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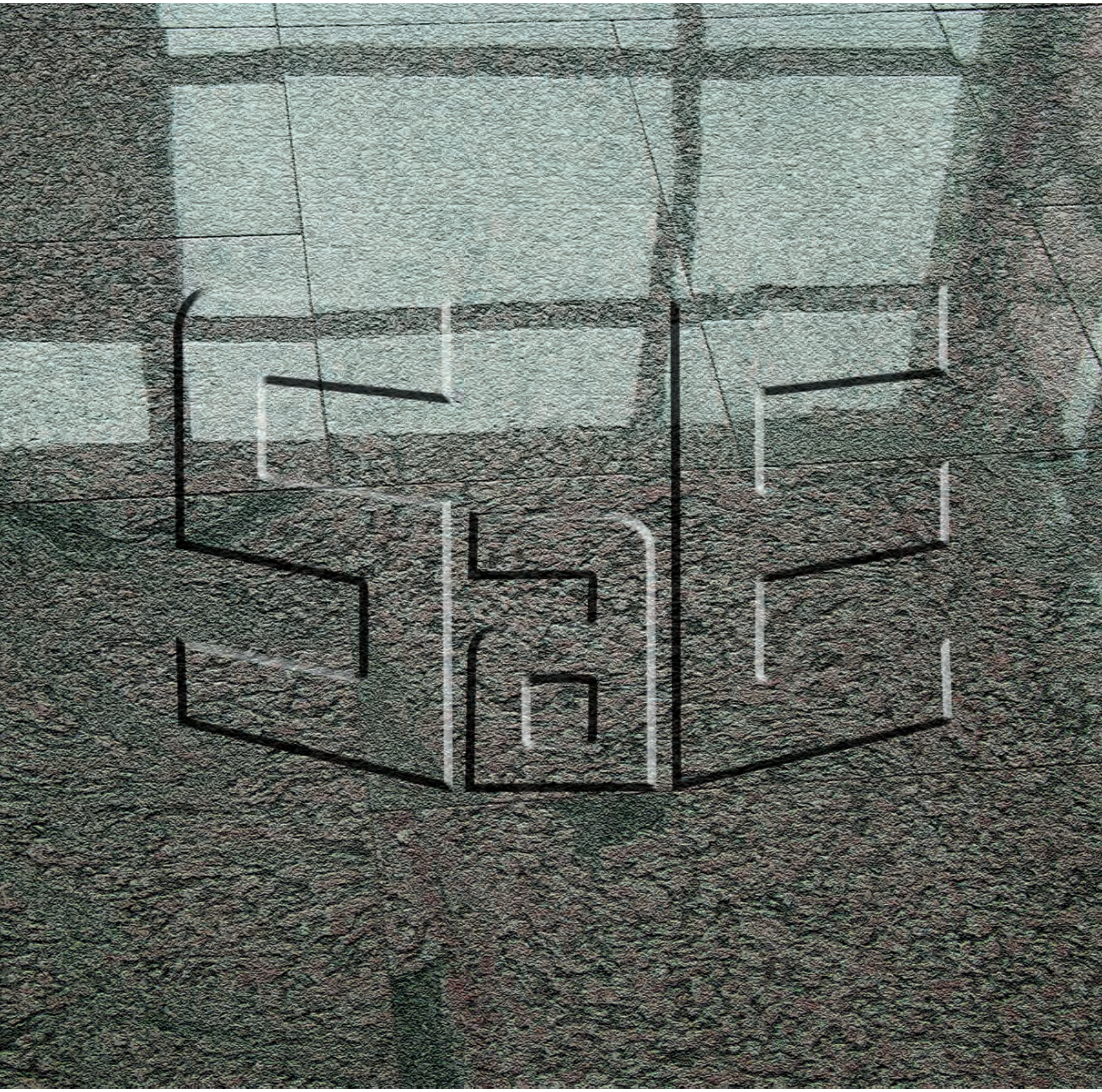

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INFLUENCE OF THE ACIDIC ENVIRONMENT ON THE PROPERTIES OF METAHALLOYSITE GEOPOLYMER COMPOSITES

WPŁYW ŚRODOWISKA KWAŚNEGO NA WŁAŚCIWOŚCI KOMPOZYTÓW GEOPOLIMEROWYCH Z METAHALOIZYTU

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Abstract

Geopolymers have been shown to exhibit a significantly higher degree of resistance to corrosive environments when compared with cement concrete. The present paper expounds on the impact of sulphuric, hydrochloric and acetic acid solutions on the durability of mortars with geopolymer binders composed of metahalloysite and alkali activators. An activator with sodium water glass to NaOH solution ratios of 1, 2 and 3 and NaOH solution concentrations of 4, 8 and 12 mol/dm^3 was used. It was found that when increasing sodium water glass content from 1 to 3 in relation to the 8M or 12M NaOH solution in the activator, a significant reduction in the compressive strength of the mortar with this geopolymer binder was obtained after 28 days of exposure to the acid solutions. A smaller decrease in strength occurred with the acetic acid solution than with the sulphuric or hydrochloric acid solutions.

Keywords: geopolymer composite, metahalloysite, acid resistance, sodium activator.

Streszczenie

Geopolimery w porównaniu do betonu cementowego charakteryzują się wysoką odpornością na większość agresywnych środowisk korozyjnych. W artykule przedstawiono wpływ roztworów kwasu siarkowego, solnego i octowego na trwałość zaprawy ze spoiwem geopolimerowym z metahaloizytu oraz aktywatora alkalicznego. Zastosowano aktywator o stosunku szkła wodnego sodowego do roztworu NaOH wynoszącym 1, 2 i 3 oraz stężeniu roztworu NaOH 4, 8 i 12 mol/dm^3. Stwierdzono, że przy zwiększeniu zawartości szkła wodnego od 1 do 3 w stosunku do roztworu 8M lub 12M NaOH w aktywatorze uzyskuje się znaczne zmniejszenie wytrzymałości na ściskanie zaprawy z tym spoiwem geopolimerowym po 28 dniach działania roztworów kwasów. Mniejszy spadek wytrzymałości występował w przypadku roztworu kwasu octowego niż siarkowego lub solnego.

Słowa kluczowe: kompozyt geopolimerowy, metahaloizyt, kwasoodporność, aktywator sodowy.

1. INTRODUCTION

The durability of materials is important factor in the lifespan of a building. Buildings must be constructed in a way that ensures sufficient structural strength and resistance to environmental factors. In comparison to conventional building materials, geopolymers exhibit enhanced resistance to a wide range of aggressive corrosive environments [1] and demonstrate superior durability in acidic environments when compared to cement concrete [2-4].

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Geopolymers consist of three-dimensional aluminosilicate frameworks composed of $[SiO_4]^{4-}$ and $[AlO_4]^{5-}$ tetrahedra connected by oxygen atoms, with alkali cations balancing the charge [5]. Inorganic aluminosilicate polymers show very good acid resistance, as both the Si-O bond and the Al-O bond in the geopolymer network structure hardly react with acid at room temperature. The decomposition rate of geopolymer in a 5% sulphuric acid solution is only one-thirteenth of that of hardened Portland cement slurry, and the decomposition rate in 5% hydrochloric acid is only one-twelfth of that of Portland cement slurry [6].

Geopolymers, due to their high durability, low shrinkage during drying and high adhesion to the substrate, can be used as a coating to provide corrosion protection for other materials that are less durable under these conditions [7]. The findings demonstrated that coating cement concrete with the application of geopolymer mortar resulted in a substantial decrease in the rate of mass loss of the specimens. Cement concrete placed in 10% inorganic acid solutions (HCl, HNO_3) reduced its mass by about 70%, while when it was covered with a 2 mm layer of geopolymer mortar there was a mass loss of only up to 1% after 28 days of exposure to inorganic acids, and for organic acids (CH_3COOH, $C_3H_6O_3$) the mass loss was no greater than 2% [1]. A similar value for the loss of cement mortars after immersion in sulphuric acid of 68% for 6 months was observed by Vafaei M. and Allahverdi [8], while for geopolymer mortars the mass loss was 32% after immersion in a 5% hydrochloric acid solution. Geopolymer mortars contained a significantly lower amount of calcium compounds when compared to cement mortars. The reaction of calcium compounds with sulphuric acid has been shown to result in the formation of gypsum crystals. This, in turn, has been demonstrated to cause internal stresses, which can lead to a range of undesirable outcomes, including cracking, spalling and accelerated material deterioration [8]. An expansive degradation mechanism can also occur through the formation of ettringite ($3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$) [9].

Geopolymer materials manufactured from class F fly ash, which contains low calcium content (3-4% CaO) exhibit enhanced durability in acidic environments [10]. Ganesan et al. [11] conducted a study on the impact of sulphuric acid 3% solution (H_2SO_4) and sodium sulphate 3% solution (Na_2SO_4) on fly ash geopolymer activated with 10M NaOH and sodium silicate solution with steel fibre. Samples that had been subjected to curing for 28 days and then placed in solutions for a further 180 days exhibited minimal change in appearance. The maximum mass loss of the geopolymer was 2.2%, and the reduction in compressive strength was 20%. By contrast, for the cement concrete specimens, the mass loss was 27 per cent, and the strength decreased by 41%.

Alibitar [3] tested the effects of a solution of 5% sodium chloride, 5% sodium sulphate and magnesium sulphate and 5% sulphuric acid on geopolymer concrete made from class F fly ash and granulated lead smelting slag activated with sodium silicate and 14M NaOH at a ratio of 1.5. The geopolymer concrete demonstrated enhanced durability in comparison to Portland cement concrete when subjected to the same solutions. Following a nine-month exposure period, the geopolymer demonstrated the least resistance to sodium sulphate solution, a phenomenon attributed to sodium hydroxide leaching from the solution. The author recommends the utilisation of an alternative activator in order to enhance the durability of the material when exposed to sodium sulphate.

Kwasny et al. [4] investigated the resistance of a 28-day cured kaolinite-based geopolymer to sodium and magnesium sulphate solutions, as well as sulphuric and hydrochloric acid. The microstructure of the geopolymer was not affected during the sulphate exposure, while samples immersed in a 1% to 5% sulphuric acid solution showed greater mass loss (a maximum of about 8% after 8 weeks of immersion) than samples placed in hydrochloric acid with concentrations ranging from 0.37% to 1.86% (a loss of about 5%).

Mehta and Siddique [12] found that a fly ash-based geopolymer with up to 30% Portland cement, immersed in a 2% sulphuric acid solution for 356 days, exhibited the highest mass loss for a 30% Portland cement content. An increase in the calcium hydroxide content of Portland cement results in the formation of a geopolymer with reduced resistance to sulphuric acid, due to the formation of calcium sulphate.

Deb et al. [13], after adding optimally 2% nanosilica to a fly ash geopolymer activated with a sodium silicate solution and 8M NaOH, obtained a material with a more compact microstructure and higher resistance to a 3% sulfuric acid solution. The mass loss after 90 days of immersion decreased from 6.0% to 1.9%, and a significant reduction in compressive strength loss was observed. In addition, Elyamany et al. [14] conducted a study on the durability of geopolymer made from slag, fly ash and with silica dust added. The geopolymer concrete, manufactured from blast furnace slag, demonstrated the highest level of resistance to sulphuric acid.

Sata et al. [15] conducted a study on the durability of geopolymer mortars composed of fly ash and lignite ash, which were activated with sodium silicate in conjunction with 10M NaOH in 3% sulphuric acid solution and 5% sodium sulphate solution. The geopolymer mortars exhibited reduced mass loss and augmented compressive strength in comparison to the Portland cement samples. In mortars where the aluminosilicate was more finely ground, higher strengths were observed. However, greater mass loss under solution was exhibited by these mortars in comparison to geopolymer mortars made from coarser-grained ash.

In the study by Ribeiro et al. [16], the resistance of a metakaolinite geopolymer reinforced with bamboo fibre to sulphuric and hydrochloric acids at concentrations of up to 15% over a period of 112 days was investigated. The findings indicated that the geopolymer exhibited adequate stability and durability when exposed to these corrosive substances, making it a promising material for structural and drainage applications subjected to such environments.

The objective of this study was to examine the impact of 5% hydrochloric acid, sulphuric acid and acetic acid solutions on the mechanical properties of metahalloysite geopolymer mortars. The geopolymer mortar contained an activator with a ratio of sodium water glass to NaOH solution of 1, 2, 3 and sodium hydroxide solution of 4M, 8M and 12M. To date, there is a paucity of information regarding the results of studies of the effect of the activator composition on the physico-mechanical properties of the metahalloysite geopolymer in an acidic environment.

2. MATERIALS AND METHODS

2.1. Materials

Halloysite in powder form with a grain size of 0-100 µm came from the Dunino mine near Legnica, Poland. Metahalloysite obtained by roasting halloysite for 2 hours at 750°C in a muffle furnace was used to produce the geopolymer. The specific surface area of metahalloysite determined by the BET method was 44.64 m^2/g. The chemical composition of halloysite determined by X-ray fluorescence (XRF) has been shown in Table 1.

Geopolymer mortars were made from EN 196-1 standard sand with a granulation <4 mm and a binder containing metahalloysite with a room-temperature activator that is a mixture of a sodium silicate solution with a molar modulus of SiO_2/Na_2O in the range 2.4-2.6 with a sodium hydroxide solution of 4, 8 and 12 mol/dm^3, with a mass ratio of 1 to 3. The weight ratio of sand to metahalloysite was 3, and the ratio of activator to metahalloysite was 0.93. The dry mortar components were mixed for a duration of 10 seconds, then the activator solution was added, and the whole was stirred for 3 minutes. The geopolymer mortar was subjected to a process of compaction on a vibrating table for a duration of one minute. Thereafter, the mortar was transferred into moulds with dimensions of 40 × 40 × 160 mm. The moulds were then covered with plastic sheeting. After 24 hours it was unmoulded and the specimen was stored for a period of 28 days at a temperature of 20°C ±2°C.

2.2. Methods

Compressive strength tests were carried out on a 40 × 40 × 160 mm beam half (compressed area 40 × 40 mm) using a Hydraulic press after 28 days of curing at an ambient temperature of 20°C ±2°C in a sealed container and after a further 28 days of immersion in 5% acid solutions. The rate of force build-up for the compressive strength test was 2400 N/s.

The acid resistance of the mortars was assessed by checking the mass loss after 7, 14 and 28 days for three specimens of each type of composite immersed in 5% solutions of sulphuric, hydrochloric and acetic acid. After 28 days of curing, the mortar bars were soaked in water and placed in acid solutions; after a set time, the specimens were removed from the solution, dried with a damp cloth and weighed before being placed back in their respective solutions.

The specific surface areas of metahalloysite and selected geopolymer mortars after 28 days of curing were determined by BET at a relative pressure p/p_o in the range 0.05-0.3 using Quantachrome's Autosorb iQ analyser from a nitrogen adsorption isotherm at 77K. Prior to testing, the samples were subjected to a pre-drying process at a temperature of 50°C. The average pore size was determined from the nitrogen adsorption curve at 77K using the density functional

Table 1. Chemical composition of halloysite

Component	SiO_2	CaO	Al_2O_3	Fe_2O_3	K_2O	MgO	Mn_2O_3	Na_2O	P_2O_5	TiO_2	LOI*
Content, %	24.17	0.89	19.49	28.63	0.09	3.74	0.29	0.13	0.83	5.18	16.41

* – roasting losses performed for 1 h at 1050°C

method (DFT). The total porosity of the tested geopolymer mortars was determined in the work [20].

The chemical composition of halloysite was determined on a Bruker S8 TIGER spectrometer.

3. RESULTS AND DISCUSSION

The compositions of the activators in the geopolymer binders are shown in Table 2.

Table 2. Composition of activator in geopolymer binder

Mortar designation	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
Molar concentration of NaOH solution [mol/dm^3]	4	8	12	4	8	12	4	8	12
Mass ratio sodium water glass to NaOH solution	1	1	1	2	2	2	3	3	3

Figures 1-3 show the mass loss of geopolymer mortar samples after 7, 14 and 28 days of storage in 5% sulphuric, hydrochloric and acetic acid solutions.

