	41	Łazienka	5 m²
M2.9	122	Balkon	9 m²
			44 m²
M2.10	42	Przedpokój	5 m²
M2.10	43	Salon z kuchnią	17 m²
M2.10	44	Sypialnia	8 m²
M2.10	45	Łazienka	5 m²
M2.10	125	Balkon	26 m²
			61 m²
M2.11	46	Przedpokój	5 m²
M2.11	47	Salon z kuchnią	17 m²
M2.11	48	Sypialnia	8 m²
M2.11	49	Łazienka	5 m²
M2.11	124	Balkon	26 m²
			61 m²

Fig. 3. Automation of apartment area schedules in Revit (source: own elaboration)

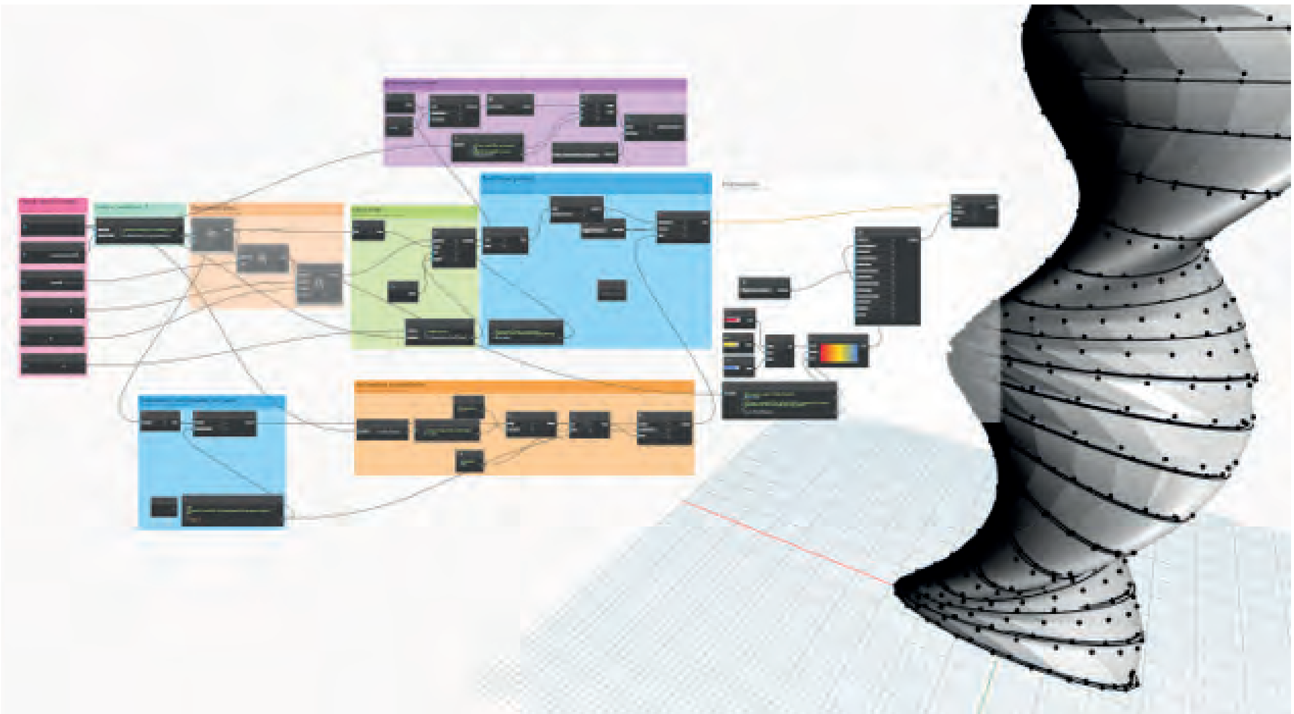

Fig. 4. Using algorithms in the Dynamo application to create a building mass

of the resulting building mass (Fig. 4). On the automatically generated mesh of the mass, you can add more elements, e.g., structural components or equipment elements. Thanks to the fact that all these elements go into schedules, you can also continuously control the form and shape of the building, while having a precise insight into, for example, costs – everything is automatically updated in the schedules.

This approach to design allows for quick creation and analysis of many variants, which significantly streamlines the decision-making process and project optimization both functionally and economically. The possibilities of interpreting and compiling data in BIM modeling are diverse and advanced. The geometry introduced in the model is always three-dimensional, which allows for accurate analysis of the structure, dimensions, and size of individual elements. These detailed data form the basis for drawing conclusions and making design decisions. By sorting elements by floor, we can easily determine the number of components at a given level. This information is crucial for estimating the time needed to build individual parts of the object. Additionally, this data enables logistics optimization, allowing precise planning of the transport of elements to the construction site. One of the biggest advantages of BIM modeling is the interactive connection between geometry and schedules. This means that any changes made to the project automatically update related schedules. When a designer modifies the geometry, the system immediately recalculates and updates all dependent data.

This dynamic relationship between the model and schedules allows for ongoing control over the project budget. Every change in geometry, materials, or specifications is immediately reflected in cost schedules. Thanks to this, designers and investors can continuously track the impact of design decisions on costs, which significantly facilitates the process of optimization and decision-making. This approach to design not only increases the accuracy of cost estimation but also allows for quick analysis of various scenarios and design variants. This enables making more informed decisions based on current and precise data, which in effect leads to a more efficient design and implementation process.

A separate issue is the costs of construction and subsequent operation. The topic of incorrect cost estimates or discrepancies has already been addressed multiple times in the literature, e.g., in [5, 6]. The article [7] presents examples of large discrepancies in the calculation of investment costs by the client and bidders, and the fundamental causes of the most common risk in practice of exceeding the parameters of an investment project. The possibilities of eliminating such significant differences through

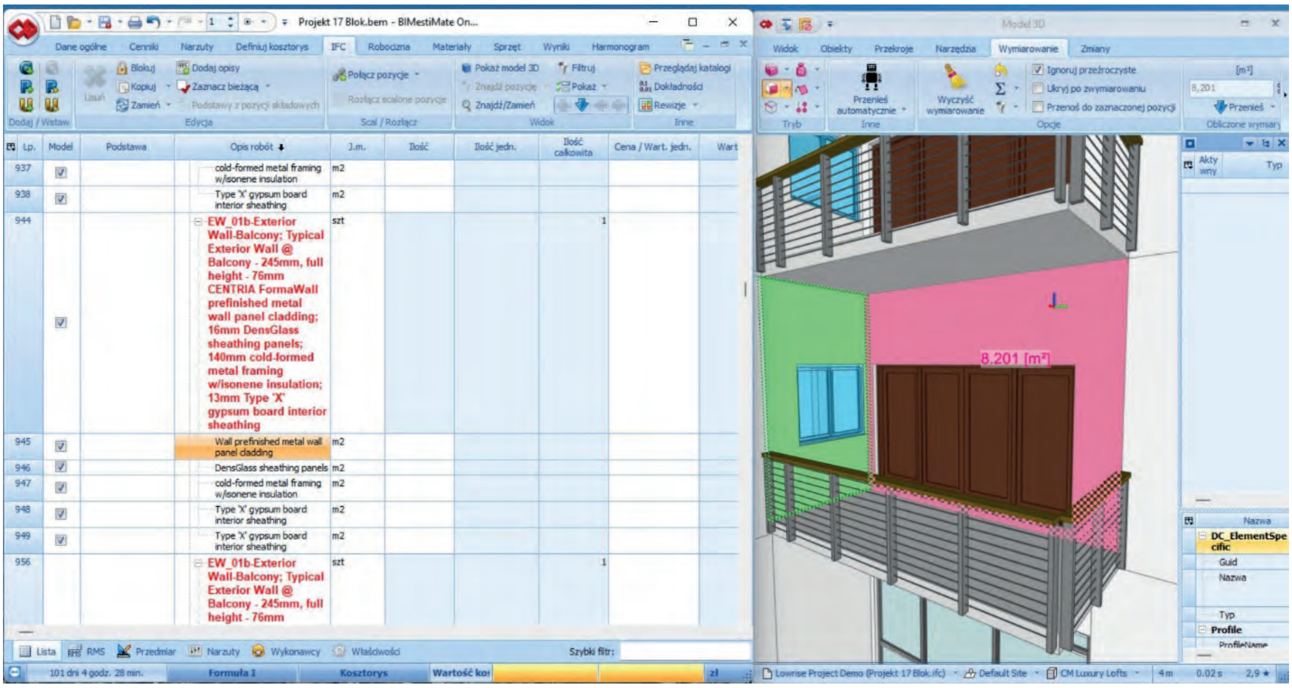

Fig. 5. Automatic creation of the scope of work in the BIMestiMate program along with quick quantity calculations "by indication" of the element and selection of the unit of measure (source: own elaboration)

the use of BIM technology and the use of uniform and consistent data by participants in the investment project were indicated.

And here BIM has two great advantages. Firstly, it significantly accelerates calculations due to the automation of the scope of work and quantity calculations, which is impossible in the case of 2D projects. The lack of the third dimension precludes automation of quantity calculations. An example of such automation is shown in Figure 5. It's enough to indicate an element, choose a unit of measure, and we get, for example, the wall area already without openings (if they were correctly modeled).

Significant acceleration of calculations has a very beneficial effect on the time devoted to cost estimate optimization. This, in turn, translates into the second benefit: precision and correctness of cost estimates. By saving time on performing the bill of quantities, the cost estimator can focus on cost optimization and the correctness of selecting prices of production factors.

4. DESIGN PHASE DURING INVESTMENT CONSTRUCTION

Cost adjustments are generally made similarly to work schedules, both in the design phase and the implementation phase. Linking activities in the schedule with 3D model elements allows for creating visualizations showing successive stages of investment implementation. This approach leads to, among others:

- better understanding of individual stages and the entire process of object creation (virtual construction before real construction),
- visual comparison of the actual state of construction progress with the planned state,
- monitoring construction progress even using augmented reality techniques,
- illustrating how the object should look at a chosen date.

It should be noted that the 3D model, although useful for visualizing the planned construction object, is static and does not allow for a clear understanding of the construction process implementation and its dynamics that characterize successive sequences of construction works. To make work sequences dynamic, it is necessary to integrate the fourth dimension, which is time. In practice, this corresponds to linking 3D elements of the BIM model with the construction project schedule. The effect of applying 4D modeling can therefore be different:

1. Static visualization: Static visualization allows for combining the three-dimensional model with the work schedule, i.e., creating an image of the works being performed or the state of the object at a specific given date. The view of the schedule itself in the form of the familiar Gantt chart or in the form of a network

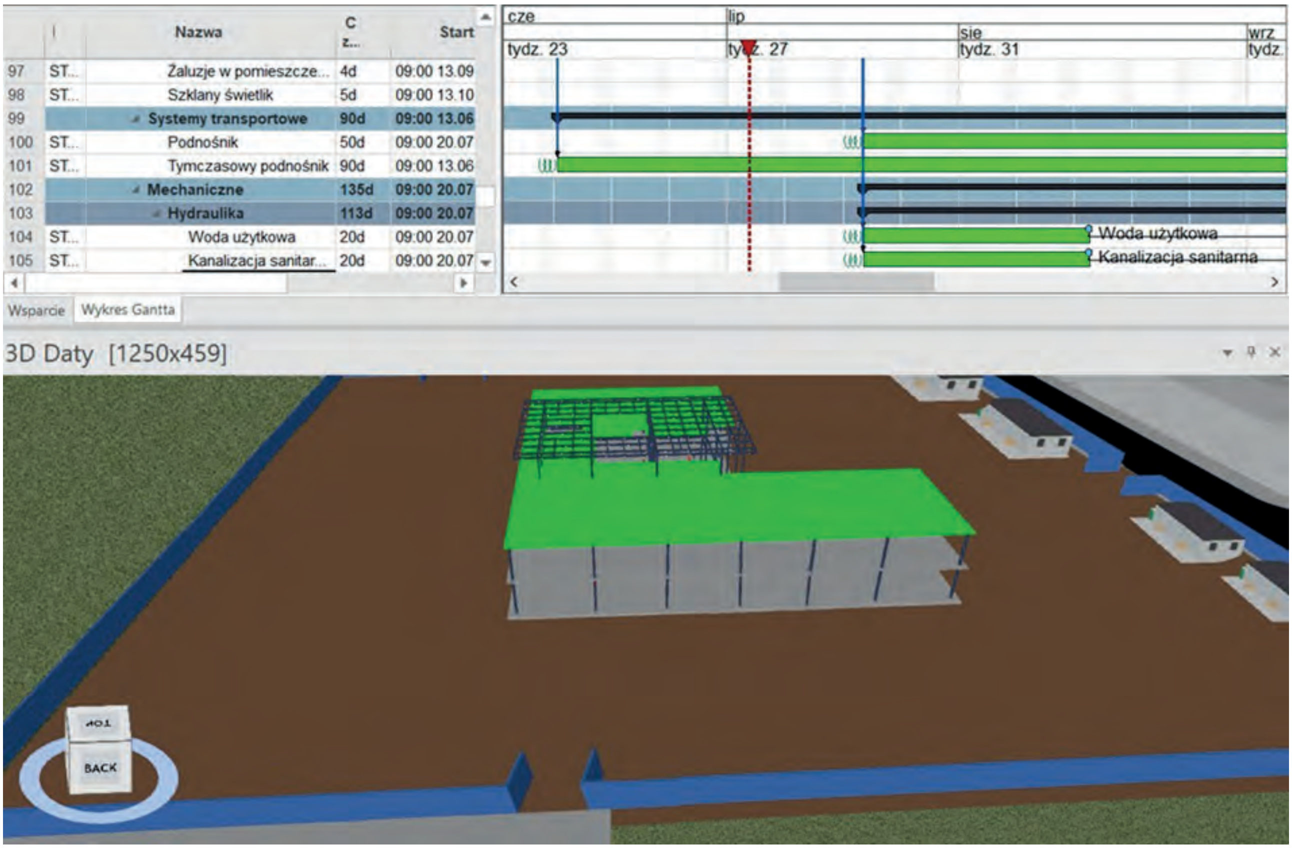

Fig. 6. BIM 4D – static image of work execution at a selected date referenced to the Gantt chart (source: own elaboration)

model or in the form of LOB (Line of Balance), often does not allow for appropriate interpretation in terms of technological and organizational sequence of construction works, and constitutes a static image at a given date (Fig. 6).

2. Dynamic visualization/simulation: Simulations and animations can be used to better illustrate the construction process. Simulations allow for eliminating, among others, organizational errors, unnecessary works, conflicts related to the wrong technological sequence of construction works. Often, simulations allow for noticing organizational problems such as, for example, collisions of equipment during construction works, for instance collisions of tower cranes, which are perfectly visible in the 3D environment, and sometimes difficult to catch on flat drawings due to differences in the heights of the cranes themselves. A similar problem is collisions with the existing surroundings, e.g., trees or existing objects. Often only during simulation can one notice difficulties in maneuvering equipment related to the small free space on the construction site, especially when the constructed building is already above ground level.
3. BIM washing: BIM 4D in the construction industry today is often just for show. On construction sites, engineers still quite rarely implement 4D in a way that can improve and facilitate communication and efficiency on site. This can be described as "BIM-washing". "BIMwashing" refers to a situation where a product or service is sold or shown as fully compliant with prevailing standards, in this case, building information modeling principles, but in reality does not meet these standards and does not provide the expected level of interoperability and collaboration. In short, BIMwashing may include exaggerated claims about the level of its implementation, interoperability, capabilities offered by the construction contractor or designer in relation to actual capabilities or actual use.

5. OPERATION PHASE AND DEMOLITION

The operation phase is not only the longest stage in the project lifecycle but also the moment when people gather the most information about the project. Due to the secular nature and complexity of property management during the operation period, as well as the loss of a large amount of information in several periods preceding operation, it is very difficult to manage [8]. To fully utilize the advantages of BIM also in the operation and renovation phase, BIM models must provide a reliable data foundation regarding the as-built state and, accordingly, the current state. However, until now, many properties were neither planned nor built using BIM, and sometimes digital planning information is not even available [9].

Data management therefore requires having reliable information contained in the BIM model, originating from the design and implementation stages of the construction investment, but also requires updating information during the long period of operation. Data from technical inspections of building elements, current and general repairs, etc., should be recorded in the BIM model. We should strive for the so-called Digital BIM (Digital Twin), in which data in the model would be collected on an ongoing basis thanks to sensors distributed throughout the building. Data from such monitoring will create a Big Data database, which may cause problems with information storage, but is useful for monitoring the building's condition, ensuring the safety of the facility.

On the other hand, the BIM model can control devices installed in the building, analyzing data from sensors and controlling, for example, temperature, humidity, opening of blinds automatically. Connecting BIM with other technologies, e.g., IoT (Internet of Things), seems to be a necessity in the development of construction digitalization. The potential results of implementing BIM with one or several technologies are much higher than in the case of a single BIM implementation, especially in the O&M (Operation & Maintenance) phase of the project. In this case, if only BIM is implemented, an important step towards intelligent management will begin, but it seems that this will not be enough. Storing a large amount of related information and updating it in real-time is complex and requires a large amount of resources to maintain the BIM model [10].

