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Orginal Article

Effectivity of BIM transfer of structural models between programs for engineers

Oskar Kotlarz[1], Adam Wosatko[2]

[1] Chair for Computational Engineering, Faculty of Civil Engineering, Cracow University of Technology; 24 Warszawska St., 31-155 Cracow, Poland; CREADIS; 10 Pilotów St., 31-462 Cracow, Poland; oskotlarz@gmail.com

[2] Chair for Computational Engineering, Faculty of Civil Engineering, Cracow University of Technology, Warszawska 24, 31-155 Cracow, Poland; CREADIS, Pilot Tower, Pilotów 10, 31-462 Cracow, Poland; adam.wosatko@pk.edu.pl 0000-0002-7763-1164

Abstract: The paper describes the verification of the quality of the data transfer between selected software dedicated to generation of building models and for their analysis using the finite element method. For comparison, models of two typical structures are constructed: a steel truss hall and a multi-storey reinforced concrete building. Both models are created simultaneously in two programs: Autodesk Revit and Tekla Structures. Next, these models are exported to computational packages: Autodesk Robot, Dlubal RFEM and SCIA Engineer. Different options of data transfer are considered, in particular: a direct link between programs as well as via open formats. The scope and limitations of the data exchange are determined in each case. Juxtaposition of the effectiveness of different transfer methods for such typical building models are helpful at the stage of cooperation between the architect and the structural designer. In addition, pilot results of a finite element static analysis for the steel hall model are also compared.

Keywords: BIM technology, data transfer, BIM interoperability, engineering software, structure modeling, finite element method

1. Introduction

The origins of BIM technology date back to the 1970s and 1980s. The acronym BIM was initially defined only as Building Information Model. Even before the era of computerization in design offices and development of CAD (Computer Aided Design), the idea of parametric design with the use of geometry objects hierarchically ordered, i.e. according to the BDS (Building Description System), was considered [1]. This approach means storing information of the model description optimally, i.e., the geometry of the position and shape of complex elements are related to the topology and their efficient assembly using basic solids. Another aspect of introducing BIM technology originates from efficient management of the investment process, including also the construction process, where the key issues are the efficient transfer of information regarding the project and realisation of the investment (as well as how the facility operates) between industry teams within established rules and defined relationships [2]. The term BIM can be defined in different ways [3], the range of applications at the early stage of the design is very wide and may include many detailed activities, such as downloading of virtual maps as a base of terrain for building a model [4] or e.g. preparation of a schedule and cost estimate integrated with the model [5]. The most common explanation of the acronym BIM is Building Information Modeling, since the whole process of modeling is taken into account and different data connected with designed building objects are stored. Not only designers or investors may be the users of various information about the model, but also, during the facility operation, the companies providing daily media or even emergency services in the event of some disaster of the structure can use BIM based data. Therefore, the use of BIM technology may cover an entire "life cycle" of the object [6]. The essential issue of a properly designed model is fast access to relevant information. The acronym BIM can be then considered as an extension of the term Building Information Management, which refers to the rational management of information concerning a building object's model. Such proper management also ensures the appropriate choice of the method of transferring the model's data by designers of particular branches, which should cooperate with each other in the most together efficient way. A chronological overview of the first tools developed and used for CAD and BIM can be found in e.g. [7], [8]. Various aspects of their use, already in accordance of the idea of BIM and also in terms of data transfer, are extensively described, e.g. in [6], [8]–[10]. Moreover, the perspectives on the further development and future of BIM are included, for example, in [3] and [11]. The future of BIM may be related to management of comprehensive yet integrated database of information for a group of building objects, rather than just the limit of working collaboratively with an integrated model for an individual building, see e.g. in [8].

This paper focuses on the quality of transferred information for a building model, where the transfer is directed from architect to structural designers using tools intended for these industries, i.e. for AEC (Architecture, Engineering & Construction) designers. The effectiveness of popular engineering programs is analysed in the context of the model obtained after the data transfer concludes. In order to make an objective assessment, two typical building models – a steel hall and a reinforced concrete structure – are created in Autodesk Revit 2020 [12] (hereafter referred to as REVIT) and Tekla Structures 2019i [13] (hereafter referred to as TEKLA) and then exported to the following computational software: Autodesk Robot Structural Analysis Professional 2020 [14] (hereafter referred to as ROBOT), Dlubal RFEM 5 [15] (hereafter referred to as RFEM) and SCIA Engineer 20 [16] (hereafter referred to as SCIA). All these programs are supported by the Finite Element Method (FEM). The data transfer is carried out in different ways: by directly linking the programs, utilising plug-ins or using a selected open standardised format, e.g. IFC (Industry Foundation Classes).

There is, of course, a native format-based data exchange that involves uploading a file which is recognised as default by one of the employed programs. This type of data exchange is applied when both programs, source and target, cannot be installed on the same computer. The main disadvantage of this approach can be the iterative transfer, repeated after each saved change made to the model, which can lead to excessive time-consumption and mistakes when working on the current version of the model. Writing and reading files exclusively in native formats is not discussed in this paper.

Direct links work for so-called real-time data exchange but usually require both programs to be installed on the same computer and corresponding knowledge of one or a team of users who design together. This approach is applicable during intentional iterative modeling of a building object or when multiple adjustments of a constructed model are allowed. In this paper, the type of data transfer is realised using applications embedded in the software where the model is generated or by special plug-ins supported by source (REVIT or TEKLA) or even target (e.g. RFEM) programs.

Data transfer via open format does not require the presence of two programs, and is even independent of used software, since it is supported by some or most of the programs of different industries. On the other hand, the use of a standardised format can lead to many errors in the model because this type of transfer can be underdeveloped. Producers of the software firstly guarantee the correctness of the data exchange via their own recommended native format. The IFC file seems to be the most popular type of open, standardised format, and many papers are still published on using it as a medium for data exchange, see e.g. [17] and [18]. The problem of the quality of data transfer via the IFC format is shown in Sections 3.1-3.3 on the example of models of both structures. However, it is worth noting that alternative file formats also exist, e.g. CIS/2 (CIMsteel Integration Standards) for steel structures, cf. [19] and [20]. In this paper, the steel hall model is transferred by various manners, i.e. from TEKLA using CIS/2 or DSTV standards.

The most basic criterion for effective model transfer can be the completeness of the representation of its geometry in space. However, there are other requirements that should ensure correct BIM transfer. In this paper, the material characteristics and correctness of profiles are also verified. Transferred information should be complete, as accurate as possible (depending on LOD, i.e. Level of Development), unambiguous and understandable, and also include, among other things, attributes of a given element and its relations with respect to the whole model and neighbouring elements, if necessary, cf. [21]. The need of correction in the model after export can also be a measure of quality, which has been verified for models presented below. The evaluation of data exchange between engineering software developed for related and various industries is still a contemporary topic that requires attention, see e.g. [22]–[24]. Another aspect of comprehensive data transfer testing includes generating a model consisting of components with different geometries and mutual affiliations, such as in [25]. In this paper, models are verified for two typical structures, but composed of elements commonly used in construction.

2. Considered models of structures

The subject of comparison are two models of: a steel hall structure and a reinforced concrete building structure. The analysis of the efficiency of data transfer for such typical structures is the basic criterion for selecting verified models. Although their geometry is not complex, incorporation of the various components, the interrelationships between the elements and mutual connections that are characteristic of a given structure allow to carry out a thorough overview of the information flow in accordance with the concept of BIM, see also [25]. Steel hall and reinforced concrete building models are, as it is well known, characterised by a predominant material of construction and specific type of structural elements.

Steel structures consist primarily of member structures, and particular attention must be paid to precision when generating the model. The ends of the bars in a joint should coincide precisely at a common point. Even by a minimum distance, a misalignment can lead to the disconnection of structural elements in the model and, consequently, to the lack of the common node at this point. The steel structure, in this case, is a truss hall 28.8 m wide by 60 m long. The hall's total height from the foundation level to the top of the ridge is 7.3 m, the height of the columns on the sides measures 5.53 m and the usable height is 4.5 m. The truss girders on the columns are spaced every 6 m along the hall. The roof slope is approximately 7 degrees. The load-bearing girders and their longitudinal bracing are made of round pipes. Steel columns are modelled as HEB I-sections, purlins as IPE-sections and longitudinal bracings of columns as channels. The hall model was built in REVIT from an AutoCAD underlay to ensure an accurate mapping of geometry. It is worth to mention to how the structure's axes and levels are prepared, as well as the position of elements aligned with respect to the profiles' symmetry axes. Taking care of the correct position of the bars affects the quality of the analytical model. When the model in TEKLA is constructed, its legibility can be enhanced by applying colour coding to the structural members, which are grouped by classes. Figure 1 shows the view of physical models of the steel hall structure formed in both programs.

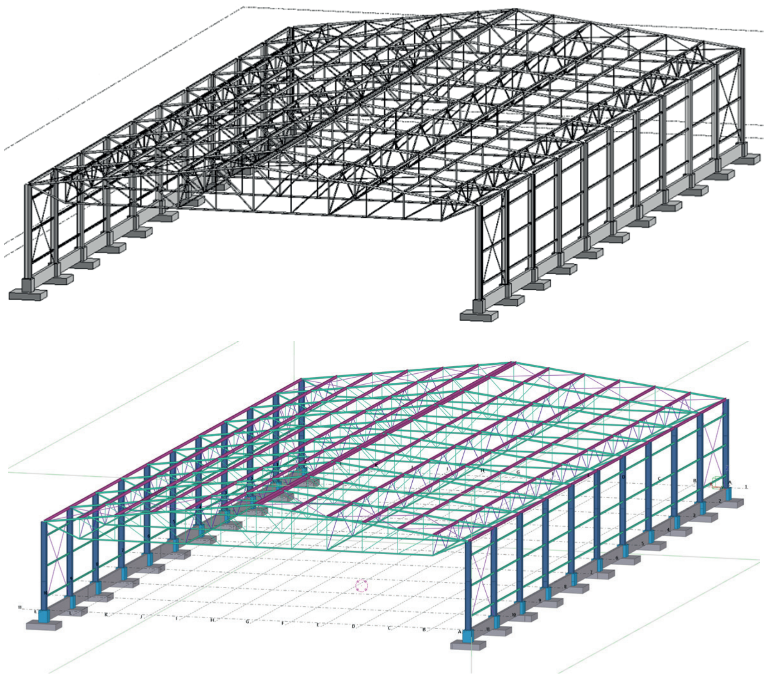

Fig. 1. View of physical models of steel structure in REVIT and TEKLA

The second model of the reinforced concrete structure is shown in Fig. 2. The building is composed of six above-ground storeys and one underground storey. Its total height read at the slab axes is 20.67 m, with the thickness of the foundation slab being 0.5 m and the thickness of the floor slab 0.2 m. The structure includes a system of columns, beams and floor slabs, stiffened by the communication riser walls and the underground storey. In addition, balcony cantilevers are modelled in one corner. On two storeys, the floor slab's shape is modified to take into account the direct connection of column and beam elements. The axial spacing of the columns is 4 or 5 m, depending on their position. The shape of the reinforced concrete structure is based on a stepped polygon plan, as shown in Fig. 3.

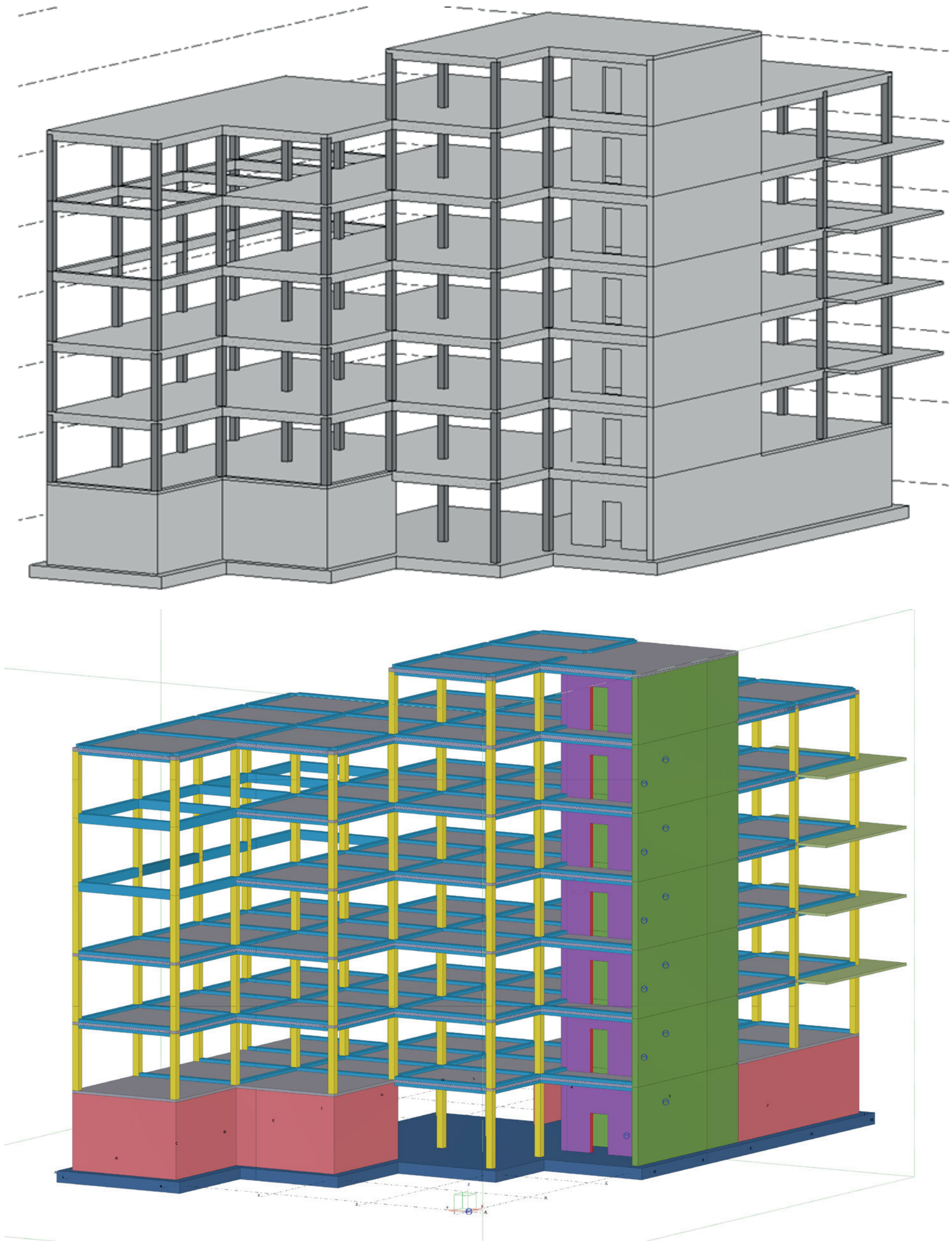

Fig. 2. View of physical models of reinforced concrete structure in REVIT and TEKLA

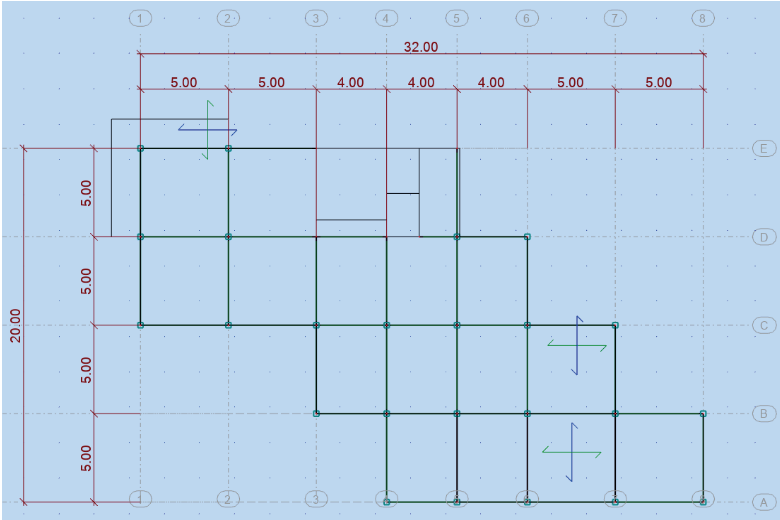

Fig. 3. Projection of reinforced concrete structure for level 4 (12.03 m) read from ROBOT

When a model of a reinforced concrete structure in REVIT or TEKLA is generated, attention must be paid to the fact that there are additional surface elements and, consequently, there are various manual or automatic options provided by the software to so-called "pull" them to the nodes. Users should setup sufficient accuracy in tools' menu of the given program to activate snap commands during modeling of the structure. The alignment of structural elements, e.g. floors and beams, is an important issue. Both programs are characterised by different improvements, e.g. REVIT recognises the ends of elements depending on the connection type, while TEKLA allows the use of built-in components, e.g. stair treads.

3. Transferring models between programmes

3.1. Data transfer to ROBOT

The first transfer discussed is unique because it involves two programs from the same company – Autodesk. In REVIT, there is a built-in tool for integrating with ROBOT, which is operated using the dialogue box shown in Fig. 4. The data transfer can take place once the analytical model is formed. Direct Link between the programs ensures not only the possibility of exporting the model but also updating it after changes are made. Additionally, it is possible to save the model as a **.smxx* file if both programs cannot be installed on the same computer. Direct Link also allows data transfer in both directions, i.e. it is possible to import the model into REVIT after FEM computations have been performed in ROBOT, so there is a return transfer option.