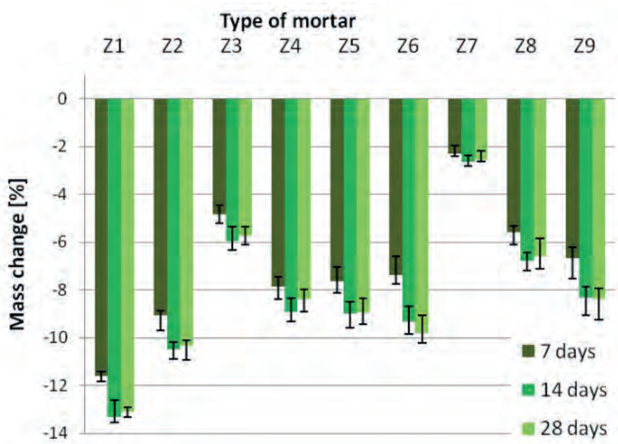

Fig. 1. Geopolymer mortar mass loss in 5% H_2SO_4 solution

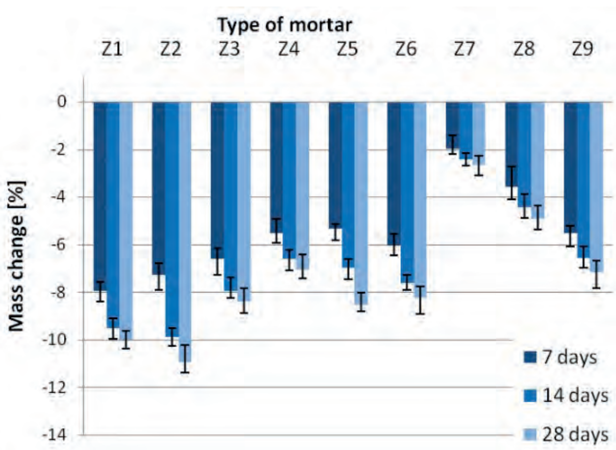

Fig. 2. Geopolymer mortar mass loss in 5 % HCl solution

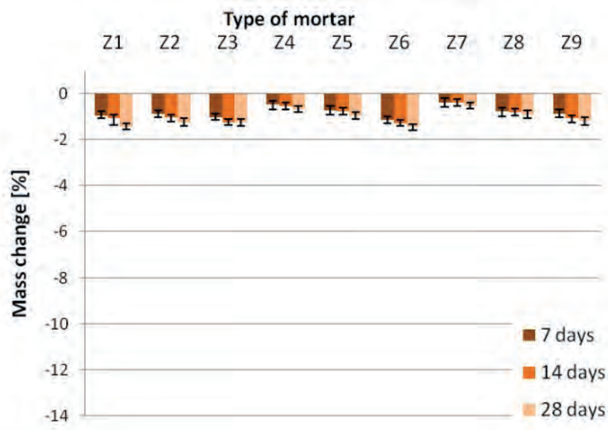

Fig. 3. Geopolymer mortar mass loss in 5% CH_3COOH solution

The most significant mass losses, amounting to several percent (Z1), were observed in mortars stored in sulphuric acid solution, while the least substantial losses were recorded in samples treated with an acetic acid solution of less than 2%. In the present study, geopolymer mortar samples Z7, Z8 and Z9, for which an activator was applied at a ratio of sodium water glass to NaOH solution of 3, were characterised by the lowest mass losses. It was established that an increase in the quantity of sodium silicate solution, from 1 to 3 relative to the NaOH solution of 4, and 8 mol/dm^3 in the activator solution, resulted in a decrease in the mass loss of the samples. According to Nguyen et al. [19], the acid resistance of geopolymer concrete is much better because sodium silicate or sodium water glass prevents acid penetration. Different results were shown by Bakharev T. [10] for FA fly ash geopolymer activated with sodium hydroxide obtained lower mass losses compared to samples immersed in sulfuric acid solution, where an activator in the form of sodium silicate solution or NaOH in combination with KOH was used.

Significantly lower losses after 28 days of 0.5% to 1.4% were recorded for samples stored in acetic acid solution than in sulphuric acid solutions, where mass losses ranging from 2.5% to 13.1% were recorded. Similar results were obtained by other researchers. Bakharev [10] for a solution of 5% sulphuric acid for 2 months, the mass loss of the sample was 12.43% and 1.15% when treated with a solution of 5% acetic acid when the fly ash was activated with a NaOH solution. In the study conducted by Kwasny et al. [4], kaolinit clay geopolymer samples were activated using a sodium silicate solution and then curing for 28 days. Following this, the samples were immersed in a 5% sulphuric acid solution for a period of eight weeks.

The results of this experiment demonstrated that there was a mass loss of approximately 8% for the samples of geopolymer that were immersed in solution. In comparison, the samples that were immersed in a 1.86% hydrochloric acid solution experienced a mass loss of around 5%. Similarly, according to Vafaei M. and Allahverdi [8], the failure rate of geopolymer mortar formed from waste glass powder and calcium-aluminium cement activated with a solution of sodium silicate and sodium hydroxide, in sulphuric acid is higher than in hydrochloric acid [8].

Following a 28-day immersion in a 5% sulphuric acid solution, a mass increase was observed in the samples in comparison to the loss that occurred after a 14-day exposure to the acid. Silica gel precipitation was observed in the container. According to Iller [17], in an acidic environment silicic acid can precipitate from silicates that contain unpolymerised SiO_4^{4-} tetrahedra.

An increase in mass and compressive strength of geopolymer exposed to Na_2SO_4 and $MgSO_4$ concentrations of 3%, 5% and 7% after 180 days was observed by Farhan et al. [18]. The primary cause of the observed mass increase was the accumulation of sulphate particles that resulted in the formation of reaction products, such as gypsum and ettringite, within the voids of the geopolymer. It has been demonstrated that exposure of geopolymer composites to sulphate or seawater results in an enhancement of strength due to the crystallisation of reaction products, leading to a thickening of the microstructure [18].

Figures 4-6 show the results of strength tests on geopolymer mortars stored in 5% sulphuric, hydrochloric and acetic acid solutions and the results of strength tests on geopolymer mortar samples matured for 28 days under laboratory conditions.

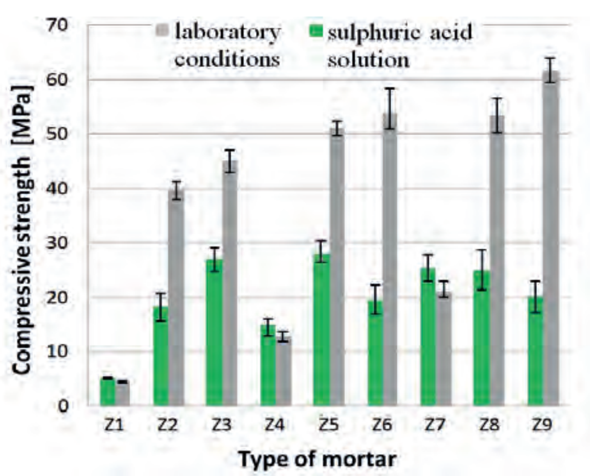

Fig. 4. Change in compressive strength geopolymer mortar in a 5% H_2SO_4 solution

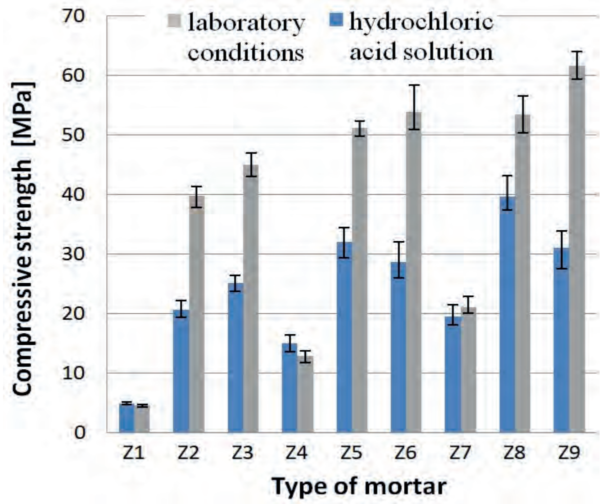

Fig. 5. Change in compressive strength geopolymer mortar in a 5% HCl solution

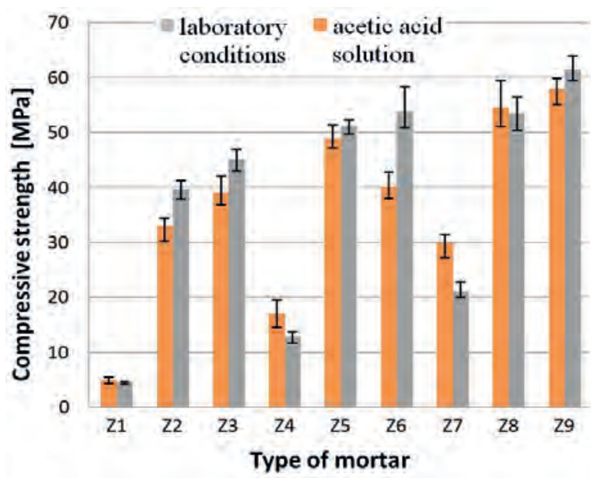

Fig. 6. Change in compressive strength geopolymer mortar in a 5% CH_3COOH solution

The compressive strength of geopolymers placed in a 5% sulphuric acid solution decreased for samples with 8M and 12M sodium hydroxide solution as the activator, while geopolymer samples Z1, Z4, Z7 with 4M NaOH increased their compressive strength by 13.5%, 14.8%, 19.7%, respectively, despite a decrease in sample weight. Similar increases in compressive strength for mortars Z1, Z4 and Z7 occurred when the samples were immersed in hydrochloric and acetic acid solutions. The increased or comparable compressive strength of the specimens stored in acid solutions compared to the reference specimens may have been due to the fact that the reference specimens were tested after 28 days of curing rather than 56 days. The effect of geopolymer binder composition on changes in the strength of the mortars in acidic environments, in turn, requires further research.

In the instance of utilising a 12M NaOH solution within the activator, a marked decline in compressive strength was observed as the sodium silicate solution content increased in comparison to the NaOH solution. Similarly, Bakharev T. [10] observed that geopolymers made from fly ash activated with a 60% sodium hydroxide solution exhibited enhanced durability in a 5% sulphuric acid solution when compared to samples with a sodium silicate solution as an activator. Degradation of geopolymer materials in acidic environments occurs as a result of depolymerisation of aluminosilicate polymers and release of silicic acid [10].

Geopolymer mortars subjected to a 28-day immersion in a 5% hydrochloric acid solution exhibited a decline in strength, exhibiting a comparable trend to that observed in samples stored in a 5% sulphuric acid solution. As posited by Nguyen et al. [19], the residual NaOH resulting from geopolymerisation has the capacity to undergo a reaction with hydrochloric acid, thereby yielding sodium chloride. The formation of NaCl demonstrates the resistance of the geopolymer concrete. Sodium hydroxide has been demonstrated to attenuate the efficacy of hydrochloric acid [19]. In the case of the analysed samples of geopolymer mortars made of metahalloysite, no deterioration in the durability of the material was observed as a result of a 5% HCl solution together with an increased amount of NaOH in the activator solution.

The lowest recorded reduction in compressive strength, ranging from 4.3% to 25.6%, was observed for geopolymers placed in acetic acid solution. In contrast, mortars Z1, Z4, Z7 and Z8 exhibited an increase in strength of 8.4%, 31.8%, 41.8% and 2%, respectively. Geopolymer mortars Z1, Z4 and Z7, which had 4M NaOH solution in the activator, exhibited the lowest 28-day compressive strength and the smallest mass loss of the samples following 28 days of acid immersion.

The stability of geopolymer materials in acidic environments is contingent on the internal ordering of the material structure [10]. The enhanced stability of the cross-linked aluminosilicate polymer structure relative to that of Portland cement specimens is a salient factor contributing to the superior resistance of this material to sulphate solutions and sulphuric acid [15].

Table 3 shows the results of the specific surface area determined by the BET method for selected geopolymer mortars.

Table 3. Results of analysis of nitrogen adsorption in metahalloysite geopolymer mortars

Sample	Specific surface area (BET) [m^2/g]	Average pore diameter [nm]	Total porosity [%]
Z1	13.62	12	24.5
Z3	14.24	7	19.0
Z4	13.82	10	23.3
Z6	22.62	9	21.0
Z7	17.58	16	22.2
Z9	26.27	7	20.6

The geopolymer mortars Z6 and Z9 with the highest specific surface area and small average pore diameter had the highest 28-day compressive strength, but also the highest percentage reduction in strength after 28 days of immersion in 5% acid solutions. As the content of sodium water glass in the activator solution increases, the specific surface area determined by the BET method increases. When the molar concentration in the activator solution is increased from 4 mol/dm^3 to 12 mol/dm^3, the specific surface area of the geopolymer mortar increases and the average pore size decreases.

The geopolymer mortars Z1, Z4 and Z7, in conjunction with an increase in the content of sodium water glass relative to 4M NaOH in the activator solution, exhibited a higher specific surface area and higher compressive strength after 28 days in sulphuric and acetic acid solution than mortars that had matured for 28 days in air.

It has been demonstrated that a more compact structure with lower porosity exhibits greater resistance to acids. A reduction in contact with the matrix has been shown to result in a decrease in mass loss and compressive strength loss [13]. Bakharev [10] posited that the strength properties of geopolymer materials are contingent on the pore structure of these materials, rather than on the total porosity. The sodium hydroxide-activated geopolymer, despite exhibiting the highest porosity, demonstrated the least compressive strength loss following immersion in a sulphuric acid solution. The author observed that the smallest average pore size of the geopolymer resulted in enhanced resistance to the sulphuric acid solution. In contrast, no such relationship was observed in the case of the analysed geopolymer mortar compositions made of metahalloysite.

4. CONCLUSIONS

The results of the study showed that:

- Geopolymer mortars with a metahalloysite binder that has been activated by a sodium silicate with sodium hydroxide solution demonstrate reduced mass loss when exposed to a 5% acetic acid solution in comparison to placed in sulphuric or hydrochloric acid solutions.
- Increasing the ratio of the sodium silicate solution to the 4M and 8M NaOH solution in the activator from 1 to 3 in the binder results in a decrease in mortar mass loss.
- It was revealed that the compressive strength of geopolymer mortars with a binder containing a 4 mol/dm³ NaOH solution increased after 28 days of exposure to 5% sulphuric, hydrochloric or acetic acid solutions.
- Increasing the ratio of sodium silicate solution to 4M NaOH solution in the activator from 1 to 3 in the binder increases the compressive strength of mortars stored in sulphuric and acetic acid solutions for 28 days compared to mortars stored under laboratory conditions.
- The percentage loss in compressive strength of geopolymer mortars with a binder of metahalloysite with 12M NaOH and a sodium silicate solution immersed in 5% acid solutions for 28 days increases with increasing specific surface area.
- It has been demonstrated that increasing the molar concentration of the sodium hydroxide solution from 4 to 12 mol/dm³ results in an augmentation of the specific surface area of the geopolymer mortar, concomitant with a reduction in the average pore size.
- A geopolymer mortar with a binder of metahalloysite with 12M NaOH and a sodium silicate solution immersed for 28 days in 5% acid solutions characterised by an increased specific surface area shows reduced compressive strength.

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THE CHALLENGES OF URBAN SPACE REVITALISATION. REVITALISATION OF A SELECTED AREA OF THE SŁONECZNE WZGÓRZE HOUSING ESTATE IN KIELCE BASED ON THE EXAMPLE OF A STUDENT PROJECT

WYZWANIA REWITALIZACYJNE PRZESTRZENI MIEJSKIEJ. REWITALIZACJA WYBRANEGO OBSZARU OSIEDLA SŁONECZNE WZGÓRZE W KIELCACH NA PRZYKŁADZIE PROJEKTU STUDENCKIEGO

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Abstract

The revitalisation of degraded areas is a multi-stage process that requires the involvement of the public, local authorities and often large financial resources. In Poland's large cities, the revitalisation process mainly focuses on revitalising deserted inner cities and the city's main representative spaces, while other smaller spaces, marginalised areas or spaces in housing estates remain forgotten. The problem of revitalisation is shaping up similarly in smaller urban centres.
The paper shows a selected student revitalisation project, carried out as part of the Revitalisation of the Urbanised Environment course by students of Architecture at the Kielce University of Technology.

Keywords: revitalisation, space, Kielce, housing estate.

Streszczenie

Rewitalizacja obszarów zdegradowanych jest wielostopniowym procesem wymagającym zaangażowania społecznego, władz lokalnych oraz często dużych środków finansowych. W dużych miastach w Polsce proces rewitalizacji skupia się głównie na ożywieniu opustoszałych śródmieść i głównych przestrzeni reprezentacyjnych miasta, natomiast pozostałe mniejsze przestrzenie, obszary zmarginalizowane czy przestrzenie na osiedlach mieszkaniowych pozostają zapomniane. Podobnie problem rewitalizacji kształtuje się w mniejszych ośrodkach miejskich.
W opracowaniu pokazano wybrany studencki projekt rewitalizacyjny, realizowany w ramach przedmiotu rewitalizacja środowiska zurbanizowanego przez studentów kierunku architektura Politechniki Świętokrzyskiej.

Słowa kluczowe: rewitalizacja, przestrzeń, Kielce, osiedle mieszkaniowe.

1. INTRODUCTION

Today, cities are the epicentre of social, economic and cultural life. However, as the urban population continues to grow, cities face increasing challenges in space management. In the context of urbanisation and changing social and economic needs, there is an

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increasingly urgent need to revitalise urban spaces. The topic of this article was developed based on a student revitalisation project carried out as part of the Urban Environment Revitalisation course by students of Architecture at the Kielce University of Technology. The project presents potential solutions that address the challenges of revitalising the space of a multi-family housing estate, aiming to create the "cities of tomorrow" – places that are designed to be responsive to the needs of residents, but also functional, aesthetically pleasing and environmentally friendly.

Revitalisation is the process of bringing degraded areas out of crisis, carried out in a comprehensive manner through integrated actions for the benefit of the local community, space and economy. These actions should be territorially concentrated, led by the revitalisation stakeholders on the basis of the municipal revitalisation programme.

Revitalisation is the process of improving the situation of degraded areas, which involves a wide range of activities aimed at bringing them back to life. This comprehensive process involves the local community and various aspects of social, economic and spatial life [1].

The word revitalisation literally means 'returning to life' and encompasses a variety of activities such as repairs, modernisations, improvements of infrastructure and transport, introduction of new functions as well as economic and social support. In the context of degraded urban neighbourhoods, neighbourhood spaces or historic areas, revitalisation aims to restore their functional, artistic, cultural and historical values by adapting them to modern needs, eliminating elements that do not fit their character or restoring their original form on the basis of scientific research. It is also intended to respond to the contemporary needs of residents, making them able to live, spend their leisure time or work in a better way.