The BIM methodology can also significantly enhance the final phase of a building's lifecycle - demolition. BIM models provide valuable information for planning and executing demolition works, including structural details, material specifications, and building components that can be potentially recycled or reused. By leveraging BIM technology during demolition planning, project teams can optimize the deconstruction sequence, minimize waste generation, and identify opportunities for material recovery. This approach supports sustainable demolition practices by enabling detailed analysis of materials that can be salvaged, recycled, or must be disposed of as waste. Furthermore, BIM can assist in planning safe demolition procedures by identifying potential hazards and structural dependencies, ultimately contributing to more efficient and environmentally conscious end-of-life building management.

6. CONCLUSION

The application of BIM systems in intelligent design opens new possibilities for optimizing processes and costs in construction. The analysis presented in the article indicates a number of benefits from implementing BIM throughout the entire lifecycle of a building. In the pre-design phase, BIM enables rapid concept creation and analysis, optimizing design decisions at an early stage. In the design phase, BIM supports effective inter-disciplinary collaboration, automates processes, and enables quick analysis of various project variants. BIM significantly streamlines the cost estimation process, increasing the precision of estimates and allowing for quick updates when project changes occur. In the implementation phase, BIM allows for better planning and control of the construction process, minimizing the risk of errors and delays. In the operation phase, BIM supports efficient facility management, enabling real-time collection and updating of building data.

The future of construction digitalization is based on the full integration of BIM technology with other advanced solutions. The development of building "digital twins", combining BIM models with IoT systems, will enable more effective facility management and optimization of their functioning. The integration of BIM with artificial intelligence and machine learning technologies will open new possibilities in design automation and optimization of construction processes. The development of augmented reality (AR) technology in conjunction with BIM will enable more intuitive project visualization and support for work on the construction site. Standardization and interoperability of BIM systems will be crucial for fully utilizing the potential of this technology across the entire construction industry. Further education and development of digital competencies among construction industry specialists is necessary to fully exploit the potential of BIM and related technologies.

Although the level of BIM implementation in Polish construction companies is still not satisfactory, the trend of construction digitalization is inevitable.

structure

Companies that successfully implement BIM and related technologies will gain a significant competitive advantage in the market. The future of the construction industry lies in an intelligent, integrated approach to designing, implementing, and managing facilities, with BIM forming the foundation of this transformation. Further development and adaptation of BIM technology in combination with innovations in artificial intelligence, IoT, and augmented reality will shape the future of construction, leading to more efficient, sustainable, and intelligent solutions throughout the entire lifecycle of building structures.

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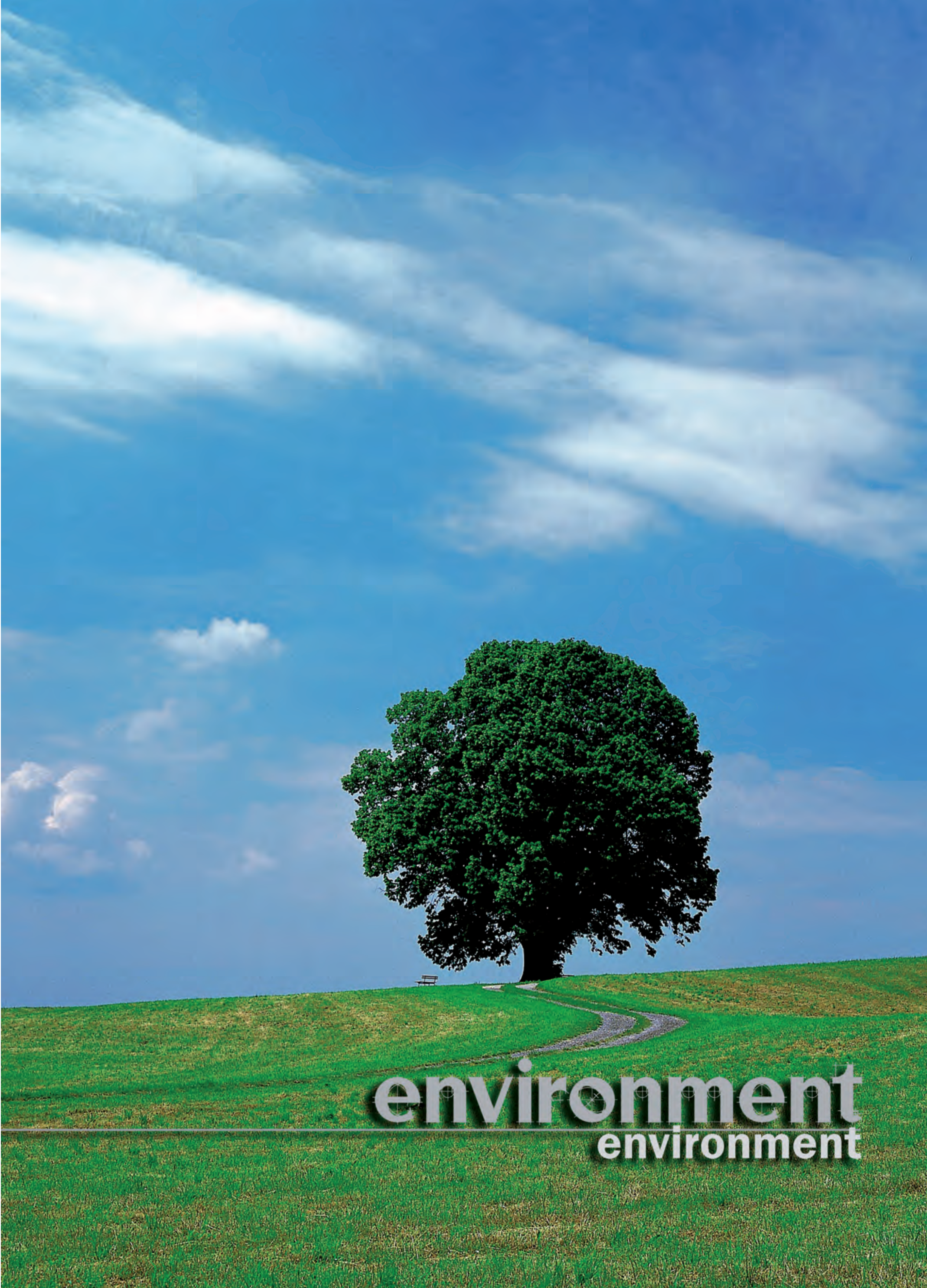
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INVESTIGATING EFFECTIVENESS OF TUNED MASS DAMPER (TMD) ON CONTROL VIBRATION OF WIND TURBINE-SOIL INTERACTION

BADANIE EFEKTYWNOŚCI DYNAMICZNEGO TŁUMIKA DRGAŃ (TMD) POD KĄTEM KONTROLI WIBRACJI W INTERAKCJI TURBINY WIATROWEJ Z PODŁOŻEM GRUNTOWYM

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Abstract

Soil-structure interaction (SSI) effects were investigated on structural responses of wind turbine. Force versus deformation (i.e., p-y curves) was simulated by multilinear elastic springs. The whole system, including the structure, control vibration system and soil nonlinear effects are simulated within a single three-dimensional finite element model. Modeling accuracy was verified using available results related to a 65 kW wind turbine discussed in the literature. Pushover analysis results indicated a fixed-base assumption ends up with overestimation of stiffness compared to the case where SSI effects are considered. Moreover, it is observed that the performance of tuned mass damper (TMD) is highly dependent on its tuned frequency domain, and its efficiency decreases significantly after SSI effects are considered. Lateral deformations of a wind turbine are much higher compared to the fixed-base condition. Therefore, SSI effects play a crucial part in designing wind turbines and should not be neglected in practice.

Keywords: dynamic analysis, pushover analysis, p-y curves, soil-structure interaction, tuned mass damper, wind turbine

Streszczenie

Zbadano wpływ interakcji konstrukcji z podłożem gruntowym (SSI) na zachowanie konstrukcji turbiny wiatrowej. Zależność siły od odkształcenia (tj. krzywe p-y) zasymulowano za pomocą wieloliniowych sprężyn elastycznych. Cały system, w tym konstrukcja, system kontroli wibracji i nieliniowe efekty podłoża, jest symulowany w ramach jednego trójwymiarowego modelu elementów skończonych. Dokładność modelowania została zweryfikowana przy użyciu dostępnych wyników dla turbiny wiatrowej o mocy 65 kW, omówionych w literaturze. Wyniki analizy statycznej (pushover) wykazały, że przy założeniu o nieruchomej podstawie dochodzi do przeszacowania sztywności w porównaniu z przypadkiem, w którym uwzględniono efekty SSI. Ponadto zaobserwowano, że wydajność tłumika TMD jest silnie zależna od jego dostrojonej domeny częstotliwości, a jego efektywność znacznie spada po uwzględnieniu efektów SSI. Odkształcenia poziome turbiny wiatrowej są znacznie większe w porównaniu z warunkami nieruchomej podstawy. Dlatego efekty SSI odgrywają kluczową rolę w projektowaniu turbin wiatrowych i nie powinny być pomijane w praktyce.

Słowa kluczowe: analiza dynamiczna, krzywe p-y, analiza statyczna (pushover), interakcja konstrukcji z podłożem, dynamiczny tłumik drgań, turbina wiatrowa

1. INTRODUCTION

Often, in practice structural and geotechnical designs are covered by two different teams who do not communicate effectively together. Nevertheless, realistic modeling of special structures like wind turbines which undergo various uncertain loading

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conditions requires a unified design strategy. This paper aims to provide an overall understanding of soil-structure interaction effects on the response of wind turbines via investigating a case study. The paper is organized as follows: First, a brief overview of previous studies is presented to clarify the theoretical background and challenges existing in the field. Next, a three dimensional numerical model is analyzed based on test results related to an actual wind turbine tested using a shake table device at the University of California, San Diego (UCSD). Validation is done by comparison of accelerations applied to different parts of the wind turbine under Landers earthquake (1992) excitation and estimation results by the current study. Then, wind turbine capacity before and after considering soil-structure interaction effects is investigated. Soil response is modelled using nonlinear elastic force versus displacement (*p-y*) curves of a stiff clay reported in the literature. Thereafter, a control vibration system tuned based on the fundamental mode of fixed-base model is added to the structure with and without considering soil-structure interaction, and their results are compared using nonlinear time history analysis. Later, the influence of wind and wave static loads on the wind turbine is investigated. It is shown that neglecting soil-structure interaction results in a significant underestimation of displacements.

2. THEORETICAL BACKGROUND

During the past few decades, the demand for using wind turbines have been increased significantly. These structures are known for their appropriate reliability and simplicity [15]. Wind turbines like cantilever structures have a low amount of redundancy and insufficient force distribution mechanism [20]. Also, due to financial obstacles and physical limitations, research on wind turbines has been mostly narrowed to numerical investigations [20]. However, few test results for these unique structures are available [29, 31-34, 37]. As shown in Equation 1, power produced by wind P, is dependent on air density ρ, rotor swept area A, and wind velocity V, where the latter is the dominant parameter. Therefore, as a rule of thumb, higher and bigger wind turbines are preferred.

$$P = \frac{1}{2}\rho A V^3 \quad (1)$$

Around 90% of offshore wind turbines are installed in Europe [40]. What makes offshore wind turbines unique is the high amount of uncertainties related to their loading conditions. Consequently, wind turbines design demands, considering too many load combinations. Hence, reducing computational time and effort is essential [12]. In general, wind turbines are affected by quasi-static (i.e., self-weight), wind, transient (i.e., start, stop, and emergency break down), rotor cyclic [12] and, intense ground motion loads. Usually, three design strategies are utilized in designing offshore wind turbines: Soft-soft (i.e., the resonance frequency of the structure is less than harmonic frequency equal to the rotor (1P) and the wave frequencies), Soft-stiff (i.e., the resonance frequency is in the range between the 1P and the blade passing frequency 3P), and Stiff-stiff (i.e., the resonance frequency is higher than the 3P) [12]. Note that 1P and 3P are around 0.12–0.3 Hz and 0.35–0.9 Hz, respectively. However, usually, soft-stiff approach is chosen for design since the stiff-stiff design is not economical, and wave loading might cause wave fatigue for the soft-soft case [12]. Load frequencies for some wind turbines are shown in Figure 1. As shown in this figure, wind turbines undergo a vast domain of loading conditions, which makes the design procedure difficult.

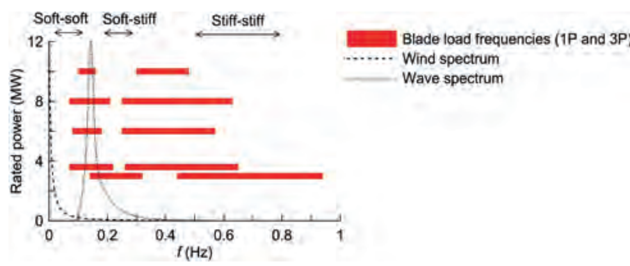

Fig. 1. Various loading frequencies for wind turbines after [2, 4], modified from [39]

In practice, the effect of earthquake loading is usually underestimated in the design process. The main reason for this issue can be the observation of limited damaged turbines under strong ground motions like North Palm Springs and Tōhoku events [1, 6, 42]. One research considering 300 earthquake records with a variety of properties (i.e., duration, frequency content, magnitude, distance from the epicenter, etc.) studied period range of wind turbines in response acceleration versus period results [19]. As illustrated in Figure 2, their findings revealed that wind turbines show similar trends as self-isolated structures due to their high natural periods, and they go under negligible lateral earthquake forces. Some studies pointed out that simple models are capable of modeling these cantilever-shape structures adequately compared to complex models [7, 27]. However, other studies like [16] indicated that strong ground motion effects are not negligible. The main reason for such a point of view is the importance of serviceability performance (i.e., controlling large displacements). For instance, a study showed a 40% surpass of lateral displacement limit based on Chinese regulation for tall structures [14, 41].

Moreover, some studies pointed out the vulnerability potential of wind turbines under vertical earthquake loading due to their low natural period in this direction [21, 35]. Consequently, the acceleration applied at the base of the tower is amplified considerably and threatens important parts like Nacelle. For instance, a study mentioned three and almost eight times the amplification of base tower acceleration for soft and rocky foundations, respectively [23]. Therefore, investigating base condition effects on the response of wind turbines is of utmost importance. SSI effects on wind turbine structure are studied in this paper.

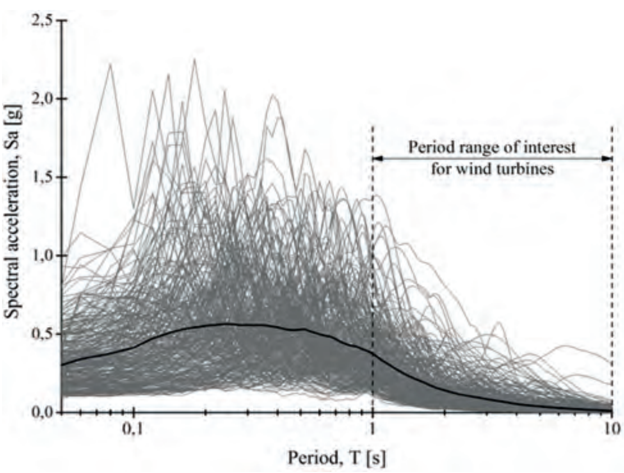

Fig. 2. Wind turbines domain in response to acceleration versus period plots, obtained from [19]

3. MODEL VERIFICATION

In this section, modeling of a wind turbine produced in Denmark, which has been tested using a shake table device at the University of California, San Diego (UCSD) under Landers earthquake (1992), is validated. This turbine is small compared to already existing wind turbines but represents fundamental aspects of these unique structures. The turbine is parked in such a way that one of the blades is toward the downside parallel to the tower direction. Wind turbine schematic and its structural properties are shown in Figure 3 and Table 1. More information regarding the test procedure is referred to [31-34].

The model is made using fully integrasted frame elements with fully fixed support at the base and the maximum mesh size of around 1 m. The tower steel has the modulus elasticity of 200 GPa, Poission's ratio of 0.3, and yield strength of 0.27 GPa. The bolades and nacelle are also modelled with materials with modulus elasticities of 0.0981 GPa and 210 GP*a*, respectively. More inforamtion about the material properties is referred to [23].