The resulting steel hall model is prepared for calculation because the quality level of transmitted information is very high. After the transfer in ROBOT, not only is the geometry of the hall model complete, but so are the corresponding cross-sections, materials, loads, supports, connections, and axes. This model remains loss-free and does not need to be corrected. An almost identical effect is obtained for the model of the reinforced concrete building structure. It is worth mentioning that the two-dimensional elements are divided, as planned, into walls and floor slabs with the correct panel thickness. The only issue is with the stair flights and landings, but this is due to the fact that they cannot be generated in the analytical model version. The view of both the structure models after having been exported from ROBOT is shown in Fig. 5.

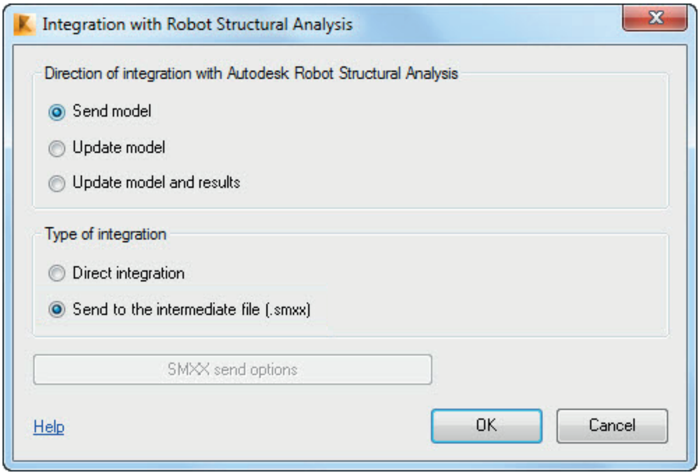

Fig. 4. Dialogue box featured in Autodesk's REVIT for integration

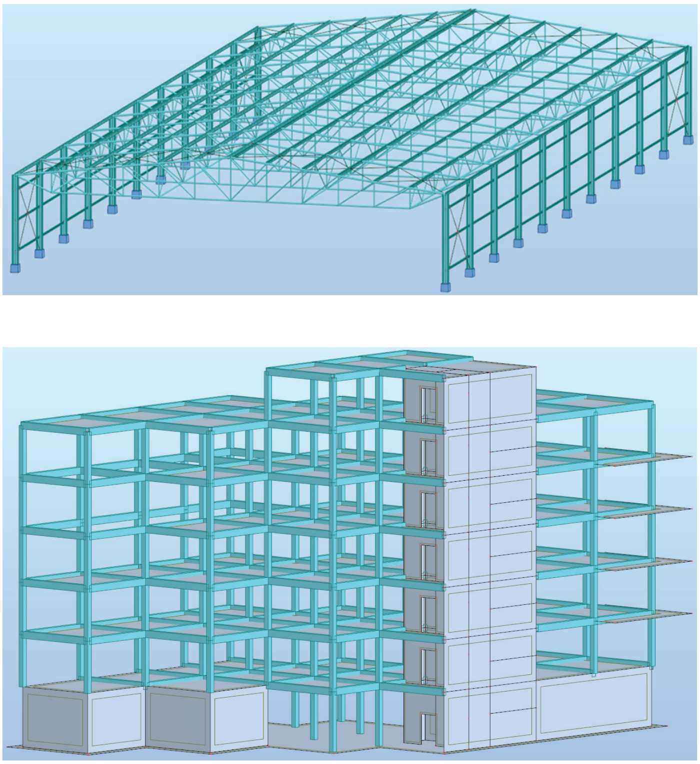

Fig. 5. View of steel and reinforced concrete structure models in ROBOT after exporting

After making changes in ROBOT, the return transfer of the hall model gives the correct representation in REVIT, and therefore it can be subjected to further information exchanges. In this case, Direct Link significantly reduces the number of errors in subsequent updates of the model. Unfortunately, making changes to the reinforced concrete building model in ROBOT subsequently causes errors when imported back into REVIT and transferred to the physical model. There is a partial overlap of some surface components. From the users perspective, the concrete type material mistakenly takes the form of a ceramic pattern. Information about the material itself is not modified, but it can create confusion for designers.

The export from TEKLA is also executed via the direct link, which requires installing the additional Robot Link application (version 1.56 used). After verifying the analytical model, the transfer is performed without further user intervention, similarly to REVIT. In the case of the hall structure, the following are preserved: geometry, materials and characteristics of all profiles except for the bracing bars. Figure 6 shows a fragment of the hall model's side elevation obtained in ROBOT from REVIT (left) and TEKLA (right) software. The red dots mark the nodes generated after the model transfer. As a result of the REVIT-ROBOT transfer, they are created in the correct positions. In contrast, after the TEKLA-ROBOT transfer, excessive nodes are visible in all of the bar intersections. Before proceeding with the FEM analysis, these nodes must therefore be eliminated, and the loads must be redefined, their combinations created, and the type of elements and their offsets verified. The direct transfer of the model of the reinforced concrete structure from TEKLA to ROBOT is also correct, although the elements originally constructed from ready-made components (stair flights) are not present in the analytical model, so their transfer is also not possible. The loss of previously defined loads occurs similarly to the data transfer for the steel hall. On the other hand, if connections or characteristics of concrete elements (including surface panels) are typical, the transfer itself does not interfere with such information and thus does not modify the obtained model. The effect of transferring of both models from TEKLA to ROBOT is almost identical to the one demonstrated one in Fig. 5.

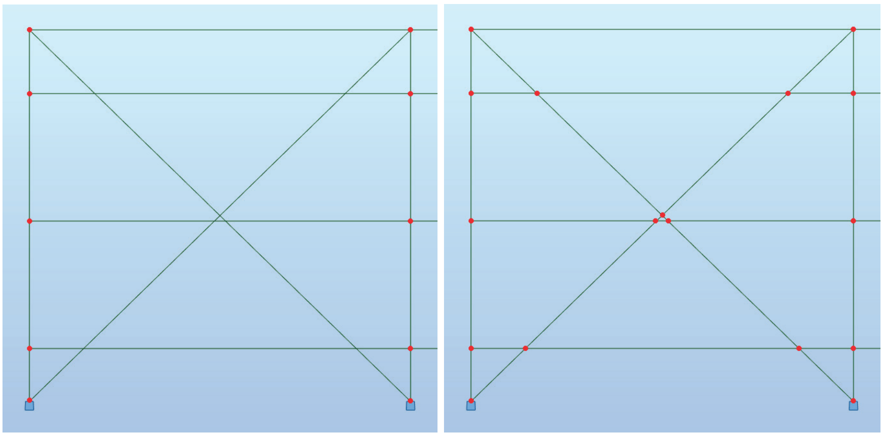

Fig. 6. Fragment of steel hall model's side elevation in ROBOT after being exported from REVIT (left) and TEKLA (right). Red dots indicate nodes created as result of data transfer

3.2. Data transfer to RFEM

The data transfer from REVIT to RFEM is carried out using the REVIT-Dlubal Link plug-in. It is also possible to transfer in the opposite direction, similarly to the REVIT-ROBOT transfer. Furthermore, this plug-in enables users to save the model in the native RFEM format **.rf5*. The exported geometry of the models is correct in both cases. For example, the steel hall model retains the rotated purlins' orientation, and the wall panels of the elevator shaft in the reinforced concrete structure model have been divided accordingly as in the original. The transfer's results can be seen in Fig. 7. On the other hand, material data is lost. Young's modulus or thermal expansion coefficient do not have assigned values, even though the material names and the corresponding self-weight (dead load) are transferred unreservedly. Incorrect definitions of hall bracing profiles are also an issue. The transfer back to REVIT in both cases does not generate additional errors, which means that the REVIT-RFEM-REVIT coupling allows the models to be modified and updated efficiently.

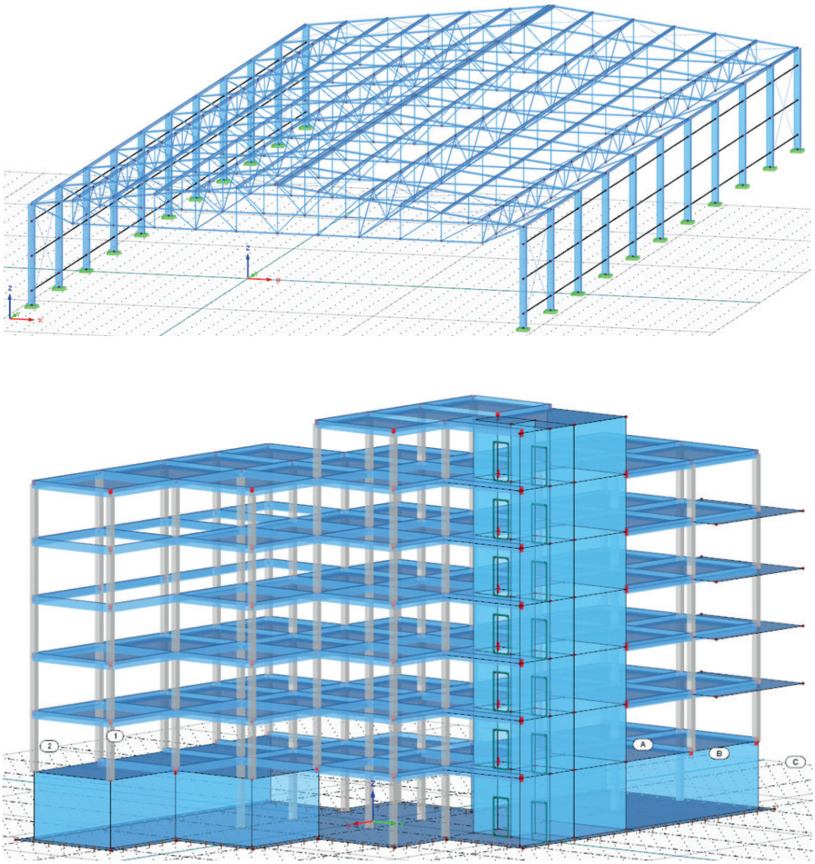

Fig. 7. View of steel and reinforced concrete structure models in RFEM obtained as result of transfer from REVIT

Another possibility is the transfer using the IFC format, using the IFC2x3 specification to be more precise (for more information, see [18], [19], [26]). The steel hall's exported model is of very poor quality, as is shown in Fig. 8. In spite of many attempts to fix the performance of this export, e.g. by installing the current version of IFC 2020 application for REVIT, the resulting model is not suitable for further analysis and its correction according to the whole list of errors would take more time than creating the model from scratch in RFEM itself.

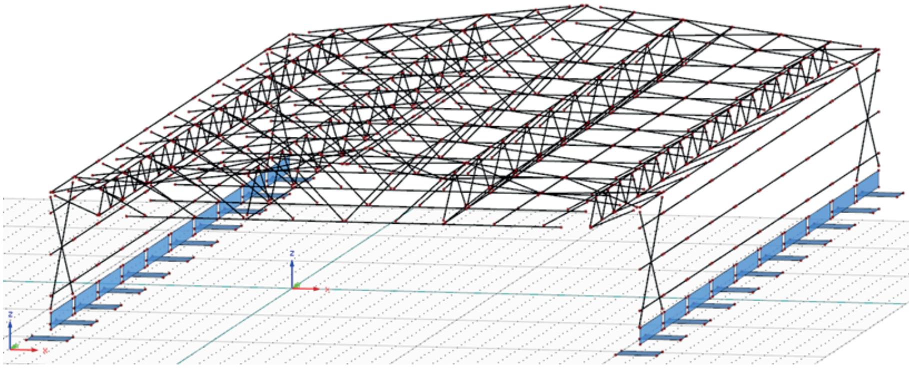

Fig. 8. View of steel structure model in RFEM after exporting it from REVIT using IFC format

RFEM offers several possibilities to import files of different types (see the dialogue box in Fig. 9). The transfer of models from TEKLA has been tested in several alternative ways. The first one is a direct link. In addition, RFEM provides the choice to import based on an analytical or a physical model. The correlation of versions of the software from source to target is also important – TEKLA's version is 2019i SP2, RFEM's version is 5.21.02. The import of models via Direct Link varies depending on the structure type. For a steel hall computational model obtained from an analytical model, the information is transferred without major errors. The problem is the newly created nodes where the bracings intersect, as is the case with the TEKLA-ROBOT transfer (see Fig. 6 on the right). The model also failed to recognise pipe shapes, despite the aptly detected HEB or IPE cross-sections. If the physical model is the base, then instead of correct definitions of supports, there are foundation feet as redundant elements in the hall's computational analysis. In case of a reinforced concrete structure model imported on the basis of the analytical model, practically all of the information is transferred correctly: geometry of elements, their connections, concrete classes or cross-sectional characteristics of individual beams, columns, floors and walls. The exception is the lack of walls with openings in the lift shaft and the lack of loads for some surfaces of floor slabs. A completely different effect is obtained from the transfer using the physical model. The structural elements have no common nodes. The position of one of the walls is shifted down the foundation. The whole model is unstable and requires accurate tracing and introduction of corrections so that further analysis (e.g. static FEM calculations) is possible. However, it may be too expensive to carry out such a correction, despite the properly provided information on profiles or concrete type.

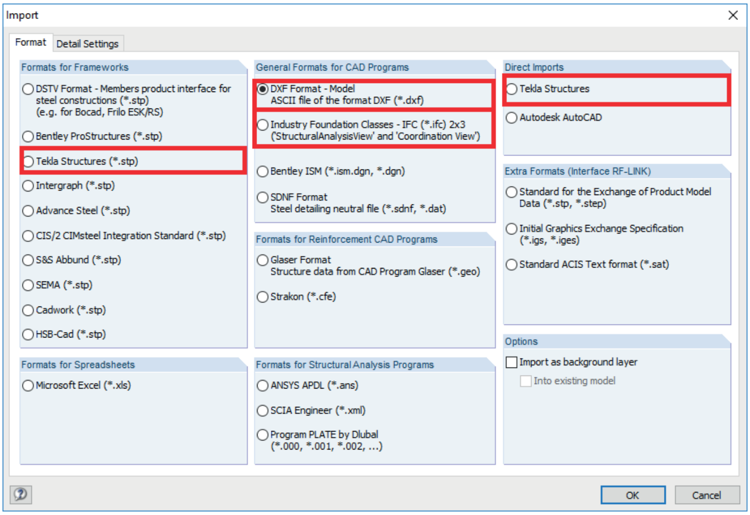

Fig. 9. RFEM import dialogue box

For steel structures, an additional way of data transfer to RFEM is possible, i.e. via formats CIS/2 (an acronym for CIMsteel Integration Standards) or DSTV (an acronym for Deutsche Stahlbau-Verband). The model is saved as an ASCII file (American Standard Code for Information Interchange), so it is quite easy to verify its contents. The model of the hall generated by the CIS/2 standard contains an acceptable number of errors: excessive nodes are created, the rotation of the purlins is interpreted in the opposite direction than intended, and the pipe profiles are not recognised, although correct names are assigned. Hence, the resulting model needs to be corrected, albeit is still feasible. If the transfer is carried out using the DSTV format, then the received model is nearly error-free, except for some profiles having incorrect labels. This type of transfer is therefore preferable. The model carried by DSTV is shown in Fig. 10.

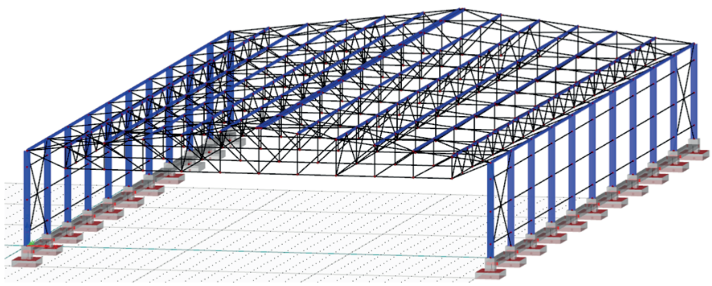

Fig. 10. View of steel structure's model in RFEM after exporting it from TEKLA using DSTV format

As a last possibility to transfer the model from TEKLA to RFEM, the 2x3 IFC format is used. Before performing the transfer in TEKLA, it is worth noting that it is crucial to define the type of the structural elements as a transferred IFC attribute. Based on this attribute of the element, RFEM automatically decides whether the element is structural. An incorrect assignment of this attribute can result in its deletion from the computational model. In both cases of structures, the resulting models cannot be applied for further analysis. For example, the hall model contains extra nodes, as well as cross-sections, which are not recognised. Shortcomings of the exported model of the reinforced concrete structure largely coincide with disadvantages known from the direct export based on the physical model. The effect of this transfer via the IFC2x3 file format is illustrated in Fig. 11. The structure is not complete. There are zero values of all material characteristics. The adaptation of both models from the versions obtained directly from the transfer via IFC to the versions ready for further analyses is not worthwhile because of the time effort involved.