The first stage important for determining on which area the activities within the revitalisation process will be undertaken is the designation of the degraded area. A degraded area is one that is disadvantaged by the concentration of a number of unfavourable social phenomena, such as unemployment, poverty, crime, poor quality of education or lack of social capital. In addition, it can be characterised by low social and cultural engagement. The second stage of urban revitalisation planning is the designation of the revitalisation area. A revitalisation area is an area covering all or part of a degraded area, characterised by a particular concentration of negative phenomena, in which, due to its significance for local development, the municipality intends to carry out revitalisation [1].

The revitalisation of degraded areas is a multi-stage process that requires the involvement of the public, local authorities and often large financial resources. In large cities in Poland, the revitalisation process mainly focuses on revitalising deserted inner cities and the city's main representative spaces, while other smaller spaces, marginalised areas or spaces in housing estates remain forgotten and deteriorate over time. The problem of revitalisation is shaping up similarly in smaller urban centres [2].

There are good examples of revitalization designs. For almost 10 years this subject had been actively developed at the Faculty of Civil Engineering and Architecture at the Kielce University of Technology. Every year students successfully perform such designs and studies concerning development of urban areas, as well revitalisation of historic towns in the Kielce region [2-5].

The student project responds to the problems of forgotten parts of the city of Kielce and focuses on revitalising an area of a housing estate that the community no longer uses due to neglect.

"Housing estates are the place of residence of 1/5 of the population of Polish cities, which translates to 7-8 million citizens. Those created in the post-war period, but also those from the 1970s and 1980s are subject to an ageing process associated with increasing adverse spatial and functional changes" [6]. Due to a major problem with the neglect of smaller areas of cities or settlement areas, the 'large-panel housing estates', some growing families are looking for their place outside the city, at the expense of inferior access to services and infrastructure. For many years, housing estates have ceased to cope with meeting the original needs of their residents, and many of their functions have been displaced by the increasing demand for space for cars and neglect of the maintenance of the space between buildings. For this reason, older estates are associated with lots of paved areas with old infrastructure and playground equipment, or as being overgrown with untidy and neglected vegetation.

The tidying up of the traffic space is not sufficient to restore the usability of the estate space. A full revitalisation is needed, including public spaces, semi-private spaces or the aesthetic appearance of the housing itself. It is important to rationally use the available spaces, ensure their proper functionality and with all this restore the balance between vehicular, cycling and pedestrian traffic. An important aspect is the restoration of the pedestrianised city model, where the most important places can be reached on foot.

In a residential environment, it is important to provide a variety of opportunities for interaction and different forms of human contact. It is therefore important to provide a variety of spaces, enabling a wealth of experiences for residents [7]. The enrichment of housing estate spaces with features such as playgrounds, structured green areas, small-scale retail, leisure and entertainment venues will increase the attractiveness of housing on the estate in the eyes of residents.

The key to success in the revitalisation aspect of a housing estate space is to understand the needs of the community, involve them in the process of change and ensure that it is effective. People will be more willing to participate in each stage of revitalisation, knowing what they are aiming for, that they are doing it for themselves and their children, to seize the opportunity to improve their lives [8]. As the research[1] shows, the formation of neighbourhood ties is influenced by social participation in the shaping of the neighbourhood space, the joint establishment and furnishing of semi-private and social spaces. Therefore, carrying out revitalisation in residential environments on neglected estates is particularly important for residents, as they need spaces on two levels – private, as housing, and social, as social, integral spaces [9].

This allows the public to feel more comfortable in their surroundings and to express a desire to deepen neighbourly relations, and it is possible to observe a reduction in residents' desire to move, which has a positive impact on the future of the estate.

2. URBAN PLANNING OF POLISH HOUSING ESTATES FROM 1950-1980 – REVITALISATION OF THE "LARGE-PANEL" ESTATES.

"The shaping of housing complexes, as well as the entire structure of the city, faces various problems that are natural consequences of urbanisation" [10]. These were the problems faced by the Polish housing estates built in the so-called 'large-panel' technology, designed in the 1950s and 1980s. The extensive large-plate housing estates that began to spring up in European cities after the Second World War were a reaction to the housing shortage at the time. In addition, the mass migration of people from rural to urban areas in search of work has contributed to the housing shortage. To remedy this, an innovative solution was proposed in the form of the construction of multi-storey residential buildings from prefabricated reinforced concrete. The standardisation of technology allowed for faster construction, which was extremely beneficial at the time due to the urgent need for more housing (Fig. 1). The first such building was constructed in 1957 in Warsaw's Jelonki[2] district. Currently in Poland, the landscape of "large-panel" estates accompanies every major city and, according to statistics, an estimated one in three Poles lives in such an block of flats. These estates are characterised by architectural repetition, simple form, lack of detail and are often not accompanied by an interesting urban layout.

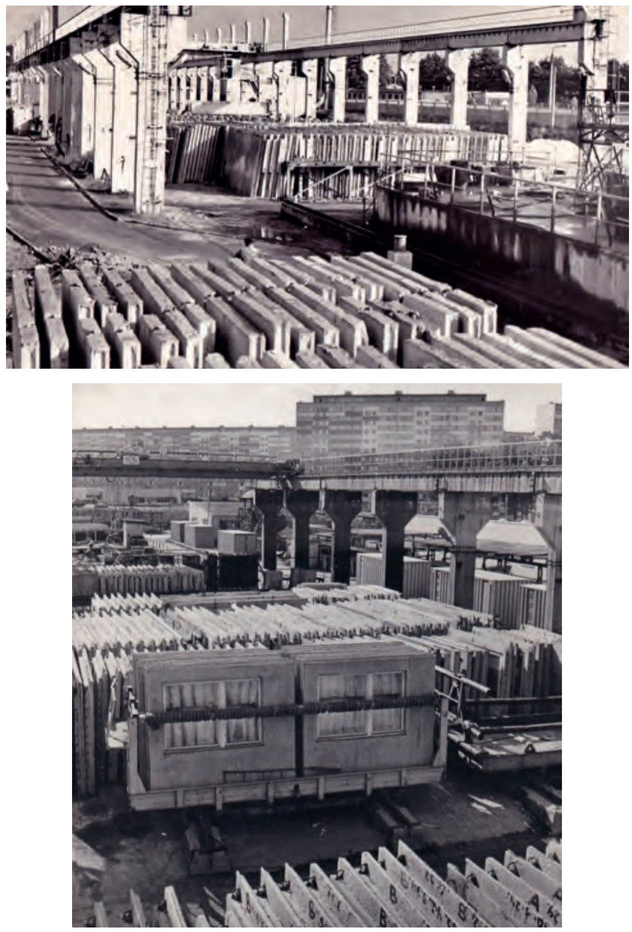

Fig. 1. Large panels factory in Popowice, 1984. Source: https://gazetawroclawska.pl/tak-budowano-w-prl-bloki-z-wielkiej-plyty-mieszkamy-w-nich-do-dzis-postoja-jeszcze-kilka-dekad-archiwalne-zdjecia/ga/c9-17339259/zd/65319899

Large-panel blocks of flats were initially designed to last 50 years. However, it is currently known that they

[1] Based on research conducted in 2007-2009 in 4 different housing estates, published by B. J. Gawryszewska in the article *Landscape of housing estates and building neighbourhood ties in revitalisation programmes.*

[2] https://twojahistoria.pl/2018/02/13/bloki-z-wielkiej-plyty-najwazniejsze-daty-liczby-i-fakty/.

will last much longer. Because of how many people still live in such estates in Poland, they are being modernised and revitalised, compared to Western Europe, where these buildings are being demolished. The main issue with large-panel housing estates is that they do not meet current housing standards and residents' expectations. Because of the prefabricated elements, the flats are not flexible in any way and it is difficult to change anything about them. In Poland, the modernisation of large-panel housing estates is limited to thermal efficiency upgrades and façade aesthetic improvements (colours). The buildings were initially designed in shades of grey and white, and over time the façade colours began to change to intense and vibrant colours. The buildings have lost their aesthetic value as the colours have faded over time, the façades have deteriorated through graffiti and staining and damage caused to the plasterwork, i.e. cracks, flaking. Currently, the urban space on the estate is being upgraded by replacing paving slabs on footpaths, repairing pavement defects in asphalt, replacing playground equipment, creating outdoor gyms or renovating sports fields.

The problem of a lack of parking spaces affects most Polish housing estates built decades ago. In the past, due to the economic conditions of the country and the limited financial possibilities of the residents, a relatively low ratio of parking spaces of around 0.5 per flat was considered sufficient. However, now that there are 1-2 vehicles per flat, the shortage of parking spaces is becoming a problem. As a result, drivers are often forced to park their cars on pavements or lawns, which impedes pedestrian traffic and negatively affects the appearance of the surrounding area [11]. This reduces the feeling of safety on the estate, increases pollution and worsens air quality. When revitalising estate spaces, this problem should be taken into account and underground car parks or parking spaces with vegetation should be designed.

Estates often lack public, semi-private and private spaces. The spaces between buildings are often neglected, overgrown with untidy, haphazard greenery. Unattractive playgrounds are appearing near the buildings, there is a lack of cycle paths and well-defined pedestrian routes. Shared spaces, if any, do not have an assigned manager, but also a recipient. There are no functional divisions in the spaces for particular groups: young people, parents with children, seniors or people with disabilities. The result is the neglect of these areas because no one feels they belong.

The appearance of the façades of large-panel buildings is a consequence of the applied technology. The architecture of these residential buildings is monotonous, uniform, with no green roofs, terraces or other green forms, making the architecture unattractive. Some of these buildings have small flats with "dark" kitchens, which does not correspond to today's housing standards. The estates deviate from the principles of sustainability, which is extremely important in the design of contemporary spaces. The main problem of the unchanging situation of the large-panel estates is the lack of finances and the problems of ownership of co-operative resources. Co-operatives are focusing on improving the conditions of housing units and, consequently, the revitalisation of estate spaces is receding into the background [10].

Despite the many disadvantages of large-panel housing estates, there are also room for a few advantages. Their attractiveness is due to their convenient location, good access to the city centre thanks to extensive communication and a comprehensive accompanying infrastructure equipped with all basic services, including a school, kindergarten or clinic. At the time of their construction, there was a strong emphasis on creating space not only for housing, but also to provide residents with comprehensive service and recreational facilities on a daily basis. Large-panel estates also contain significant green areas.

In terms of urban design, the estates in question may be good examples worth following, but they are in need of modernisation and revitalisation. Three areas of action are highlighted, which should be pursued simultaneously in order for the modernisation of this type of development to be successful. The macro scale, which includes urban and architectural transformations of entire housing estates, the meso scale, which includes transformations concerning so-called neighbourhood spaces, and the micro scale – functional and spatial changes to individual flats[3]. Macro-scale measures should include: the introduction of modern playgrounds, sports areas, cycle paths and new leisure spaces/facilities. On a meso scale, the activities should include: reorganising existing urban interiors, courtyards, systematising greenery, introducing

[3] Gronostajska B., *Modernisation of public spaces in large-panel housing estates/ Modernizacja przestrzeni publicznej w osiedlach mieszkalnych z wielkiej płyty*; Czasopismo techniczne 2-A/2010, zeszyt 5

various functions, small architecture, lighting or water elements. Interiors should blend coherently with their surroundings. Measures on the micro scale should include changes to the interiors of flats – rearranging dwellings where possible or changing their function from residential to commercial. The façades of the buildings should also be modernised.

Public participation is extremely important in reshaping the estate. Residents should be encouraged to look after the revitalised area together in order to strengthen their belonging to the community and neighbourhood. Home gardens for ground floor residents are a good way of doing this, making it a semi-private zone and making them feel more responsible for it. They can also act as a buffer between building windows and playgrounds or recreation areas. The estate space should be a zone where social relationships are built and provide a place for all ages. There should be playgrounds, recreation areas with small architecture, but also rest areas for the elderly. In summary, it is intended to be a green space that divides from a large monotonous area into smaller areas targeted for a particular age group [11].

3. HISTORY OF THE SŁONECZNE WZGÓRZE HOUSING ESTATE IN KIELCE

The Słoneczne Wzgórze housing estate is located in the north-eastern part of Kielce (Fig. 2), in the vicinity of the Adolf Dygasiński Park. It is situated on a hill at the foot of which lies Kielce, surrounded by the Świętokrzyskie Mountains range. Its construction began in the first half of the 1980s (Fig. 3). The development consists of two-storey and four-storey residential buildings as well as high-rise buildings of seven to eleven storeys and, like most housing estates of the period, was built using large-panel technology[4].

The estate has a primary school, kindergarten, health centre and shopping pavilions. Right next door, in the area of the Świętokrzyskie estate, is the church of St. Jadwiga the Queen. The Słoneczne Wzgórze estate is bordered by housing estates: Świętokrzyskie (to the north), Uroczysko (to the west), Nowy Folwark (to the east) and Bocianek (to the south). The streets were named in 1997, but took effect in April 2001. The introduced street names, i.e.: Elizy Orzeszkowej, Florentyny Malskiej, Marii Krzyżanowskiej, Emilii Znojkiewiczowej, Mieczysławy

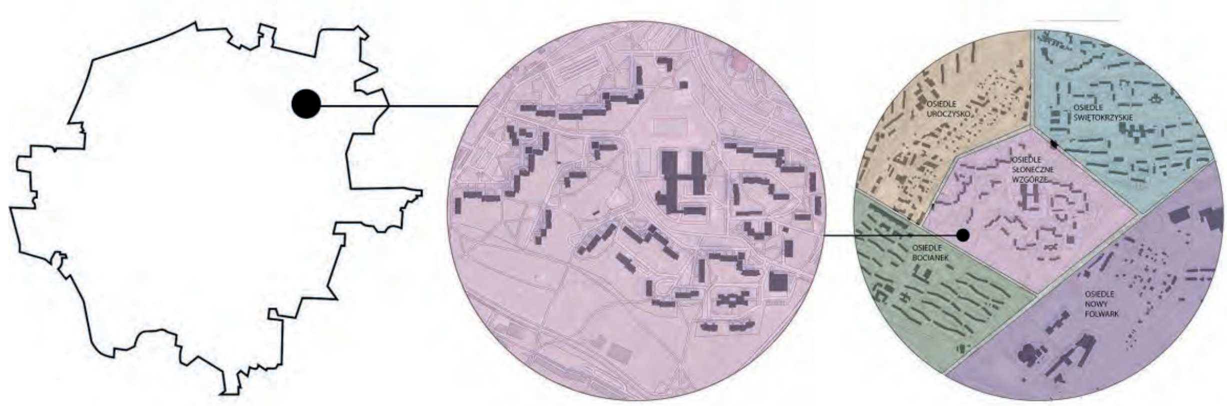

Fig. 2. Location of the Słoneczne Wzgórze estate within the city of Kielce and in relation to neighbouring estates [12]

Fig. 3. Słoneczne Wzgórze large-panel housing estate in Kielce, 1986. Source: https://kielce.naszemiasto.pl/takie-bylo-kieleckie-osiedle-sloneczne-wzgorze-tak/ga/c1-9466395/zd/84991619

[4] https://kielce.naszemiasto.pl/tak-40-lat-temu-wygladalo-sloneczne-wzgorze-w-kielcach/ar/c1-8977021.

Ćwiklińskiej, Aleksandry Dobrowolskiej, Gabrieli Zapolskiej are still in use today. At the same time, the building numbers, assigned according to the order in which the blocks were built, were changed to ascending numbers for a specific street. For the first few years, old numbers could be seen painted on the buildings, as well as plaques with new numbers. As the façades of the buildings were upgraded, the old building numbers faded away[5].

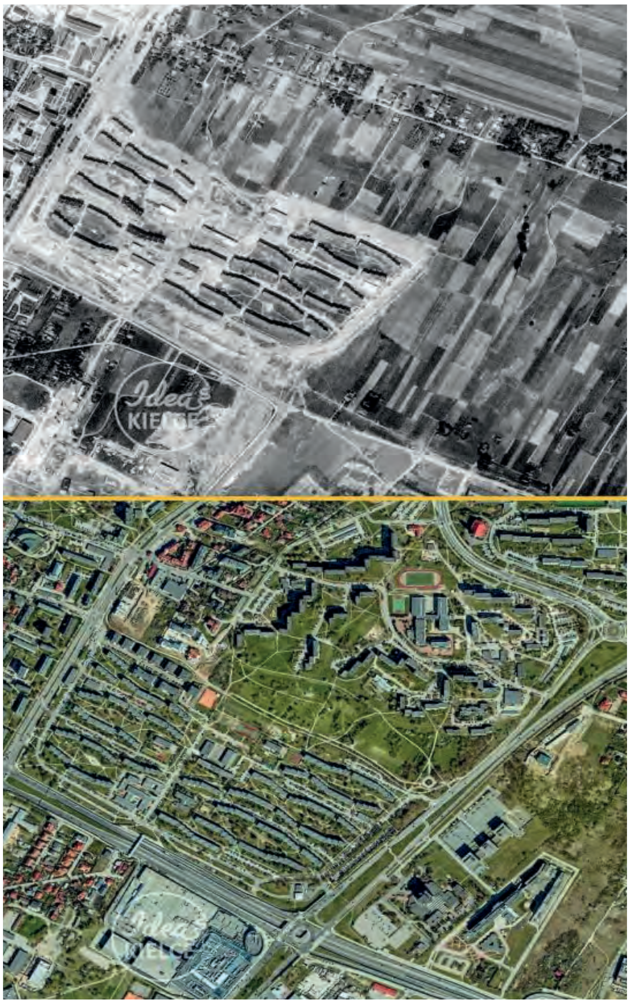

Fig. 4. Comparison of the 1977 and 2019 maps. Source: https://www.facebook.com/groups/330329694123904/

According to information provided by the Housing Association[6], the Słoneczne Wzgórze estate is inhabited by almost 5,000 people, while the usable area of the flats is approximately 86,000 m^2.