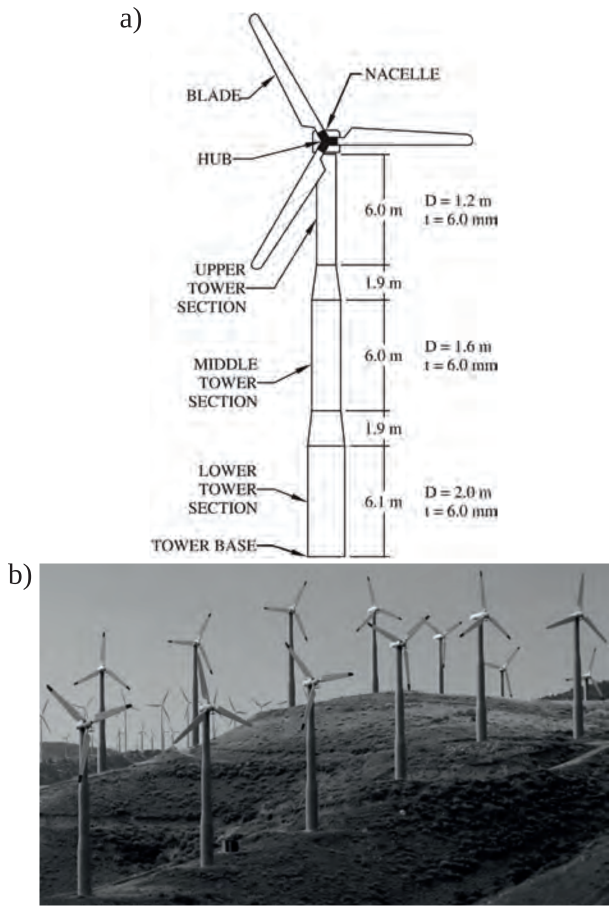

Fig. 3. Wind turbine dimensions (a) and its in situ schematic (b), (source [32, 34])

Table 1. Considered wind turbine characteristics, modified from [31]

Property	Value
Rated power	65 kW
Rated wind speed	33.8 km/h
Rotor diameter	16.0 m
Tower height	21.9 m
Lower section length	7.9 m
Lower section diameter	2.0 m
Middle section length	7.9 m
Middle section diameter	1.6 m
Top section length	6.0 m
Top section diameter	1.1 m
Tower wall thickness	Around 6 mm
Rotor hub height	22.6 m
Tower mass	6400 kg
Nacelle mass	2400 kg
Rotor mass (with hub)	1900 kg
Damping	1%

Moreover, natural frequencies and mode shapes of the tested structure using OpenSees in the literature [32] and results achieved in this study presented in Figure 4 are quite similar. Moreover, a comparison between the estimated acceleration time series of different points on the wind turbine obtained in this study and video photogrammetry techniques, as well as numerical simulations in previous studies, indicates acceptable modeling accuracy (Fig. 5). Notice that acceleration induced at the base of the tower was amplified significantly in Nacelle, which can interrupt turbines' adequate performance. Hence, implementing control vibration systems to mitigate structural responses to the wind turbine is needed.

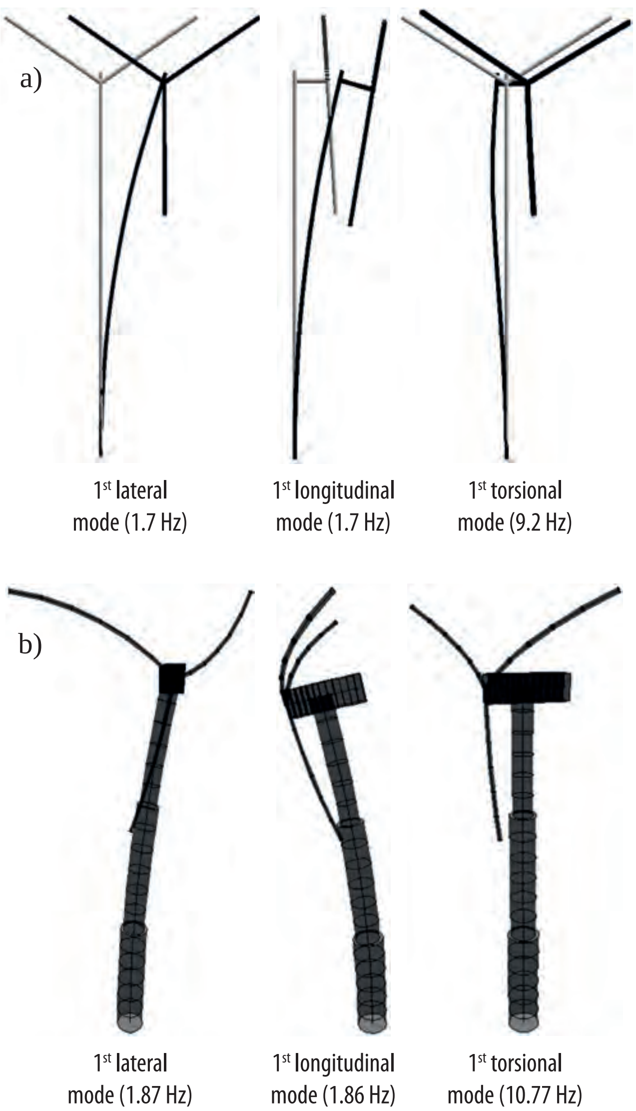

Fig. 4. Comparison between natural frequencies of considered wind turbine obtained using OpenSees (a) [32] and, obtained results in this study (b)

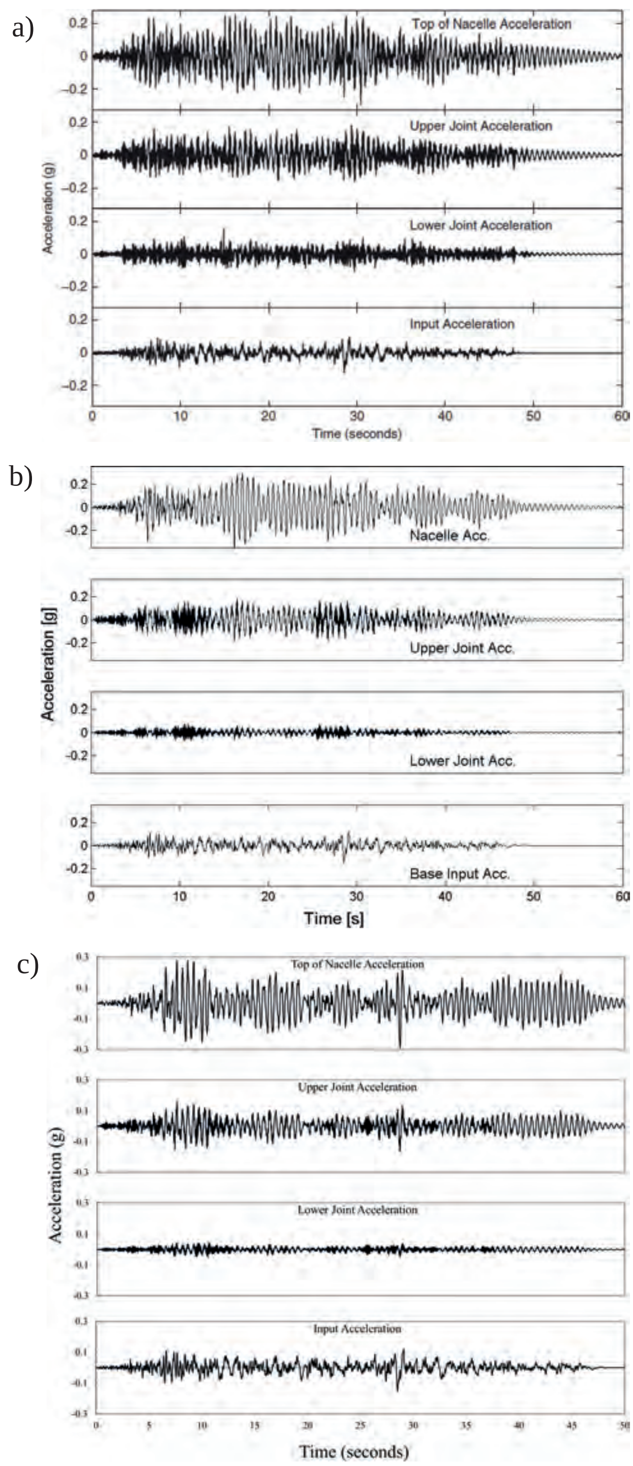

Fig. 5. Comparison of acceleration time history between experimental results (a) [32], numerical model from literature (b) [23] and, this study (c)

4. SOIL-STRUCTURE INTERACTION (SSI) EFFECTS

So far, it was assumed that the base structure is fixed to the ground. In most cases, by taking SSI effects into account, the frequency of the structure decreases, and simultaneously damping increases [17]. As a result, it is usually considered as a beneficial aspect in designing structures [38]. However, this is a crucial assumption specifically for wind turbines which undergo a wide range of dynamic loading frequencies. By neglecting SSI effects, principal frequencies and damping might be different than what was calculated for fixed-base structure [26]. For instance, Figure 6 illustrates the difference in structural performance under two cases of with and without considering SSI effects. It is apparent that simplicity in modeling might overlook additional displacements in practice [17]. Nevertheless, SSI effects are usually neglected in many cases due to complexities (i.e., nonlinear soil behavior, the right strategy for modeling, choosing appropriate software, etc.) and case dependency aspects [38].

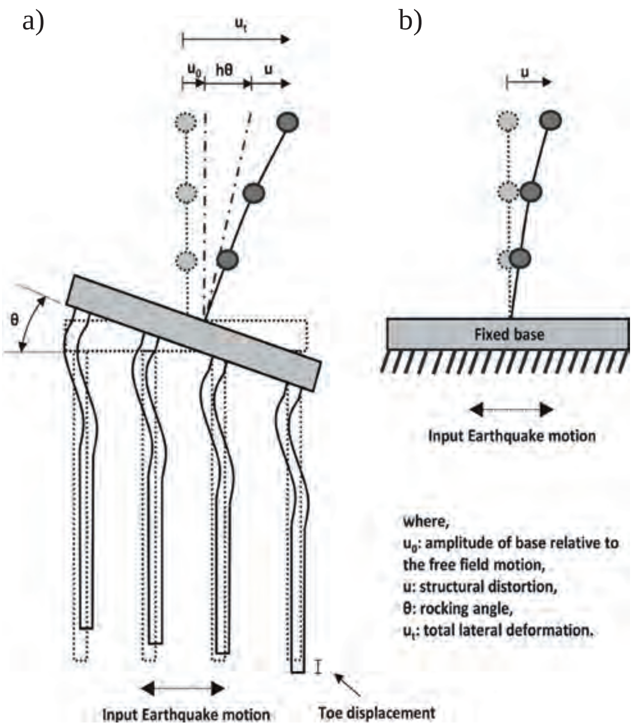

Fig. 6. Structural behavior under two cases of deformable (a) and fixed-base (b), modified from [17]

Soil behavior was shown to be highly nonlinear in terms of stiffness and damping [24]. This nonlinear behavior is affected by many parameters like plasticity index, confining stress, void ratio, etc. However, soil nonlinearity itself, considering very small, small, and large strains are out of the scope in this study and is referred to [8, 13, 43]. One of the most common methods to model SSI effects considering soil nonlinearity is force-displacement (i.e., *p-y* curves) concept introduced in the late 50s by [28]. In this method, nonlinear soil behavior is defined via multilinear elastic or plastic springs (depending on the type of analysis and model complexities). This approach is relatively simple, with the advantage of fast computing procedure. However, the drawback of this method is the lack of continuous modeling of soil layers [22]. In this research, a general approach is utilized for considering soil-pile interaction by modeling and analyzing the whole system (i.e., wind turbine, foundation, pile, soil springs, proper boundary condition, etc.) within a constant platform. Lateral force-displacement data (i.e., *p-y* curves) used in this study are gathered from previous study in the literature [3]. Soil type is a stiff clay, and bedrock is located 10 m beneath the ground surface. As shown in Figure 7, force values increase with depth until reaching a certain level, and softening occurs between 0.005 until 0.015 m.

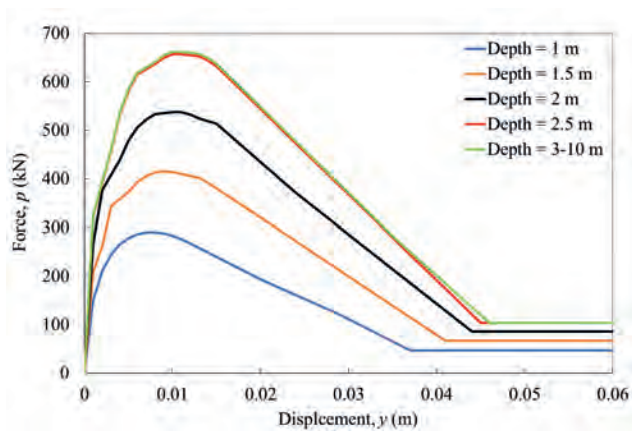

Fig. 7. Force versus displacement (i.e., p-y) graphs, (source [3])

Moreover, displacement control pushover analysis is utilized to evaluate the wind turbine's performance rather more sophisticated time history analysis, which needs unloading data as well. Pushover analysis exposes predefined lateral load to the wind turbine and increases the load step by step until reaching the desired displacement value [26]. It is observed that the first frequency of the structure is obtained 0.49 Hz, which is significantly different than the fixed-base structure. Moreover, as shown in Figure 8, the capacity curve obtained from pushover analysis under the case in which SSI effects are taken into account gives a softer response compared to the fixed-base structure. Note that more ductile behavior does not necessarily mean beneficial in terms of wind turbines with highly uncertain loading conditions. Therefore, modeling these slender structures with considering SSI effects is highly recommended.

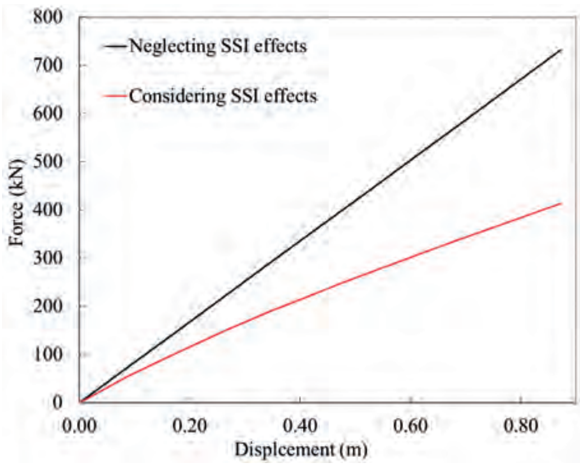

Fig. 8. Capacity curves for two cases of with and without taking SSI effects into account

5. CONTROL VIBRATION SYSTEM

Vibrations higher than 0.1 g can disrupt the performance of structures [18]. One of the most well-known techniques for controlling vibrations is utilizing the tuned mass damper (TMD) system. In this passive system, vibrations are controlled via additional mass oscillating in the opposite direction of base structure movements. This method is simple, economical, and independent of an external actuator and, as a result, less delay in operation compared to active systems [18]. However, more complex systems presented in literature like semi-active systems tried to increase the efficiency of this type of system and reduce delaying time [30].