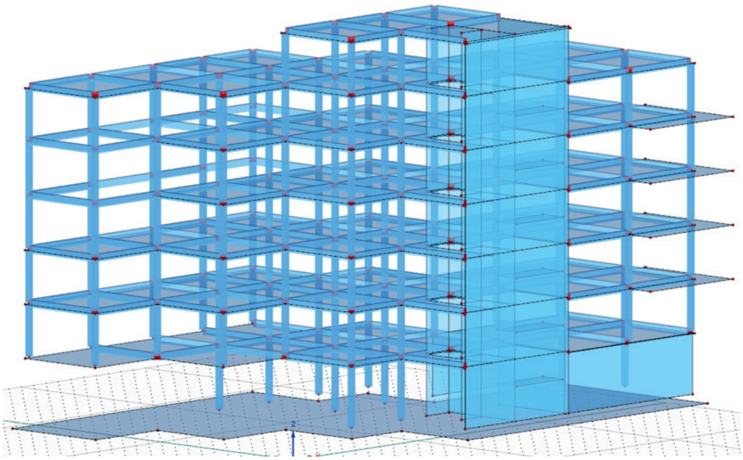

Fig. 11. View of reinforced concrete structure's model in RFEM after exporting it from TEKLA using IFC format

3.3. Data transfer to SCIA

The third target program in which FEM computations can be performed is SCIA. The first discussed transfer is operated via the plug-in called CADS Revit SCIA Engineer Link. Once it's installed to REVIT, the user can access a tab and the dialogue box presented in Fig. 12. The export is based on an automatically generated analytical model and preliminary definition of some information, e.g. design standard. Data transfer is saved as a **.r2s* file recognised by SCIA. During the transfer of the truss hall construction model, the process is interrupted, and the user has to map the type of materials and sections which are not automatically detected. It is possible to skip the step of "manual" mapping during the transfer, but this results in the loss of some information, e.g. the material is remembered as "Unknown". The mapping of certain model features is both a disadvantage and an advantage. For small structures, it can provide a point of verification and guarantee that the resulting model is correct, but for very large structures (with thousands of different structural elements and their attributes), this activity can turn out to be too time-consuming. The application of this plug-in also offers the possibility to transfer in the opposite direction, whereby REVIT again requires to map the unrecognised model characteristics when importing. Figure 13 depicts models of the steel hall and the reinforced concrete building in SCIA. The export process for the model of the reinforced concrete structure is identical – the user has to enter the material data and some profiles by himself, thus mapping the relevant information is needed. A re-transfer is possible in the same manner. In summary, the REVIT-SCIA plug-in provides good results, and the process of information mapping replaces correction of the exported model.

An alternative approach may be to employ the IFC2x3 format for transfer. Similar as in the previous cases, the use of the IFC standard results in a model that is not suitable for further analysis due to too many required corrections, e.g. for the trusses of a steel hall, the bottom and top chords are detected as "generic solids" without any additional properties. Overall, the IFC transfer produces a much better model in SCIA than in RFEM, but inaccuracies in the geometry (e.g. position of nodes) and missed information concerning materials or profiles, eliminates this type of transfer from further analysis. The transfer of the reinforced concrete structure model using IFC from REVIT to SCIA has not been analysed.

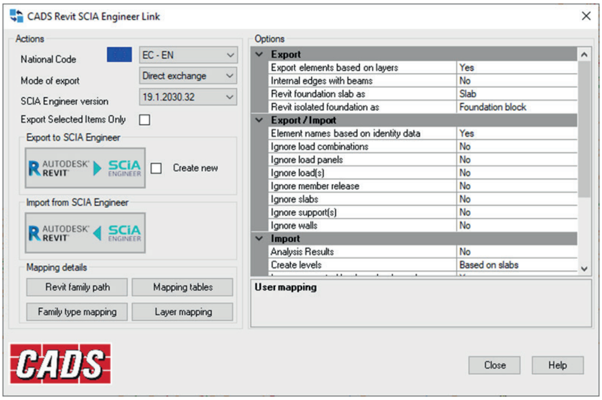

Fig. 12. Dialogue box of CADS Revit SCIA Engineer Link plug-in

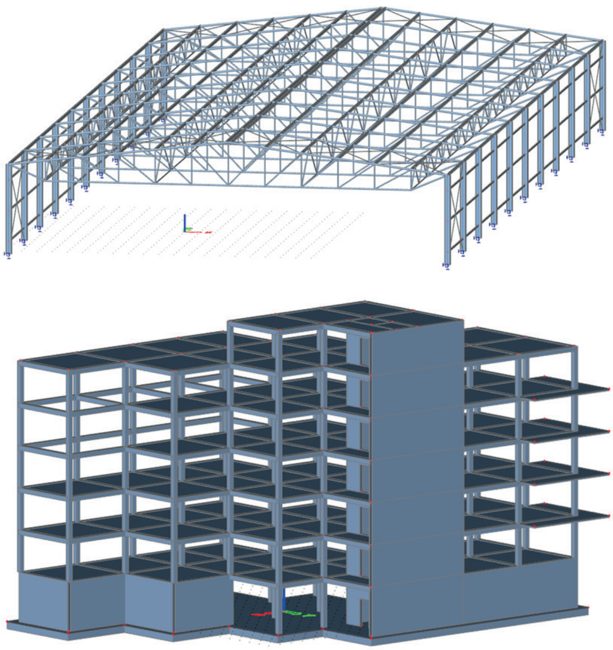

Fig. 13. View of steel and reinforced concrete structure's model in SCIA after exporting if from REVIT using plug-in

Although the SCIA-Tekla link plug-in exists and allows to generate an **.s2t* type file, the versions of the programs used in this paper do not allow the use of this tool. The possibility to export the steel structure using IFC2x3 format is briefly described below. An adaptation of the resulting model is possible, but the number of necessary corrections is quite expensive in terms of time. Hence, using the IFC standard produces a model, which has the correct structural configuration and correct cross-sections, but it requires material definitions or, e.g. "tightening" of the position of nodes where they connect. If comparison of transferred models is limited solely to those obtained with the IFC format, the TEKLA-SCIA data transfer, although with the loss of some important information, gives the best output via IFC among all the variants presented in the paper that employ this standard.

4. FEM static analysis of steel hall girder – model comparison

For further comparison of the quality of the transfers, a simple FEM analysis (fundamentals of the Finite Element Method – for more see, e.g. [27]–[29]) is carried out in each target program, limited only to the static calculation of the steel hall and one load case. The model in ROBOT is obtained via the direct link with TEKLA. The structure analysed in RFEM is derived from the physical model originally built also in TEKLA. Computations in SCIA are performed based on the model being transferred by the plug-in from REVIT. A typical, uniform and linear load applied to the purlins of the roof slopes along the hall is employed. The analysis is valid for the whole structure, but the results presented below refer only to a selected truss girder.

Figure 14 depicts the diagrams of axial forces N in bars for the selected module of the structure determined in all three calculation programs. Figure 15 shows the corresponding forms of deformation under the given load. The extreme values of the axial forces in the upper and lower chords, as well as the maximum values (in terms of modulus) of the vertical displacement are summarised in Tab. 1. The results obtained are consistent – comparing the numerical values in the table and the corresponding illustrations of the figures' results. In conclusion, the models imported into different programs are equivalent to each other, and the effect of the transfer used does not falsify the solution.

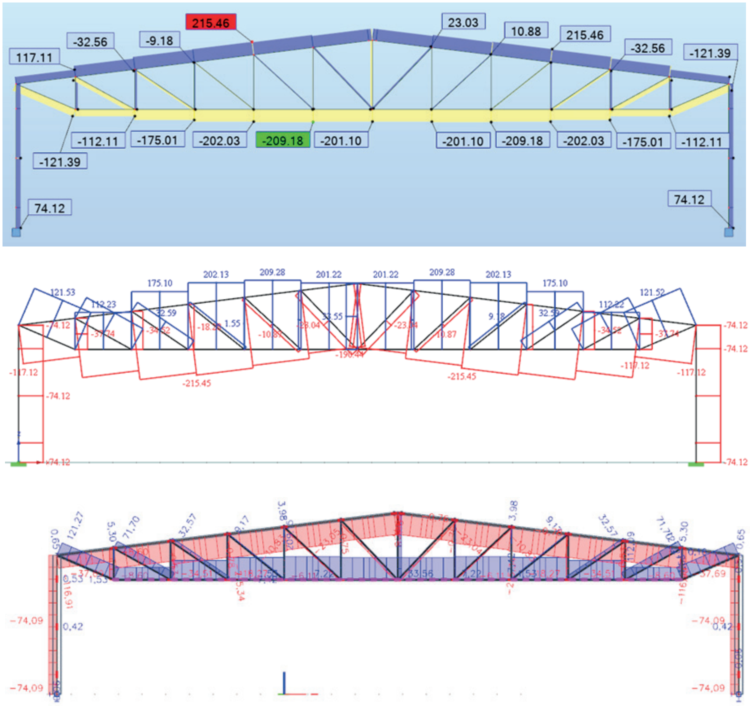

Fig. 14. Diagrams of axial forces N [kN] for selected truss module of steel structure in: ROBOT, RFEM and SCIA

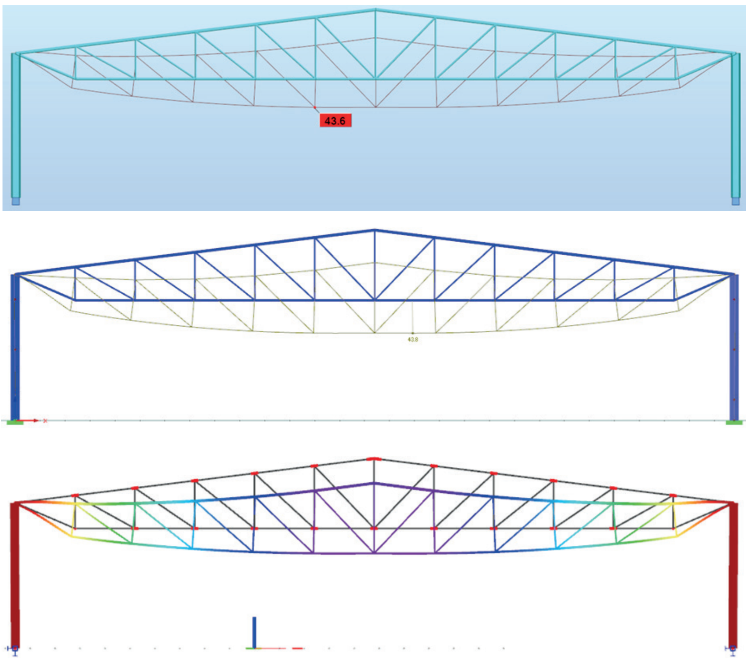

Fig. 15. Illustration of deformation for selected truss module of steel structure in: ROBOT, RFEM and SCIA

Table 1. Extreme values of axial forces and vertical displacement of selected truss module of steel structure

	Top chord	Bottom chord	
Program	Axial force [kN]	Axial force [kN]	Displacement [mm]
ROBOT	215.46	209.18	43.6
RFEM	215.45	209.28	43.7
SCIA	215.34	209.15	43.5

5. Final overview of model transfers

Tables 2-5 summarise all the transfers demonstrated in the paper. Table 2 deals with the transfer of the steel structure model from REVIT as the source program, and Tab. 3 – from TEKLA as the source program. Similarly, Tabs 4 and 5 are related to the transfer of the reinforced concrete building structure model. The following table columns are presented: the target program, method of the transfer, effects of the transfer with respect to the correctness of the geometry, materials and cross-sections (profiles) and a remark if extra corrections of the model are needed.

In addition, the sign * is used to indicate that the resulting model cannot be further analysed, and the sign ⁑ character is used to indicate that the computational model needs to be adjusted if it employs components that aren't created in the analytical model. When a +/– sign appears in the table, it means that certain information is partially transferred. For example, the REVIT-RFEM transfer using the plug-in for the hall model (see the third row in Tab. 2) transfers the geometry correctly, but it does not transfer the material data and it causes an issue when the data for some profiles is moved improperly, in this case – for bracings.

Table 2. Effects of transfer of steel structure's model from REVIT

Target program	Transfer method	Geometry	Material characteristics	Correctness of profiles	Correction required
ROBOT	Direct Link	+	+	+	NO
RFEM	REVIT-Dlubal Link plug-in	+	–	+/–	YES
RFEM	IFC2x3	–	–	–	*
SCIA	CADS REVIT-SCIA Link plug-in	+	+/–	+/–	YES
SCIA	IFC2x3	–	–	+/–	*

* Model disqualified for further use, not subject to further correction.

Table 3. Effects of transfer of steel structure's model from TEKLA

Target program	Transfer method	Geometry	Material characteristics	Correctness of profiles	Correction required
ROBOT	Robot Link 1.56	+	+	+/–	YES
RFEM	Direct Link Physical model	+	+	+/–	YES
RFEM	Direct Link Analytical model	+	+	+/–	YES
RFEM	CIS/2	+/–	+	+/–	YES
RFEM	DSTV	+	+	+/–	YES
RFEM	IFC2x3	+/–	–	–	*
SCIA	IFC2x3	+/–	–	+	YES

* Model disqualified for further use, not subject to further correction.

Table 4. Effects of transfer of reinforced concrete structure's model from REVIT

Target program	Transfer method	Geometry	Material characteristics	Correctness of profiles	Correction required
ROBOT	Direct Link	+	+	+	NO ⁑
RFEM	REVIT-Dlubal Link plug-in	+	+/–	+	YES
SCIA	CADS REVIT-SCIA Link plug-in	+	+/–	+/–	YES

⁑ Model needs to be adjusted in case of components being used when source programs do not generate analytical model elements.

Table 5. Effects of transfer of reinforced concrete structure's model from TEKLA

Target program	Transfer method	Geometry	Material characteristics	Correctness of profiles	Correction required
ROBOT	Robot Link 1.56	+	+	+	NO ⁑
RFEM	Direct Link Physical model	–	+	+	*
RFEM	Direct Link Analytical model	+/–	+	+	YES
RFEM	IFC2x3	–	–	+	*

* Model disqualified for further use, not subject to further correction.

⁑ Model needs to be adjusted in case of components being used when source programs do not generate analytical model elements.

It should be noted that the paper omits data transfer between TEKLA and REVIT, where in both programs the use of the Export to Revit Geometry plug-in as well as the use of the open IFC format is effective. Moreover, a successful transfer is possible in both directions, possibly by mapping of some model attributes, e.g. profiles or materials.

6. Conclusions

The paper verifies available data transfers for two typical structural models between selected modeling and computational analysis software. The first object is a model of a steel industrial hall. The second object is a reinforced concrete residential building. Both models are created in Autodesk Revit 2020 [12] (REVIT) and Tekla Structures 2019i [13] (TEKLA). The target programs in which FEM calculations (e.g. static) can be performed, are: Autodesk Robot Structural Analysis Professional 2020 [14] (ROBOT), Dlubal RFEM 5 [15] (RFEM) and SCIA Engineer 20 [16] (SCIA).

When using the Direct Link transfer, the resulting models generally correctly reflect the structural layout, which can be subjected to further computational analysis. The usage of plug-ins has a similar effect and also leads to models that require relatively minor corrections. However, attention should be paid to the fact that in the source programs (REVIT or TEKLA), the corresponding model components are created so that they are visible in the analytical model. Then the model is immediately applicable for further use, such as in the transfer REVIT-ROBOT. Thus, a correct analytical model is usually the starting point for the proper performance of data transfer. The ability to transfer models efficiently can speed up the work of design offices. It is also possible to exchange data between different equipment (two different computers, servers or tablets). Another variant of data transfer is via so-called open formats. They differ from native formats because their structure should be available in commonly used software. For this purpose, formats of two different types have been studied:

dedicated and fully open. CIS/2 and DSTV type files are specifically intended for the transfer of steelwork models, with the DSTV format producing better results. An alternative way is to transfer via an open IFC file. As shown in this article, the effectiveness of transferring models via the IFC format is rather poor since the resulting model is not even suitable for further adjustment in order to prepare it for calculations. The transfer TEKLA-SCIA is an exception because the obtained model can be adapted for further FEM analysis.

The possibility of data transfer (interoperability) of AEC software, i.e. programs dedicated for architect and structural designers, provides a basis for effective inter-branch cooperation in design offices, regardless of their location in the world. The reason of less fruitful collaborations are rather limitations of hardware and resources of the software itself in individual offices. Therefore, despite the difficulties presented in the article, it is worth popularising and developing the use of transfer via open formats such as IFC. All the more so, as open standards may in the future become the primary tool for communication between engineering software from different producers in the world. Depending on the components used during modeling and the level of complexity of the objects, the appropriate type of transfer can be selected. This paper discusses the different degrees of correctness for the transfer of models and their possible repair requirements after they are exported. As shown, the best data transfer can be achieved by direct link or by using a plug-in. Based on the comparisons and observations made in the paper, the designer can evaluate the available tools and make a decision regarding the need to use transfers between programs, as well as the cost of time-consuming model corrections in the context of own skills.

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Orginal Article

Analysis of the state of preservation the historic arcaded houses in Vistula Delta listed in the National Inventory of Historical Monuments

Tomasz Zybała

Faculty of Civil and Environmental Engineering, Gdańsk University of Technology;
11/12 G. Narutowicza St., 80-233 Gdańsk, Poland;
tomasz.zybala@pg.edu.pl *0000-0001-9186-4960*

Abstract: Historic arcaded houses are part of the material heritage of the Vistula Delta. Unfortunately, their number is decreasing year by year. The article is the result of a query of available sources and field research carried out by the author in 2015-2020. The paper presents the current state of preservation the historic arcaded houses in Vistula Delta listed in the National Inventory of Historical Monuments. Criteria for the selection of test objects are described. The author has prepared a tabular list of arcaded houses with information about their location, type according to Kloeppel statistics, date of construction, technical condition and functions. The summary of the analysis are pie charts with a statistical presentation of the data collected by the author during the research.