Fig. 5. Aerial view of the estate from 1990 i 2012. Source: https://www.facebook.com/groups/330329694123904/ https://www.facebook.com/Slwzg

4. ANALYSIS OF THE CURRENT STATE – SELECTED AREA OF THE SŁONECZNE WZGÓRZE HOUSING ESTATE IN KIELCE

The first stage of work prior to developing a concept and design for the revitalisation of the selected area on the Słoneczne Wzgórze estate was for the students to carry out an analysis of the estate's existing condition – from the general to the specific. The area selected for revitalisation is the courtyard area between the blocks of flats on Marii Krzyżanowskiej Street, which is bordered to the north, east and west by large-panel multifamily residential buildings (5-8 storeys), and to the south by a single-storey commercial building. Revitalisation in the student project was carried out in two areas of action – meso and micro scale[7]. The revitalisation area includes the courtyard with the

[5] https://pl.wikipedia.org/wiki/S%C5%82oneczne_Wzg%C3%B3rze

[6] https://www.sloneczne-wzgorze.pl/

[7] meso scale – neighbourhood spaces; micro scale – individual transformations involving functional and spatial changes to e.g. flats – Gronostajska B., *Modernisation of public... op. cit.*

surrounding residential buildings, the service building, car parks and traffic routes.

Three general analyses of the estate were carried out – building function, communication and green space. An analysis of the function of the development showed that the area surrounding the proposed redevelopment area is an estate of multi-family residential buildings with small services. There are 5 storey buildings to the north and east on the site and an 8 storey building to the west. A single-storey service building with a pizzeria, a grocery shop, a beautician and a hairdresser is located to the south. The estate also has several grocery shops, a vegetable shop, a medical clinic, a pharmacy and a centre for people with disabilities. The analysis showed that the area lacks a leisure area for seniors, which could be designed in the ground floor of one of the blocks of flats and part of the courtyard could be used to introduce such a function. A garden space for a restaurant (pizzeria) can also be proposed in the area. Other important services are available in the immediate vicinity.

The transport analysis showed that the neighbourhood is very well connected through easy access to public transport and public bikes, making it easy to access the city centre. A cycle path runs along Solidarności Avenue and Jaworskiego Street. There are several car parks located directly next to the residential buildings and there are also dedicated larger guarded car parks. A residential street runs around the revitalisation area. In this area, the existing car parks under the residential buildings should be tidied up and a dozen additional parking spaces should be designed on the south side.

The green analysis showed that the area around the Słoneczne Wzgórze estate is very green. Almost everywhere there is low greenery – grasses, medium greenery – shrubs and high greenery – trees, but unfortunately mostly untidy and neglected. The largest concentration of greenery stands out to the south of the plot – the location of the Adolf Dygasiński Park. There are several playgrounds on the Słoneczne Wzgórze estate, including one that is currently disused and unattractive to children in the study area. However, the one in the redevelopment phase will be removed and replaced with a new, larger, safer and more attractive one for children. The greenery on the plot should be systematised, some neglected plants should be cut down and replaced with new greenery that is visually attractive and tidy. There are no bodies of water in the area – it is worth introducing them into the project for their aesthetic and compositional qualities, as well as having a calming effect on people.

An analysis of archival photographs of the area and a photographic analysis of the existing state shows how the area has changed. The change in the colour scheme of the buildings, the space occupied by surrounding greenery and the number of cars and parking spaces is noticeable (Fig. 6, Fig. 7).

Fig. 6. Revitalisation area of 1986 and 2022. Source: https://www.facebook.com/groups/330329694123904/

Fig. 7. Revitalisation area from a bird's eye view of 1986 and 2023. Source: https://www.facebook.com/groups/330329694123904/

Fig. 8. Analysis of the revitalisation area [12]

The students also carried out a detailed analysis of the entire revitalisation area including the surrounding buildings. The façades of the buildings are in a poor state of repair – the colours have faded, damp patches and dirt are visible. The buildings have recently been thermally upgraded and such work is currently underway again and the colours are returning to neutrals (white and grey). The service building also has visible damage – cracks in the walls, plaster coming off and numerous stains. The stairs leading to the pizzeria and shop are dilapidated. There is a playground in the study area with only one piece of equipment, which is reluctantly used by children. There is a lot of neglected and haphazard greenery in the courtyard and around the blocks. Some of these are shrubs and others are larger trees. There are only 2 footpaths, a few benches and street lamps in this area.

The car parks are mostly made of openwork slabs, but vegetation does not grow there. The delivery route to the pizzeria is in poor repair. The paving has cavities and bulges in some areas. Grass and weeds are growing out of the kerbs and between the pavement blocks. The courtyard area has differences in height – it slopes evenly downwards from the residential buildings.

In summary, the analyses showed that this area needs to be revitalised in order to make it attractive and usable again by local residents. Currently, there are no leisure activities for any age group available. Carrying out the revitalisation process in the area will help to improve the lives of the estate's residents, encourage them to tighten their neighbourhood ties and look after the new areas as if they were their own (Fig. 8).

5. SOCIAL STUDIES AND REVITALISATION PROGRAMME

An important element of the revitalisation process, through which the success of the process is guaranteed, is social research. Consultation with residents, the main stakeholders, aims to find out their opinions and to introduce solutions that satisfy the majority of residents. The research carried out will make it possible to propose a tailored revitalisation programme that meets the needs of the main users, i.e. the residents of the estate.

Social studies carried out on the Słoneczne Wzgórze estate has shown that the people living there are mainly families with children and senior citizens. Understanding the needs of the community, involving them in the process of change and ensuring effectiveness is an extremely important issue in the revitalisation process. This area is the local ”hub”, so the residents should be able to spend their leisure time there. The aim of revitalising the area is to make it suitable for the needs of the residents – seniors, parents with children and young people – and to improve the condition of the buildings and pavement.

Discussions with residents revealed the need to locate a new and safe children’s playground and recreation and meeting places for parents in the area. Interviews with the elderly residents revealed the need to provide a senior-focused area. Residents on the ground floor suggested developing spaces for gardens accessible directly from the flats, while a large group of respondents would request the design of more parking spaces and the replacement of the surface of existing spaces. The study also highlighted the development of a summer zone with tables for customers of local services – pizzeria.

Taking into account the needs of the residents and the results of the analyses carried out, the students developed a revitalisation programme for the Słoneczne Wzgórze estate space, in which they propose, among other things:

- decommissioning of the existing playground, which is not well-equipped, in order to design a new one with a sensory path and various safe equipment,
- design of flower/vegetable gardens accessible to residents directly from the flats located on the ground floor; separate garden area from the public area,
- designing an outdoor area with tables for the restaurant;
- tidying up of existing surface car parks, design of a dozen additional spaces in the southern part; replacement of paving with openwork slabs with space for vegetation;
- modernisation of the façade of residential buildings – repair of cracked plaster, thermal upgrades with change to neutral colours (white/grey);
- in the ground floor of the residential building (in the western part), designing a Senior Citizens’ Club with access to the courtyard and a separate area for seniors in the courtyard space with gazebos and a meeting place;
- design of new greenery planting and walking paths with seating in the area;
- design of water reservoirs with fountains;
- design of recreation and relaxation areas for adults and young people with small architectural elements, i.e. benches, deckchairs, gazebos;
- cutting back neglected greenery and planting new shade vegetation in pots with seating; planting lower, tidy greenery near building entrances;
- maintaining and matching the function of the site to the tallest and oldest trees;
- design of low greenery (flowers) around the recreation areas for visual purposes;
- replacement of the pavement leading to the residential blocks with large concrete slabs;
- replacing pavement and repairing stairs near services;
- proposal for free-standing lighting and small waste bins.

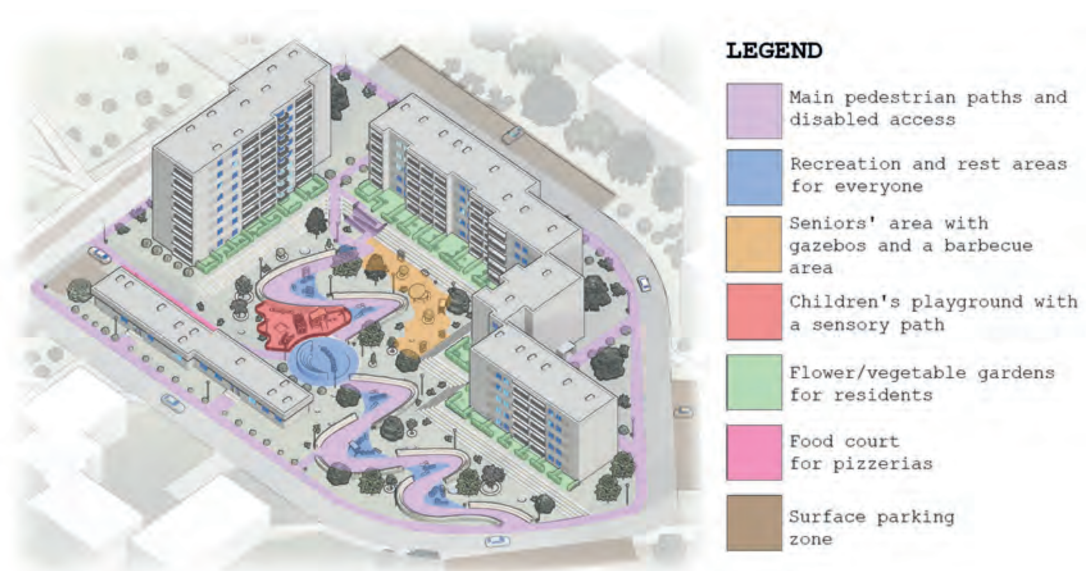

Fig. 9. Functional and spatial diagram [12]

The proposed revitalisation programme for the Słoneczne Wzgórze estate space is not only suitable for the residents, but also fits in perfectly with current architectural trends. The analysed needs of the community, taken into account in the developed programme (Fig. 9), focus on creating a space that is attractive and functional for all age groups. An important aspect of the programme is the involvement of the estate's residents in the planning process for change, ensuring that they are happy and feel part of where they live. Improving the condition of buildings and infrastructure, taking into account everyone's needs, is key to creating a welcoming and harmonious space. In addition, the inclusion of landscaping elements, water retention ponds and vegetation adds to the aesthetic and functional aspect of the revitalisation.

6. A PROPOSAL FOR THE REVITALISATION OF A SELECTED AREA OF THE SŁONECZNE WZGÓRZE HOUSING ESTATE IN KIELCE BASED ON THE EXAMPLE OF A STUDENT PROJECT

The students' proposal for the revitalisation of the estate space is in line with modern design trends and responds to the problems of the local community arising from analysis and research. Changes have been made on a meso scale by completely changing the courtyard area and associated elements, and on a micro scale by changing the function of one of the flats (Fig. 10).

All the tenets of the revitalisation programme have been introduced, while retaining the visually interesting ribbon urban layout to extend the walking time. A green staircase has evened out the difference in height and so gardens have been designed for residents, which also act as a buffer zone. The large area is divided into smaller zones, each tailored for a specific age group. As a result, everyone can feel comfortable there. Systematically arranging the greenery will provide an easier opportunity to residents to look after it. The space has no barriers as a disabled exit has been designed and there are no height differences in the pavement level. A path with seating runs from north-west to south-east. A connection was also made next to the pizzeria. A circular leisure area with a pond and green steps connects the middle of the path (Fig. 11, Fig. 12). The main pedestrian routes are designed with concrete slabs, while the relaxation and senior-focused areas are distinguished by wooden pavement. The playground is located close to the refreshment area so that parents can see their children playing from it. Trees and gazebos have been proposed in the senior-focused area to provide shade. From the main path it is possible to step down from time to time onto the lawn, where seating under the trees has been designed. Water reservoirs serve an aesthetic function, cooling the air in summer, and water can also be used to water vegetation. All this is accompanied by flower beds with a variety of plant species. The surface parking spaces are designed with openwork slabs with space for vegetation. The biologically active area occupies more than 60%. The façades of the buildings during the revitalisation process have been refreshed and look more attractive. Such a proposed space could definitely improve the daily life of the residents of the Słoneczne Wzgórze estate.

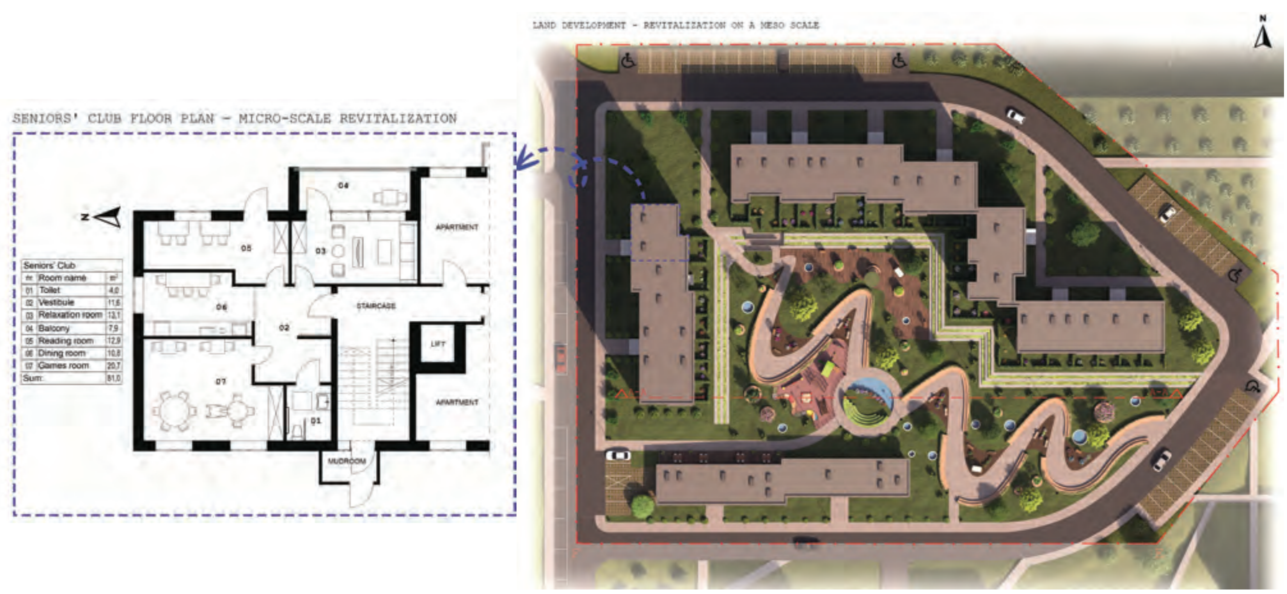

Fig. 10. Meso scale – land development and micro scale – Senior Citizens' Club [12]

Fig. 11. Photograph showing the current state, 2023, photo by author. Revitalisation project – visualisation [12]

Fig. 12. Photograph showing the current state, 2023, photo by author. Revitalisation project – visualisation [12]

7. SUMMARY AND CONCLUSIONS

Today, the issue of urban revitalisation is becoming increasingly important in the context of changing social, economic and environmental needs. Cities are the epicentre of social, economic and cultural life, which requires space to be properly managed and adapted to the needs of the inhabitants. The revitalisation project, carried out by architecture students at the Kielce University of Technology, is a valuable example of an initiative to improve the quality of life on the estate through sustainable, functional and aesthetically pleasing transformation of the estate space. The following findings show that the student project fitted into the general guidelines of urban revitalisation. Through a comprehensive approach to the revitalisation process, taking into account meso- and micro-scale aspects, this project represents a significant step towards improving the quality of life on the estate. The conclusions analyse the different areas of action, the proposed solutions and the advantages and challenges of the student revitalisation project, such as:

- Improving the quality of life for the residents: The student project to revitalise the estate fits in with the need to improve the quality of life for residents by adapting the space to their needs and expectations. Analyses carried out by the students showed that existing large-panel housing estates are characterised by neglect, lack of attractive recreational places and inadequate landscaping.
- Public participation: An important element of the project is the involvement of the local community in the revitalisation process. By involving residents in shaping the space, the project can better respond to their needs, leading to a greater sense of belonging to the community and creating neighbourhood bonds.
- Diversity of space functions: The focus of the student project is to create a space that caters to the diverse needs of local residents, encompassing recreational spaces for children, leisure areas for adults and the elderly, as well as summer zones for customers of local services.
- Infrastructure modernisation: By upgrading infrastructure, including building façades, paving or car parks, the project aims not only to improve aesthetics, but also to increase functionality and convenience for residents.
- Sustainable development: In designing the new estate space, the students were guided by the principles of sustainability, taking into account the needs of current residents and future generations. The space will be more human and environmentally friendly through the use of modern urban and ecological solutions.

- Adaptation to modern standards: The student project aims to bring the existing estate space up to contemporary housing standards, eliminating the inconvenience of lack of parking spaces, inadequate recreational infrastructure or inadequate green space.
- Functional balance: The estate space of the project is intended to provide a balance between different functions, such as housing, services, recreational spaces and green areas, to contribute to the better functioning of the estate as a whole.
- Efficiency of measures: Through a comprehensive revitalisation programme, the project aims to achieve outcomes that will bring real benefits to residents, such as improved aesthetics, improved accessibility to recreational and service spaces and an increased sense of safety and social belonging.
- Support for different age groups: The project takes into account the needs of different age groups of residents, from children to young people, adults to the elderly, to contribute to a more sustainable and versatile use of the estate space.
- Strengthening social ties: By creating a space that encourages interaction and joint activities between residents, the project aims to strengthen social ties, which contributes to building a more integrated and harmonious local community.