The controlling force in these dampers is dependent on input acceleration to their system (i.e., TMDs are acceleration dependent), and their equation of motion is presented in Equation 2. As shown in Figure 9, the schematic of a TMD system is presented. Mass of the TMD is defined by mass ratio μ (usually a value between 0.02-0.1) given by Equation 3. Optimal frequency ratio α_{opt} and optimal damping ratio ξ_{opt} used in this study are obtained by Equations 4-5 available in the literature [10]. However, there are other empirical relations and techniques proposed by other researchers to tune TMD parameters, mostly their differences originate from uncertainty in considering loading conditions or accuracy of modeling [5, 25]. TMD is modlled using a link (i.e., spring) element in the model. Loading induced to the structure is five cycles of sine-shape dynamic load with the frequency corresponding to the first mode of the structure (1.87 Hz), and μ is set to 0.05. As illustrated in Figures 10 and 11, under the fixed-base assumption, a wind turbine with TMD decreased the displacements (around six times) of the Nacelle over the whole loading time. Moreover, input energy also decreased remarkably after adding TMD to the base structure (around 19 times). Nevertheless, by considering SSI effects, the same TMD did not show adequate performance and even increased the structural response in the early stages of loading. TMD performance is not much satisfactorily out of its tuned frequency. Therefore, other methods like adaptable control vibration systems or using multiple TMDs are proposed in the literature to cover this disadvantage [9].

$$m\ddot{x} + c\dot{x} + kx = -m\ddot{u} \tag{2}$$

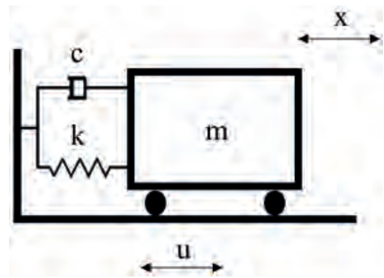

Fig. 9. Tuned mass damper (TMD) modeled as a simple single degree of freedom system

$$\mu = \frac{TMD\ mass}{Total\ mass} \tag{3}$$

$$\alpha_{opt} = \frac{1}{1+\mu} \tag{4}$$

$$\xi_{opt} = \sqrt{\frac{3\mu}{8(1+\mu)^3}} \tag{5}$$

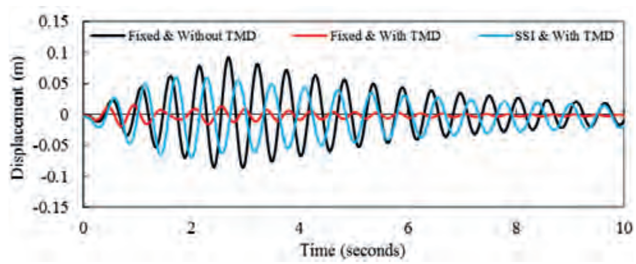

Fig. 10. Comparison of nacelle displacement concerning base condition and control vibration system

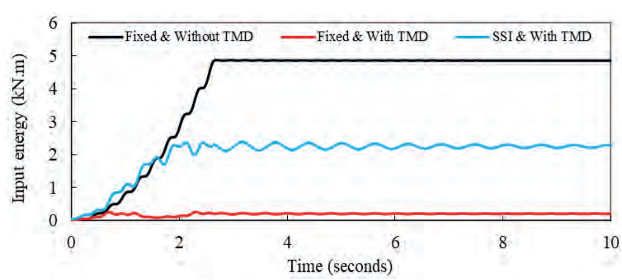

Fig. 11. Comparison of input energy concerning base condition and control vibration system

6. WAVE AND WIND LOADS

Unfortunately, due to lack of data related to taller wind turbines, only the effects of wave and wind loads of a hypothetical condition on the low-rise 65 kW wind turbine are investigated in the following. It should be noted that in practice, much taller structures are used for offshore cases, but methodologies discussed here are the same as for the taller wind turbines. As mentioned earlier, wind turbines loading conditions are sophisticated, with a high degree of uncertainty and variability. However, details of loading conditions itself are not studied in this research, and both wave and wind loads are calculated using the API recommended practice [11]. The wave force is obtained by Equations 6 and 7, known as Morison's approach. In these equations F_H is hydrodynamic force per unit length, F_D is drag force per unit length, F_I is inertia force per unit length, C_D is drag coefficient, W is weight density of water, g is gravity acceleration, A is projected area normal to element axis per unit length, V is displaced volume per unit length, U is component of the water particle velocity applying normal to the axis of the element, C_M is the inertia coefficient, dU/dt is the water particle acceleration. The wave loads are distributed along with the structural elements between mudline and wave surface.

$$F_H = F_D + F_I \tag{6}$$

$$F_H = C_D \frac{W}{2g} A U |U| + C_M \frac{W}{g} V \frac{dU}{dt} \tag{7}$$

The design wind load is also given by Equation 8 in which $U(z)$ is the one-hour mean wind velocity (*ft/s*) at height *z*. I_u is turbulence intensity at height *z*. $U(z)$ and I_u are computed by Equations 9 and 10, respectively.

$$u(z,t) = U(z)\left[1 - 0.41 I_u(z) \ln\left(\frac{t}{t_0}\right)\right] \tag{8}$$

$$U(z) = U_0\left[1 + \left(0.0573\sqrt{1 + 0.0457 U_0}\right)\ln\left(\frac{z}{32.8}\right)\right] \tag{9}$$

$$I_u(z) = 0.06\left[1 + 0.0131 U_0\right]\left(\frac{z}{32.8}\right)^{-0.22} \tag{10}$$

Moreover, wind drag force is calculated utilizing Equation 11 where F_W is wind force, ρ is the density of air (*slugs/ft*^{3}), u is wind speed (*ft/s*), C_S is shape coefficient, and A is an area of the object (*ft*^{2}).

$$F_W = \left(\frac{\rho}{2}\right) u^2 C_S A \tag{11}$$

All in all, the assumptions and characteristics used for wave and wind loads used in this research are presented in Table 2. Also, wave pressure and its horizontal wave velocity are illustrated in Figure 12.

Table 2. Wave and wind load characteristics investigated in this study

Property	Value
One-hour mean wind speed at 32.8 ft	30 m/s
Wind average period	600 s
Wave theory	Airy (linear)
Wave height	1.5 m
Wave period	12 s
Stormwater depth	7.5 m
Wave kinematic factor	1
Number of wave crest positions considered	1
Global height coordinate of vertical datum	7.5 m
Mudline from datum	-7.5 m

a)
b)

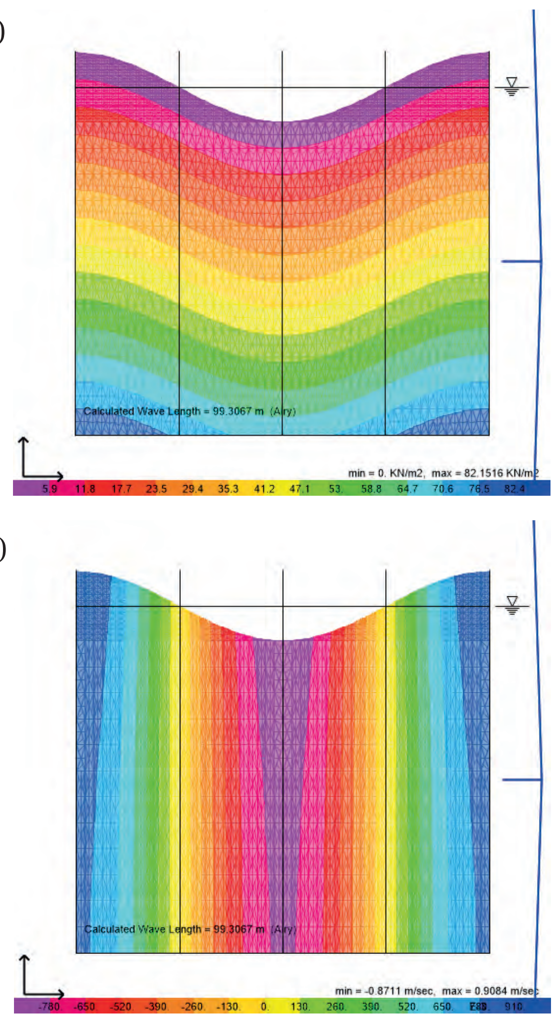

Fig. 12. Schematic of defined wave load: pressure (a), horizontal wave velocity (b)

As shown in this figure, maximum pressure and horizontal velocity occur near the mudline and at the side of the wave load, respectively. Moreover, as expected, the lateral displacement of the wind turbine in the case where SSI is taken into account is much more compared to the simplified fixed-base condition (Fig. 13). The main reason for such a significant difference in displacement values between two considered cases is that where SSI effects are considered, deformations are affected by both relative and absolute movements. Still, in fixed-base condition, absolute movements of the wind turbine are neglected.

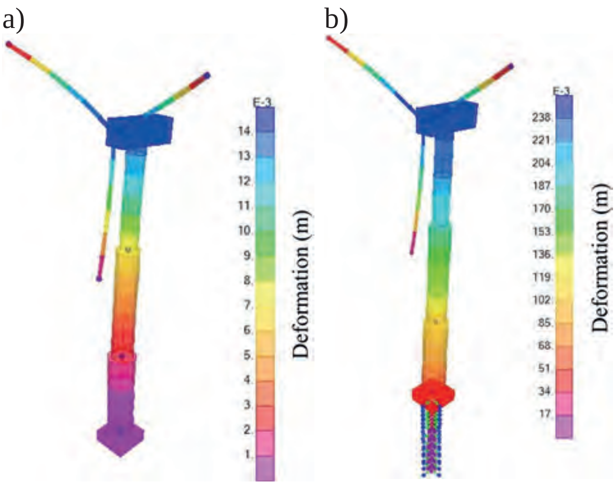

Fig. 13. Wind turbine deformation under a wave and wind load in two cases of a fixed-base (a) and considering SSI effects (b)

7. CONCLUSIONS

A 65 kW wind turbine was discussed in this study. A three-dimensional finite element model of the real wind turbine was validated based on a comparison between principal frequencies and acceleration applied to different parts of the structure. SSI effects were taken into account by modeling *p-y* curves utilizing multilinear springs. Capacity curves showed a fixed-base model acts stiffer than other model in which SSI effects were considered. Also, TMD was added to the models to decrease structural responses. However, it was shown that TMD does not perform satisfactorily out of its tuned frequency domain. Therefore, considering SSI effects is highly recommended before tuning TMD properties.

Moreover, wind turbine's behavior was investigated under wave and wind loads. It was observed that a flexible-base structure deformed more than the fixed-base structure. All in all, implementing simplified models will have significant drawbacks, such as underestimating displacements and incorrect tuning parameters for control vibration systems. Therefore, SSI effects are an essential part of wind turbines design procedure and shall not be neglected. To develop the current study, it is suggested to investigate soil-structure interaction effects on taller wind turbines. In addition, wind turbine's response utilizing adaptable control vibration system and multiple TMDs are recommended for future studies.

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„BAOBAB" IN LUBLIN AS AN EXAMPLE OF CREATING A NEW QUALITY OF SOCIAL INTEGRATION SPACE

„BAOBAB" W LUBLINIE JAKO PRZYKŁAD TWORZENIA NOWEJ JAKOŚCI PRZESTRZENI ZINTEGROWANEJ

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Abstract

The outbreak of the war with Russia in Ukraine has caused an increase in the number of refugees arriving in Poland and other European countries. From the early days of the conflict, support and integration centers began to emerge in many cities, changing the landscape of public and cultural spaces and creating new opportunities to address the migration crisis. Lublin quickly responded to this crisis at the start of the conflict. After more than two years, the city has gained about 20.000 new residents. Their presence is evident socially and through new places and functions for integration, assistance, and humanitarian support. The organization of these places has significantly changed, initially relying on temporary solutions and later developing permanent informational and integration centers. A notable example of successful integration is the Baobab[1] Multicultural Integration Center in central Lublin, which serves as a high-quality, inclusive space for building connections, and integrating residents.

Keywords: multicultural integration, intervention architecture, migration, safe spaces

Streszczenie

Wybuch wojny z Rosją na Ukrainie spowodował wzrost liczby uchodźców przybywających do Polski i innych krajów europejskich. Od wczesnych dni konfliktu w wielu miastach zaczęły powstawać centra wsparcia i integracji, zmieniając krajobraz przestrzeni publicznej i kulturalnej oraz stwarzając nowe możliwości rozwiązania kryzysu migracyjnego. Lublin szybko zareagował na ten kryzys na początku konfliktu. Po ponad dwóch latach miasto zyskało około 20 000 nowych mieszkańców. Ich obecność jest widoczna społecznie oraz poprzez nowe miejsca i funkcje integracji, pomocy i wsparcia humanitarnego. Organizacja tych miejsc uległa znacznej zmianie, początkowo polegając na rozwiązaniach tymczasowych, a później rozwijając stałe centra informacyjno-integracyjne. Godnym uwagi przykładem udanej integracji jest Centrum Integracji Wielokulturowej Baobab w centrum Lublina, które służy jako wysokiej jakości, inkluzywna przestrzeń do budowania połączeń i integrowania mieszkańców.

Słowa kluczowe: integracja wielokulturowa, architektura interwencyjna, migracja, bezpieczna przestrzeń

[1] The Baobab Multicultural Integration Center, abbreviated as CIW Baobab, is the first multicultural integration space created by the Homo Faber Association in collaboration with the City of Lublin and other organizations.

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1. INTRODUCTION

In recent months, it has often been said in social organizations that the reality we live in is somehow a permanent crisis. It consists not only of migration movements caused by wars or political instability in a country or region, political populism, but also the climate crisis and the still-remembered pandemic.

The war in Ukraine, which began with Russia in 2014 and escalated dramatically in February 2022, has led to one of the largest migration crises in Europe since World War II. The conflict not only destroyed infrastructure and caused thousands of casualties, but also forced millions of people to flee their homes.

As a result of Russian aggression, more than 13 million people have been forced to flee their homes. Of this number, about 8 million were internally displaced, and more than 5 million found refuge in neighboring countries such as Poland, Romania, Hungary and Slovakia. Poland became the largest „recipient" of Ukrainian refugees, taking in more than 3 million people [1].

Social factors and dramatic events are not the only causes of the migration crisis. The rising curve of global warming will make entire regions of the planet uninhabitable in the next decade, which will entail a migration movement of enormous proportions [2].

1.1. Social Integration in the Context of Creating a New Quality of Architecture and Public Spaces

There are different aspects of integration:
– institutional, legal, and political,
– economic,
– social,
– cultural,
– spatial [3].

This article addresses the spatial aspect and the role of architecture in social integration.

The philosophy of integrative architecture focuses on creating spaces that foster mutual understanding, cooperation, and sustainable coexistence of different cultures. In the context of multiculturalism, integrative architecture plays a key role in building communities that are open, diverse, and cohesive.

In integration analyses, attention is paid to various „meeting spaces" [4] or „domains of integration" [5], not only neighborhood relations but also contacts during daily life: in public places (e.g., streets, parks, neighborhoods), in institutionalized spaces such as workplaces, schools, social organizations, and in places of entertainment and consumption.

Human behaviors not only fill spaces, encountering various types of conflicts, but they can also shape them [6].

New users appearing in public spaces can evoke different emotions among „old residents," both positive (curiosity, compassion, willingness to help) and negative (reluctance, irritation, fear). The more migrants appear in a given place in a short time, the stronger these emotions may be. The task of architecture in the social dimension can be to minimize potential tensions and conflicts by creating friendly places for integration.

The role of architecture as a tool for social integration and the prevention of social exclusion and potential conflicts has been recognized by many researchers [7].

A separate research issue is the role of the architectural features of the residential environment in creating safe and friendly living spaces for residents of different backgrounds and cultural contexts [8].

Already in 1974, Henri Lefebvre, in his groundbreaking work *The Production of Space* [9], highlighted that space is not merely a neutral backdrop, but rather something shaped by social and cultural influences. Lefebvre argued that space is produced through various social, economic, and political processes, thus ceasing to be simply a material reality and becoming a complex socio-cultural construct. Although Lefebvre's work does not directly address multicultural architecture, his theories have helped to understand how space is used and perceived in complex societies. They laid the foundation for concepts that would later become significant in designing spaces for multicultural integration. In 1983, Kenneth Frampton, in his essay *Towards a Critical Regionalism: Six Points for an Architecture of Resistance* [10], addressed the concept of critical regionalism as a response to the cultural homogenization resulting from globalization. Frampton believed that architecture should draw inspiration from local cultural traditions, creating designs that both preserve local character and meet the needs of various groups. Critical regionalism suggests integrating elements of cultural traditions into modern projects, which helps to build a spatial identity and avoid the loss of unique cultural values. Frampton argued that architecture can be a form of „resistance" against globalization, preserving cultural diversity in designed spaces. In his 1994 book *Architecture* *and Disjunction* [11], Bernard Tschumi analyzes how architecture can serve as a space of encounters and interactions between diverse cultural groups. For Tschumi, architecture should not be bound by traditional norms but instead used as a tool to break conventional patterns and forms. Spaces designed with multiculturalism in mind, which diverge from traditional architectural principles, have the potential to bring together people from different backgrounds and experiences. Tschumi emphasizes that architecture should foster inclusivity and serve as a space where people can explore new forms of interaction, positively impacting intercultural relationships. In the 2017 work *Heritage and Hybrid Spaces: Integrating Cultural Identity in Architectural Design* [12], L. Hussein discusses the importance of integrating cultural identities in architecture through so-called hybrid spaces. These spaces combine various styles and symbolic elements that reflect the cultural diversity of a community. Hussein suggests that architects, by designing hybrid spaces, can promote community and intercultural dialogue. Hybrid spaces foster building intercultural bonds by including elements recognizable to different groups, allowing everyone to feel a sense of belonging and acceptance. This is especially important in cities where cultural diversity is a key element of the social fabric. Modern urban architecture influences the integration of different cultural groups by designing spaces that promote multiculturalism. Contemporary architect Giancarlo Mazzanti [13] notes that architecture can be a generator of new behaviors and human relationships, inspiring people to explore unconventional ways of thinking and acting. In his projects, Mazzanti emphasizes that appropriately designed space affects users' behaviors, both physically and mentally, becoming a tool that encourages people to engage in interactions they might not have undertaken otherwise. This is particularly evident in public spaces such as parks, community centers, or meeting places, where people from diverse backgrounds can come into contact and discover new ways of building relationships. Mazzanti suggests that architecture can not only reflect cultural diversity but actively support it by creating spaces that encourage new forms of coexistence and mutual understanding.

1.2. Materials and Methods

The aim of the study was to analyze the phenomenon of creating and maintaining permanent informational, integrative, and supportive places, and to determine their role in creating a multicultural urban landscape and supporting social integration. To this end, an analysis was conducted of places offering various forms of support and integration for migrants that have been established since March 2022 (both existing and non-existing). Their locations, offerings, and degree of integration, as well as their impact on public space (immediate surroundings), were then examined. During the research, the Baobab Integration Center was identified as a standout implementation. This facility and the building it occupies became the subject of detailed research – a case study. Additionally, 25 surveys were conducted among users of the MIC Baobab, along with a series of interviews with employees and volunteers.