Keywords: arcaded houses, Vistula Delta, historical monuments of the Vistula Delta

1. Introduction

The arcaded houses were a common element of the wooden architecture of former Poland, Silesia, Pomerania and Prussia. They differed from each other in size, shape, structure and interior layout. The main reason for the use of columns in the construction of buildings was to create a roofed space; they served as a cover for the entrance door against precipitation, as well as a rest area. The arcades reflected the owner's property status, lifestyle, ethnicity, as well as the development of carpentry techniques in a given period. Arcades were found not only in residential buildings, but also in churches, town halls, granaries and forges [1], [2].

The arcaded houses from the area of Vistula Delta (also called in Polish Żuławy Wiślane) are the most characteristic, historic residential buildings in the region [3], [4]. They are a distinguishing feature of the cultural environment of the Vistula Delta. In the past, residential houses with columns were a permanent element of the architecture of the village of Żuławy [5].

Currently, they are few and scattered examples of the old architecture of the Vistula Delta. The process of degradation of arcaded houses is progressing [6], [7]. Actually, the main factors reducing the number of arcaded houses in Żuławy are insufficient care of the owners to keep them in good technical condition and the lack of funds for construction and conservation works.

The aim of the article is to make a quantitative statement of the preserved historic arcaded houses from the Vistula Delta (as of 2020). The article is also a summary of the field research carried out by the author in 2015-2020[1] and update and supplement to the results made by other researchers.

2. State of research

The available literature describing the arcaded houses located in Vistula Delta can be divided into items created before 1945, mainly German[2], and those published after the end of the war, mostly Polish.

The first scientific studies focused mainly on the architectural form of arcaded houses. Architectural historians have included descriptions of only some of the houses from the Vistula Delta [8], [9]. Another source of information about the number of houses existing before 1945 are the lists and reports of German conservators[10], [11], [12]. However, these works do not contain information about all arcaded houses that existed before the war in Żuławy.

The first study that gives an approximate number of preserved arcaded houses from the Vistula Delta is the post-war study by Jerzy Stankiewicz[3], who defined the state of preservation at 131 objects, but it is incomplete[4] [3]. In the 1960s, descriptions by Lech Krzyżanowski were created, with extensive photographic documentation of the houses [13]. Information on the state of preservation of the historic structure of settlements, including arcaded houses, from the 1980s was included in doctoral dissertation on the development and typology of the Żuławy village by Bogna Lipińska [14]. The latest work that discusses the state of preservation of arcaded houses in Vistula Delta is the doctoral dissertation of Marta Koperska-Kośmicka [7] published in 2020 [15]. The author has compiled a list of historic arcaded houses listed in the National Inventory of Historical Monuments from the area of Żuławy Wiślane and a part of the Elbląg Upland (as of 2013). In it, she presented a table with 63 objects. It also included houses with a recessed arcades, monuments that have lost their arcade, farm buildings, as well as objects that did not exist during the preparation of the work or they were in ruins. Marta Koperska-Kośmicka in her dissertation also described the process of degradation of arcaded buildings in the area of the Vistula Delta in the 20th century. The analysis also included those houses that were not listed in the register of monuments. The state of preservation was determined at 108 objects (as of 2013).

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1 The author visited all the places with arcaded houses listed in the National Inventory of Historical Monuments of the Pomeranian Voivodeship [18] and Warmian-Masurian Voivodeship [19]. During the research, the author made photographic documentation and interviewed the owners of the monuments.

2 Before the second world war, arcaded houses in Vistula Delta were also the subject of research by Poles: Gerard Ciołek [29] and Władysława Łęga [30].

3 Jerzy Stankiewicz (1923-1994) architectural historian, professor at the Gdańsk University of Technology.

4 It is not an exact number. The list was not complete because it did not include all the preserved arcaded houses. The reasons were transport problems and the lack of sufficient time to carry out detailed field research.

Today, there is no current list of the existing historic arcaded houses of the Vistula Delta listed in the National Inventory of Historical Monuments[5]. There are also no collective studies specifying their technical condition, date of construction or type[6]. There are also no updates and supplements to the inspection of historical buildings made by other researchers dealing with arcaded houses in Żuławy. The lack of the above-mentioned analyses prompted the author of the article to start field research and perform a query of available sources.

3. Research method

The article uses a varied research method containing elements of three methods: historical-interpretative, quantitative and statistical [16], [17]. The basis for starting work on the state of preservation was a library and archival query of items describing historic arcaded houses of the Vistula Delta. The author got acquainted with the collections of: the historical section of the Main Library of the Gdańsk University of Technology, the archives of the National Heritage Board of Poland in Gdańsk, the Main Library of the University of Gdańsk, the Żuławy Museum in Nowy Dwór Gdański, the C.K. Norwid Library in Elbląg[7] and available internet sources [18], [19], [20]. The article presents a numerical list of preserved, historic arcaded houses from the Vistula Delta. The author gives the results of his research in the table (tab. 1). The houses have been arranged chronologically. The table also contains information about the type of house and the province in which the monument is located. The last column contains information about the technical condition, construction and conservation works in recent years and the current function. The summary of quantitative research is a graphical representation of the results in pie charts. They present a statistical view of the data collected by the author during field research (2015-2020).

4. Research field – criteria for selecting objects for research

The author's research area is a low-lying plain – the Vistula Delta with an area of 2460 km^2, also known as Żuławy Wiślane [21], [22]. The following are distinguished: Żuławy Gdańskie located west of the Vistula, Żuławy Malborskie between the Vistula and the Nogat, and Żuławy Elbląskie east of the Nogat and south of Elbląg. The list does not include arcaded houses from the Elbląg Upland, the Iławskie Lakeland, the Walichnowska Lowlands, the Starogard Lakeland and the Kashubian Lakeland [21].

The subject of the author's research are objects entered in the register of monuments[8] [18], [19], considered the most valuable and representative. In accordance with the Act on the protection and care of monuments: „*monument – real estate or movable property, their parts or complexes, being a work of man or related to his activity and being a testimony of a bygone era or events whose preservation is in the public interest due to their historical, artistic or scientific value"*[23]. Hence, by the decision of the conservation authorities, objects

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5 The author takes into account only those houses that have a arcade.

6 Status for 2020, summary taking into account the losses of the last 5 years (duration of the author's field research).

7 Footnotes to individual items are given in the text.

8 There are arcaded houses in Vistula Delta which are not listed in the register of monuments. Examples are houses in: Świerki no. 28, Brzózki no. 13, Cedry Małe no. 7 (ruin), Cyganek-Żelichowo no. 31a or a house with a built-up arcade in Marynowy no. 7, which by some internet sources is incorrectly defined as an object listed in the register of monuments [18]. Objects not included in the list of historical monuments may be the basis for the preparation of a another article.

that meet the above-mentioned criteria are listed in the register. In addition, each arcaded house entered in the register of monuments has its own record card, where it is possible to find information about its history, architecture, and repairs[9]. Confirmed information about technical interventions is important for the author, who, in his research, focuses on the technical and conservation issues of historic arcaded houses construction [24], [25], [26].

The group of objects analysed by the author are arcaded residential houses. According to Kloeppel's statistics, established in the 1920s (confirmed after the war by Stankiewicz), we distinguish three basic types from the Vistula Delta: type I, type II and type III [3], [8] (Fig. 1). The oldest form is type I. It is a house on a rectangular plan, with columns located in the gable wall (Fig. 1a). In the 17th century, type II began to appear (Fig. 1b), a house with pillars located in the gable wall, with an additional side wing. The arcade of houses type I and II were based on 7, 8 or 9 pillars. Additionally, in both types there is a storey on the entire plan of the building. Type III appears in the second half of the 18th century (Fig. 1d, e). It is a house with a central portico perpendicular to the ridge. The first floor is kept only in the portico. The number of columns is from 4 to 7[10] in the front. The use of additional pillars reduces the depth of the portico[11]. In the development of the architectural form of the arcaded houses in Żuławy there is also an intermediate type, between II and III (Fig. 1c). It is characterized by a central portico supported on columns, perpendicular to the ridge, the number of pillars is 8. The storey is maintained throughout the building plan or there is a mansard roof.

The research field has been narrowed down to the above-mentioned group of houses with aportico in the gable wall or central portico perpendicular to the ridge [12]. In the mid-nineteenth century, there was a significant reduction in the avant-corps based on columns in the houses (Fig. 1f). Over time, the portico transforms into a decorative porch, which only refers to the old and traditional form of the house in the Vistula Delta[13]. Therefore, the group of objects analyzed by the author are the oldest arcaded houses. Their structures reach large spans[14] and sizes of construction elements[15]. The temporal scope of the preserved objects belonging to the traditional arcaded houses in Żuławy is from the 17th to the 2nd half of the 19th century (tab. 1).

The last factor in selecting monuments for field research was their primary function. In the past, arcaded houses had a residential role[16]. Forges cannot be included in this group[17] and farm buildings with arcade too[18], even though they are listed in the register of monuments.

9 Each technical intervention in a historic building must be approved by the Provincial Conservator of Monuments. Information about renovations and repairs is placed in the Architecture and Building Historical Monument record [31], [32].

10 For example, arcaded house in Koszwały.

11 For example, a house in Orłowo (1 Wspólna Street), has 4 pillars in the front and 4 side pillars.

12 In the research, the author does not take into account other forms of arcaded houses in the Vistula Delta (for example, a house with a recessed arcade in Pruszcz Gdański – 6 Krótka Street).

13 For example, a house in Tuja built in 1871. (the date is above the main entrance to the facility).

14 For example a house in Nowa Kościelnica, the span of roof structure is 11.80 m [25].

15 The building structure is then more loaded and the internal forces are greater. This is the material for the development of mechanical analyzes, as well as for the recognition of the technology of making these constructions.

16 The oldest houses, type I and II, also had a storage function. Grain was stored in the attic.

17 The arcaded forge in Gdańsk Orunia, 10 Gościnna Street.

18 The arcaded barn in Krzewsk no. 29.

Fig. 1. Types of arcaded houses: a) type I house in Klecie, b) type II house in Trutnowy, c) type II-III house in Stalewo no.14, d) type III house in Koszwały, e) type III house in Markusy, f) type III house in Mikoszewo no. 68 (*photo by the author*)

5. Preserved arcaded houses – quantitative specification

The basis for the field research were the National Inventory of Historical Monuments of the Pomeranian Voivodeship [18] and the Warmian-Masurian Voivodeship [19][19]. The analysis of both collections shows 74 existing arcaded houses[20]. After taking into account the territorial scope (houses located in the Vistula Delta), the number of monuments decreased to 51. In the Pomeranian Voivodship, out of 42, there were 41 houses, and in the Warmian-Masurian Voivodship, out of 32 houses remained 10.

During the field research, the author, upon arrival at the site, stated that despite being entered in the register of monuments, some objects do not exist or are destroyed. These are

[19] Both registers are from 2015, when the author began work on determining the state of preservation of historic arcaded houses.

[20] The register also includes arcaded houses that have undergone destruction. Next to a given item there is an annotation “does not exist” (for example, the arcaded house in Orłowo no. 27 [18]).

houses in Lasowice Małe (Fig. 2a)[21], Kławki (Fig. 2b)[22] and Świerki (Fig. 2c)[23]. The list of historical monuments (as of 2015) also includes an arcaded house in Złotów, which burned down in 2014[24].

a) b) c)

Fig. 2. Destruction of arcaded houses: a) Lasowice Małe, b) Kławki, c) Świerki (*photo by the author*)

There are also irregularities in the register of monuments, in the village of Krzewsk there is an outbuilding with an arcade in the gable wall, incorrectly classified as an arcaded house [19].

During five years of research, the state of preservation decreased by one monument (Fig. 3a). In 2017, the house in Izbiska from 1778 was completely destroyed[25]. In May 2017, as a result of a strong wind, the arcade collapsed (Fig. 3b), in November 2017 the house burned down. No attempt was made to rebuild it (Fig. 3c, d)[26].

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21 The house is in ruins. Only part of the ground floor of the building has survived (as of 2016).

22 The house was demolished, in 2016 there was only a chimney.

23 The house is partially destroyed (1/3 of the roof collapsed).

24 The house was rebuilt after a fire, but it lost its historic value irretrievably. Its construction is new.

25 In 2016, the author measured the geometry of the break as well as the height and cross-sections of the columns.

26 In 2020, only the foundations of the house and construction rubble from its demolition are left.

a) b) c) d)

Fig. 3. Destruction of the arcaded house in Izbiska: a) August 2016, b) June 2017, c) view of the farm – August 2016, d) view of the farm – September 2020 (*photo by the author*)

Some houses have lost their avant-corps as a result of breakdowns or reconstructions and are no longer arcaded houses. Examples of such activities are houses in Marynowe no. 23/25 (Fig. 4a) and Stalewo no. 18 (Fig. 4b)[27].

a) b)

Fig. 4. Houses in: a) Maynowy no. 23/25 b) Stalewo no. 18 (*photo by the author*)

[27] The house was heavily rebuilt, completely lost its features of an arcaded house, decorations were removed.

The above-described situations resulted in the reduction of the research field by 8 objects. the number of monuments included in the analysis decreased from 51 to 43.

The latest register of monuments (as of 2021) [27], [28] does not show any major changes from 2016, when the author began field research. The list was reduced only by the one arcaded house in Izbiska.

The results of the author's research are presented in a table containing: addresses of arcaded houses, voivodeship , classification according to Kloeppel's statistics, date of construction, comments on the technical condition[28], the current function of the monument, repairs and additional observations of the author (Table 1).

Table 1. The current state of historic arcaded houses, as of 2020

No	localization	voivodeship	House type according to Kloeppel statistics	date of construction	remarks
1	Gdańsk Lipce, 297 St. Wojciech Tract	Pomeranian	I	1600[1][29]	technical condition of the house: very good, the oldest preserved arcaded house in Vistula Delta, renovated in 2005, currently used as a hostel
2	Trutnowy, 7 Podcieniowa Street (Fig. 1b)	Pomeranian	II	1720	technical condition: very good, currently the house is a residential building, it houses the seat of the Gdańsk Żuławy Association and an art gallery
3	Miłocin 8	Pomeranian	II	1731	technical condition: very good, house after complete renovation in 2011, currently a multi-family building, in the attic there is a conference and exhibition room for a local cultural centre
4	Lubieszewo 50	Pomeranian	III	1747	technical condition: sufficient, residential house
5	Rozgart 24	Warmia – Masuria	III	1749	technical condition: good, residential house

[28] The technical condition was determined on the basis of the job experience of the author who worked in the technical department of Gdański Zarząd Nieruchomości Komunalnych. A four-level scale describes the general technical state of the structure: walls, staircases, ceilings, roof trusses and roofing (very good condition means no remarks, good condition means the presence of minor defects that do not endanger the inhabitants, some building elements may require replacement in the future or repair, sufficient condition means that the building requires renovation but it does not threaten a construction disaster, insufficient condition means that there is a high risk of a construction disaster and requires urgent renovation works). In the article, the author does not assess the correctness of the technical interventions made in relation to the principles of monument conservation.

[29] The exact date of the construction of the arcaded house in Gdańsk Lipce is unknown. Researchers describing the monument give the following periods: Otto Kloeppel 1600r.[8], Jerzy Stankiewicz 17th century [3], Ignacy Tłoczek 1600 [1], Lech Krzyżanowski 17th century [33], Tomasz Ważny 1572 [34], Marta Koperska-Kośmicka end of XVIth century [7].