In conclusion, the student revitalisation project, makes a significant contribution to improving the quality of life on the Słoneczne Wzgórze estate. Through an appropriate approach to the revitalisation process, this project demonstrates that successful revitalisation requires close cooperation between different stakeholders. Any revitalisation project should be tailored to the needs of local residents, taking into account the results of the public consultation carried out, while not adversely affecting the environment.

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APPLICATION OF CENTRAL COLLINEATION IN UNDERSTANDING OF INTERSECTION STRUCTURE OF SOLIDS IN THE ACTIVITY OF ENGINEER

ZASTOSOWANIE KOLINEACJI ŚRODKOWEJ W ANALIZIE PRZECIĘĆ BRYŁ W DZIAŁALNOŚCI INŻYNIERSKIEJ

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Abstract

Modern design takes place in systems that use solid geometry. There, you receive ready-made geometric models of complex architectural and construction elements. This is not always accompanied by the engineers full understanding of the spatial relationship between the elements creating a complex geometric object. The authors propose the use of central collineation in the creation and analysis of the correctness of spatial geometric structures.

Keywords: Intersection of solids, central (axial) collineation, Desargues' theorem, AutoCAD.

Streszczenie

Współczesne projektowanie odbywa się w systemach, gdzie wykorzystywana jest geometria brył. Otrzymuje się tam gotowe modele geometryczne złożonych elementów architektonicznych i budowlanych. Nie zawsze towarzyszy temu pełne zrozumienie przez inżynierów relacji przestrzennych między elementami tworzącymi złożony obiekt geometryczny. Autorzy proponują wykorzystanie kolineacji środkowej w nauczaniu tworzenia i analizy poprawności przestrzennych struktur geometrycznych.

Słowa kluczowe: przecięcie brył, centralna (osiowa) kolineacja, twierdzenie Desargues', AutoCAD.

1. INTRODUCTION

Design in construction and architecture, in its geometric part, is currently carried out in the CAD environment and is often implemented in 3D. What is important here is the structure of geometric elements and their mutual connections, as well as mapping in the classic convention of orthographic projections [1]. In geometric terms, it is a sequence of cross-sections and intersections of elements, their visualization and presentation in a orthographic projection, perspective or axonometry. In order to fully understand the geometric structure of the object constructed in 3D (and at the same time to check the correctness of its execution), it is advisable to perform a geometric analysis in rectangular and axonometric projections. This is particularly important in BIM technology,

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where individual interconnected parts of the project are mutually verified [2, 3]. In geometric verification, it is convenient to use a transformation called central (axial) collineation. There are four types of central (axial) collineation in the affine plane [4-6]. Individual implementations of alignment on the plane, depending on the affine nature of the center and axis of alignment, are illustrated in Figure 1. Further drawings illustrating the use of the transformation to analyze and create geometric structures are presented in the form of a cartoon (Figs. 2, 3, 5). It is important that flat realizations can also be interpreted as solutions to problems in 3D (Fig. 3).

The algorithmic nature of central collineation can become the basis for innovative approach to geometrical analysis and creation of structures both in RhinoGrasshopper and in Revit environments [7, 8]. The geometric analysis method supports the development of spatial imagination and understanding of 3D geometry in engineering.

2. AFFINE TYPES OF CENTRAL COLLINEATION

2.1. Affine plane

An *affine plane* is a set, whose elements are called points, and a set of subsets, called lines, satisfying the following three axioms, A1-A3.

A1. Given two distinct points P and Q, there is one and only one line containing both P and Q.

A2. Given a line l and a point P not on l, there is one and only one line m which is parallel to l and which passes through P.

A3. There exist three non-collinear points (A set of points $P_1, P_2, \ldots, P_n$ is said to be collinear if there exists a line l containing them all.) [5].

2.2. Ideal points and the projective plane

Let Af be an affine plane. For each line l $l \in Af$, we will denote by $=\{l\}$ the pencil of lines parallel to l, and we will call $\{l\}$ an *ideal point*, or *point at infinity*, in the direction of l. We write $L^{\infty}=\{l\}$ [5].

We define the completion Pr of Af as follows. The points of Pr are the points of Af, plus all the ideal points of Af. A line in Pr is either:

a) an ordinary line l of Af, plus the ideal point $L^{\infty}=\{l\}$ of l,

or

b) the *line at infinity* l^{∞}, consisting of all the ideal points of Af.

As it turns out, the plane completed in this way Pr is the projective plane, in the sense of the following definition.

2.3. Projective plane

A *projective plane Pr* is a set, whose elements are called points, and a set of subsets, called lines, satisfying the following four axioms.

P1. Two distinct points P, Q of Pr lie on one and only one line.

P2. Any two lines meet in at least one point.

P3. There exist three non-collinear points.

P4. Every line contains at least three points [5].

2.4. Collineation and central collineation

A *collineation* (*homology*) is a one-to-one onto mapping of the projective plane to itself in which collinear points are mapped to collinear points. The collineation is *central* if there is a *center*, a point S (S^{∞}) where all lines on S (S^{∞}) are fixed, meaning the line is mapped to itself, although individual points on the line need not be fixed. A a collineation is central exactly when it has a line of fixed points, an *axis* [9].

Hence, central collineation can be considered as axial collineation. This property is justified by Desargues' theorem [8].

More precisely, the definition of central collineation is justified by the property of closing the Desargues configuration (DG) [10-13]. The essence of DG is that in creating the image of the triangle $A_1B_1C_1$, the lines A_1B_1, A_2B_2 (which „were not constructed") and the collineation axis turn out to be co-bundle (i.e. they pass through one point) (cf. [9, 13]).

Desargues' theorem forms the basis of the principles of perspective used in photography, art, and engineering.

We say that two triangles have a *perspective point*, when we can label them $A_1B_1C_1$ and $A_2B_2C_2$ in such a way, that lines A_1A_2, B_1B_2, C_1C_2 pass through a common point S (S^{∞}). Pairs of points A_1, A_2; B_1, B_2; C_1, C_2, are then called *homologous*. The point S (S^{∞}) is then called *perspectivity center* of the two triangles $A_1B_1C_1$ and $A_2B_2C_2$.

We say that two triangles have a *perspective line*, when we can label them $A_1B_1C_1$ and $A_2B_2C_2$, in such a way (see Fig. 1), that the points of intersection of pairs of lines $a_1(B_1C_1)$, $a_2(B_2C_2)$; $b_1(A_1C_1)$, $b_2(A_2C_2)$; $c_1(A_1B_1)$, $c_2(A_2B_2)$ are contained in the same line s (s^{∞}). Pairs of lines $a_1(B_1C_1)$, $a_2(B_2C_2)$; $b_1(A_1C_1)$, $b_2(A_2C_2)$; $c_1(A_1B_1)$, $c_2(A_2B_2)$ are then called *homologous*. Line s (s^{∞}) is called *perspectivity axis* of the two triangles $A_1B_1C_1$ and $A_2B_2C_2$.

Theorem. (*Desargues*) Two triangles have a perspectivity center if and only if they have a perspectivity axis [8].

An example of the construction of an axial affinity triangle image is shown in Figure 2.

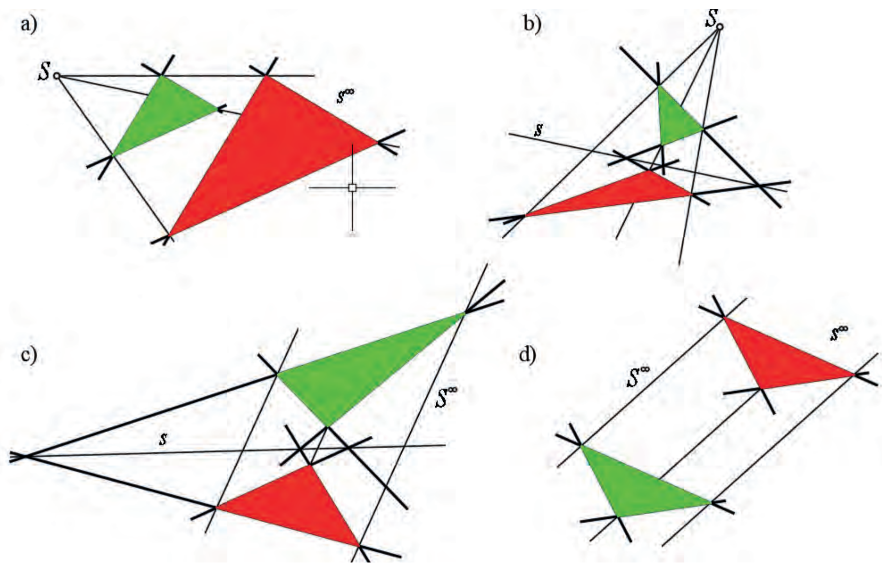

Fig. 1. Types of central collineation (homology) on a plane: a) central dilatation (center of collineation → ordinary point (S), axis of collineation → line at infinity (s^{∞})), b) central collineation (center of collineation → ordinary point (S), axis of collineation → ordinary line (s)), c) axial affinity (center of collineation → ideal point (S^{∞}), axis of collineation → ordinary line (s)), d) translation (center of collineation → ideal point (S^{∞}), axis of collineation → line at infinity (s^{∞}))

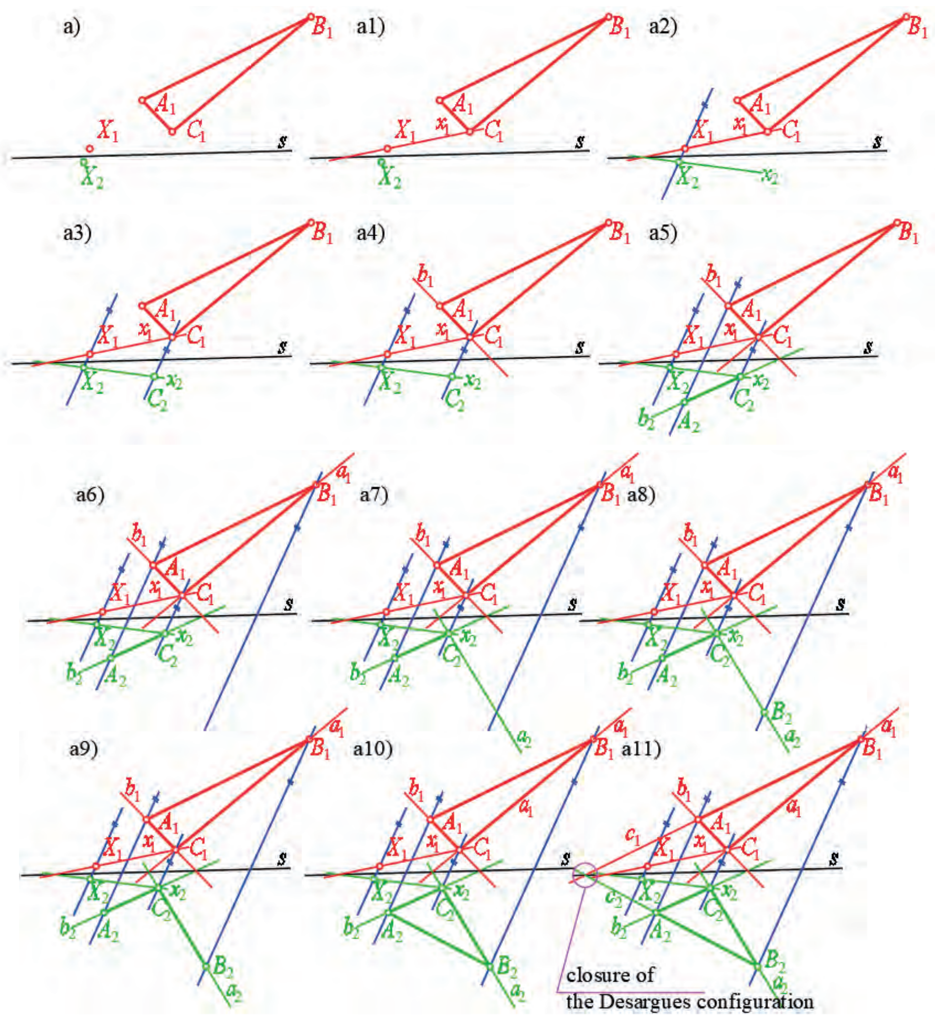

Fig. 2. The construction of the triangle $A_1B_1C_1$ image in axial affinity, closing of the Desargues configuration [9, 11, 12]

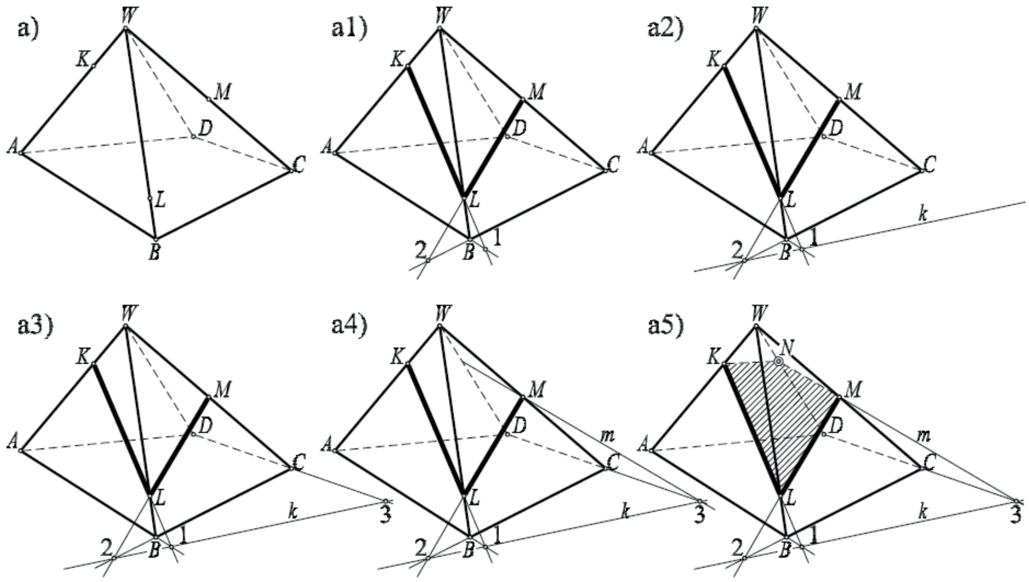

Fig. 3. Realization of axial (central) alignment in three-dimensional 3D space (axis of collineation k and center of collineation W) when finding a cross-section of a pyramid

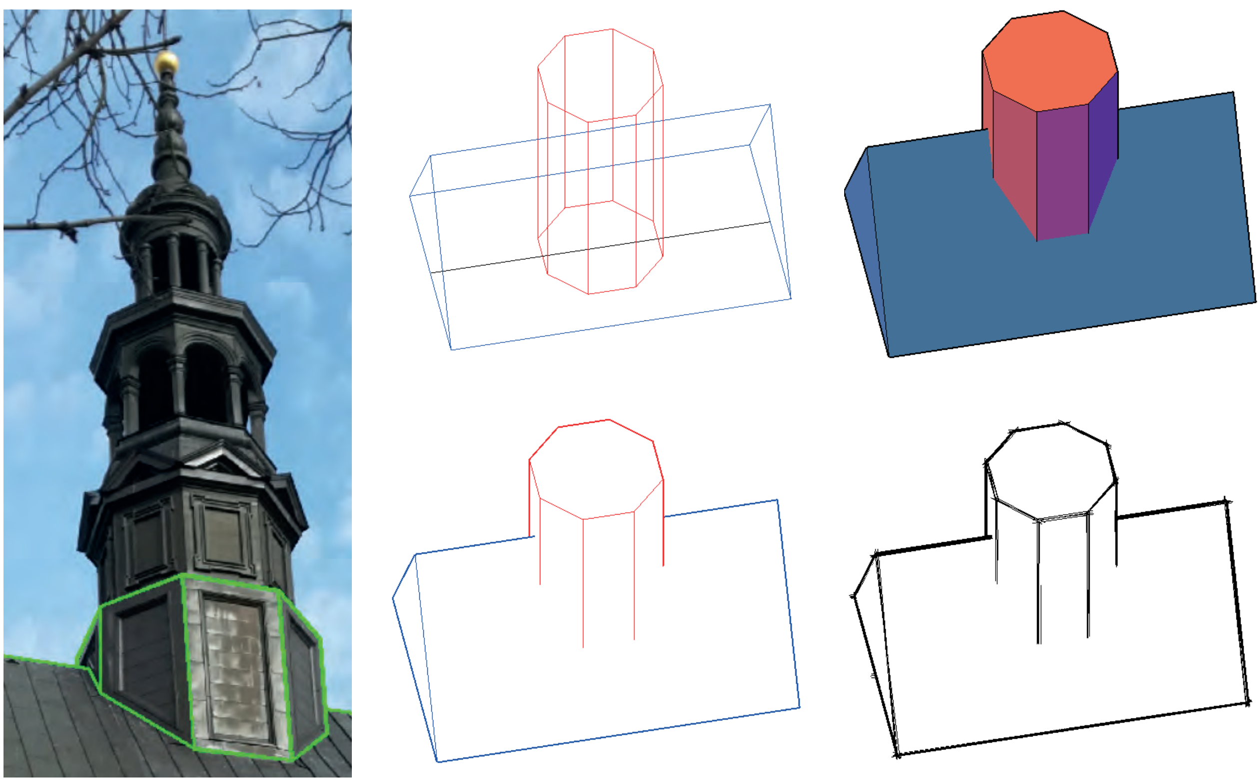

Fig. 4. Tower of the Cathedral Basilica of the Assumption of the Blessed Virgin Mary in Kielce. Interpenetration line of the tower with the roof (photo taken for the analysis of the problem 1). Next: a 3D model of the connection between the tower and the roof used for the geometric analysis of the structure Several AutoCAD visualization options: 3D wireframe, conceptual, 3D hidden, sketchy