The analysis of available press information and reports from humanitarian organizations formed the basis for formulating the main research assumptions, as well as for obtaining quantitative and qualitative information.

2. MULTICULTURAL LUBLIN YESTERDAY AND TODAY

A city embodies diversity, which results in creating a space for exchange – a characteristic of urban spaces recognized since ancient times [14]. Lublin is the largest city in eastern Poland, with a population of approximately 324,000 residents. For about 20 years, multiculturalism has been one of the key elements in building the city's promotional policy and brand. Until 2014, this multiculturalism was primarily understood as part of the city's historical cultural identity. Lublin's multicultural history is linked to its location and political-economic conditions. From the beginning of Lublin's urbanization, there was significant „Ruthenian" settlement, and from the second half of the 15th century, Jewish settlement began to develop. By the mid-16th century, synagogues and the first social welfare institutions existed in the Jewish-inhabited Podzamcze. Since 1668, a privilege granted by King Sigismund Augustus protected the rights of the ghetto's Jewish community and prohibited non-Jews from buying or leasing land there – privilege de non toleransi Christianis [15]. Residents from Western Europe significantly contributed to Lublin's industrial development by initiating important economic and social enterprises. Among these „industrialists'' were the Vetter, Moritz, Kern, Hess, and Krauze families [16]. Strong Russian influences during the Russian partition resulted in the stationing of a large military contingent and influential officials in the city.

2.1. Multiculturalism Reflected in the City's Space and Architecture

Multiculturalism has been reflected in the city's space and architecture. The Jewish Quarter, encompassing the area of the former Podzamcze, began to expand northward along present-day Lubartowska Street in the 19th century. The Ukrainian population settled near the church. The first industrial plants were located in the city center (occupying abandoned buildings, including former monastic ones), with subsequent ones emerging near the railway line. These buildings and complexes stood out in the urban structure. Before the war, the city had about 125,000 residents, of whom 42,830 were Jews and 574 were Ukrainians. The Second World War brought an end to this multiculturalism. It was only at the beginning of the 21st century that the city began to „rediscover" its multiculturalism, striving to build the city's brand on it.

As part of the city's tourism policy, the „Multicultural Lublin" tourist trail has been operating for years, including sites such as the Evangelical-Augsburg Church, the building of the former Greek Church, the site of the Great Synagogue, and the Orthodox Church. The city's most valuable monument (on the UNESCO list) is the Chapel of the Holy Trinity with Byzantine-Ruthenian frescoes. Regular events promoting multiculturalism include the Ukraine in the Center of Lublin Festival, the Sonosfera Lubelska music event, and the Different Sounds Festival. Multicultural Lublin today results from political processes, economic conditions, and the policies of the city and various institutions striving for internationalization. This process is most visible in the academic environment. As the total number of students decreases, the process of internationalization increases (Kruk). In 2019, Lublin ranked 4th in the country in terms of the number of foreign students.

Research conducted after several weeks of assistance to Ukrainian refugees by the Union of Polish Metropolises showed that as of April 1, 2022, 17% of Lublin's residents were Ukrainian citizens (a 20% increase in the city's population). Ukrainian residents have become „noticeable" since 2013. In 2013, nearly a hundred people gathered at Litewski Square – Lublin's main public space – to protest the Ukrainian government's decision to postpone signing the association agreement with the European Union. A year later, protests against the war in western Ukraine took place in the city center, successfully drawing public attention. In 2015, the influx of labor migrants and complicated residence legalization processes caused queues at the Department for Foreigners, leading to protests in the streets of Lublin. The outbreak of war in Ukraine dramatically changed the situation, becoming a test of hospitality, willingness to provide immediate and long-term assistance, and, above all, readiness to embrace the true, permanent multiculturalism of the city.

3. ACCOMMODATION SPACES AND PLACES OF SOCIAL INTEGRATION WITHIN THE STRUCTURE OF LUBLIN

In the first months of the war, accommodation locations included hotels, dormitories, and

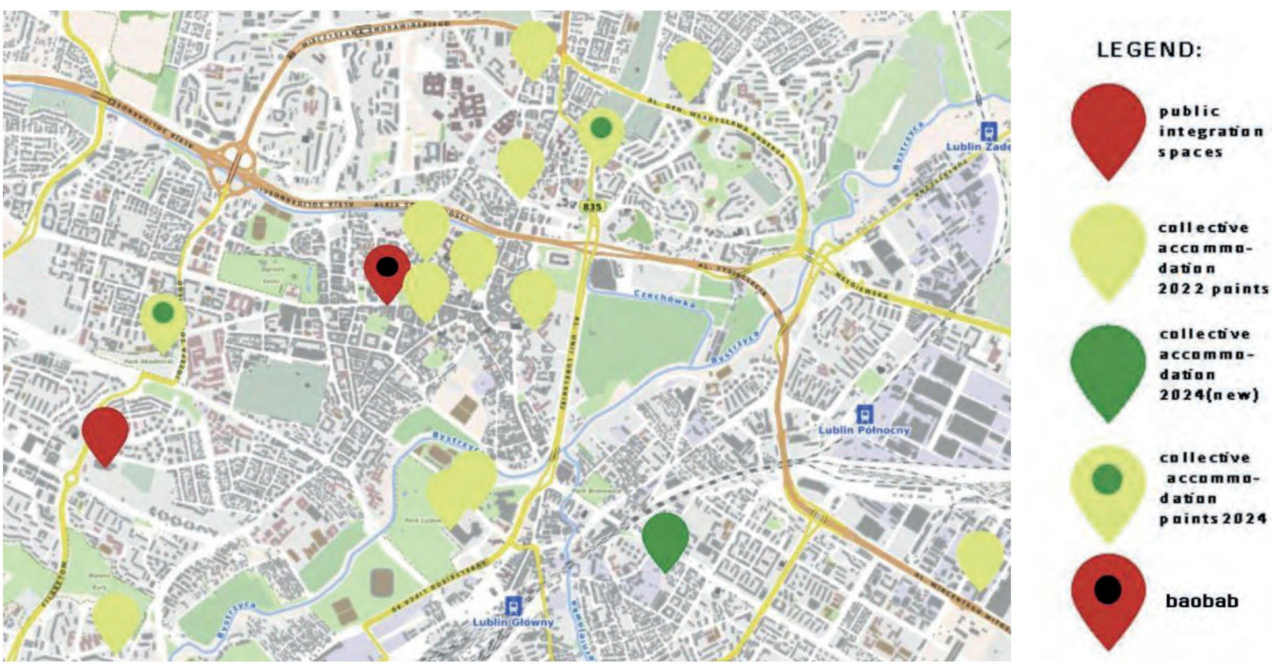

Fig. 1. Analysis of the distribution of service and integration spaces in the Lublin area. Compiled by Y. Posuniak

repurposed spaces such as swimming pools, school gymnasiums, and a hostel for the deaf. In the next phase of migration, places were organized to offer organizational help, support, and cultural and integration events. These functions were hosted in spaces either used „one-time" for specific events or in buildings for which this new function was a chance for the „life" of the building (Fig. 1).

The map shows the city of Lublin with points marked by colorful markers, indicating places associated with integration and assistance processes, as well as collective accommodation points from February 2022 and April 2024. The analysis covers the period from February 2022 to April 2024 and identified 16 locations housed in various adapted facilities.

The analysis reveals a concentration of different accommodation points in the central and northeastern parts of the city, with several integration spaces strategically located. These spaces are crucial for supporting the integration process of migrants, allowing them to interact with the local community in open and accessible places. MIC Baobab stands out due to its central location in the city, rather than in a residential district.

Fig. 2. Selected service and integration spaces in Lublin: a) the corridors of Lublin Culture Center (2022) have become a space for celebrating Christmas in the Orthodox rite, b) concert and cinema hall as a command center from the first days of the war, c) information center (2023) and shop (2024), d) mosir swimming pool hall as an accommodation space (2022), photo by Maciej Rukasz, Bartek Żurawski

Table 1. Overview of basic information regarding analyzed objects

No#	Type of Support Function	Type of Primary Function/Occupied Building	Remarks	Functioning time
1	accommodation point	swimming pool hall/ Hala Mosir	one of the first points	until spring 2022
2	accommodation point	sports hall /Podwale	–	until spring 2024
3	accommodation point	dormitory/ dormitory UMCS Helios	accommodated nearly 410 people	still
4	accommodation point	dormitory/ dormitory UM Chodźki	accommodated nearly 70	still
5	accommodation point	dormitory/hostel for Deaf Individuals	–	until spring 2024
6	accommodation point	sports hall/ Start	–	until spring 2022
7	accommodation point	hotel/Hotel Europa	–	until summer 2023
8	accommodation point	hotel/Hotel B&B	–	until summer 2023
9	accommodation point	hotel/Hotel	–	until summer 2023
10	„Command Center"	cultural centre/ Centrum Kultury	–	until summer 2022
11	„Command Center"	restaurant bar/Astoria	currently on the ground floor shop	until 2023
12	Integration Center	sports hall/Hala Globus	on the district rock	still
13	Integration Center „Baobab"	an inactive/former bank	on a city scale	still
14	accommodation point	school/Zemborzycka	–	until 2023
15	accommodation point	hostel/Magnoliowa	–	until 2023
16	accommodation point	kindergarten/Bronowicka	nearly 50 people were accommodated	still

Against the backdrop of the analyzed initiatives and facilities, MIC Baobab stands out for its lasting function and significant development potential. Its central location enhances accessibility. The building is occupied by the Homo Faber organization, which, in collaboration with other non-governmental organizations and with the support of the city of Lublin, manages the space and continuously adapts it to meet the users' needs.

4. CASE STUDY: FUNCTIONAL AND SPATIAL STRUCTURE OF MIC BAOBAB

MIC Baobab is a multifunctional space designed to meet the diverse needs of the community. The architecture combines modern solutions with accessibility and flexibility. The headquarters of MIC Baobab is housed in a building constructed between 1923-1925, originally the Bank of Polish Land (designed by architect B. Żurkowski), which is the first building in Lublin with a reinforced concrete frame structure [17]. Until 2012, the building served as a PKO Bank branch. By 2022, the space was unused due to its specific function. In 2022, the city of Lublin, the construction company Strabag, and Ikea supported the organization in preparing the building for its new function. Located in the city center among tenement houses, the building has five floors, including two underground levels.

The entrance to the building is from Krakowskie Przedmieście Street, which at this section extends the main pedestrian route in the city center, known as Deptak. Since the building is in the second line of buildings, the entrance is preceded by a gate in the first-line tenement and a cozy courtyard.

The ground floor is arranged as the "Witalnia". In Ukrainian (вітальня), it means living room, while in Polish, (witalny) means welcoming. To understand the difference, compare the English term (living room) with the German (Lebensraum). For English speakers, a (room) is just part of a house's interior, while a (living room) is defined by the daily activities of its residents. In the concept of (Lebensraum), the sense of life approaches what philosopher Martin Heidegger described as the fundamental feeling of dwelling – not just occupying a built world but the process of inhabiting the earth [18]. The philosophy of the Witalnia is about meeting, conversing, and being together. The central point of the "Witalnia" is the information point (Front desk), clearly marked to ensure easy orientation and communication. This space, through its arrangement and functionality, aims to create a home-like atmosphere, representing the daily space of a home.

On the ground floor, a multilingual library is organized. This space is located in the corner of the building and has the potential to expand as the number of volumes grows. Large windows provide natural lighting for the reading area. An essential element is the children's play area – a safe, colorful space designed according to child safety principles.

A multifunctional culinary space with modern equipment supports communal cooking and learning. A multifunctional stage with appropriate lighting and sound is used during cultural events, though it faces some acoustic issues due to strong reverberation.

Another important daily use area is the coworking space, an adaptable work environment equipped with ergonomic furniture, promoting collaboration and individual work.

The ground floor restrooms are accessible to all users, designed with convenience and hygiene in mind, and are architecturally accessible.

The first floor houses workshops, offices, and workspaces. One of the workshops is an advanced kitchen with a space for cooking lessons, appropriate equipment, an ergonomic layout, and dining areas. Another workshop is the "Light Workshop" – a space for manual work requiring precision, with customized workstations. It is spacious and well-lit.

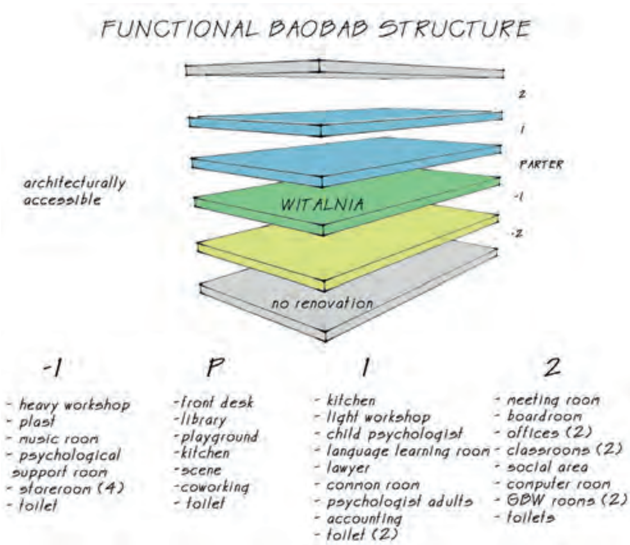

Fig. 3. Functional diagram of the Baobab Multicultural Integration Center in Lublin. Compiled by Y. Posuniak

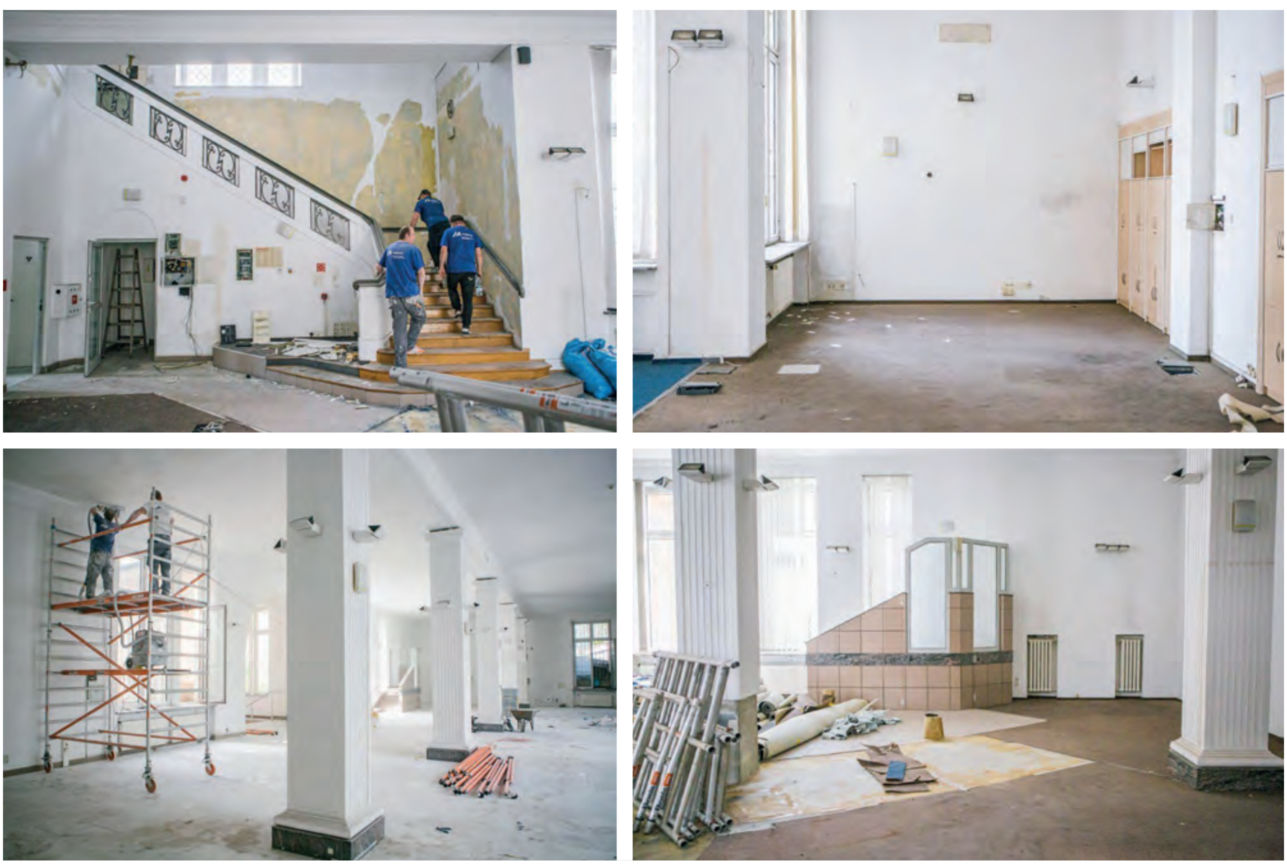

Fig. 4. Interior of the Baobab Multicultural Integration Center during adaptation works. Photo by Bartek Żurawski

On the second floor, the following have been organized: a child psychologist's office (a cozy office with colorful decoration, adapted to work with children, well-lit), a psychologist's office for adults (providing privacy and comfort, with neutral, calming decor), language study rooms (fully equipped classrooms with modern teaching aids and flexible arrangement of furniture, blackboard and large screen), a lawyer's office (providing privacy and comfort for clients, with appropriate office equipment). The whole is complemented by a common room. It is a space for spending time together, with facilities for children, with comfortable seating and interactive elements, books and toys, and has a separate toilet.