No	localization	voivodeship	House type according to Kloeppel statistics	date of construction	remarks
6	Nowa Kościel-nica 64	Pomeranian	II	mid-18th century	technical condition: good, after general renovation in 2013, uninhabited house, one-third of the building is adapted for residential purposes, the rest is used as a warehouse
7	Klecie 4 (Fig. 1a)	Pomeranian	I	around 1750	technical condition: sufficient, residential house, village lounge on the ground floor
8	Stalewo 14 (Fig. 1c)	Warmia – Masuria	II-III	1751	technical condition: sufficient, uninhabited house, put up for sale
9	Steblewo 15/17 (Fig. 6c,d)	Pomeranian	III	2nd half of XVIII	technical condition: unsatisfac-tory, residential house
10	Steblewo 22/24 (Fig. 6a,b)	Pomeranian	II-III	2nd half of XVIII	technical condition: unsatisfac-tory, residential house
11	Zwierzno 51	Warmia – Masuria	III	1773	technical condition: good, residential house in a Dutch homestead
12	Różany 28	Warmia – Masuria	III	1777	technical condition: good, resi-dential house in a Dutch home-stead, currently it is for sale
13	Różyny, 47-49 Gdańska Street	Pomeranian	III	1784	technical condition: good, residential house
14	Markusy 12 (Fig. 1e)	Warmia – Masuria	III	1789	technical condition of the house: good, residential build-ing in a Dutch homestead, farm buildings underwent significant destruction
15	Przemysław 4 (Fig. 5c)	Pomeranian	III	1789	technical condition: very good, house after complete renova-tion in 2005, now it is a house for rent
16	Koszwały, 21 Gdańska Street (Fig. 1d)	Pomeranian	III	1792	technical condition: good, residential house
17	Myszewko 4a	Pomeranian	III	1793	technical condition: good, residential house
18	Żuławki 32-33	Pomeranian	III	1797	technical condition: sufficient, residential house
19	Rozgart 13a	Warmia – Masuria	I	end of XVIII	technical condition: good, residential house
20	Zwierzno 39	Warmia – Masuria	III	end of XVIII	technical condition: good, residential house

No	localization	voivodeship	House type according to Kloeppel statistics	date of construction	remarks
21	Nowy Dwór Gdański, 74 Morska Street	Pomeranian	III	1800	technical condition: good, residential house
22	Mikoszewo 55 (Fig. 5b)	Pomeranian	III	1800	technical condition: very good, reconditioned in 2017, residential house
23	Krzywe Koło 36	Pomeranian	III	early XIX	technical condition: very good, the building houses the Caritas Center of the Gdańsk Archdiocese
24	Lubieszewo 29	Pomeranian	III	early XIX	technical condition: good, residential house, part of the building is used as a guesthouse
25	Orłowo, 1 Wspólna Street	Pomeranian	III	1802	technical condition: good, currently uninhabited
26	Orłowo, 66 Żuławska Street (Fig. 5a)	Pomeranian	III	1802	technical condition: very good, after complete renovation 2013-2018, residential house
27	Marynowy, 19/19a Podcieniowa Street (Fig. 5d)	Pomeranian	III	1803	technical condition: very good, house after general renovation in 2012, residential house, part of the house intended as a guest house for tourists
28	Żuławki 64	Pomeranian	III	1803	technical condition: very good, renovated in 2014, residential house
29	Marynowy, 70/70a Nowodworska Street	Pomeranian	III	1804	technical condition: sufficient, residential house
30	Kępniewo 36	Warmia – Masuria	III	1810	technical condition: sufficient, residential house
31	Pordenowo 36	Pomeranian	III	1811	technical condition: good, residential house
32	Bystrze 5/7	Pomeranian	III	1819	technical condition: sufficient, residential house
33	Nowy Staw, 11 Gdańska Street	Pomeranian	III	1820	technical condition: good, residential house
34	Nowa Cerkiew 12	Pomeranian	III	1820	technical condition: sufficient, residential house

No	localization	voivodeship	House type according to Kloeppel statistics	date of construction	remarks
35	Żuławki 6	Pomeranian	III	1825	technical condition: very good, residential house
36	Rybina 12	Pomeranian	III	1st quarter of XIX	technical condition: very good, house after renovation in 2017, residential house
37	Lasowice Wielkie 12	Pomeranian	III	1837	technical condition: sufficient, uninhabited house
38	Nowa Kościelnica 50/51	Pomeranian	III	1840	technical condition: good, residential house
39	Osice 20	Pomeranian	III	1844	technical condition: sufficient, residential house
40	Orłowo, 11 Mennonicka Street	Pomeranian	III	1847	technical condition: good, residential house in a Dutch homestead
41	Gniazdowo 28/29	Pomeranian	III	1st half of XIX	technical condition: good, residential house
42	Mikoszewo 68 (Fig. 1f)	Pomeranian	III	mid of XIX	technical condition: good, residential house
43	Żuławki 75	Pomeranian	III	1859	technical condition: very good, residential house

a)

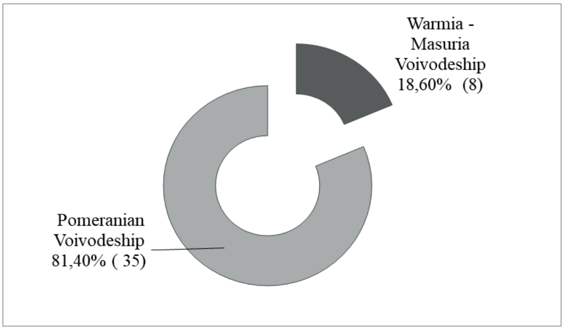
b)

c)

d)

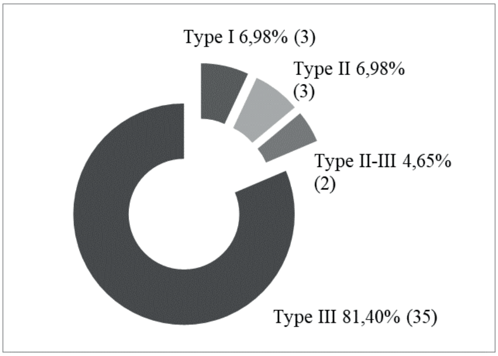
Fig. 5. Arcaded houses in: a) Orłowo no. 66, during construction and conservation works in 2015, b) Mikoszewo no. 55, during construction and conservation works in 2017, c) Przemysław no. 4, d) Marynowy no. 19 / 19a (*photo by the author*)

Until 2020, 43 arcaded houses from the Żuławy Wiślane area, entered in the register of monuments, have survived. Most of them are located in the Pomeranian Voivodeship – 35 houses (81.40%), the remaining 8 (18.60%) are located in the Warmia – Masuria Voivodeship (graph 1).



Graph 1. The number of arcaded houses in the Voivodeships: Pomeranian and Warmia – Masuria (*author's work*)

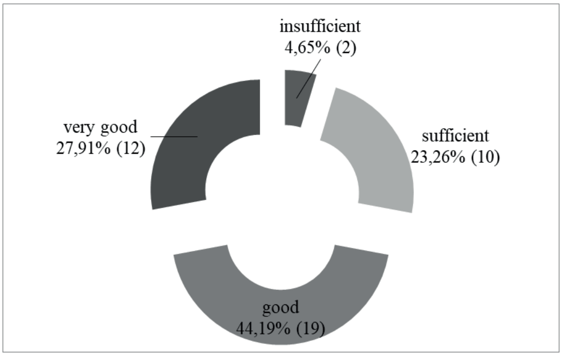
The least numerous group of preserved monuments are houses: type I - 3 houses 6.98% (Gdańsk Lipce, Klecie No. 4, Rozgart No. 13a), type II – 3 houses 6.98% (Miłocin No. 8, Trutnowy No. 7, Nowa Kościelnica No. 64) and type II-III 2 houses 4.65% (Stalewo No. 14, Steblewo No. 22/24). Type III houses are the most numerous group – 35 buildings 81.40% (graph 2).



Graph 2. The number of preserved arcaded houses – types division (*author's study*)

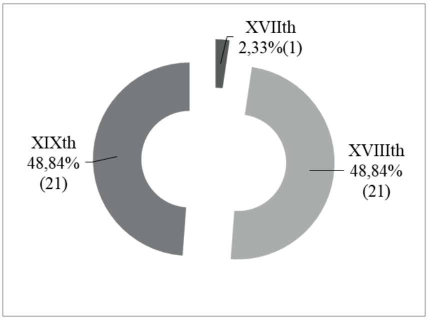
12 houses (27.91%) are in a very good technical condition, 19 houses are in a good condition (44.19%), 10 houses are in sufficient condition (23.26%), 2 houses are in insufficient condition (4.65%) – monuments in Steblewo (Fig. 6) (Graph 3).

Fig. 6. Houses in: a) Steblewo 22/24, b) Steblewo 22/24 the catastrophic condition of the gable wall of the portico, c) Steblewo 15/17, d) Steblewo 15/17 leaking roofing (*photo by the author*)



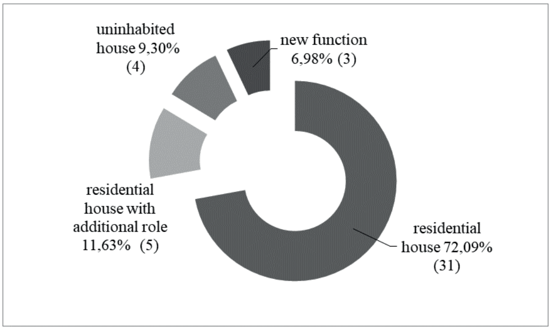
Graph 3. Technical condition of arcaded houses, as of 2020 (*author's study*)

Only one house from the 17th century (2.33%), 21 houses from the 18th century (48.84%) and 21 from the 19th century (48.84%) (graph 4) have survived to the present day.



Graph 4. Age of arcaded houses (*author's work*)

31 houses (72.09%) have a residential function, 5 preserved buildings (11.63%) have an additional role (Trutnowy 7, Miłocin 8, Klecie 4, Lubieszewo 29, Marynowy 19 / 19a). Four houses (9.30%) are uninhabited (Nowa Kościelnica 64, Stalewo 14, Orłowo 1, Lasowice Wielkie 12). Three houses (6.98%) have a new function: Gdańsk Lipce – hostel, Przemysław 4 – guesthouse, Krzywe Koło 36 – Caritas Center (graph 5).



Graph 5. The function of the preserved arcaded houses (*author's work*)

6. Conclusions

Only 43 historic buildings, which are listed in the National Inventory of Historical Monuments, have survived to the present day.

This number is likely to decrease within a few years. Two houses in Steblewo require immediate construction and conservation works. Their technical condition is insufficient. Lack of adequate funds for repairs and little involvement of the owners in saving them will result in the loss of more monuments from the 18th century.

The destruction of the house in Izbiska confirms that the process of degradation of arcaded houses is progressing.

A significant part of the preserved monuments of 31 houses (72.10%) is in good or very good technical condition. This is due to the general renovations in some facilities (Table 1), which saved them from destruction. The owners showed determination in obtaining funding and properly carrying out construction and conservation works. In most cases, a good technical condition is a consequence of constant maintenance (Tab. 1). It is worth adding that systematic repairs and renovations do not require large financial outlays. They guarantee a good technical condition of the facility.

The number of preserved arcaded houses from the 18th and 19th centuries is noteworthy, they are equal (21 objects).

Most of the houses, 36 of them, which constitutes 83.72%, have retained their original residential function. A much smaller part has a new role or is uninhabited. Houses that are currently unoccupied are used by their owners as warehouses or holiday homes (e.g. houses in Nowa Kościelnica No. 64, Lasowice Wielkie No. 12, Orłowo 1, Stalewo No. 14). Such functions of objects do not cause their destruction or deterioration of their technical condition. The owners care about the monuments and their surroundings.

The above list is the basis for the author's further research on the historic arcaded houses of the Vistula Delta.

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Orginal Article

Role and factors of solar facades shaping in contemporary architecture

Janusz Marchwiński

Faculty of Architecture; University of Ecology and Management in Warsaw
12 Olszewska St., 00-792 Warsaw, Poland;
j.marchwinski@wseiz.pl *0000-0003-3897-3580*

Abstract: The article deals with the issue of solar facades as the main external walls of a building, adapted to make use of solar energy. The aim of the article is to define the role of the facades and the factors that influence shaping thereof. The goal is of cognitive nature, whereas its implementation may contribute to strengthening the relationship between presumptions related to energy and architecture in the design of buildings. The need for the article results from the necessity to search for a possible balance between technical and humanistic spheres while shaping contemporary pro-ecological architecture, especially one aimed at receiving solar energy as a renewable energy source.

In the article, both analytical and comparative methods are applied. The research was conducted on the example of four designs with solar facades of different characteristics, including two buildings planned by the author.

The research results are observations that define relationship between the energy-related role of solar facades and urban, functional and aesthetic issues. These observations lead to the conclusion that the energy aspect, is not the only one to be considered while shaping solar facades in contemporary architecture. The solar facade combines both functional and artistic features.

Keywords: solar facades, solar architecture, pro-ecological architecture, energy-saving architecture, photovoltaics

1. Introduction

The design and material solutions of external walls as barriers between the interior and the surroundings exert an impact on the use of solar energy in the building. The main emphasis is placed on the walls subjected to direct insolation, the so-called solar-active walls. This, in turn, is associated with the introduction of technological, constructional and architectural solutions, uncommon in the case of other walls. The dynamically developing technology of glazing combined with advanced solar technology solutions (shading systems, PV modules, etc.) is significant in this respect. In this case, solar facades are now under discussion while a secondary role is assigned to the remaining elevations.

There are various definitions of the facade. As stated by Joanna Tymkiewicz [1], "the concept of facade is becoming more and more popular in works in the field of architecture. In dictionary definitions, this term denotes the most important front elevation of the building, which usually houses the main entrance, and is distinguished from the remaining elevation by its composition and richness of details" [Author's own trans.]. Further, the author quotes Scruton, Rewers and Knack. According to the first author mentioned, "the facade is the face of the building, it is something that stands in front of us and has all the buildings' expression" [Author's own trans.]. Rewers, in turn, draws attention to the twentieth century disappearance of the facade in favor of the modernist elevation. He further states that "the abandoned concept (of the facade – author's note) was annexed by the social sciences, followed by cultural studies". On the contrary to Rewers, Tymkiewicz notices that "the concept of a facade in architecture has not been completely abandoned, but has changed its meaning and expanded its capacity" [Author's own trans.]. He quotes Knack, who maintains that "the facade appeared as soon as the architects managed to separate the external structure of the building from its load-bearing function" [Author's own trans.].

The way in which the term 'facade' is understood in the present article is closer to the dictionary definition and the above-cited observation by Tymkiewicz. By adopting this point of view, a number of solar buildings can be distinguished that are characterized by a facade which can be labelled a solar facade. It is the facade of the building, the shape of which assumes controlled solar gains. Here, modern technological solutions are applied, such as solar protection glazing, thermal insulation glazing, photovoltaic (PV) technology, or various systems that comprise solar element. The accumulation of these components causes the solar-active wall to dominate, not only in terms of construction and technology, but also in terms of its form and aesthetics.

The phenomenon of solar facades as external walls adapted in order to make use of solar energy stems from functional and energy-related reasons. Such attitude is commonly adopted in contemporary projects like e.g. Solar City by Elon Musk and Peter Rive [2] At the same time, pro-ecological architecture seeks balance between technical and humanistic spheres [3]. The question thus arises whether solar facades result entirely from considering the functional aspects related to optimization of solar energy use. Do they take into account or ignore issues of shaping the architecture of the building as regards aesthetics, elements of urban planning, as well as the functional purpose of the rooms?

It becomes important to examine and compare the contemporary shaping of solar facades of buildings more broadly, i.e. both the constructional, technological and energy solutions of the building, as well as the functional purpose of the rooms, the relationship of the building with the surroundings and its aesthetics.

For this purpose, examples of four buildings with solar facades were used. The buildings reflect various approaches and assumptions to shaping of the facades, as well as they showcase certain limitations associated with it.

2. Analysis of solar facade solutions in contemporary buildings with various functions

2.1. Public utility building ”Solar-copper house” in Wrocław (concept), arch. author (2013)

The project of the “Solar-copper” house (SCH) was created with a view to creating a prototype public utility building with an area of approx. 250 sq. m. The building was supposed to contribute to constituting future architectural and construction-technical standards in the field of energy conservation. In line with these standards, it was assumed that the facility would produce energy exclusively from renewable sources and that the energy yield would exceed its demand (plus energy building).

The energy-related goals were accompanied by the assumption to create modern architecture with a strong connotation of ecology and energy saving. The main measure towards attaining these goals has become the implementation of solar techniques and solutions with the main role of photovoltaic technology [4].

The building has a strongly defined and exposed solar facade equipped with PV modules (photovoltaic facade). It is marked with southern orientation that provides the most advantageous exposure in terms of energy gains.

Already at the pre-design stage, preliminary decisions were made to select a plot of land that would make it possible to achieve the assumed goals, as well as to secure optimal functioning of the PV facade. The project is located in the heart of the city, to the west of the Pomeranian Bridge. The advantage of the location lies in the fact that the plot is located directly on the Odra River embankment, it borders the river to the south. This location and the spatial conditions of the plot itself guaranteed full solar exposure of the southern facade, while ensuring the possibility for unlimited observation of the building from the other side of the river. The vicinity of the river is also important due to microclimatic benefits, including lower air temperature outside the building during warm periods, which has a positive impact on the efficiency of PV modules operation.

In addition to the energy-related targets, efforts were made to give the PV facade characteristic aesthetic features. The aesthetic concept is based on the diagonal breaking of the visual and painting composition of the facade with the use of different types of PV modules and traditional glass transparent panels. PV modules made of amorphous silicon cells of varying colors and translucency were applied, i.e. non-transparent (ASI opaque) and semi-transparent (ASI-thru). Owing to the modules, original artistic and painting effects were created in the form of a “colored mosaic” contrasted with a curtain wall made of transparent glass with a PV print. This special feature distinguishes the building from previous BIPV projects implemented worldwide. The uniqueness of the solution lies in the combination of multi-colored PV modules, not only marked with a varying degree of translucency (0%, 20%, 30%), but also in shape, which, together with traditional glass panels, form a glass curtain wall. This solution uses the latest achievements of photovoltaic technology that consist in the use of colored films in the glass laminate from the outside of the PV cells. Unlike previously, his modification does not cause unreasonably large energy losses [5].

Semi-transparent PV modules and traditional fully transparent glazed panels offer a valuable element of the aesthetic concept, but also provide a compromise between energy and utility demands. Such modules allow to increase the share of natural light in the lighting of the interior of the building and provide eye contact with an attractive environment. The transparent glazed panels in the PV facade eliminate the false tint of natural light that comes through the colored PV modules. Their introduction next to semi-transparent PV modules, however, is associated with a reduction in the power of the entire PV system, and thus lower energy gains from the sun.

At the same time, it should be assumed that, although compensated by a significant share of neutral-colored glazing, including glazing with PV print, the quality of lighting is not satisfactory to house permanent work stations in the elevation space (only simplified simulations were conducted at the concept stage). Removing work stations from the vicinity of PV modules results also from thermal reasons. The PV facade, being a smooth glazed curtain wall, creates a problem of protecting the interior from direct solar radiation, as the use of external shading systems would negate the application of PV modules. Thermal protection was provided by introducing a buffer space, designed as a large-space interior over the entire height of the building . The solution is aimed at increasing the efficiency of air exchange, which plays important role in passive solar cooling [6]. This space may be seen as the "lungs of the building" and offers benefits in terms of cooling the surface of the PV modules from the inside as well. This contributes to an increase in their efficiency. During the heating season, the space acts as a thermo-buffer zone, whereas in the sunny periods, it serves as a passive heat collector. The decision to introduce a thermo-buffer space, however, resulted in the need to move the offices deeper into the building plan and locate them towards the less favorable sides: the eastern and western sides.