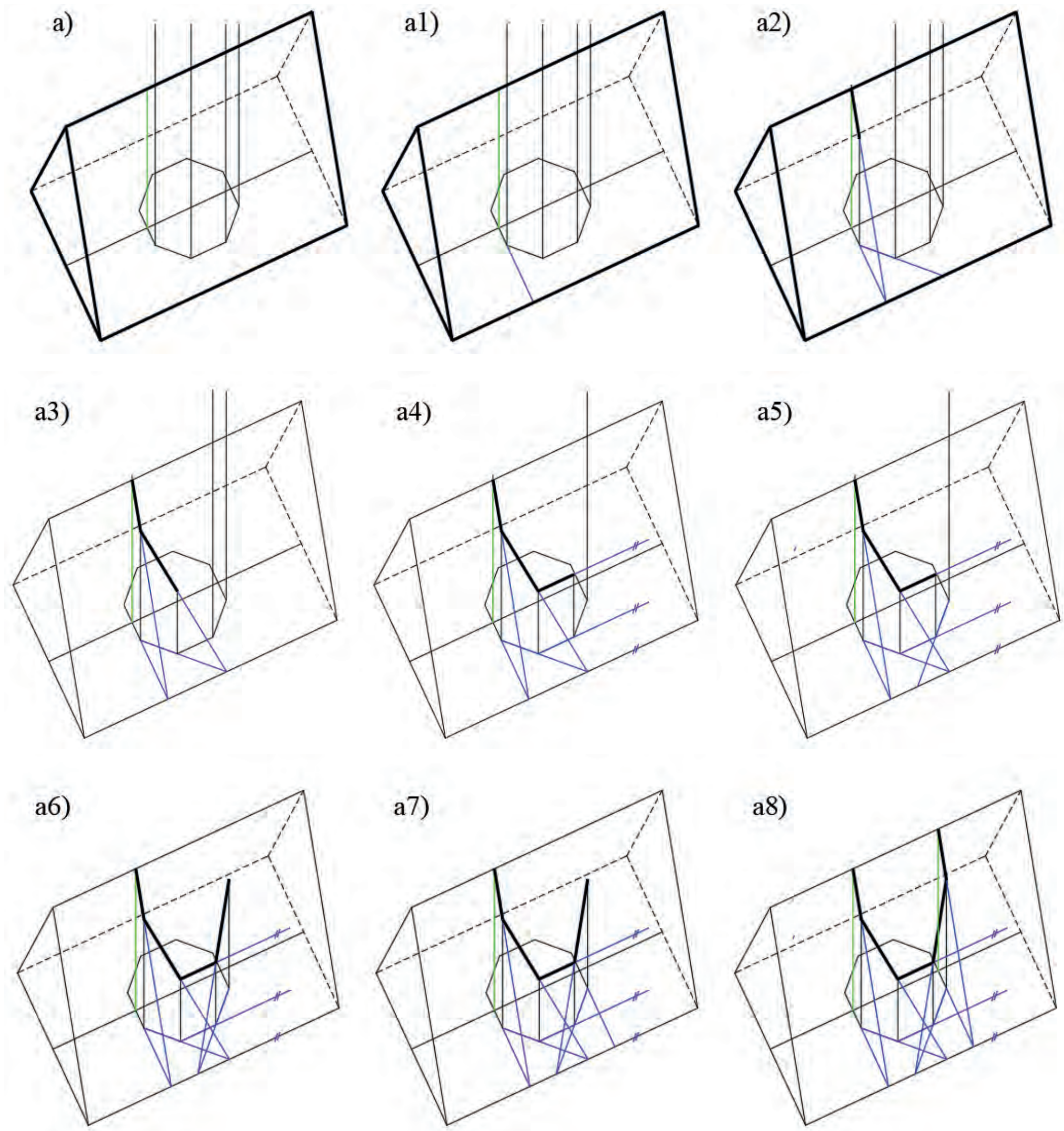

Fig. 5. Construction of the tower-roof interpenetration line using axial affinity

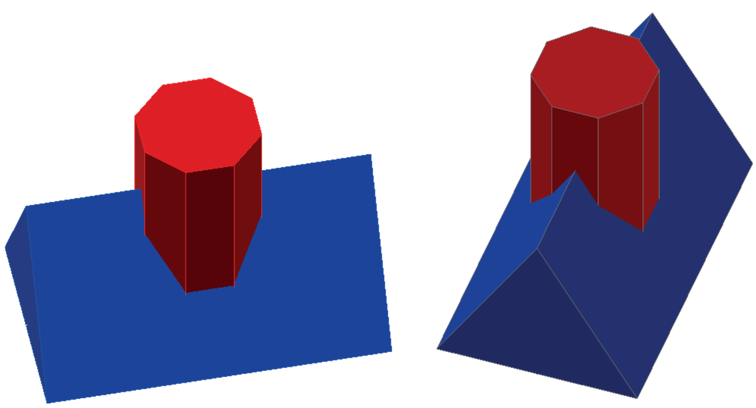

Fig. 6. The analyzed 3D model of the tower-roof interpenetration in realistic visualization in AutoCAD

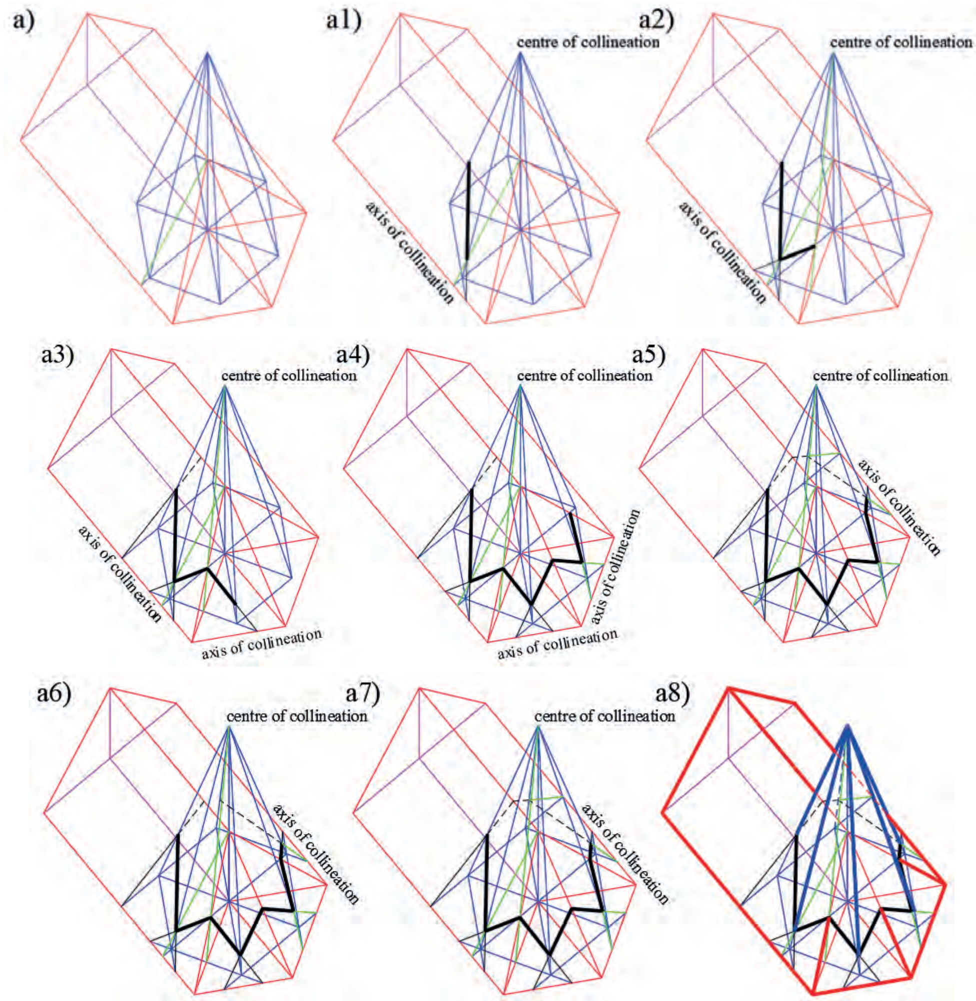

Fig. 7. Construction of the interpenetration line of a pyramid with a roof in axonometry – the method of collinear transformations

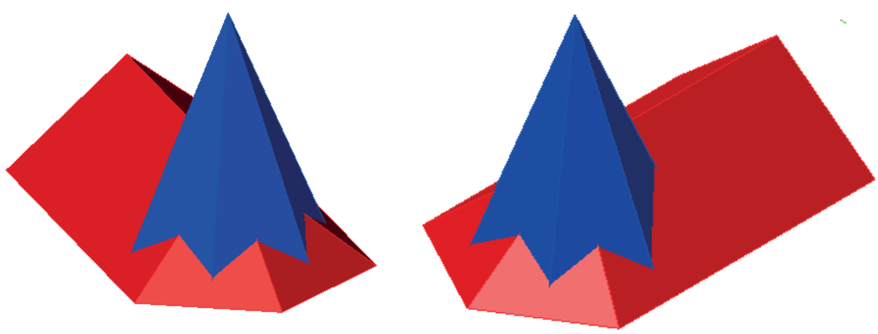

Fig. 8. 3D model of the interpenetration of a pyramid with a roof used to analyze the geometric structure

3. APPLICATION OF COLLINEATION – CASE STUDY

In this chapter, we present the use of collineation in three structures: cross-section (problem 1) and interpenetration of two solids (problems 2 and 3).

3.1. Problem 1

Task 1. Given: the pyramid *ABCDW* and the points *K*, *L*, *M* on its edges *AW*, *BW*, *CW* (Fig. 3a). Find the cross-section of the pyramid *ABCDW* with the α(*KLM*) plane.

To construct a cross-section of a given pyramid in projection, we proceed as shown in Figure 3. This is done by applying the so-called *nodal point theorem* (*For any three planes, the edges of each pair of these planes pass through one point* [14]) for several times. Just apply the procedure twice: find the common point of two edges and then the third edge must pass through this point. This is how we find points 1 and 2 defining the line *k*, which can be considered as the axis of collineation (Fig. 3a1, 3a2). Using this collineation, we find the remaining points of the section. The *KLMN* cross-section is an image of the quadrilateral *ABCD* in collineation with center *W* and axis *k*. Using the collineation with the *k* axis and the center *W*, we find the missing point of the cross-section (Fig. 3a3, 3a4). The *KLMN* cross-section is an image of the quadrilateral *ABCD* in the collineation with center *W* and axis *k* (Fig. 3a5).

3.2. Problem 2

How to justify (or verify) the shape of the intersection of the tower with the roof on the example of the Cathedral Basilica of the Assumption of the Blessed Virgin Mary in Kielce?

This is an example of the interpenetration of a gable roof (a prism with an isosceles triangle base) and a prism with a regular octagon base.

The following geometric task can be formulated on the basis of a photograph presented in Figure 4.

Task 2. Determine the lines of intersection of the gable roof with the tower, which geometrically is a prism with a regular octagon base. The angle of inclination of the gable roof to the horizontal projection is 60°. We solve the task in axonometry (Fig. 5).

To solve a 3D problem a planar construction has been developed in AutoCAD by using an axial affinity properties.

First, finding a point on the roof ridge in the axonometric projection and in the axonometric (pictorial) projection of the orthogonal projection (Fig. 5a, green line) as corresponding points, we determine the axial affinity, where the axis is the roof eaves (Fig. 5a1-5a2), and the direction is determined by the vertical edges of the tower. The points of the interference line are determined by applying the axial affinity (Fig. 5a3-5a8).

3.3. Problem 3

Central collineation can be also used in order to construct the penetration line between tower in the shape of a pyramid with a regular hexagonal base and a multi-slope roof in axonometry and in Monge projections (A). The solution using central collineation shows the arrangement of the interference lines.

Task 3. Determine the line of intersection of the multi-slope roof with the tower – a pyramid with a regular hexagon base in axonometry (Fig. 7a) and in horizontal projection (Fig. 9a).

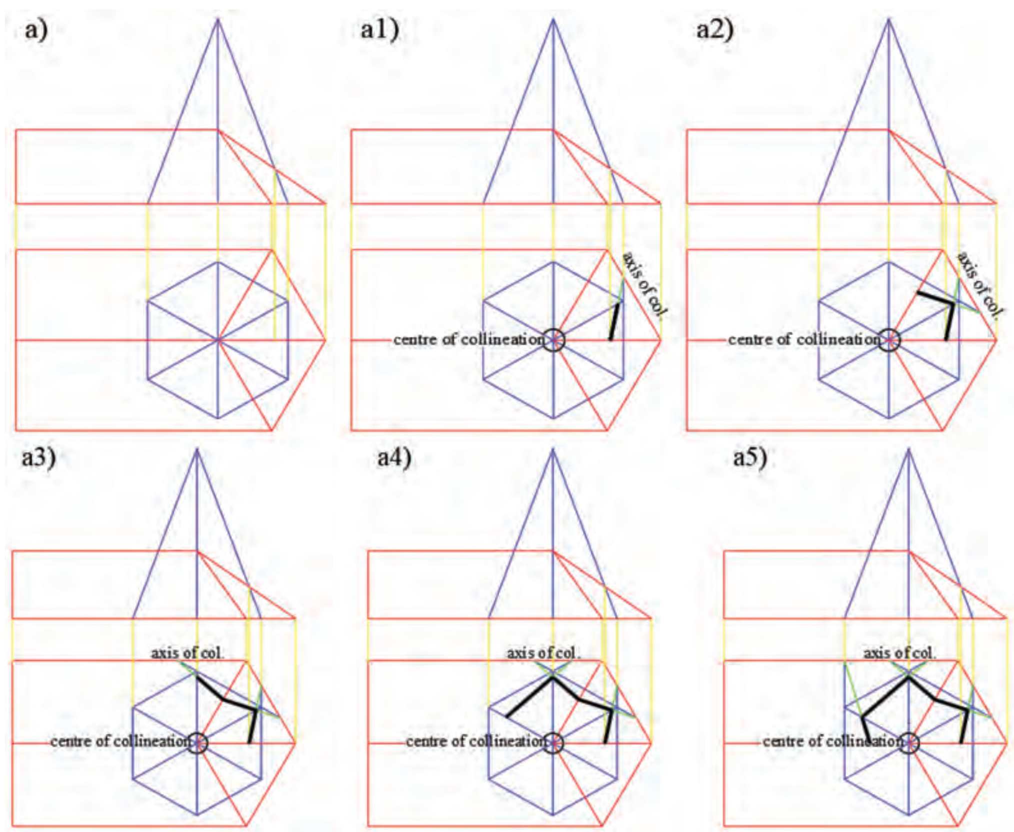

Fig. 9. Construction of the interpenetration line of a pyramid with a roof in Monge projections – the method of collinear transformations

First we solve the task in axonometry (Fig. 7a). In this case, we use four axial collineations with the same center and four different axes (Fig. 7a1-7a8).

We can compare the obtained flat drawing as a solution to task 3 with the one created in the AutoCAD environment 3D drawing (Fig. 8).

We can also use central collineation to create an object using orthographic (Monge) projections (Fig. 9). After determining the first point of the interference line (Fig. 9a), we construct a horizontal projection using two alignments with the same center (Fig. 9a1-9a5). Due to the symmetry of the horizontal projection in Figure 9, only part of it was made. Similarly, the construction of the vertical projection was omitted, which we supplement using the standard method of common elements.

4. CONCLUSION

The first quarter of the 21st century is coming to an end, and drawing is still one of the basic elements of everyday work for every engineer. Drawing is an inseparable element both in the design office and on the construction site, because it is impossible to imagine even the simplest project without presenting it in the form of a drawing. Drawings must be made according to strictly defined rules so that there is always a possibility of determining the real shape and dimensions of the designed structure and the correct location in three-dimensional space. From a geometric point of view, making such drawings is simply a certain transformation of a spatial or flat figure into a flat figure, which falls within the field of projective mappings

As it has been shown in the solved here tasks, central collineation can be successfully used when creating three-dimensional geometric objects in engineering practice. The solution method is then orderly, clear and shows the spatial system of the structure. The presented method (cartoon film) is sparse in text and reading the drawings is enough to understand the structure. The method presented fits into the general trend in interpersonal communication of moving away from text in favor of images in the form of drawings, graphics, diagrams, photographs, icons, emoticons, etc. This is especially important in teaching, in the education of engineers, in textbooks and various other teaching aids. This is the role of this article.