The administrative area, which is distinguished by limited access (locked, exit only for employees with access), is also located on the first floor. The accounting office, with ergonomic equipment conducive to administrative work, has 3 workstations and an archive with a separate entrance from the corridor.

For the second floor level, there are also two toilets adapted to hygienic standards.

The second floor houses offices, administrative rooms (including management offices), a meeting room (spacious rooms with appropriate technical equipment, suitable for meetings and conferences for the team). This level also houses two classrooms with flexible furniture layout and modern teaching equipment, a computer room (equipped with modern computers and internet access, designed for study and work). GBV Room (2): classrooms for group activities and workshops, with flexible furniture layout and appropriate equipment.

Additional features include restrooms and a social space for employees and building users, conducive to relaxation and integration. Below-ground levels are currently partially utilized. On level –1, several studios have been organized:

Heavy Workshop: A space equipped with ergonomic workstations and tools for heavier manual tasks, including areas for electronics work. The design incorporates ventilation and meets occupational health and safety standards.

Art Studio: A lounge for Ukrainian scouts with a separate entrance, ensuring independence from other areas in the building. It comprises a large room, restroom, storage area, and vestibule.

Music Room: Fully equipped for musical activities.

Psychological Aid Room: A comfortable, intimate space designed for privacy and tranquility, featuring decor and colors that support relaxation and safety.

Former bank vaults have been repurposed into four warehouses, serving as functional and spacious storage facilities, such as for office materials. The restroom on level -1 includes a shower but is not accessible to persons with disabilities.

The second underground level is currently unused but awaits adaptation, potentially for future development or as reserve space to meet changing needs.

Analyzing the functional-spatial layout and architectural features, architectural accessibility is a key consideration. The building is listed as a historical monument, requiring adaptations for users with special needs, particularly for the Baobab MIC headquarters. Currently, the ground floor is fully architecturally accessible, with plans to install an internal elevator for the remaining levels.

The functional-utility scheme of the analyzed facility exemplifies the introduction of a modern, multifunctional space into a historically significant structure whose original function became obsolete. Through thoughtful architectural adaptation, the interior promotes social integration, education, and psychological support. The space is also accessible to users with pets.

4.1. Integration through activation: A case study of Baobab Multicultural Integration Center

MIC „Baobab" offers a wide range of activities that can be conducted within its space. The community must be free from physical and social threats, including all forms of violence, and should serve as a focal point for residents, providing various types of living and integration spaces, and creating life opportunities. Residents should have the opportunity to play a significant role in both long-term planning and making immediate decisions. In the case of MIC „Baobab," a series of cultural and support events, as well as ideas for addressing specific architectural issues, have been consulted with users. The space and its potential activities are expanding systematically and flexibly adapted to current needs. MIC „Baobab," as a place on the cultural map of the city, is increasingly noticeable and recognizable to the residents of Lublin, making the space more visible within the cityscape. The former bank building has acquired a new function that aligns with its original architectural structure and allows the facility to be returned to public use.

The results of the survey answered how MIC „Baobab" truly meets the needs of its users and the merits of its current architectural arrangement (Fig. 6).

Fig. 5. Selected activities integrating the local community and migrants at the Baobab Multicultural Integration Center. Photo by Bartek Żurawski

The integration of multicultural communities can be significantly strengthened through activation, which involves creating opportunities for social and cultural engagement. Activation encourages individuals from diverse backgrounds to participate in collective activities, fostering understanding and cooperation. Organizing social events, educational programs, and cultural activities allows people to connect on a common platform, breaking down barriers and stereotypes. Social activation creates space for mutual understanding and building lasting relationships, not only among multicultural and multigenerational groups, which is crucial for integration processes.

One way of integration is through the process of creating and caring for shared spaces. The „Heavy” and „Light” studios offer opportunities for woodworking, furniture repair, welding, electrical work, sewing, and embroidery, providing a hands-on way for participants to get to know each other.

Another aspect of activation is access to education: classes in Polish and English language, computer software training, lessons on the job market, human

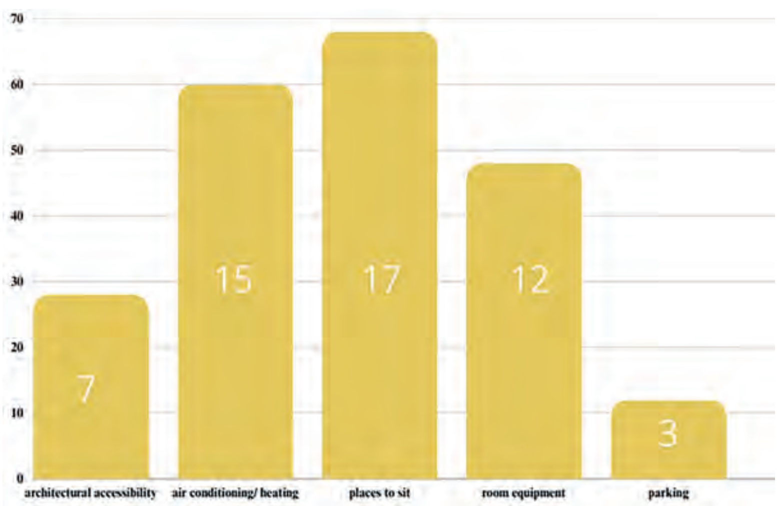

Fig. 6. Architectural amenities identified by respondents as most important – percentage share of responses in a multiplechoice survey. The number of mentions is indicated on the bars. Compiled by Y. Posuniak

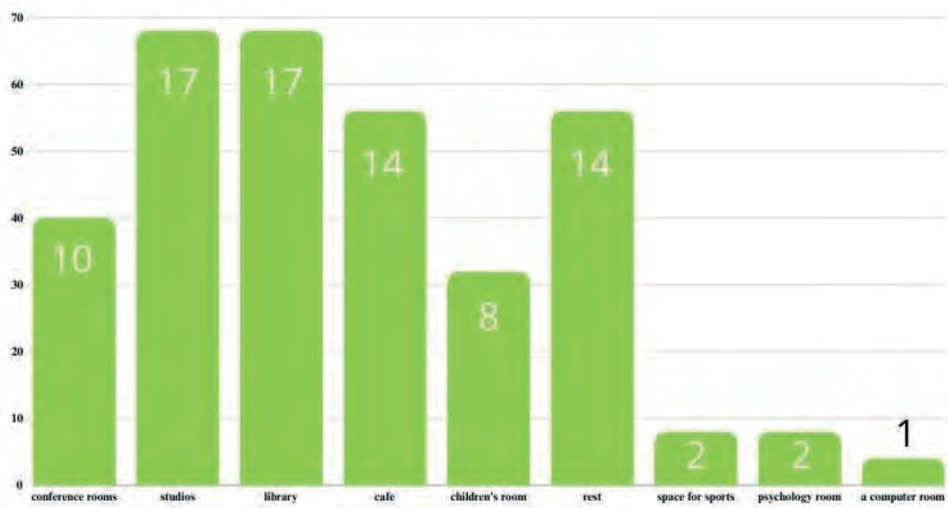

Fig. 7. Functions identified by respondents as most important at the Baobab Multicultural Integration Center – percentage share of responses in a multiple-choice survey. The number of mentions is indicated on the bars. Compiled by Y. Posuniak

rights, and minority groups. Users of Baobab are encouraged not only to use the facilities but also to co-create and independently organize events for others.

This situation is similar to spatial planning, where participants can be individuals, groups of people, or more or less formalized organizations. All participants in urban space management can be classified based on the type and activities of active and passive participants [9]. The opportunity to realize one's social potential contributes to a sustainable process of assimilating individuals with varying migration experiences, as well as „ordinary" residents of Lublin.

The bar chart illustrates the results of a multiple-choice survey where respondents indicated the most important architectural amenities (Fig. 6). Each bar represents a different amenity, with its height corresponding to the percentage share of responses. The numbers on the bars indicate the number of responses for each amenity. The categories „seating areas" received the most responses (17 answers), followed by „air conditioning/heating" (15 answers), suggesting that these fundamental aspects are considered most important by the respondents.

Other categories such as „room facilities" (12 answers), „architectural accessibility" (7 answers), and „parking" (3 answers) were also considered but received fewer votes. This indicates a diversity of user needs, but with a strong emphasis on comfort related to seating areas and climate control within buildings.

From the analysis of responses regarding the current functional program, it appears that the most important facilities for respondents are „studios" and „library," each receiving 17 mentions (Fig. 7). The next significant functions are „cafe" and „rest area" with 14 mentions each. „Conference rooms" received 10 mentions, and the „children's room" received 8. The least significant were „sports area," „psychological room" (both with 2 mentions each), and „computer lab" (1 mention).

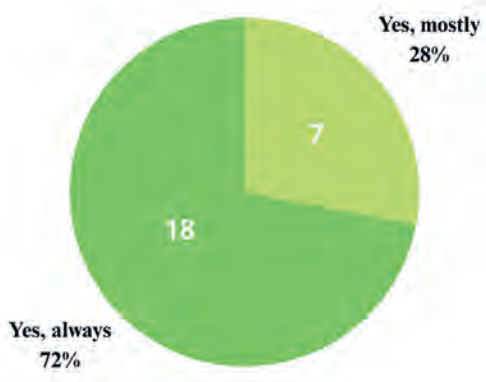

Fig. 8. Pie chart reflecting respondents' answers to whether they feel safe at the Baobab Multicultural Integration Center. The numbers are indicated on the segments. Compiled by Y. Posuniak

The issue of safety is crucial in the context of designing integration spaces. Individuals using such places should have the opportunity to experience meetings and open themselves to new cultures and religions. At the same time, it's important to consider that migrants may have traumas associated with migration experiences. Well-designed spaces can facilitate their adaptation by creating conditions that promote a sense of security and emotional comfort. All respondents answered positively regarding their sense of safety at MIC Baobab.

5. CONCLUSIONS

The analysis of the relatively short but intense period (2022-2024) of creating new spaces for social integration and support in Lublin highlights the significant role these functions potentially play in shaping new quality social spaces and in revitalization processes.

In recent years, Lublin has practically returned to its multicultural tradition, with the war acting as a catalyst for this process. Before the conflict in Ukraine, the city's international character was primarily defined by its academic environment [19]. However, the war has brought noticeable changes not only to Lublin's social structure but also to its public spaces. A new symbolism, language, and new users have become visible. Among the functions and services that emerged with the outbreak of the war (supportive, intervention, and cultural), those that align with the city's cultural offerings have persisted to this day. Baobab serves as an example of an institution with both integrative and cultural functions. Its implementation in a previously unused historic building contributed to its revitalization and made it accessible to „new and old" residents of Lublin.

6. SUMMARY

Diversity offers an opportunity for development and enrichment, but for it to be effectively used as a tool for positive change, education and openness to experiences of otherness are essential. Throughout the centuries, we have embraced various cultural elements like Italian Baroque, French Gothic, or enjoying Indian tea from German porcelain, often forgetting that everything we touch is woven from the culture and people who create it.

Adolf Loos recognized that modern life unfolds on two independent yet interconnected planes: individual experience and social existence. These are two irreducible but related systems. Interior spaces speak the language of culture and experience, while exterior spaces speak the language of civilization and information [20]. Often, these languages intersect and complement each other, sometimes challenging to understand, and their combination should be seen as an ongoing process. The role of architecture in multicultural integration is also a part of this process.

Architecture and migration are closely linked in the context of integration because urban design significantly influences the integration process of migrants. Well-planned architecture can support community-building through public spaces that facilitate meetings and interactions among residents of diverse backgrounds. Conversely, neglecting this aspect in urban planning can lead to ghettoization and isolation of migrants, hindering their social and cultural integration. Therefore, a balanced approach to urban design is crucial for effective migrant integration into society [21].

It is noteworthy that researchers from diverse backgrounds have begun to develop methods to study the connections between public spaces and urban life simultaneously. They all responded to the fact that people have been overlooked in urban planning [22]. Migrants and ethnic minorities are becoming invisible residents of cities.

Thoughtful design of public spaces and facilities, such as integration centers, supports meetings and interactions among residents. Architecture that considers the needs of different social groups promotes inclusivity and accessibility, creating an environment conducive to integration. Examples of such projects include open shared spaces that can be used for various activities, and buildings designed with multiculturalism in mind, where diverse groups can feel comfortable and safe. Architecture, as a physical expression of social values, can effectively support integration processes through activation.

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PROBLEMS OF ENVIRONMENTAL INTERFERENCE IN EMERGENCY REPAIRS OF RAILWAY SECTIONS – A CASE STUDY

PROBLEMY INGERENCJI W ŚRODOWISKO PRZYRODNICZE PRZY NAPRAWIE AWARYJNYCH ODCINKÓW LINII KOLEJOWYCH – STUDIUM PRZYPADKU

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Abstract

This article presents the history of identifying the causes of emergency threats and the repair of a section of the railway line within the Wolin National Park. The author focuses on issues related to the legal aspects of environmental protection in a specially protected area that arose during the design and execution of repair works on the railway infrastructure.

Numerous meetings between the Management of the Railway Line Department in Szczecin and the Management of the Wolin National Park, with both sides fully understanding the essence of technical and environmental problems of the project, led to a consensus. The scope and method of repair were established, allowing the minimization of the negative impact of the investment process on the park's natural and environmental values while ensuring the safety of train traffic.

Despite the typical and straightforward nature of the repair task, due to environmental protection constraints, non-standard construction problems were encountered, which consequently increased costs and extended the construction time.

Keywords: slope, erosion, emergency threat, railway line, environmental protection, train traffic safety, landslide

Streszczenie

W artykule przedstawiono historię ustalenia przyczyn zagrożenia awaryjnego i naprawy odcinka linii kolejowej w obrębie Wolińskiego Parku Narodowego. Autor skoncentrował się na problemach związanych z prawnymi aspektami ochrony środowiska przyrodniczego na terenie obszaru szczególnie chronionego, które wystąpiły w trakcie projektowania, jak i wykonywania budowanych robót naprawczych kolejowej infrastruktury komunikacyjnej.

Liczne spotkania pomiędzy Dyrekcją Zakładu Linii Kolejowych w Szczecinie a Dyrekcją Wolińskiego Parku Narodowego, przy pełnym zrozumieniu przez obie strony istoty problemów technicznych i środowiskowych przedsięwzięcia, doprowadziły do uzyskania konsensusu. Ustalono zakres i sposób naprawy, który pozwolił na zminimalizowanie negatywnego oddziaływania procesu inwestycyjnego na walory przyrodnicze i środowiskowe parku przy zapewnieniu bezpieczeństwa ruchu pociągów.

Mimo typowego i prostego w realizacji zadania przy wykonaniu naprawy, ze względu na obostrzenia wynikające z ochrony środowiska przyrodniczego, natrafiono na niestandardowe problemy budowlane. W konsekwencji wpłynęło to na wzrost kosztów oraz wydłużenie czasu realizacji robót budowlanych.

Słowa kluczowe: skarpa, erozja, zagrożenie awaryjne, linia kolejowa, ochrona środowiska przyrodniczego, bezpieczeństwo ruchu pociągów, osuwisko

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1. INTRODUCTION

A long-standing and seemingly insolvable conflict exists between the broadly understood development of industrial production facilities or technical infrastructure and the preservation of the natural environment's conditions in an untouched state. While obtaining a consensus is less problematic during the design phase of new investments, it becomes a challenging issue for existing investments that have suffered failures and disrupted the environmental equilibrium.

The importance of the problem is linked to the legal protection category of the natural environment on one side and the significance of the constructed facility for the state on the other (e.g., inclusion of the investment in critical infrastructure).

These problems frequently arise in the context of communication infrastructure, particularly railway lines, due to the extensive national railway network, its construction history, the pace of industrialization and development of specific regions, and primarily local geo-environmental conditions. Additionally, the situation is complicated by the fact that railway lines are a crucial element of Poland's critical infrastructure.

2. REQUIREMENTS FOR RAILWAY STRUCTURES

Railway regulations, consistent with the Construction Law Act [9], the Railway Transport Act [10], and industry regulations such as the MTiGM on technical conditions for railway structures and their location [7], as well as instructions [8, 12, 13], mandate the durability of the railway line structure.

The railway line's reliability must be ensured regardless of operational impacts and destructive factors and processes under all geo-environmental conditions. The subgrade is designed for a durability of 100 years, while the track (the upper part of the subgrade on which the track is laid) should be designed for a durability of 20 to 50 years, depending on the category of the railway line.