The design of the PV facade, created largely by the aesthetic factor and constituting a kind of "showpiece" of the building, did not provide sufficient energy gains, as expected in line with a plus energy building concept. The implementation of this aesthetic goal forced the introduction of the aforementioned spatial and architectural solutions (passive systems) and other installation solutions (including a heat pump) in combination with energy-saving technical and construction solutions. One of the features of the building is its high thermal insulation properties of the remaining external walls combined with a radical reduction in the share of glazing, especially in the northern elevation. This influenced a simplified aesthetic vision of these walls, which emphasized the leading importance of the described southern facade as a solar facade.

Fig. 1. "Solar-copper house" in Wrocław (concept): solar facade with PV modules of various colors and translucency. *Source: author*

2.2. Single family building – Solar house in Bytom, arch. Author + design office ”Atlant”(2007)

The Solar house (SH) was designed in accordance with solar architecture design principles. The project assumes the maximization of natural lighting, passive thermal gains from sunlight, while maintaining a high level of thermal insulation, as well as natural ventilation of the rooms. Active and passive solar measures were introduced. The active measures are represented by a vacuum solar collectors system intended for the preparation of domestic hot water. The connection with the solar facade is provided by a passive measure in the form of built-in greenhouse, which is designed on the southern side of the building.

The spatial form of the building is defined by two solids – a one-storey one with a flat roof and a two-storey one with a sloping roof. The two components form the “L” shaped plan of the building. The shape of the construction is derived from the classical trend of solar architecture. In line with the principles of shaping forms of helioactive buildings [7], the two-story body descends towards the north – the surface area of the northern elevation has been decreased and has been provided with a reduced amount of glazing. On the opposite direction – i.e. the sunny southern side – the outer wall is the largest one – it forms the solar facade (additionally, the facade glazing stretches towards the eastern wall).

The solar facade should not be understood as a front facade in the traditional sense, i.e., it is not oriented towards the entrance or the driveway. It is visible mainly from the side of a semi-open courtyard that functions as a private garden. However, such facade serves as the dominant external wall of the building in the aesthetic sense, which factor somehow defines the architecture of the building.

The two-storey high glass curtain wall that forms the facade is responsible for passive solar gains that are utilized room heating in winter and stimulate natural vapour ventilation in warm periods. The combination of the glass curtain with a massive internal brick wall as the so-called “thermal mass” provides an important feature in terms of optimizing the use of solar energy. These elements create a thermal system based on indirect solar gains. The massive wall serves to accumulate heat from solar gains. In winter, the heat is radiated to the surroundings, which supports the building’s heating system. In summer, the heat is transferred to the outside by means of circulation panels designed in the solar facade. During the warm seasons, these panels remain in the open position, which allows air circulation; the lower panels are responsible for the inflow of cooled outside air near the ground, whereas the upper ones let the heated air out. For this purpose, the front of the facade was designed in the form of biologically active areas favourable in terms of microclimatic conditions, including those that alleviate the daily temperature amplitude, i.e. cooling down near the ground during warm periods.

The space between the curtain wall and the brick wall is intended for the implementation of the corridor and has the character of a thermo-buffer space. It protects rooms against the negative effects of direct insolation and losing thermal energy on cold days with little solar radiation. In the corridor space, right behind the curtain wall, floor nooks were designed for greenery to act as a modifier of the microclimatic conditions in the interior.

Originally in the project, the facade was equipped with an external shading system with a certain slant and an arrangement of fixed slats, with account to the apparent path of the sun across the horizon. The slant was set so as to let in the sunlight falling at a lower angle in winter and to reflect the summer rays outwards. Finally, for financial and aesthetic reasons, the facade was implemented as a smooth wall equipped with solar-protection reflective glazing with a coefficient of $g = 35\%$. Glazing in the graphite colour was considered to exert a positive effect on the aesthetics of the building. The architectural expression was enhanced by the colour contrast between the glazing and the bright body of the building. This solution, however, is less favourable than originally anticipated, due to the reduction of thermal gains from insolation during the heating period, although it represents a passive measure to prevent he building from overheating [8].

Fig. 2. Single-family building in Bytom: solar facade as an element of a passive solar system. *Source: author*

2.3. Administrative building MDK in Lahr (Germany), arch. Harald Roser, Günther Pfeifer, Christoph Kuhn (1999)

The cuboid structure on an elongated rectangular plan is characterized by the dominant areas of the northern and southern external walls. The southern elevation, which forms the solar facade of the building, has been fully glazed. Such a large glazing area required protection against the sun from the side exposed to solar radiation. The function of solar-protection measure is served by an extensive system of shading lamellas. These elements were extended over the face of the wall by several dozen centimetres. They form as many as 5 rows in the upper part of the glazing of each floor and the same amount of rows in the lower part. Additional support is provided by horizontal footbridges, which serve as a kind of balconies and technical platforms. The lower set of lamellas serves also as a railing. The lamellas are made of translucent, smoked glass. They have been permanently fixed on a steel structural frame.

The arrangement of the lamellas allows for the use of solar radiation for passive heating in winter and takes advantage of the benefits of daylight. In the period from May to August, the lamella system creates a complete barrier for direct sunlight to enter the interior. The building is not equipped with mechanical air conditioning. Opening balcony doors helps to avoid overheating of the interior.

In the aesthetic aspect, the facade is characterized by an expressive "play" of rhythms created by sections of the glazed wall and the shading system. The accumulation of these elements creates an illusory image that blurs the physical border between the inside and the outside. Thus, the facade acquires three-dimensional features. Owing to the elimination of lamellas in the strip above the main entrance, the area is perfectly exposed. An impressive forefield with greenery and a water reservoir has been designed. It is conducive to cooling and maintaining high quality of the air flowing into the building.

The northern facade is also made up of a fully glazed wall, but no shading system has been introduced, due to its location in relation to the corners of the world. The composition of glass panels and opaque blends, as well as openable vents offer a certain liveliness to the composition. As a result, the whole creates an interesting effect, which, however remains inferior to the southern facade in terms of aesthetic values.

In the northern zone, a winter garden has been designed, which functions as a heat buffer in winter, as well as a reservoir of cool air in summer. Opened vents are used for this purpose. In addition, air in this area is supplied from an underground heat exchanger located in the southern part of the plot.

The solution applied for the northern elevation can be considered consistent with the internal function of the building. However, it should be assumed that the decision to introduce a large-area glazed wall on the north side, controversial in terms of energy efficiency of the construction, forced the interior to be arranged in a particular manner. It seems that the decision to introduce a fully glazed elevation is based on an aesthetic reasons resulting from urban-planning and location conditions. The northern elevation, rather than the southern one, is an intuitive front of the building, adjacent to one of the main access streets that lead to the city center. Thus, the building is subject to the strongest visual perception from the northern side. This elevation, therefore, is most strongly predestined to be the showpiece of the whole construction. For this reason, in an aesthetic sense, the northern elevation required particularly careful approach.

However, this elevation is not equipped with the main entrance and is less decorative. The southern wall can only be viewed from the parking lot of the building. There is no way for it to be observed from a greater distance. The urban context decreases the role of this particular wall as a facade [9].

Fig. 3. Administrative building MDK: solar facade (left) and northern elevation (right). *Source: author*

2.4. Xicui Entertainment Hall in Beijing, arch. Simone Giostra & Partners Inc. (2008)

Xicui Entertainment Hall (XEH) is currently one of the most recognizable buildings with a solar facade worldwide. The building was implemented within dense development of the Chinese capital, on the Xicui Road that runs along the north-south direction. Due to the existing urban conditions, most of the buildings located by this street have front elevations that face the west and the east. The remaining elevations are poorly exposed. This is also the case with the 9-storey building with an original, first facade to use the PV technology and LED lighting worldwide. The facade is oriented towards the east, which is not most favourable in terms of energy gains generated by the PV system. Nevertheless, it uses cladding of semi-transparent PV modules on the surface of the elevation wall that measures 2,200 sq. m, which at the time of the building's construction made it the largest such wall in China. Glass-glass modules with spaced polycrystalline silicon PV cells inside were used. The 89x89 cm PV modules were moved away from the external wall and attached to it with steel brackets [10].

The spacing of PV cells is varied, thanks to which the cells create an individual graphic pattern on each of the modules. Such a solution introduces the division into elements of "low", "medium" and "high" transparency among the PV modules. The greater the distance, the greater the transparency, although certainly it comes at the expense of the built-in power of the PV module, and thus the entire PV system [11].

The PV cells spacing is correlated with the needs for natural lighting of the interior, as traditional elevation glazing has been introduced within the inner skin (behind the PV modules). Thus, in the vicinity of rooms that require sun protection or access to natural light is not particularly important, PV cells are densely arranged, while rooms with high requirements for the light environment (e.g. offices) are equipped with modules with PV print of lower density.

The described solution results also from clearly legible aesthetic factors. By juxtaposing individual PV modules with different cell configurations with each other, the facade acquires an original pattern, which is intended as an artistic image called "seascape". To enhance the effect, the PV modules, owing to their cantilever structure, are inclined at various angles – i.e. 5 degrees to the left or to the right, which is a metaphor for sea waves. This effect is visible during the day. It should be noted, that only the deviation towards the south is rational from the energy point of view (maximization of solar gains) and it is only on these panels that PV cells were introduced [12].

At night, artistic effects created by PV cells are complemented by LED lighting. Multi-coloured LED diodes in the form of 2,292 spot lights are used behind the rear surface of the PV modules, so that the semi-transparent PV modules are illuminated from the rear. As a result, the facade illuminated by points radically changes its image in relation to the daytime graphics. Its surface creates a huge screen – a kind of billboard that dynamically changes the displayed image [10].

The facade has been nicknamed "organic wall" and "self-sufficient wall". This is due to the fact that it fits in with the idea of sustainable development. PV modules indirectly cover the energy demand of the LED lighting, i.e. the energy consumption associated with powering the LED lighting is compensated by the daily production of electricity by the PV system, which is fed back to the municipal electricity grid.

The aesthetic features of the facade and its connotations with environmental protection have a strong marketing and symbolic overtone. First of all, the colourful, dynamic facade, clearly visible at a distance, is an element that attracts the attention of passers-by. It is a kind of message to inform the viewer what is happening in the building. It is also a factor that promotes the integration of advanced technology with the architecture of the building. However, it seems that the more important aspect related to the integration of LED as energy-saving lighting with PV technology based on renewable energy source is related to the image of Beijing as a city of technological innovation and growing environmental awareness.

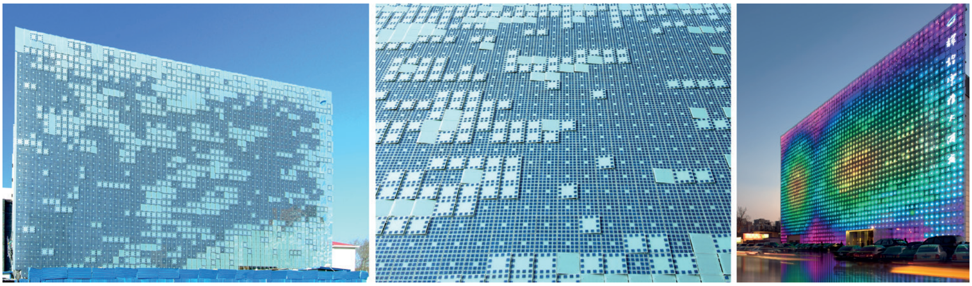

Fig. 4. Xicui Entertainment Hall in Beijing: solar facade as a screen composed of PV modules and LED lighting. *Source: Simone Giostra*

3. Definition of the relationship between energy-related role of a solar facade and the urban, functional and aesthetic issues

Table 1. Definition of the relationship between energy-related role of a solar facade and the urban, functional and aesthetic issues in the discussed buildings – collective juxtaposition. *Source: own study*

		SCH	Solar house (SH)	MDK	XEH
Type and orientation of the facade		Photovoltaic (PV) facade/ southern	Glazed smooth facade – greenhouse structure partition (passive solar system) / southern	Glazed facade with the external shading system – solar windows (passive solar system)/ southern	Multimedia facade PV+LED/ eastern
Main energy-related role of the facade		Production of electricity for utility purposes of the building	Passive solar heat gains (indirect gain)	Passive solar heat gains and natural lighting (direct gain)	Electricity production for the lighting supply (LED) of the facade
Urban relations	Urban issues impact	The urban conditions were an important factor to decide on the choice of a plot in order to create a well-exposed (representative) facade from the south	Due to the orientation and shape of the plot, as well as the access road location, the solar facade could not have become the front facade	Conflict in meaning: the northern elevation on the street side is subject to the strongest visual perception and is intuitively perceived as a facade – the function which it does not serve, in fact (the effect of turning the building „with its back to the street”)	Not optimal in terms of energy gains east orientation, forced by the layout of the street and buildings
	Influence on the buildings surroundings arrangement	Removal of vegetation potentially shading the PV facade, its foreground in the form of low greenery without high-rise street furniture	The dominance of unhardened and green areas (lawn) to improve the microclimate parameters by the facade	As in the case of SH + water reservoir in front of the facade, as an element to improve thermal conditions in summer (air cooling and humidification)	No clear impact

		SCH	Solar house (SH)	MDK	XEH
Functional relations	Influence of functional issues	The need for natural lighting of the interior: reduction of the PV system power due to the introduction of semi-transparent and traditional glass panels within the facade	No influence	Southern part of the building as a quiet zone intended mainly for the main rooms that require high parameters of the thermal and lighting environment – influence on the shape of the solar facade (densely arranged lamellas)	PV cells print density (PV module transparency) dependent on the functional purpose of the room at the PV facade
	Impact on the functional arrangement	The need to create a buffer space – moving offices away from the immediate proximity of the PV facade	The functional layout accounts for the principle of thermal zoning – in the zone in vicinity to the facade, the corridor acts as a passive heat collector and the „lungs of the building" – the residential part is moved to the other side of the corridor	No clear impact	No clear impact
Aesthetic relations	The influence of aesthetic issues	Aesthetic solutions (colour, transparency of PV modules) at the expense of maximizing the PV system power	Dark reflective glass contrasting with the bright facade, considered a valuable aesthetic element, is not conducive to maximizing heat gains during the heating period	No clear impact	Diversification and elimination of PV cells print as measures to reduce the power of the PV system
	Impact on the aesthetic function of the building	The facade as a multi-coloured „photovoltaic mosaic" of various shapes and transparency, combined with traditional translucent glazing and with the PV overprint - Original material and composition features of the facade defining the building's architecture	Glazed large-area smooth solar facade – different (from the rest of the walls) colour and texture as well as the reflection of the the surroundings – these features make the facade a characteristic aesthetic element of the building	Dense rhythms of exposed lamellas create expressive compositional effects; the effect of doubling the facade and the illusory image blurring the physical border between the interior and the surroundings	The original composition of PV modules combined with multi-coloured LED lighting: expressive compositional and artistic-painting effects, image variability – these features determine the uniqueness of the PV facade aesthetics and the entire building, which is a characteristic point in the surroundings

3.1. Relationship between energy-related role of the solar facade and urban issues

- Energy considerations exert a strong influence on the orientation of solar facades, i.e., the emphasis is on their southern exposure. In situations where its domination is possible also in the urban context, the energy-related and urban role of the solar facade is consistent. It happens when, while ensuring optimal orientation to create favourable conditions for insolation, the facade serves as the formally most important wall, in the urban sense, e.g. subject to the strongest visual perception (SCH).

When the situation is different (MDK), the pursuit of southern exposure of the solar facade leads to inconsistencies. The elevation perceived as a facade in an urban sense is not one in an aesthetic sense.

- A strongly defined urban context (location of buildings, roads, etc.) may force the resignation of the optimal exposure of the solar facade in terms of energy (XEH).
- There is a difference in the approach to shaping the forefields of buildings with solar facades. The forefield of facade that uses passive solar systems (solar windows, green-house structures) requires more attention in terms of the impact of its development on the thermal and lighting conditions of the building. Biologically active areas are preferred. The winter (solar thermal gain) and summer (solar protection) scenarios are considered separately. For this reason, natural elements are often designed that are characterized by seasonally changing properties, e.g. deciduous trees, lawns and water reservoirs that reduce the temperature amplitude, as well as the variable seasonal albedo that depends on the angle of sunlight angle of incidence (MDK). The preferred solution are also unhardened surfaces, non-susceptible to absorb and radiate solar heat in summer (SH).

Forefields of facade with active solar systems, incl. PV facade require undisturbed exposure to solar radiation (also in summer), which translates into the elimination of all spatial objects, including tall trees in the development of the forefields to solar facade. The needs for active solutions dominate in facade solutions that combine passive and active solar systems (SCH). The influence of solar radiation on the thermal and lighting environment is controlled by design methods, other than shaping the forefield (e.g. by using PV modules as shading systems).

3.2. Relationship between energy-related role of the solar facade and functional issues

- Requirements related to the functional purpose of the rooms in the area in vicinity of the facade exert a strong influence on the shape of the solar facades. This is related to the desire to ensure comfortable thermal, lighting and visual conditions inside the rooms. A particularly visible impact concerns PV facades, in which the above-mentioned goal is implemented through irrational actions in the energy-related sense. These include, for example, reducing the number of PV cells (XEH), mixing PV panels with traditional glass panes or selecting PV modules with a lower built-in power, such as semi-transparent modules (SCH).