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GLASS FAÇADES AS A COMPONENT OF SUSTAINABLE ARCHITECTURE – ANALYSIS OF SELECTED CASES

FASADY SZKLANE JAKO ELEMENT ARCHITEKTURY ZRÓWNOWAŻONEJ – ANALIZA WYBRANYCH PRZYPADKÓW

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Abstract

The governance of sustainable energy represents one of the principal concerns in the current era. The escalation of global warming and the depletion of natural resources have become progressively pertinent issues, underscoring the crucial role of sustainable architecture in addressing these pressing concerns. In the context of advancing sustainable development and environmental preservation, contemporary construction processes hold significant importance. Sustainable design in architectural practices plays a crucial role in strategizing the construction of buildings to curtail their energy consumption and utilization of natural resources. In the context of escalating standards for energy conservation, twin-layered façades are gaining significant traction. This paper aims to substantiate that incorporating a double façade in structures is not just a trend, but a critical component in the execution of sustainable growth. These façades play a key role in improving energy management and enhancing the quality of urban life, by yielding quantifiable ecological and energy outcomes.

Keywords: glass façade, sustainable development, sustainable design, friendly city, bioclimatic comfort.

Streszczenie

Zrównoważone zarządzanie energią stanowi jedną z kluczowych kwestii współczesnych czasów. Wraz ze zmianami zachodzącymi na świecie zmieniają się również potrzeby i pojawiają się nowe wyzwania, którym musimy sprostać. Nowoczesne budownictwo odgrywa istotną rolę we wspieraniu zrównoważonego rozwoju. Elementy zrównoważonego projektowania w architekturze obejmują m.in. planowanie budynków w taki sposób, aby minimalizować ich zużycie energii i zasobów naturalnych. W związku z rosnącymi standardami energooszczędności coraz większą popularność zyskują fasady dwupowłokowe, znane również jako fasady z „podwójną skórą". Są to tradycyjne fasady, na które nałożono dodatkową, zewnętrzną warstwę, zazwyczaj wykonaną ze szkła. Celem artykułu jest wykazanie, że wprowadzenie podwójnej fasady do budynków jest istotnym elementem realizacji zrównoważonego rozwoju, umożliwiającym efektywniejsze zarządzanie energią. Korzyści wynikające z realizacji takich obiektów, dzięki zastosowaniu odpowiednich technologii i metod budowlanych, mają kluczowe znaczenie dla jakości życia w mieście. Wpływają one na poprawę właściwości termoizolacyjnych budynków, komfortu cieplnego oraz mikroklimatycznego, a także przynoszą wymierne efekty ekologiczne i energetyczne.

Słowa kluczowe: fasada szklana, zrównoważony rozwój, projektowanie zrównoważone, miasto przyjazne, komfort bioklimatyczny.

1. INTRODUCTION. SUSTAINABLE ARCHITECTURE

Sustainable development combines socio-economic advancement with political, economic, and social initiatives, ensuring the preservation of natural equilibrium and the durability of essential environmental procedures. These initiatives are conceived to fulfil the requirements of contemporary society in a manner that does not infringe upon

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the capacities of future generations to satisfy their individual needs [1].

Sustainable design, a crucial constituent in implementing the Sustainable Development Goals, responds to challenges encompassing "urban sprawl", the contraction of non-renewable energy resources, excessive water discharge, and territory desertification. By addressing these challenges, sustainable architecture significantly enhances the quality of life, inspiring us to continue our efforts in this field [2].

The evolution of sustainable development discourse concerning architecture or construction can be traced back to the 1990s. References such as "A Primer on Sustainable Building" [3] and "Handbook of Sustainable Building" [4] can be cited in this context. The existing corpus of investigation concerning sustainable development is exceptionally comprehensive. In her research, M. Stawicka-Wałkowska has elucidated the fundamental tenets of sustainable development concerning the construction industry [5]. Concurrently, A. Baranowski, through his scholarly work, has explained the concept of sustainable design and endeavoured to formulate a sustainable design methodology within the discipline of architecture [6]. The issue of creating sustainable architectural designs and their evaluation is discussed in the works of S. Wehle-Strzelecka, who investigates solar architecture and its relation to residential environmental quality [7]. Similarly, E. Niezabitowska and D. Masły explore the evaluation of built environment quality and its importance in advancing sustainable building concepts in their research [8]. M. Jagiełło-Kowalczyk [9] and L. Kamionka [10] also embark on detailed research concerning the sustainable design of living environments in their works, with the latter delineating a strategy for addressing architectural design issues from the perspective of sustainable development.

The proliferation of research on sustainable design is unquestionably fuelled by designers' escalating consciousness about the irreversible repercussions of global warming, such as rising sea levels, extreme weather events, and loss of biodiversity. The construction industry is projected to contribute significantly to these environmental and societal implications, accounting for an estimated 40% of global energy consumption and 36% of greenhouse gas emissions.

According to World Economic Forum data, the improvement and use of structures contribute 38% of CO_2 discharges and are responsible for approximately 30% of worldwide waste [11]. The data emphasises the substantial role of the modern architect, whose endeavours should aim to reduce energy use and prudently manage natural resources, thereby impacting human life quality [12].

The endeavour to establish sustainable architecture is intrinsically tied to selecting technical methods, which indisputably influence the shape of the planned and implemented structures.

Materials such as wood and natural stone are generally considered to be eco-friendly. In contrast, others, like concrete, which contributes to CO_2 emissions; plastics, which lead to global littering; and glass, which results in building overheating during summer and heat loss during winter, are viewed as detrimental to the environment.

The paradigm of construction and its associated technologies has been reevaluated due to climate change. Manufacturers of materials are striving to enhance and diminish their ecological impact, such as fabricating concrete with a lowered carbon footprint or amalgamating photovoltaic components embedded in the façade with dynamic façade systems. The implementation of sustainable development principles necessitates substantial alterations in the methodology of architectural planning. Opting for an appropriate building façade provides an array of possibilities in this context, acting not merely as the interface between the interior and the external environment, demarcating thermal sectors and shielding against unfavourable meteorological conditions, but also influencing the energy efficacy of the structure. An appropriately engineered glass façade exhibits multifunctionality, shaping both the aesthetic appeal and architectural shape of the structure while establishing a synergy between the interior and exterior and facilitating efficient room ventilation [13]. This type of façade can be exemplified by the "double-skin façade".

2. AIM OF THE STUDY

The aim of this study is to discuss the potential of double-skin façades for improving energy efficiency, enhancing thermal comfort, and contributing to sustainable development in architecture.

The documented advantages of implementing such building façade typologies significantly influence the standard of living while delivering satisfactory outcomes in terms of ecological and energy efficiency.

A crucial component of this analysis involves delineating the advantages of utilising glass façades as an alternative to conventional building exteriors. By highlighting them as innovative solutions that harness contemporary technological capabilities, we can inspire excitement about the future of sustainable architecture.

3. METHODOLOGY

The research applies a descriptive analysis based on selected case studies. The adopted criteria for analysis are derived from the diagram presented in Figure 1, which outlines key aspects of double-skin façades systems in the context of sustainable design. The main evaluation criteria include:

- energy efficiency – potential for reducing energy consumption;
- thermal insulation – ability to improve building insulation;
- indoor comfort – enhancement of thermal comfort and indoor air quality;
- natural ventilation – possibility of using passive or mechanical ventilation systems;
- architectural and urban integration – contribution to the aesthetic and functional quality of the building and its urban surroundings.

These criteria were used to analyse the selected examples presented in the case study section.

4. "SECOND SKIN" FAÇADE

From an architectural perspective, windows constitute a crucial component of the building envelope. They establish the physical demarcation between the interior and exterior while safeguarding the interior from the influence of the external environment. Furthermore, they perform a significant function in the energy efficiency of structures, owing to their capability to permeate daylight and solar warmth (Fig. 2).

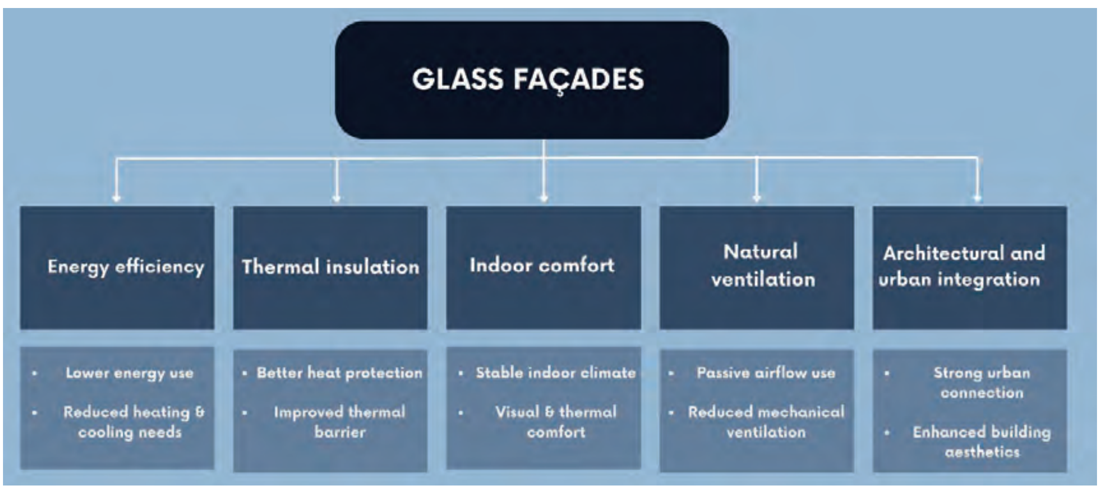

Fig. 1. Benefits of double-skin façade systems. Diagram summarizing the analytical criteria applied in the case study evaluation (study by S. Mochocka)

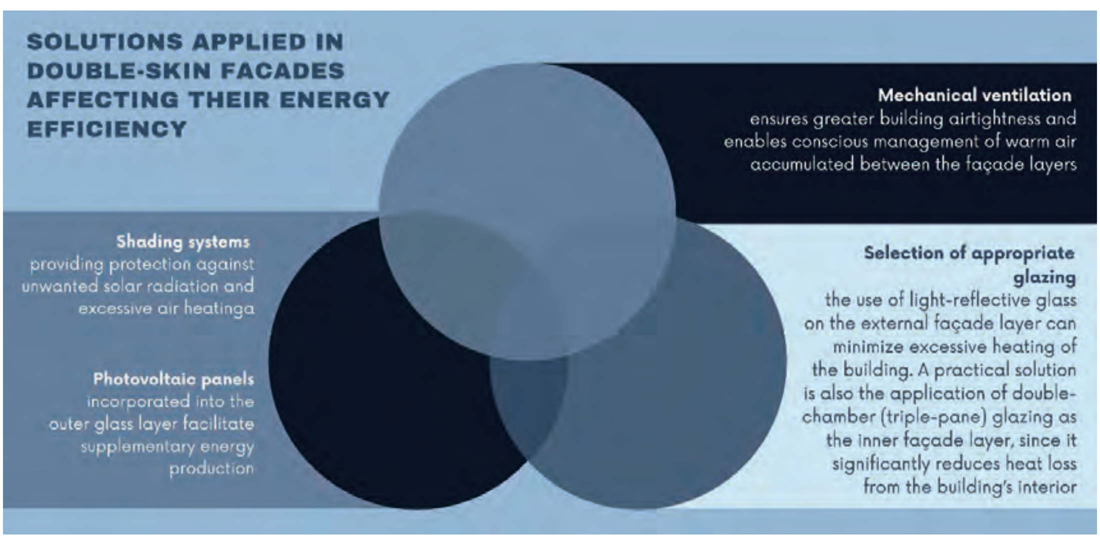

Fig. 2. Technological solutions in glass façades systems. Conceptual diagrams summarizing the design considerations discussed in the study (study by W. Kaczmarczyk)

Glass is one of the most prevalent materials, significantly influencing structure and aesthetic appeal and delineating the connectivity of a building with its external surroundings. The beginning of contemporary glass and steel infrastructures can be traced back to The Crystal Palace, which was erected in 1851 in London, following the architectural blueprint of Joseph Paxton [14]. After this period, there have been substantial advancements in materials technology, with objectives encompassing mitigating their detrimental environmental effects. Contemporary fenestration technologies are centred on enhancing the thermal insulating properties and inhabitant convenience while curtailing the energy consumption of structures. An instance can be observed in the so-called "double skin" façade, representing a conventional façade supplemented with an additional exterior layer, frequently made of glass. The first known example of using a "double skin" façade is the Steiff Corporation's machine hall building from 1903. The dual glass sheathing primarily facilitated acoustic insulation while functioning as a thermal buffer and ventilation conduit. One instance of the pioneering application of this technology is embodied by the building of the Faculty of History at the University of Cambridge, erected from 1964 to 1968 under the supervision of James Sterling. This initiative incorporated novel strategies based on a dual-layered glass structure, wherein the exterior layer comprised dynamic components such as ventilators, whilst the interior layer was constituted by sandblasted glass. The substantial influence of Polish initiatives dating back over four decades warrants emphasis. Examples such as the Double Shell Glass Façade in Zachęta II by O. Hansen, L. Tomaszewski and St. Zamecznik, or the Houses of the Centre in Warsaw by Z. Karpiński, E. Wacławek and J. Jakubowicz (with the technical development of the wall by Borowski) remain an inspiration for today's advanced projects [15].

A vital component of the double façade system is the air gap between the two barriers, offering additional operational space, such as for terraces. Depending on their design, these can serve as leisure areas that enhance the building's reception by its occupants or as installation zones for ventilation systems without detriment to the building's aesthetic appeal. Furthermore, this area facilitates indirect air circulation via the buffer zone, typically accessed through dedicated ventilation openings in the outer façade [16]. The air is disseminated within the buffer zone, infiltrating spaces with operable windows. The exterior glass layer attenuates wind blasts at significant elevations, enabling the application of gravitational ventilation even at the level of multiple tens of floors. The double façade can be subject to natural or mechanical ventilation, contingent on the employed system, and it enables the implementation of supplementary installations within the inter-skin space to channel the accumulated air into the building's energy regulation system, which could profoundly influence the operational expenditures of the entire building [17].

An appropriate selection of glass combination is pivotal to maximise the advantages derived from using a double façade [18, 19]. Furthermore, the strategic placement of windows and doors on the façade and incorporating additional components like awnings, shutters, sun breakers, or louvres is of great significance [20]. All these elements considerably influence the comfort of building users, are associated with appropriate temperature, humidity, and indoor air quality, and are associated with the structure's energy performance [21]. From a broader perspective, they affect the comprehensive quality of life within the urban setting [22].

5. CASE STUDY 1 – UBER WORLD HEADQUARTERS, SAN FRANCISCO (FIG. 3)

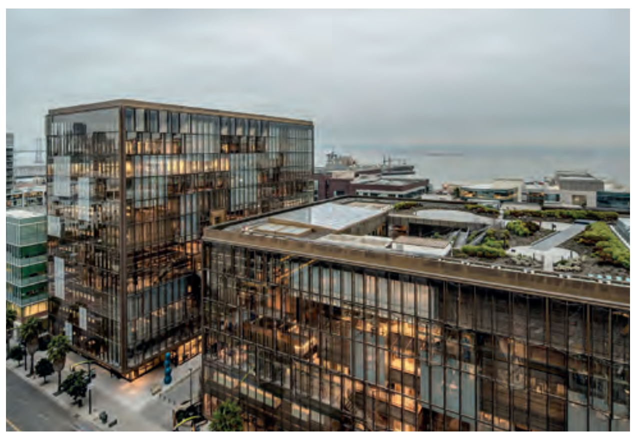

Fig. 3. Uber Technologies headquarters in San Francisco. Source: https://www.qa-us.com/project/uber-world-headquarters (accessed: 01 July 2024)

The seat of Uber Technologies in San Francisco, situated centrally in Misson Bay, encompasses two towers – a structure of six levels and another of eleven – interconnected via perspicuous overpasses above Pierpoint Lane. Both buildings feature technologically advanced façades, equipped with systems enabling the regulation of openings for natural ventilation and daylight control. The permeable façades link interior and exterior environments via full-dimension atria (Fig. 4).

Fig. 4. Uber Technologies headquarters, bridges connecting buildings. Source: https://www.qa-us.com/project/uber-world-headquarters (accessed: 01 July 2024)

The headquarters of Uber Technologies is not merely practical but also technologically superior, integrating architectural design with cutting-edge façade strategies. Within the functional programme's scope are offices, cafés, childcare provisions and retail outlets situated on the ground level [23]. Applying a dual façade in the building facilitated impressive architectural formation and more efficient exploitation of solar energy for internal illumination. It enhanced the inhabitants' welfare by integrating interior atriums, supplementary leisure areas (Fig. 5).

Fig. 5. Uber Technologies headquarters, view of exterior façade. Source: https://www.qa-us.com/project/uber-world-headquarters (accessed: 01 July 2024)

Double-skin façade technology contributes to higher energy efficiency by optimizing solar gains and reducing the need for artificial illumination. It contributes to thermal insulation by introducing a buffer zone for the two façade skin to reduce heat loss and improve thermal performance in buildings. The façade design also contributes to indoor comfort by stabilizing the interior temperatures, providing natural daylighting, and sufficient air quality through integrated natural ventilation systems.

The presented case was analyzed according to the criteria in Figure 1, demonstrating its potential in terms of energy performance, indoor comfort, and architectural integration.