A crucial requirement for railway lines is forecasting changes in the subgrade and ground base for the broader safety of train traffic. Meeting these requirements is an engineering necessity for maintaining the natural environment's equilibrium.

Any failure or catastrophe of a railway line section disrupts the environmental balance and requires repairs to the level prescribed by the durability regulations of the building structure.

The problem highlighted in the article title will be illustrated with the case study of the post-emergency repair of the railway line section No. 401 Szczecin Dąbie – Świnoujście Port at km 84.800÷84.860 near the Międzyzdroje railway station (West Pomeranian Voivodeship, Kamień County, Międzyzdroje Municipality).

3. SHORT CASE DESCRIPTION

3.1. Location and Construction History of the Railway Line

Railway line No. 401 Szczecin Dąbie – Świnoujście Port was initially built as a single-track line, with sections gradually opened to traffic, and the entire line was operational by June 1, 1901. Between 1975 and 1980, the line was expanded to a double track. During the modernization, curve radii were changed, embankments were extended, and electrification was carried out.

The railway line on the discussed section is constructed in a cut, with a depth reaching approximately 10.0 meters [1-3].

3.2. Geological structure and terrain morphology

The discussed area is within the physiographic unit of the Uznam and Wolin Islands (313.21). The landscape of the discussed sheets has its unique features, marked by the contrast between low, expansive, and flat areas of the Świna Gate and the varied surface of the Uznam and Wolin highlands. These two sets of landforms are of different ages. The depression is entirely young Holocene, while the highland areas' relief was finally shaped during the last ice sheet's retreat [4, 5].

Both have a varied relief and structure. The western part of the area features fluvial and coastal accumulation plains, while the eastern part consists of hilly highlands. These are made of deposits from the Pomeranian phase of the North Polish Glaciation, in the form of stacked moraines and forms of aeolian and marine accumulation [5].

3.3. Existing condition at the time of research

Research work began on the emergency section when its condition threatened the safety of train traffic. The technical condition resulted from years of progressive slope degradation and occasional temporary repairs. The problem arose from the construction of two tracks with a significant correction of alignment and profile. The modernization resulted in a cut with a depth reaching 10.0 meters in homogeneous sands of a stabilized dune formed by aeolian processes.

To determine the technical condition of the ground base necessary for identifying the causes of the failure and designing repair works, appropriate

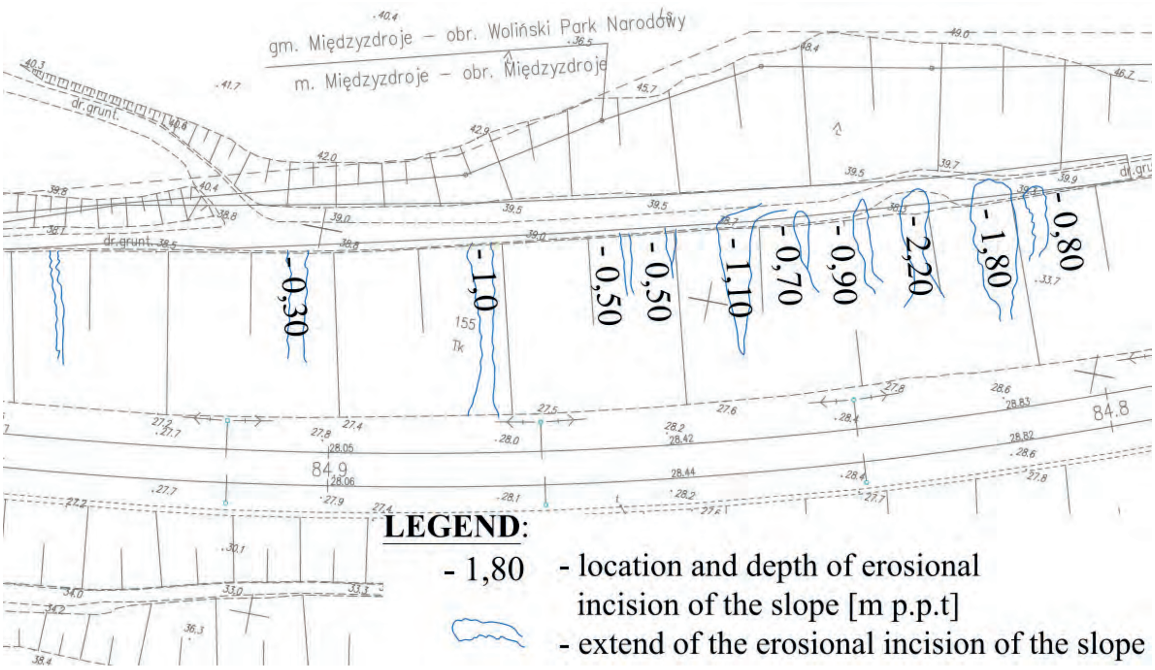

Fig. 1. Map of the railway line section with marked locations, depths, and extents of the erosive cuts on the slope

Phot. 1. Erosive funnel with washed-out fine sandy material. Photo by Tomasz Sobkowiak

geotechnical surveys were conducted, including 25 test holes, 15 light dynamic penetration tests (DPL), 10 heavy dynamic penetration tests (DPH), geodetic measurements, and laboratory tests. Additionally, the drainage condition within the railway line and adjacent area was analyzed, along with a review of construction and operation history and testimonies from individuals diagnosing the technical condition of the railway section.

The slope of the cut on the side of track No. 1 clearly showed signs of deformation in the form of erosive cuts with depths of up to 2.0 meters, and in some sections, the slope geometry was completely destroyed. This condition was a permanent state of the slope, which repeatedly underwent local landslide processes, directly threatening the safety of train traffic on this line [2].

3.4. Development mechanisms of destructive processes

Technical destruction of the slope results from the sum of exogenous phenomena and processes occurring within the ground base, construction, modernization, and maintenance history of the line, as well as zoogenic processes involving mechanical trampling of the slope within animal migration paths. The destruction zone is within the Wolin National Park. The phenomena and processes within this structure are objective.

The cut on the examined railway line section, as mentioned, was made within fine dune sands. These sediments are characterised by a very low value of the coefficient of differential grain size Cu, which for these soils is in the range of approx. Cu = 2.0. This value of the coefficient of differential grain size Cu indicates that the soil from which the excavation is built belongs to homogeneous, poorly compactible and easily loosened soils. Uniformly graded soils are easily loosened by external impulses such as vibrations and dynamic impacts, and surface water erosion is very intense on the slope surface. Dynamic probing results showed moderately compacted states bordering on loose states to significant depths below the surface.

The near-surface zone of the slope undergoes permanent, significant loosening (granular

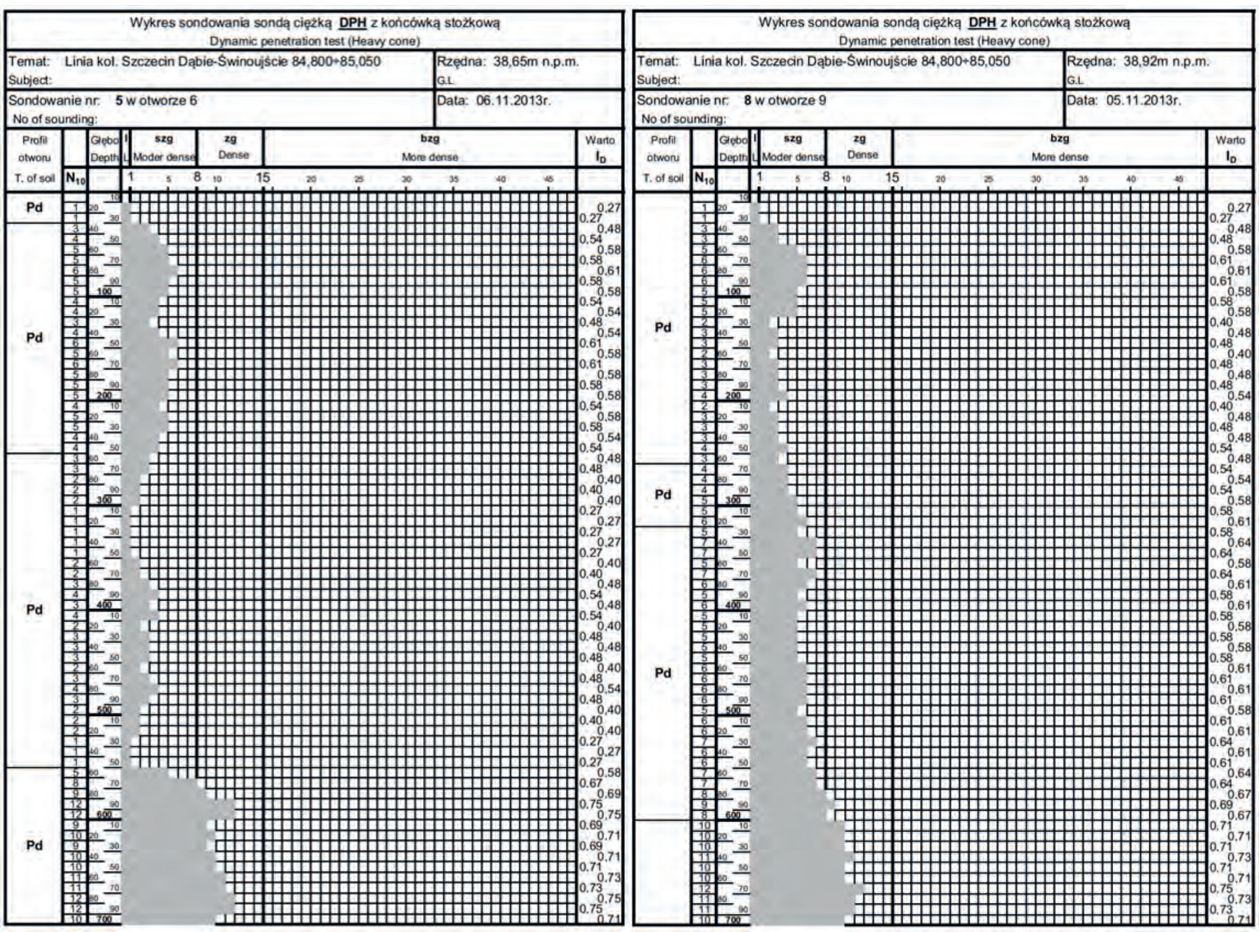

Fig. 2. Dynamic probing (DPH) test charts

disintegration) due to surface freezing and thawing, lack of vegetation (southern exposure with intense sunlight, especially in summer), runoff of rainwater, and significantly due to the movement of wild animals on the slope surface. The contribution of wild animals to the destruction of the slope also involved the construction of a system of underground burrows within it. The "channeled" runoff of rainwater in one place and the movement of wild animals specifically in the erosive cuts are the primary causes of slope instability.

The slope of the cut on the side of track No. 1, despite its depth exceeding 10.0 meters, has an almost uniform inclination. According to engineering standards, a slope with a height exceeding 6.0 meters must have a berm with a width of 1.0-2.0 meters with an outward slope or a variable inclination, starting with a smaller inclination at the base and increasing toward the upper part of the slope.

3.5. Wolin National Park directorate's position

The discussed section of the railway line is located within the Wolin National Park (abbreviated as WPN), therefore, the Investor - PKP Polskie Linie Kolejowe S.A., before commencing work, had to obtain approval for the design solutions, methods of conducting repair works, approval of materials anticipated for use during repair works, logistics arrangements within WPN, consent regarding the extent of territorial interference within WPN, and approval and conditions for the location of construction facilities.

For a number of specific aspects regarding the possibility, or rather the necessity, of repairing the railway line within WPN, approval had to be obtained from the Minister of Environment.

Consequently, on April 23, 2014, the Directorate of the Wolin National Park requested the Minister of Environment to issue a decision allowing deviations from the prohibitions in force within the Wolin National Park as specified in Article 15, paragraph 1, points 1, 3, 5, 9, 15, 18, 19, and 20 of the Nature Conservation Act [11] for the project *"Emergency repair of the cut slope of the railway line Szczecin Dąbie-Świnoujście"*, on the section passing through part of the Wolin National Park [6].

The WPN Directorate attached an opinion to the letter, explaining the essence of the project, describing the natural habitat, and addressing the repair method that allowed minimizing the negative impact of the investment process on the park's natural and environmental values.

3.5.1. Conditions for emergency repair - WPN's position

Despite challenging negotiations between the Investor and the WPN Directorate, both parties reached a consensus, fully understanding the technical and environmental problems. The following WPN opinion (in brief) was presented and accepted by the Ministry of Environment:

"The investment will be carried out entirely in the National Park area where semi-natural plant formations occur, partly natural habitat patches. These are xerothermic grasslands maintained by human activity limiting natural succession processes. In this context, the investment, with planned reclamation activities using only local materials and re-spreading the collected topsoil after the investment, ensures both their durability and local improvement of the state. The slope repair location and technology were designed to exclude interference with natural habitats and species habitats protected in the Natura 2000 area" [6].

The designer and contractor were obliged to:

1. Inform WPN about the actual implementation dates of active protection measures at least 7 days in advance and ensure the possibility of control during their execution.
2. Agreement with WPN on the methods and execution of land reclamation after the completion of the project within plot 42/7, including particularly the used access road, to enable the spontaneous restoration of forest plant communities.
3. Reclaim the repair site by restoring the topsoil layer using the collected topsoil with plant and fungal survival forms for profiling and filling geocells.
4. Prohibit the use of foreign materials like rubble and fertile soil for slope stabilization, geocell filling, or road adaptation.
5. Temporarily strengthen the access road surface in a fully removable manner after work completion using environmentally neutral materials [6].

3.5.2. Adopted repair assumptions

A compromise was negotiated, obliging the designer and contractor to undertake a challenging task, using innovative and rare (forgotten) construction technologies.

The following method was adopted for repairing the railway cut slope:

1. Reconstructed embankment geometry by filling erosion cuts with soil collected from slope profiling, binding new material with existing embankment through slope benching, and reinforcing the upper slope edge with geocell layers.

2. Implemented soak wells to manage runoff from the highland surface towards the cut.
3. To protect the slope surface from exogenous processes and the destructive impact of migrating animals, a flat geogrid and a cellular geogrid with a height of 100 mm were selected, fastened to the slope surface using a polymer rope system with polymer pins. This solution did not guarantee mechanical reinforcement of the slope.
4. Used CHANCE screw anchors without injection for mechanical reinforcement, marking a first in Poland's railway lines.
5. Completed the repair by restoring drainage along the tracks adjacent to the repaired slope.

3.6. Consequences of the agreement

The repair method presented in the previous chapter seems typical and straightforward in execution. However, upon examining the details, the repair turned out to be difficult and very challenging in terms of logistics and execution. Here are some of the problems that had to be faced:

1. **Selection of the slope reinforcement method – the use of screw-in nails.**
   Constraints resulting from the agreements between the investor and the WPN management obligated the contractor to use nails that do not introduce chemicals into the natural soil. The Polish construction market primarily offers injection nails and anchors proposed by various manufacturers. The essence of these reinforcement systems is the introduction of a chemical injection (mainly cement-based) into the natural soil to bind the soil with the drill rod, increasing friction, sealing, and thereby achieving the desired load-bearing capacity of the nail/anchor. To meet the environmental requirements imposed on the design solutions, it was decided to use, for the first time on railway lines in Poland, the American

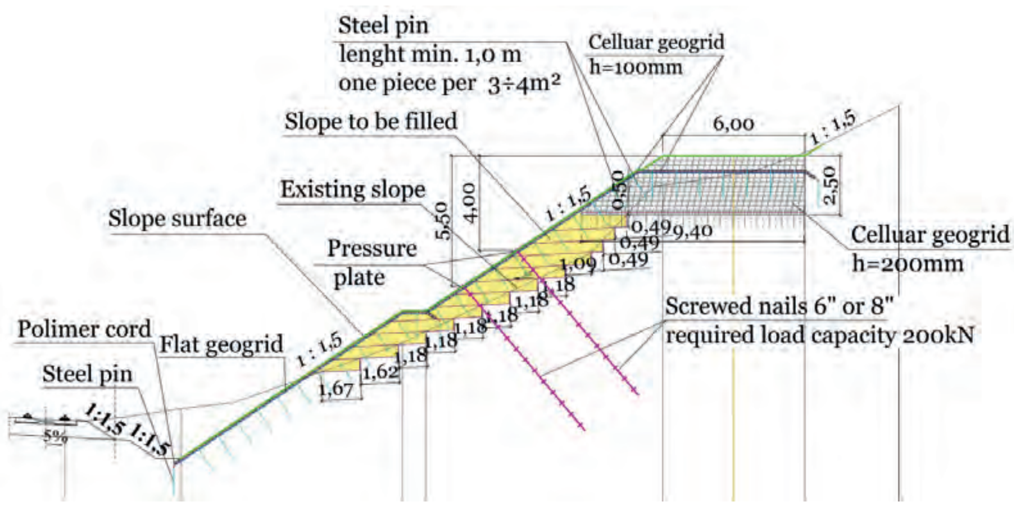

Fig. 3. Example cross-section from the construction project of the cut slope

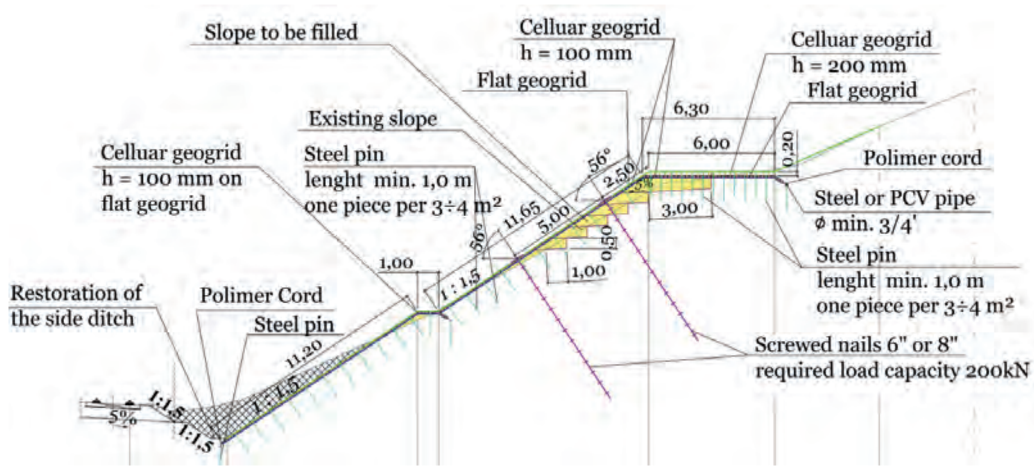

Fig. 4. Example cross-section from the construction project of the cut slope

Phot. 2. Installation of CHANCE non-injection nails. Photo by Tomasz Sobkowiak

technology of CHANCE screw-in nails. Organizing the entire screwing process required numerous procedures, as the selected technology mandated real-time control of the anchorage strength values. The screwing of the nails had to be conducted using factory-calibrated and equipped heads. The second significant problem that had to be addressed was the condition of obtaining a warranty for this technology from the producer of CHANCE screw-in nails. Supervision of the works had to be carried out by a person with credentials granted by the manufacturer. Due to the novelty and uniqueness of this technology in Poland, the author of this article, along with several other individuals, urgently attended the first appropriate course in Poland and obtained the manufacturer's certification for designing and supervising the installation of the CHANCE system.