The functional purpose of the rooms is also a factor that influences the shaping of solar facades with passive solutions. Facade surfaces intended for permanent human residence (MDK) may require particularly careful design of solar windows as solutions with direct benefit, i.e. the most sensitive ones to the effects of solar radiation energy. The goals of energy and comfort are, however, more similar than in the cases when PV facades are used.

- The introduction of solar facades, especially the highly glazed ones, may have an impact on the functional zoning of the interior. In the case of such facades as the walls that gain large, difficult to control amounts of solar radiation energy, a recurring phenomenon is to create thermal buffer spaces (SCH, SH) in the internal zone by the facade. These are intended to serve functions not related to the permanent use by the users. As a consequence, zones of constant use are shifted to other areas of the building.

3.3. Relationship between energy-related role of the solar facade and aesthetic issues

- The influence of aesthetics is especially clear in the case of solar facades, in which aesthetic decisions are in opposition to energy premises, such as the resignation of PV cells in the case of panels that are unfavourably oriented to the sun (as a component of the "seascape" (XEH) effect), selection of coloured semi-transparent PV modules with a low built-in power compared to traditional PV modules (SCH), or solar protection glazing with a distinct colour, that reduces thermal gains from insolation (SH).
- Solar facades have great potential to influence the aesthetic function of a building. This is related to the creation of original artistic effects: flat composition and tectonics (3-d effect), with the use of various configurations, geometry, colours and construction of solar solutions, including PV modules, displaying the elements that acquire and control the inflow of solar energy (glazing, shading systems). An interesting direction is to integrate PV with other systems in order to obtain an enriched aesthetic effect, e.g. integration of PV with LED lighting (XEH).
- In the broad sense of the relationship between solar facades and the aesthetic function of a building, their roles may be connected with areas related to creating a non-verbal message, symbol, and creating pro-environmental connotations (SCH, XEH). In addition, it may also be the subject of direct communication used for information or marketing purposes (XEH).

4. Conclusions

The aforementioned examples of buildings confirm that the energy aspect of shaping solar facades, which underlies their application, is the leading aspect in their implementation. It accompanies each of the discussed buildings. Energy aspirations that consist in creating optimal conditions for the use of solar energy in a building have a significant impact on the shaping of not only the facade itself, but indirectly on solutions on a micro-urban scale (plot arrangement) and the function of the building. At the same time, energy issues are influenced by these factors. The examples of XEH and MDK show that mutual relationship between the facade as a helioactive wall and the context of the place may require compromise solutions.

The development of solar facades is related to the needs to create comfortable microclimatic and lighting conditions for the rooms that are hidden behind the facade. There is a strong relationship between design of these facades and the needs concerning environmental conditions, depending on the purpose of the rooms. Therefore, consistency of formal solutions for the facade with the function of the object may be noticed.

At the same time, a strong role of aesthetics is observed, even a tendency towards decorativeness. Emphasis is shifting from strictly utilitarian aspects towards aesthetic aspirations. This is especially visible in the example of the XEH building, in which the desire to create an aesthetically attractive solar facade resulted in a number of decisions that, from the energy-optimization point of view, may be considered irrational. A similar approach was demonstrated by the author in the SCH concept.

It seems that the evolution of solar facades is aimed at tightening the relationship between their utilitarian, including energy-related, role and their aesthetic function. This is favoured by the technological development of elements of solar measures oriented towards integration with architecture (e.g. BIPV) and the search for new areas for cooperation with related technologies (e.g. LED). Assuming that this trend continues, it may be expected that an enrichment in the architectural language is to be observed in the coming years. This will bring new, unique solutions for solar facades.

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Orginal Article

A universal standard for health-promoting places. Example of assessment – on the basis of a case study of Rahway River Park

Monika Trojanowska

Department of Architecture and Urban Design; Faculty of Civil and Environmental Engineering and Architecture; PBS University of Science and Technology in Bydgoszcz; 7 prof. S.Kaliskiego Av., 85-796 Bydgoszcz, Poland; monika.trojanowska@pbs.edu.pl iD *0000-0001-8168-0746*

Abstract: The purpose of this paper is to contribute to development of approaches to the evaluation of the design of public open green spaces (POS). This paper presents a universal standard for the design of health-promoting urban places. The standard is a conceptual framework which was developed after visiting over one hundred public parks and therapeutic gardens in Europe and the United States. The universal standard is a simple and effective tool that can be used by both professional designers and non-professionals to improve the health-promoting qualities of open green spaces. Rahway River Park, designed by Olmsted Brothers in 1925, serves as a case study.

Keywords: therapeutic landscapes, health-promoting places, universal standard of design, pattern of design

1. Introduction

The COVID-19 crisis highlighted human need to engage in open green spaces in cities. Current pressures due to urbanization have impacted the health and well-being of many people. Scientists confirm that everyday contact with nature is crucial for mental and physical health [1], [2]. Public parks can become places for mental and physical regeneration, physical activity, and social contacts. Green public spaces can act as therapeutic landscapes. Numerous researchers from various fields, e.g., environmental psychology, medicine, sociology, architecture, landscape design, and urban planning, have already described the main qualities of therapeutic landscapes [1], [2]. However, application of scientific approach is still needed [3]. The purpose of this study was to contribute to the development of methods of the evaluation of the design of public open green spaces (POS), particularly concerning therapeutic qualities of landscape for the promotion of the health of their users. The identified gap in knowledge results from the fact that existing quality assessment tools measure the physical activity infrastructure and sustainable solutions, while the therapeutic qualities of public open green spaces are rarely measured. This universal standard could be used to evaluate public open green spaces (POS), encompassing practical implications of design recommendations and the justification of specific choices to facilitate the promotion of public health. It was developed after performing scoping literature review and on-site observation of over a 100 of POS in various countries (France, Poland, Sweden, and the USA).

2. Literature overview

Gesler (1996) defined therapeutic landscapes as places where "physical and built environments, social conditions and human perceptions combine to produce an atmosphere which is conducive to healing [4]." However, individual perceptions of therapeutic landscapes may vary. Erwin Zube (1987) noticed that experience, personal utility functions, and social and cultural contexts were involved in shaping perceptions and responses to landscapes [5]. The landscape is 'a product of the human mind, and of material circumstances' [6]. Spaces that are perceived as therapeutic by one person could be experienced as unsettling by another [7]. However, there are examples of places well-known for their enduring potential to promote healing, for example, Lourdes in France, St. Anne de Beaupre in Quebec, Canada, Epidaurus in Greece, and Bama village in China [8]-[11]. In practice, the term therapeutic landscapes usually refers to specific places of established salutogenic reputation. The term health-affirming landscapes is more extensive and refers to more common places that unite the qualities of therapeutic landscapes to influence people's physical, mental and spiritual healing [12].

Both health-promoting places and therapeutic landscapes have therapeutic attributes. Though therapeutic landscapes are places which have an established reputation as well-known places of healing, the spiritual and symbolic aspects giving them an additional advantage. Material aspects alone can create human-friendly public spaces, but social conditions are needed to create health-promoting places, while spiritual and symbolic aspects further define therapeutic landscapes (Fig. 1).

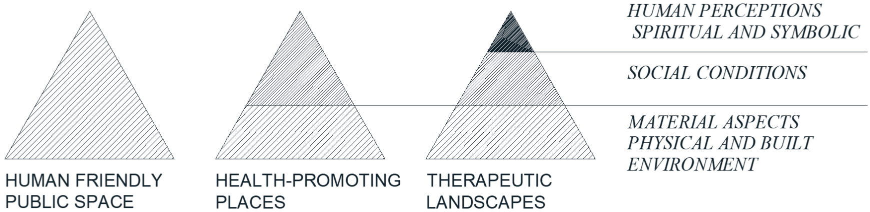

Fig. 1. Diagram showing the attributes directly related to therapeutic landscapes, overlapping with general qualities of human -friendly public spaces. *Source: author, 2020*

2.1. Healing contact with nature

Many researchers consider therapeutic landscapes as the presence of nature in the form of 'green' or 'blue' materialities [14]. Natural physical beauty is treated as a determinant of a salutogenic environment [15], [16]. Contact with nature can improve well-being and reduce stress level [17], [18]. Even watching nature can have a reassuring effect on patients before surgical operations and speeds up the post-surgery recovery [19]. Results of medical researches have shown that watching nature can stimulate significant physiological reactions within a few minutes, i.e. can cause changes in the electrical activity of the brain, blood pressure, heart, and the muscular system [19], p 91].

Therapeutic landscapes provide an opportunity to slow down and gain a sense of being present and attentive to the world [7]. Healing has been linked to the fact that people have opportunity to focus on something other than their current problems. Therefore, elements which engage attention, stimulate senses, and provoke interest are attributed to *therapeutic landscapes* [20]-[22]. The human mind needs an optimal level of complexity and thrives in a sensory-rich environment [17, 23-24]. An experience of overcoming controllable danger, i.e., climbing a mountain, or crossing a river, demands full focus and provides a feeling of accomplishment [22], [25].

2.2. Social bonds

The therapeutic properties of landscape depend on the social context of the place [4]. Even superficial social contacts can have a beneficial influence on human health [18], [26]-[30]. Green public spaces are conducive both to having strong relationship with the living environment, and to giving opportunities for social contacts [28]-[29], [31], [32]. Designers may have little impact on the social environment, but they can facilitate bringing people together. Jan Gehl has listed three categories of outdoor activities in the public areas: "necessary activities", "optional activities," and "social activities" (2011) [33]. "Necessary activities" are activities that the participants have no choice about, such as walking to school. "Optional activities" depend on the participants' desire to engage, such as going for a walk for pleasure. "Social activities" require engaging in contact with other people, such as children playing, friends talking, and passers-by briefly greeting each other. In a well-designed physical environment, the optional and social activities occur with high frequency. POS are places which can offer the possibility to restore mental health, as well as physical activity and social contacts.

2.3. Mental restoration

Salutogenic landscapes are often associated with places to rest in silence and solitude [19], [33]-[34]. Secluded gardens, which offer a sense of enclosure, have been mentioned in numerous researches over the years [20], [34], [35]. An interesting theoretical framework has been developed for the design of therapeutic gardens [36]. Many researchers have focused on the spiritual meaning of healing and the positive relationship between spiritual activity and health and well-being [14], [21], [37].

2.4. The importance of physical activity

Greenspace exposure is positively associated with moderate to vigorous physical activity and physical activity is directly linked to promotion of health and well-being [37]. A team of Japanese doctors led by Takehito Takano (2002) has already proven that a well-designed system of green areas encouraging walking is a factor which can directly affect the longevity of senior citizens [38]. According to Gibson's theory, affordances of an environment are what it offers to users (2014) [39]. Affordances are all the possible actions that may occur in a place, and the actions needed to be discoverable by the user. The promotion of health is one of the possible affordances of public open green spaces (POS) [41]. With careful design, healing affordances should be easily perceptible to users and public open green spaces would "tell people what to do with them", i.e., rest in silence and solitude, observe wildlife and other people's activities, engage in socializing with other people, play sports, etc. A recent study demonstrated the positive effect of a sensory garden on ‘apparently well’ people in the workplace [42].

2.5. Current frameworks for classifying parks

In this study, places are defined as public open green spaces (POS). POS are classified in the literature in many ways. The classification schemes are based on the size and distance to potential users, as well as their primary functions [42], [43]. A comprehensive typology was proposed by the Government of Western Australia (2012). It identifies three primary types of open spaces according to function (primary use and expected activities): recreation spaces, sport spaces, and nature spaces, as well as four categories based on catchment hierarchy (typical size and how far a user might travel to visit the site), which includes: local open space, neighbourhood open space, district open space, and regional open space.

2.6. Measure-oriented approaches to POS design

There are tools available for the assessment of a park users’ physical activity levels, e.g., SoPARC, SoPLAY, or EARPS. These can be used to foster the quality and for improvement of the POS. However, they do not include the evaluation of restorative qualities. Thus, despite growing attention to this topic, there is a lack of specific tools that enable a structured analysis of therapeutic qualities of the POS.

3. Methods

This long–term study began in 2001 with the aim of systematizing the qualities of therapeutic landscapes. It was driven by the objective to develop a universal standard of health-promoting places which could be implemented in various cultural settings.

The study was carried out by the author on over a hundred (*n*=125) public open green spaces (POS) and private therapeutic gardens in Europe and the United States. The choice of the cities in this study resulted from personal experience. The list mostly includes cities where the author has lived, worked or studied. Therefore, it includes well-known parks in New York and Paris, as well as several parks in Poland. A full list of the parks and gardens is presented in Table 2. Public parks and therapeutic gardens visited during the field research. The POS were visited frequently, on multiple occasions, which allowed for repeated observations in different time frames to give a broader and deeper perspective on users’ behaviour.

The aim was to visit and assess not only famous parks, but also less well-known places which have been referred to as favourite places of recreation by residents of the neighbourhoods. These human perceptions were treated as a social proof of the therapeutic qualities of a landscape.

This study has concentrated on determining what has worked well in the parks visited. The time spent in each of the public parks ranged from two to multiple hours. The length of stay usually depended on the size of a park and the number of its attributes. The data collection methods included study walks exploring the entire park territory, observation of users’ activities and preferences, as well as unstructured interviews with park users.

Table 1. Public parks and therapeutic gardens visited during the field research

Country	City and Vicinities	Number of Parks Visited	Public Parks and Therapeutic Gardens
USA	New York	12	Central Park, Paley Park, Bryant Park, Gramercy Park, Madison Square Park, Union Square Park, Washington Square Park, Stuyvesant Square Park, John Russel Wheeler Park in Linden, NJ, Rahway River Park, Cheesequake State Park, Rutgers University Gardens
France	Paris	50	Bois de Boulogne, Bois de Vincennes, Parc André Citroën, Jardin d'Acclimatation, Jardin Bagatelle, Parc de Belleville, Parc de Bercy, Parc George-Brassens, Parc de la Butte-du-Chapeau-Rouge, Parc des Buttes-Chaumont, Parc Floral, Parc Kellermann, Parc Monceau, Parc Montsouris, Parc de la Villette, Jardin Atlantique, Jardin de l'UNESCO, Jardin du Luxembourg, Jardins du Palais Royal, Jardin du Trocadéro, Jardin des Tuileries, Jardin des Plantes, Jardin Villemin, Promenade plantée, Promenade des Berges de la Seine, Square de Batignolles, Parc Martin Luther King, Grand Parc de Docks de Saint Ouen, Jardin thérapeutique- Grain de Vie Hôpital Curie, Jardin de L'Ile Seguin, Parc de Billancourt, Jardin Catherine Labouré, Square Boucicaut, Jardin Tino Rossi, Jardin de Reuilly, Square Jean XXIII, Square R.Viviani, Square du Vert Galant, Square Lois XIII, Jardin de la Valée Suisse, Square L-Frapié, Jardin des Fougères, Square E.-Fleury, Square du Serment-de-Koufra, Parc des impressionnistes – Clichy, Parc de Sceaux, Parc de Versailles, Parc de Fontainebleau, Parc de Chantilly, Parc de Saint Cloud, Parc Du Chemin De L'Ile
Sweden	Stockholm	3	Djurgarden, Trygghansa, Kronobergsparken
Poland	Poznań	19	Botanical Garden, Park Fryderyka Chopina, Park Cytadela, Park Czarneckiego, Park Jana Kasprowicza, Park Karola Kurpińskiego, Park Karola Marcinkowskiego, Park Adama Mickiewicza, Park Stanisława Moniuszki, Park Sołacki, Park Tysiąclecia, Park Thomasa W. Wilsona, Park Henryka Wieniawskiego, Park Stare Koryto Warty, Spatial Orientation Park in Owińska, Malta, Park Wodziczki, Park Szelągowski, Park Zwycięstwa
	Cracow	16	Botanical Garden, Planty, Bulwary Wiślane, Park Strzelecki, Park Tadeusza Kościuszki, Park Henryka Jordana, Park Ludwika Decjusza, Park Wojciecha Bednarskiego, Park Wincentego a Paulo, Park Lotników Polskich, Stanislaw Lem Garden of Experiences, Biblical Garden, Proszowice, Therapeutic Garden, Rabka, Park Zdrojowy, Rabka, Kalwaria Zebrzydowska, Archeological Museum
	Bydgoszcz	10	Botanical Garden, Park Dolina Pięciu Stawów, Park Balaton, Park in Myslęcinek, Park im. Kazimierza Wielkiego, Park Jana Kochanowskiego, Park Henryka Dąbrowskiego, Park Księżycowy, Park Zbigniewa Załuskiego, Park in Ostromecko
	Gdańsk	15	Park Oliwski, Park Oruński, Park Kuźniczki, Park Haffnera, Park Steffensów, Park Ronalda Regana, Medicinal Plant Garden, Park Haffnera, Sopot, Park Kiloński, Gdynia, Kamienna Góra, Gdynia, Park im. A. Majkowskiego, Wejherowo, Kalwaria, Wejherowo, Tricity Landscape Park, Park Starowiejski, Rumia

4. Findings and analysis

During this study, a conceptual framework for a universal standard of health affirming places was developed in an iterative process. The first draft was gradually amended with new findings. The final draft of the standard is presented in Table 2. A universal standard for health-promoting urban places. The qualities were divided into five categories: 1. Sustainability, 2. Accessibility, 3. Amenities, 4. Design and 5. Placemaking. Those categories were used to organize the qualities of therapeutic landscapes in a legible manner.