6. CASE STUDY 2 – CULTURAL CENTRE AS A LOCAL CREATIVE SPACE (FIG. 6)

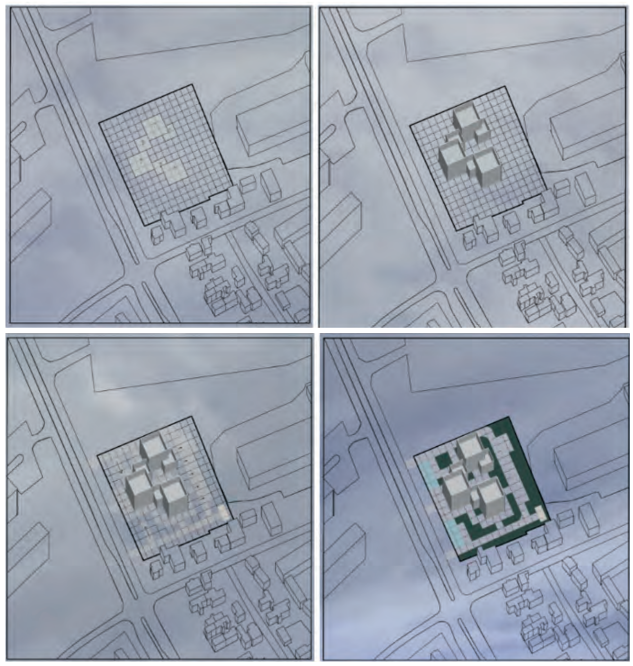

Fig. 6. Diagram illustrating the shaping of the building's form, by the author: W. Kaczmarczyk

An intriguing application of a glass façade as a "second skin" is demonstrated in the conceptual project of the cultural centre situated in a scenic area of Kielce. The dissertation's primary objective was to devise a multifunctional establishment that serves as a "hospitable" building, appealing to children, adolescents, and adults. It is intended to be open and accessible to various societal groups, provide comfort, facilitate active time expenditure, and, crucially, enhance human relationships. A further proposition entailed the construction of an entity capable of simulating human conduct. The uncomplicated and amenable architecture of the structure transforms it into a sort of communal domain and an accessible locale, thereby fostering a more "congenial" ambience within the urban environment.

The building's architectural design and structural configuration facilitated the versatile moulding of functional areas. The culture centre is made up of six cubes of two different heights. The building is partitioned into three operational segments, interconnected via a linkage, each provisioned with an independent entrance and an individual stairwell. The lucid functional arrangement contributed to effortless spatial and interior navigation, concurrently enhancing the accessibility of the infrastructure. The building has an underground car park with three stairwells, providing access to the critical sections of the structure. The application of an external façade and the strategy of elevating it beyond the height of the structure's walls has facilitated the incorporation of practical, whilst not disrupting the aesthetics of the building. These roofs serve as shared areas for sports and leisure activities.

This exemplifies a glazed building designed to represent an intelligent structure with considerable energy conservation through enhanced efficiency. The distinctive, simple design achieved by using a double glass façade has strengthened the object's connection with the urban context. On the other hand, the curvilinear arrangement of the razors, in addition to its aesthetic function, acts as an effective shading system, improving thermal insulation and reducing unwanted solar heat gains. The result is a dynamic façade surrounding the centre, filtering daylight to improve indoor comfort and visual quality (Fig. 7).

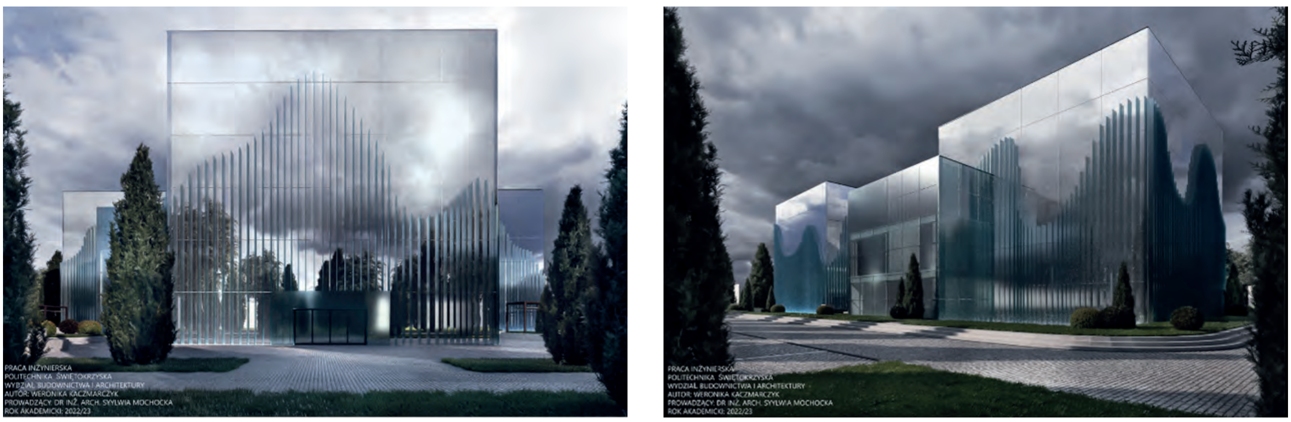

Fig. 7. Cultural centre as local creative space, engineering design (conceptual design, author: W. Kaczmarczyk)

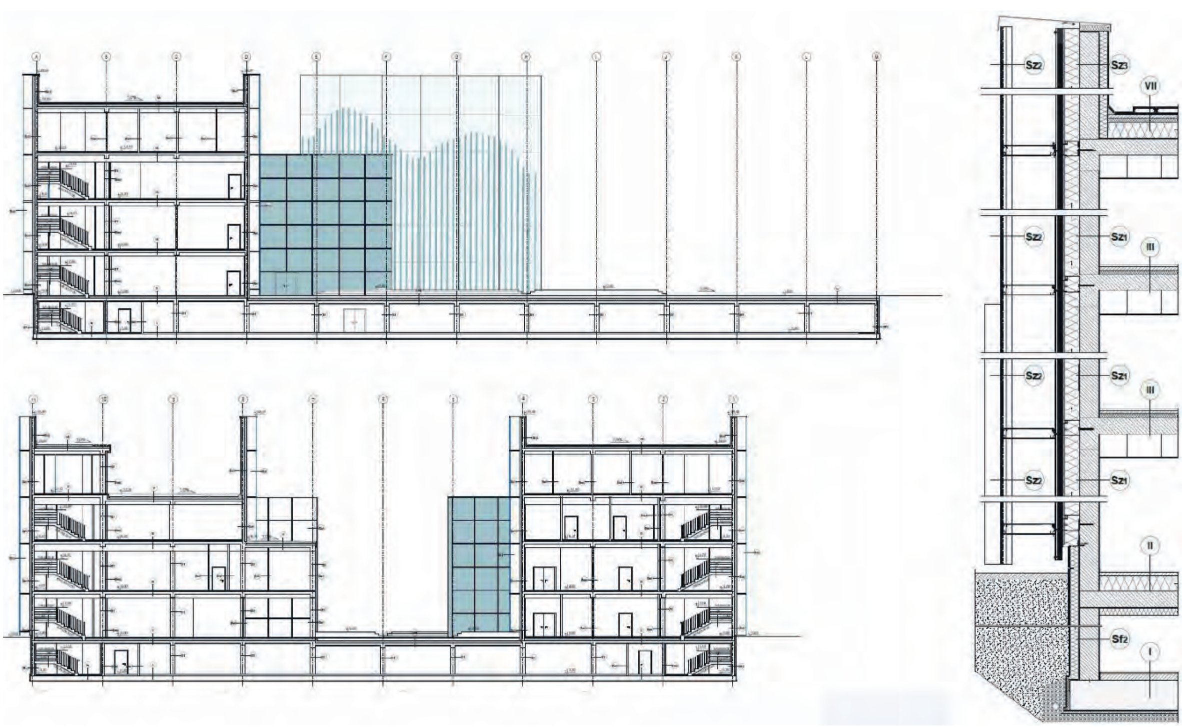

Fig. 8. Cultural Centre – cross-section and detail, engineering design (conceptual design, author: W. Kaczmarczyk)

The distance between the two façades permitted the construction of additional terraces. Implementing intelligent systems has resulted in a notable reduction in energy consumption. The project employed a mechanical (active) ventilation system, supporting natural ventilation strategies during transitional seasons and improving air quality, which is particularly advantageous during winter. The energy expended in heating the building can be conserved through recovery, which can notably impact the building's operating costs. Furthermore, utilising suitable systems facilitates efficient ventilation, directly enhancing indoor comfort and maintaining a stable indoor climate [24]. Using appropriate construction technologies and methodologies within a facility is paramount to the quality of life of the facility's users and, subsequently, the city's quality of life (Fig. 8).

The cultural centre design project reflects the application of double-skin façades systems with consideration of the analysis criteria. The project highlights the potential for energy savings, improved thermal insulation, enhanced indoor comfort, and positive architectural contribution to the urban context.

7. SUMMARY

Incorporating sustainable design principles into the design and implementation process is contingent upon, among other things, the level of awareness of the irreversible effects of global warming among all participants in the investment process. The consequences of irreversible climate change prompt consideration of the courses of action to be taken in constructing the building and its most prominent feature, the façade.

The façade that separates the inner and outer worlds must respond to the challenges posed by the energy crisis. The appropriate form of the façade, the size and configuration of windows, and other elements such as blinds and sun-breakers significantly impact the reduction of the building's energy demand.

In developing energy-efficient and sustainable buildings, adopting an integrated approach to material selection and technological solutions is essential. The choice of an appropriate type and glass parameters is a crucial aspect in designing a thermal barrier, such as a façade. As with other solutions within the facility, the objective should be to minimise energy consumption.

The popularity of façades with a double skin is increasing, as they provide thermal insulation for buildings and offer enhanced ventilation for rooms, preventing heat accumulation and facilitating energy recovery through appropriate systems. These highly efficient systems reduce energy consumption and represent a significant component of sustainable architectural design. Sustainable architecture aims to enhance the thermal insulation properties of buildings, improve bioclimatic and thermal comfort, minimise condensation and manage energy economically. This benefits the users of the buildings and, more generally, the quality of life in the city.

The analyzed case studies confirm the relevance of double-skin façades as an architectural solution addressing key aspects of sustainable design. Both cases meet the analysis criteria, demonstrating their effectiveness in improving energy performance, thermal comfort, indoor air quality, and architectural integration.

Although further empirical studies are needed to fully assess their effectiveness, the presented cases illustrate the potential of double-skin façades in supporting sustainable architecture.

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INFLUENCE OF THE ACIDIC ENVIRONMENT ON THE PROPERTIES OF METAHALLOYSITE GEOPOLYMER COMPOSITES

WPŁYW ŚRODOWISKA KWAŚNEGO NA WŁAŚCIWOŚCI KOMPOZYTÓW GEOPOLIMEROWYCH Z METAHALOIZYTU

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Abstract

Geopolymers have been shown to exhibit a significantly higher degree of resistance to corrosive environments when compared with cement concrete. The present paper expounds on the impact of sulphuric, hydrochloric and acetic acid solutions on the durability of mortars with geopolymer binders composed of metahalloysite and alkali activators. An activator with sodium water glass to NaOH solution ratios of 1, 2 and 3 and NaOH solution concentrations of 4, 8 and 12 mol/dm^3 was used. It was found that when increasing sodium water glass content from 1 to 3 in relation to the 8M or 12M NaOH solution in the activator, a significant reduction in the compressive strength of the mortar with this geopolymer binder was obtained after 28 days of exposure to the acid solutions. A smaller decrease in strength occurred with the acetic acid solution than with the sulphuric or hydrochloric acid solutions.

Streszczenie

Geopolimery w porównaniu do betonu cementowego charakteryzują się wysoką odpornością na większość agresywnych środowisk korozyjnych. W artykule przedstawiono wpływ roztworów kwasu siarkowego, solnego i octowego na trwałość zaprawy ze spoiwem geopolimerowym z metahaloizytu oraz aktywatora alkalicznego. Zastosowano aktywator o stosunku szkła wodnego sodowego do roztworu NaOH wynoszącym 1, 2 i 3 oraz stężeniu roztworu NaOH 4, 8 i 12 mol/dm^3. Stwierdzono, że przy zwiększeniu zawartości szkła wodnego od 1 do 3 w stosunku do roztworu 8M lub 12M NaOH w aktywatorze uzyskuje się znaczne zmniejszenie wytrzymałości na ściskanie zaprawy z tym spoiwem geopolimerowym po 28 dniach działania roztworów kwasów. Mniejszy spadek wytrzymałości występował w przypadku roztworu kwasu octowego niż siarkowego lub solnego.

THE CHALLENGES OF URBAN SPACE REVITALISATION. REVITALISATION OF A SELECTED AREA OF THE SŁONECZNE WZGÓRZE HOUSING ESTATE IN KIELCE BASED ON THE EXAMPLE OF A STUDENT PROJECT

WYZWANIA REWITALIZACYJNE PRZESTRZENI MIEJSKIEJ. REWITALIZACJA WYBRANEGO OBSZARU OSIEDLA SŁONECZNE WZGÓRZE W KIELCACH NA PRZYKŁADZIE PROJEKTU STUDENCKIEGO

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Abstract

The revitalisation of degraded areas is a multi-stage process that requires the involvement of the public, local authorities and often large financial resources. In Poland's large cities, the revitalisation process mainly focuses on revitalising deserted inner cities and the city's main representative spaces, while other smaller spaces, marginalised areas or spaces in housing estates remain forgotten. The problem of revitalisation is shaping up similarly in smaller urban centres.

The paper shows a selected student revitalisation project, carried out as part of the Revitalisation of the Urbanised Environment course by students of Architecture at the Kielce University of Technology.

Streszczenie

Rewitalizacja obszarów zdegradowanych jest wielostopniowym procesem wymagającym zaangażowania społecznego, władz lokalnych oraz często dużych środków finansowych. W dużych miastach w Polsce proces rewitalizacji skupia się głównie na ożywieniu opustoszałych śródmieść i głównych przestrzeni reprezentacyjnych miasta, natomiast pozostałe mniejsze przestrzenie, obszary zmarginalizowane czy przestrzenie na osiedlach mieszkaniowych pozostają zapomniane. Podobnie problem rewitalizacji kształtuje się w mniejszych ośrodkach miejskich.

W opracowaniu pokazano wybrany studencki projekt rewitalizacyjny, realizowany w ramach przedmiotu rewitalizacja środowiska zurbanizowanego przez studentów kierunku architektura Politechniki Świętokrzyskiej.

APPLICATION OF CENTRAL COLLINEATION IN UNDERSTANDING OF INTERSECTION STRUCTURE OF SOLIDS IN THE ACTIVITY OF ENGINEER

ZASTOSOWANIE KOLINEACJI ŚRODKOWEJ W ANALIZIE PRZECIĘĆ BRYŁ W DZIAŁALNOŚCI INŻYNIERSKIEJ

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Abstract

Modern design takes place in systems that use solid geometry. There, you receive ready-made geometric models of complex architectural and construction elements. This is not always accompanied by the engineers full understanding of the spatial relationship between the elements creating a complex geometric object. The authors propose the use of central collineation in the creation and analysis of the correctness of spatial geometric structures.

Streszczenie

Współczesne projektowanie odbywa się w systemach, gdzie wykorzystywana jest geometria brył. Otrzymuje się tam gotowe modele geometryczne złożonych elementów architektonicznych i budowlanych. Nie zawsze towarzyszy temu pełne zrozumienie przez inżynierów relacji przestrzennych między elementami tworzącymi złożony obiekt geometryczny. Autorzy proponują wykorzystanie kolineacji środkowej w nauczaniu tworzenia i analizy poprawności przestrzennych struktur geometrycznych.

GLASS FAÇADES AS A COMPONENT OF SUSTAINABLE ARCHITECTURE – ANALYSIS OF SELECTED CASES

FASADY SZKLANE JAKO ELEMENT ARCHITEKTURY ZRÓWNOWAŻONEJ – ANALIZA WYBRANYCH PRZYPADKÓW

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Abstract

The governance of sustainable energy represents one of the principal concerns in the current era. The escalation of global warming and the depletion of natural resources have become progressively pertinent issues, underscoring the crucial role of sustainable architecture in addressing these pressing concerns. In the context of advancing sustainable development and environmental preservation, contemporary construction processes hold significant importance. Sustainable design in architectural practices plays a crucial role in strategizing the construction of buildings to curtail their energy consumption and utilization of natural resources. In the context of escalating standards for energy conservation, twin-layered façades are gaining significant traction. This paper aims to substantiate that incorporating a double façade in structures is not just a trend, but a critical component in the execution of sustainable growth. These façades play a key role in improving energy management and enhancing the quality of urban life, by yielding quantifiable ecological and energy outcomes.

Streszczenie

Zrównoważone zarządzanie energią stanowi jedną z kluczowych kwestii współczesnych czasów. Wraz ze zmianami zachodzącymi na świecie zmieniają się również potrzeby i pojawiają się nowe wyzwania, którym musimy sprostać. Nowoczesne budownictwo odgrywa istotną rolę we wspieraniu zrównoważonego rozwoju. Elementy zrównoważonego projektowania w architekturze obejmują m.in. planowanie budynków w taki sposób, aby minimalizować ich zużycie energii i zasobów naturalnych. W związku z rosnącymi standardami energooszczędności coraz większą popularność zyskują fasady dwupowłokowe, znane również jako fasady z „podwójną skórą”. Są to tradycyjne fasady, na które nałożono dodatkową, zewnętrzną warstwę, zazwyczaj wykonaną ze szkła. Celem artykułu jest wykazanie, że wprowadzenie podwójnej fasady do budynków jest istotnym elementem realizacji zrównoważonego rozwoju, umożliwiającym efektywniejsze zarządzanie energią. Korzyści wynikające z realizacji takich obiektów, dzięki zastosowaniu odpowiednich technologii i metod budowlanych, mają kluczowe znaczenie dla jakości życia w mieście. Wpływają one na poprawę właściwości termoizolacyjnych budynków, komfortu cieplnego oraz mikroklimatycznego, a także przynoszą wymierne efekty ekologiczne i energetyczne.