2. **Logistical Problems**

According to the agreements, the park's internal roads could only serve as access routes for small construction equipment. Building materials, construction facilities, as well as large construction equipment, had to be delivered to the construction site by rail using railway platforms. Implementing the repair works according to the accepted project required the use of several crawler excavators, including the "Long" type, making logistics a significant challenge. For the entire duration of the works, the track adjacent to the damaged slope was taken out of service, along with the deactivation and partial dismantling of the electric traction. Temporary construction using geotextile and old wooden railway sleepers was necessary to protect the railway surface. On the adjacent track, the train speed was reduced along the length of the section where the construction works were being carried out. Preparing the working platform for the crawler excavator required building an additional earth buttress of appropriate width along the entire section of the works. Organizing the construction site and delivering equipment and materials was time-consuming, logistically challenging, and costly.

3. **Slope Seeding**

Seeding the slopes of embankments and cuts of earthworks for roads and railway lines is usually a standard part of construction completion and land reclamation. However, for the slope of the cut within Wolin National Park, this seemingly simple task became unfeasible. The condition set for the contractor regarding slope seeding was the prohibition of using any grasses other than those occurring naturally in the park – specifically, endemic grasses.

Providing seeds of grasses native to the park by Wolin National Park proved to be absolutely impossible, as the Park did not have such seeds, and selecting and purchasing the correct species composition and proportions of grasses was unfeasible. Despite the engineering awareness of an imperfectly completed repair, the requirements of the agreement between the investor and the park management were met by leaving the slope unseeded, hoping that nature would eventually replenish this deficiency on its own.

Phot. 3. Transport of a crawler excavator on a track temporarily out of service. Photo by Tomasz Sobkowiak

Phot. 4. Section of the ditch slope after completion of repair works. Photo by Tomasz Sobkowiak

The above describes only three of the many problems encountered during the project process and repair execution. Other issues that could be described include: the method of constructing soak wells without the use of heavy equipment, tree cutting for the purpose of conducting works, and the restoration of firebreaks.

4. CONCLUSIONS

Undertaking repair activities for a section of the railway line within protected areas involves non-standard construction problems, which consequently leads to increased construction costs and extended construction timelines.

The case analyzed in this article involved eliminating the erosive incision of the cut slope and the runoff of eroded sandy material onto the railway line surface. The location of the investment in a valuable natural area within the boundaries of Wolin National Park necessitated close cooperation between the Investor and the Park Directorate at every stage of the repair work. A repair variant was chosen that allowed minimizing the negative impact of the investment process on the park's natural and environmental values. The slope repair technology was designed and executed in such a way that it excluded the possibility of interference with natural habitats and animal species sites, including those protected under the Natura 2000 area [6].

These actions primarily aimed to secure the operational parameters of the railway line in accordance with train traffic safety requirements. At the same time, the repair implementation did not conflict with the overarching goal of protecting the natural values of Wolin National Park [6].

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EFFECT OF THE ADDITION OF CHEMICALLY DEGRADED POLY(ETHYLENE TEREPHTHALATE) ON THE RHEOLOGICAL PROPERTIES OF BITUMEN

WPŁYW DODATKU POLI(TEREFTALANU ETYLENU) PODDANEGO CHEMICZNEJ DEGRADACJI NA WŁAŚCIWOŚCI REOLOGICZNE ASFALTU

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Abstract

The study explores the feasibility of incorporating poly(ethylene terephthalate) (PET) plastomer into processed asphalt through chemical degradation. The depolymerization process involved subjecting the PET plastomer to aminolysis reaction with ethylenediamine. Consequently, the resultant monomer exhibited reduced rigidity and increased machinability. Enhancing its degree of fragmentation facilitated improved homogenization with bitumen. The resulting blend of bitumen and degraded plastomer underwent evaluation for creep resistance in accordance with the Multiple Stress Creep Recovery (MSCR) methodology at a temperature of 64°C. Moreover, fundamental standard tests were conducted, including penetration, softening point, and Fraass breaking point. The incorporation of additional amino groups in the form of degraded PET into the bitumen reduced its susceptibility (Jnr3200 < 0.5 kPa^{-1}) to the creep process and lowered the brittle temperature (approximately –3°C) in comparison to 50/70 neat bitumen. Furthermore, the proposed depolymerization technology for PET and its application to bitumen represents a viable approach for the utilization of PET plastomer.

Streszczenie

W pracy przedstawiono możliwość aplikacji plastomeru poli(tereftalan etylenu) PET do asfaltu przetworzonego poprzez zastosowanie chemicznej degradacji. Proces depolimeryzacji polegał na poddaniu plastomeru PET reakcji aminolizy z wykorzystaniem etylenodiaminy. W efekcie uzyskany monomer uzyskał mniejszą sztywność oraz był łatwy w obróbce mechanicznej. Zwiększenie jego stopnia rozdrobnienia umożliwiło lepszą homogenizację z asfaltem. Uzyskaną mieszaninę asfaltu i zdegradowanego plastomeru poddano ocenie odporności na proces pełzania zgodnie z metodyką MSCR w temperaturze 64°C. Ponadto wykonano podstawowe badania normowe takie jak: penetracja, temperatura mięknienia oraz temperatura Fraassa. Wprowadzenie dodatkowych grup aminowych w postaci zdegradowanego PET do asfaltu zmniejszyło jego podatność (Jnr3200 < 0,5 kPa^{-1}) na proces pełzania oraz temperaturę łamliwości (około –3°C) w porównaniu do asfaltu 50/70. Ponadto zaproponowana technologia depolimeryzacji PET i jego implementacja do asfaltu jest sposobem, który można wykorzystać do utylizacji plastomeru PET.

APPLICATION OF BIM SYSTEMS IN INTELLIGENT DESIGN – PROCESS AND COST

ZASTOSOWANIE SYSTEMÓW BIM W INTELIGENTNYM PROJEKTOWANIU – OPTYMALIZACJA PROCESÓW I KOSZTÓW

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Abstract

The article analyzes the application of BIM (Building Information Modeling) systems in intelligent design, focusing on process and cost optimization in construction. The authors discuss the benefits of implementing BIM throughout the entire life cycle of a building, from the pre-design phase to operation. BIM enables rapid concept analysis, supports interdisciplinary collaboration, streamlines cost estimation, and improves construction management. During the operational phase, BIM supports efficient facility management through real-time data collection and updates. The authors emphasize that the future of construction lies in integrating BIM with technologies such as IoT, artificial intelligence, and augmented reality. Despite the low level of BIM adoption in Polish companies, the trend of digitalization in construction is inevitable, and firms effectively implementing these technologies will gain a competitive advantage.

Streszczenie

Artykuł analizuje zastosowanie systemów BIM (Building Information Modeling) w inteligentnym projektowaniu, koncentrując się na optymalizacji procesów i kosztów w budownictwie. Autorzy omawiają korzyści płynące z wdrożenia BIM w całym cyklu życia obiektu budowlanego, od fazy przedprojektowej po eksploatację. BIM umożliwia szybką analizę koncepcji, wspiera współpracę międzybranżową, usprawnia kosztorysowanie i zarządzanie budową. W fazie eksploatacji BIM wspiera efektywne zarządzanie obiektem poprzez gromadzenie i aktualizację danych w czasie rzeczywistym. Autorzy podkreślają, że przyszłość budownictwa leży w integracji BIM z technologiami takimi jak IoT, sztuczna inteligencja i rozszerzona rzeczywistość. Mimo niskiego stopnia wdrożenia BIM w polskich firmach trend digitalizacji budownictwa jest nieunikniony, a firmy skutecznie implementujące te technologie zyskają przewagę konkurencyjną.

INVESTIGATING EFFECTIVENESS OF TUNED MASS DAMPER (TMD) ON CONTROL VIBRATION OF WIND TURBINE-SOIL INTERACTION

BADANIE EFEKTYWNOŚCI DYNAMICZNEGO TŁUMIKA DRGAŃ (TMD) POD KĄTEM KONTROLI WIBRACJI W INTERAKCJI TURBINY WIATROWEJ Z PODŁOŻEM GRUNTOWYM

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Abstract

Soil-structure interaction (SSI) effects were investigated on structural responses of wind turbine. Force versus deformation (i.e., p-y curves) was simulated by multilinear elastic springs. The whole system, including the structure, control vibration system and soil nonlinear effects are simulated within a single three-dimensional finite element model. Modeling accuracy was verified using available results related to a 65 kW wind turbine discussed in the literature. Pushover analysis results indicated a fixed-base assumption ends up with overestimation of stiffness compared to the case where SSI effects are considered. Moreover, it is observed that the performance of tuned mass damper (TMD) is highly dependent on its tuned frequency domain, and its efficiency decreases significantly after SSI effects are considered. Lateral deformations of a wind turbine are much higher compared to the fixed-base condition. Therefore, SSI effects play a crucial part in designing wind turbines and should not be neglected in practice.

Streszczenie

Zbadano wpływ interakcji konstrukcji z podłożem gruntowym (SSI) na zachowanie konstrukcji turbiny wiatrowej. Zależność siły od odkształcenia (tj. krzywe p-y) zasymulowano za pomocą wieloliniowych sprężyn elastycznych. Cały system, w tym konstrukcja, system kontroli wibracji i nieliniowe efekty podłoża jest symulowany w ramach jednego trójwymiarowego modelu elementów skończonych. Dokładność modelowania została zweryfikowana przy użyciu dostępnych wyników dla turbiny wiatrowej o mocy 65 kW, omówionych w literaturze. Wyniki analizy statycznej (pushover) wykazały, że przy założeniu o nieruchomej podstawie dochodzi do przeszacowania sztywności w porównaniu z przypadkiem, w którym uwzględniono efekty SSI. Ponadto zaobserwowano, że wydajność tłumika TMD jest silnie zależna od jego dostrojonej domeny częstotliwości, a jego efektywność znacznie spada po uwzględnieniu efektów SSI. Odkształcenia poziome turbiny wiatrowej są znacznie większe w porównaniu z warunkami nieruchomej podstawy. Dlatego efekty SSI odgrywają kluczową rolę w projektowaniu turbin wiatrowych i nie powinny być pomijane w praktyce.

„BAOBAB" IN LUBLIN AS AN EXAMPLE OF CREATING A NEW QUALITY OF SOCIAL INTEGRATION SPACE

„BAOBAB" W LUBLINIE JAKO PRZYKŁAD TWORZENIA NOWEJ JAKOŚCI PRZESTRZENI ZINTEGROWANEJ

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Abstract

The outbreak of the war with Russia in Ukraine has caused an increase in the number of refugees arriving in Poland and other European countries. From the early days of the conflict, support and integration centers began to emerge in many cities, changing the landscape of public and cultural spaces and creating new opportunities to address the migration crisis. Lublin quickly responded to this crisis at the start of the conflict. After more than two years, the city has gained about 20.000 new residents. Their presence is evident socially and through new places and functions for integration, assistance, and humanitarian support. The organization of these places has significantly changed, initially relying on temporary solutions and later developing permanent informational and integration centers. A notable example of successful integration is the Baobab Multicultural Integration Center in central Lublin, which serves as a high-quality, inclusive space for building connections, and integrating residents.

Streszczenie

Wybuch wojny z Rosją na Ukrainie spowodował wzrost liczby uchodźców przybywających do Polski i innych krajów europejskich. Od wczesnych dni konfliktu w wielu miastach zaczęły powstawać centra wsparcia i integracji, zmieniając krajobraz przestrzeni publicznej i kulturalnej oraz stwarzając nowe możliwości rozwiązania kryzysu migracyjnego. Lublin szybko zareagował na ten kryzys na początku konfliktu. Po ponad dwóch latach miasto zyskało około 20 000 nowych mieszkańców. Ich obecność jest widoczna społecznie oraz poprzez nowe miejsca i funkcje integracji, pomocy i wsparcia humanitarnego. Organizacja tych miejsc uległa znacznej zmianie, początkowo polegając na rozwiązaniach tymczasowych, a później rozwijając stałe centra informacyjno-integracyjne. Godnym uwagi przykładem udanej integracji jest Centrum Integracji Wielokulturowej Baobab w centrum Lublina, które służy jako wysokiej jakości, inkluzywna przestrzeń do budowania połączeń i integrowania mieszkańców.

PROBLEMS OF ENVIRONMENTAL INTERFERENCE IN EMERGENCY REPAIRS OF RAILWAY SECTIONS – A CASE STUDY

PROBLEMY INGERENCJI W ŚRODOWISKO PRZYRODNICZE PRZY NAPRAWIE AWARYJNYCH ODCINKÓW LINII KOLEJOWYCH – STUDIUM PRZYPADKU

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Abstract

This article presents the history of identifying the causes of emergency threats and the repair of a section of the railway line within the Wolin National Park. The author focuses on issues related to the legal aspects of environmental protection in a specially protected area that arose during the design and execution of repair works on the railway infrastructure.

Numerous meetings between the Management of the Railway Line Department in Szczecin and the Management of the Wolin National Park, with both sides fully understanding the essence of technical and environmental problems of the project, led to a consensus. The scope and method of repair were established, allowing the minimization of the negative impact of the investment process on the park's natural and environmental values while ensuring the safety of train traffic.

Despite the typical and straightforward nature of the repair task, due to environmental protection constraints, non-standard construction problems were encountered, which consequently increased costs and extended the construction time.

Streszczenie

W artykule przedstawiono historię ustalenia przyczyn zagrożenia awaryjnego i naprawy odcinka linii kolejowej w obrębie Wolińskiego Parku Narodowego. Autor skoncentrował się na problemach związanych z prawnymi aspektami ochrony środowiska przyrodniczego na terenie obszaru szczególnie chronionego, które wystąpiły w trakcie projektowania, jak i wykonywania budowanych robót naprawczych kolejowej infrastruktury komunikacyjnej.

Liczne spotkania pomiędzy Dyrekcją Zakładu Linii Kolejowych w Szczecinie a Dyrekcją Wolińskiego Parku Narodowego, przy pełnym zrozumieniu przez obie strony istoty problemów technicznych i środowiskowych przedsięwzięcia, doprowadziły do uzyskania konsensusu. Ustalono zakres i sposób naprawy, który pozwolił na zminimalizowanie negatywnego oddziaływania procesu inwestycyjnego na walory przyrodnicze i środowiskowe parku przy zapewnieniu bezpieczeństwa ruchu pociągów.

Mimo typowego i prostego w realizacji zadania przy wykonaniu naprawy, ze względu na obostrzenia wynikające z ochrony środowiska przyrodniczego, natrafiono na niestandardowe problemy budowlane. W konsekwencji wpłynęło to na wzrost kosztów oraz wydłużenie czasu realizacji robót budowlanych.