Table 2. A universal standard for health-promoting urban places. *Source: updated by the author* [44]-[46]

1. SUSTAINABILITY	2. ACCESSIBILITY	3. AMENITIES	4. DESIGN	5. PLACEMAKING
1.1. Place Area Location Surrounding urban pattern **1.2. Environmental characteristics** Soil quality Water quality Air quality Noise level Forms of natural protection Green and Blue Infrastructure **1.3. Biodiversity protection** Parts of open green space not available to visitors Native plants Native animals Natural maintenance methods **1.4. Sustainable water management** Rainwater infiltration Irrigation with non-potable water **1.5. Parks of Second (New) Generation** **1.6. Urban metabolism** **1.7. Ecological energy sources**	**2.1. Distance to park** **2.2. Sidewalk Infrastructure-** Width of sidewalk Evenness of surface Lack of obstructions Slope Sufficient drainage **2.3. General conditions of walkways** Maintenance Overall aesthetics Street art Sufficient seating Perceived safety Buffering from traffic Street activities Vacant lots **2.4. Traffic** Speed Volume Number and safety of crossings Stop signs On-street parking **2.5. User Experience** Air quality Noise level Sufficient lighting Sunshine and shade Visibility of nearby building **2.6. Public transport stops** **2.7. Sufficient Parking**	**3.1. Psychological and physical regeneration** Natural Landscapes Green open space Presence of water Places to rest in the sunshade Places to rest in silence and solitude **3.2. Promotion of Physical Activities** Sports and recreational infrastructure Community gardens Addressing the needs of people with disabilities **3.3. Catering for basic needs** Safety and security (presence of guards, cleanliness, maintenance, etc.) Places to sit and rest Shelter Restrooms Drinking water Food (possibility to buy food in the park or in the closest vicinity)	**4.1. Architectural design** Human scale Focal points and landmarks Structure of interior connections Framed views Long vistas (Extent) Pathways with views Invisible parts of the scenery (Vistas which engage the imagination) Possibility to watch other people Possibility to see wildlife **4.2. Salutogenic design** Optimal levels of complexity Engaging features Risk Mystery/ Fascination Movement **4.3. Sensory stimuli design** Sensory stimuli: Sight Sensory stimuli: Hearing Sensory stimuli: Smell Sensory stimuli: Touch Sensory stimuli: Taste Sensory path	**5.1. Enhancement of Social Contacts** Organization of events Meeting places for groups **5.2. Human perception -spiritual & symbolic** Sacred places Works of Art Monuments Culture and connections to the past Thematic gardens Personalization **5.3. Community Engagement** Personalising the architectural process Participation of all stakeholders, including inhabitants and users Determining the rules of conduct and self- management Space for social contacts – third places – fourth places

4.1. Proposed methodology of assessment with the universal standard for health-promoting urban places

Each of the five categories includes sub-categories and individual attributes. The final draft of the universal standard of design for health-promoting places can be used for binary or detailed assessment. The binary assessment has only 2 categories (0;1):

0 – No, not observed.

1 – Yes, satisfactory.

The maximum number of points for binary assessment are presented in Table 3. Maximum number of points for binary assessment. Simple manual calculation method was used to add the points. A customized Excel spreadsheet was used to verify the results.

The detailed assessment required a written explanation why the researcher thought that the attribute was present, satisfactory, and worthy granting a point.

Table 3. Maximum number of points for binary assessment. *Source: author*

	MAXIMUM NUMBER OF POINTS
TOTAL	91
CATEGORIES	
1. SUSTAINABILITY	15
1.1.Place	Category with no points
1.2.Environmental characteristics	6
1.3.Biodiversity protection	4
1.4.Sustainable water management	2
1.5.Parks of Second (New) Generation	1
1.6.Urban metabolism	1
1.7.Ecological energy sources	1
2. ACCESSIBILITY	26
2.1.Distance to park	1
2.2.Sidewalk Infrastructure	5
2.3.General conditions of walkways	8
2.4.Traffic	5
2.5.User Experience	5
2.6.Public transport stops	1
2.7.Sufficient Parking	1
3. AMENITIES	15
3.1.Psychological and physical regeneration	5
3.2.Promotion of Physical Activities	4
3.3.Catering for basic needs	6
4. DESIGN	21
4.1.Architectural design	10
4.2.Salutogenic design	5
4.3.Sensory stimuli design	6
5. PLACEMAKING	14
5.1.Enhancement of Social Contacts	2
5.2.Human perception -spiritual & symbolic	6
5.3.Community Engagement	6

Proposed methodology for assessment of individual categories was provided in tables 4-8. Each of the tables provides the number of points possible to gain in each category for every individual feature as well as general description of requirements. For better clarity, the results of the assessment were grouped into five tables (Tables 4-8).

The standard consists of five categories.

1. *Sustainability*

This section is dedicated to assessments of the general characteristics of a local area (table 4). In the case of existing parks, most of these characteristics, e.g., place: area, location, surrounding urban patterns, are beyond the control of park designers. However, at the planning stage, decisions about the location of a park can be discussed. Design criteria should always be oriented on the location, its environmental characteristics, and landscape values.

Environmental characteristics (biodiversity, soil, water, and air quality) can significantly improve or undermine the therapeutic qualities of a location [46], [47].

This section includes all the aspects relating to the sustainable design of public parks: the protection of native fauna and flora and enabling the natural infiltration of rainwater and harvesting it for irrigation. Sustainable management of water and soil require special maintenance techniques and may limit the choice of plants, but it is beneficial for both our planet and people.

Table 4. Draft table for *sustainability assessment* (right column – number of points). *Source: author*

1. SUSTAINABILITY		15
1.1. Place		Category with no points
Area	Provide detailed description	Category with no points
Location	Provide detailed description	Category with no points
Surrounding urban pattern	Provide detailed description	Category with no points
1.2. Environmental characteristics		6
Soil quality	Sufficient for recreational use. No visible traces of pollution	1
Water quality	Sufficient for recreational use. No visible traces of pollution	1
Air quality	Sufficient for recreational use. No visible traces of pollution	1
Noise level	No nuisance to moderate noise nuisance	1
Forms of natural protection	Are there any forms of natural protection?	1
Green and Blue Infrastructure	Does the park form part of the green and blue infrastructure? If YES – 1 point	1
1.3. Biodiversity protection		4
Parts of open green space not available to visitors	Are there any secluded areas for biodiversity protection?	1
Native plants	Planting with native species	1
Native animals	Are there native species present in the park? If YES – 1 point	1
Natural maintenance methods	What kind of methods of maintenance are used? If only natural – 1 point	1
1.4. Sustainable water management		2
Rainwater infiltration	Porous, permeable surfaces.	1
Irrigation with non-potable water	If irrigation with non-potable water is used – 1 point	
1.5. Parks of Second (New) Generation		1
	Can the park be considered as a park of second (new) generation	1
1.6. Urban metabolism		1
	Is waste segregation facilitated? If YES – 1 point	1
1.7. Ecological energy sources		1
	Are there ecological energy sources used in the park? If YES – 1 point	1

2. *Accessibility*

In the case of health-affirming urban places, the qualities of the entrances and pedestrian routes leading to the park are as important as the design of the park itself (table 5). This category could be called the 'walkability assessment' [47]. Universal accessibility, understood as addressing the needs of people with disabilities, is directly linked to the therapeutic potential of a park and the possibilities for the promotion of health.

Table 5. draft table for *accessibility assessment* (right column – number of points). *Source: author*

2. ACCESSIBILITY		26
2.1.Distance to park		1/1
	Is it possible to walk to park? If YES – 1 point	1
2.2.Sidewalk Infrastructure		5
Width of sidewalk	Sufficient for walking	1
Evenness of surface	Sufficient for walking	1
Lack of obstructions	Lack of obstructions	1
Slope	Flat, no significant slope	1
Sufficient drainage	Sufficient for walking	1
2.3.General conditions of walkways		8
Maintenance	The park is perceived as clean. No visible traces of litter	1
Overall aesthetics	The park is perceived as aesthetically pleasing	1
Street art	The park is perceived as a safe place	1
Sufficient seating	Multiple benches	1
Perceived safety	The park is perceived as a safe place	1
Buffering from traffic	Sufficient	1
Street activities	Occasional events, organised or spontaneous	1
Vacant lots	No vacant lots adjacent to park. The park is perceived as a safe place	1
2.4.Traffic		5
Speed	Slow. The park is perceived as a safe place	1
Volume	Moderate. The park is perceived as a safe place	1
Number and safety of crossings	Numerous possibilities for crossing the street	1
Stop signs	Yes. The park is perceived as a safe place	1
On-street parking	Yes. The park is perceived as a safe place	1
2.5.User Experience		5
Air quality	Good. The park is perceived as a safe place	1
Noise level	Moderate. The park is perceived as a safe place	1
Sufficient lighting	Yes, numerous lamps. The park is perceived as a safe place	1
Sunshine and shade	Yes. Trees provide shade	1
Visibility of nearby buildings	Yes. The park is perceived as a safe place	1
2.6.Public transports stops		1
	There are bus stops near the park	
2.7.Sufficient Parking		1
	Yes, there are numerous parking spots in the park	1

3. *Amenities*

This section concerns sports and leisure equipment, as well as park facilities related to promoting physical and mental rejuvenation, encouragement of physical activities and moderate social contacts (table 6). A fourth category relates to the basic needs of park users, such as shelter, restrooms, drinking water, food, and places to sit and rest. It also includes properties that bring a sense of safety and security: the presence of guards, cleanliness, and maintenance.

Table 6. Draft table for *amenities assessment*. (right column – number of points). *Source: author*

3. AMENITIES		15
3.1.Psychological and physical rejuvenation		5
Natural landscapes	Are there places which give an impression of a pristine natural landscape? If YES – 1 point	1
Green open space	Are there any green open spaces? If YES – 1 point	1
Presence of water	Is there any water in the park? If yes, in what form? If YES – 1 point	1
Places to rest in the sun and shadow	Multiple places to sit and rest in the sun and shadow	1
Places to rest in silence and solitude	Multiple benches to rest and enjoy silence and solitude	1
3.2.Physical Activity Promotion		4
Sports infrastructure	Are there any sports infrastructure in the park? Is it satisfactory for various age groups? If YES – 1 point	1
Recreational infrastructure	Is it satisfactory for various age groups? If YES – 1 point	1
Community gardens	Are there any community gardens? If YES – 1 point	1
Addressing the needs of people with disabilities	Are the pathways wide and even? Is the park area accessible? If YES – 1 point	1
3.3.Catering for basic needs		6
Safety and security (presence of guards, cleanliness, maintenance, etc.)	Assessed as a safe place. If YES – 1 point	1
Places to sit and rest	Are there any? Are they satisfactory? If YES – 1 point	1
Shelter	Are there any? Are they satisfactory? If YES – 1 point	1
Restrooms	Are there any? Are they satisfactory? If YES – 1 point	1
Drinking water	Are there any? Are they satisfactory? If YES – 1 point	1
Food (possibility to buy food in the park or close vicinities)	Are there any? Are they satisfactory? If YES – 1 point	1

4. *Design*

This section encompasses the distribution of functions within the park space and the organization of its grid of connections (table 7). It is important that the design of a park is comprehensible and the composition harmonious. Some attributes are important when it comes to engaging the interest of users, such as mystery, risk, and movement. A separate category is dedicated to multi-sensory stimuli and sensory paths.

Table 7. Draft table for *design assessment* (right column – number of points). *Source: author*

4. DESIGN		21
4.1.Architectural design		10
Human scale	Is the design respecting the human scale? If YES – 1 point	1
Architectural variety of urban environment	Is the Architectural variety observed in the surrounding urban environment? If YES – 1 point	1
Focal points and landmarks	Are there any clear landmarks? If YES – 1 point	1
Structure of interior connections	Is there a clear structure of interior connections? If YES – 1 point	1
Framed views	Are there any? Are they satisfactory? If YES – 1 point	1
Long vistas (Extent)	Are there any? Are they satisfactory? If YES – 1 point	1
Pathways with views	Are there any? Are they satisfactory? If YES – 1 point	1
Invisible parts of the scenery (Vistas which engage the imagination)	Are there any? Are they satisfactory? If YES – 1 point	1
Possibility to observe other people	Are there any possibilities to observe other people? Are they satisfactory? If YES – 1 point	1
Possibility to observe animals	Are there any possibilities to observe animals? Are they satisfactory? If YES – 1 point	1
4.2.Salutogenic design		5
Optimal levels of complexity	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Engaging features	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Controlled Risk	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Mystery/Fascination	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Movement	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
4.3.Sensory stimuli design		6
Sensory stimuli: Sight	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Sensory stimuli: Hearing	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Sensory stimuli: Smell	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Sensory stimuli: Touch	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Sensory stimuli: Taste	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Sensory path	Are there any features in this category? Are they satisfactory? If YES – 1 point	1

5. *Placemaking*

The most important feature of a human-friendly landscape is a sense of safety and belonging of all users (table8). Public parks offer an ideal possibility for various kinds of social contacts for people from usually isolated and disadvantaged social groups (the elderly, disabled, etc.). Placemaking is related to the popularity of a park. Here, the attributes which relate to the promotion of moderate social contacts and human perceptions have been combined into one category.

Table 8. Draft table for ***placemaking assessment*** (right column – number of points). *Source: author*

5. PLACEMAKING		14
5.1.Social Contact Enhancement		2
Organization of events	Are there any events organised? Are they popular/ frequented? If YES – 1 point	1
Meeting places for groups	Are there any? Are they satisfactory? If YES – 1 point	1
5.2.Human perception – spiritual & symbolic		6
Sacred places	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Works of Art	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Monuments	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Culture and connections to the past	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Thematic gardens	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
Personalisation	Are there any features in this category? Are they satisfactory? If YES – 1 point	1
5.3.Community Engagement		6
Personalising the architectural process	Are the persons responsible for the design, construction and management known to the public? If YES – 1 point	1
Participation of all stakeholders, including inhabitants and users	Do all stakeholders, including inhabitants and users have a real influence on the design and maintenance through participatory process? If YES – 1 point	1
Determining the rules of conduct and self-management	Are there any rules of conduct and self-management established and publicly available? Are there any information boards with rules of conduct and self-management placed in the public space? Were the rules of conduct and self-management established in a participatory process? Do all stakeholders including inhabitants and users agree upon the common rules of conduct and self-management? If YES – 1 point	1
Space for social contacts	Is there an inclusive, accessible space for social contacts available to all? If YES – 1 point	1
– third places	Can it be the third place for anyone? If YES – 1 point	1
– fourth places	Can it be the fourth place for anyone? If YES – 1 point	1

5. Case study of Rahway River Park, NJ, USA

Rahway River Park in Union County, NJ, USA (Fig. 2) was chosen as a case study to demonstrate the way of using the universal standard. This park is well-documented in the history of landscape design and well-known internationally, as it was designed by the Olmsted brothers. Firstly, this place was recommended to the author by regular parkgoers who described it as a good place to disengage from the problems of everyday life. One of them described this experience: "After one hour spent in the park, the weariness of the daywork in front of the computer disappears. I come back home from this park with new energy." The research question was what makes this park a health-promoting place in terms of the architectural and landscape design? (Fig. 2-10).

Fig. 2. Rahway River Park as seen from above. *Source* [48]

Fig. 3. Rahway River Park – wildlife. *Source: author's photography*
Fig. 4. Rahway River Park in the winter – play areas. *Source: author's photography*

Fig. 5. Rahway River Park – one of the smaller exercise areas. *Source: author's photography*
Fig. 6. Rahway River Park – play areas. *Source: author's photography*

Fig. 7. Rahway River Park – Central open space. Source: *Author's photography*
Fig. 8. Rahway River Park. Source: *Author's photography*

5.1. Description

The park was created by the Union County (New Jersey) Parks Commission in 1921 as one of the neighbourhood parks in a county-wide continuous linear park system – Rahway River Parkway. It was designed by landscape architect Percival Gallagher, a partner at the Olmsted Brothers company. The park was created for the enjoyment and psychological health benefits it could provide for its users. This was the original idea of the park commissioners along with the landscape architects, and it represented a shift away from the City Beautiful Movement method of planning; to design more for people's health and well-being.

5.2. Assessment

The park was evaluated using the final draft of the universal standard of design for health-promoting places. Both a binary and a detailed assessment were performed. The binary assessment has only 2 categories (0;1):

0 – No, not observed

1 – Yes, satisfactory

The binary assessment is reported under section points (Tables 9-13). The detailed assessment required a written explanation why the researcher thought that the attribute applies. The detailed observation required numerous visits to the park, studying the plans and maps of the park area, as well as scoping the literature evidence. For better clarity, the results of the assessment were grouped into five tables (Tables 9-13).

Rahway River Park was created to protect the natural scenic beauty of the area from development and possible destruction. One of the main early rules of Frederic Law Olmsted (1822-1903) was respect for scenery. This approach is still visible in the park.

The accessibility evaluation was carried out on one road – Parkway Drive – as it is the main access for pedestrians.

The beauty of the park is in the overlapping of nature and recreational activities within its boundaries. There are quiet places to sit and contemplate, observe wildlife or people from a distance. The park houses a variety of sport equipment and recreational amenities, including two circular loops frequented by joggers along with multiple sport fields.

Table 9. Assessment of Rahway River Park – part 1. *Source: author*

		POINTS
1. SUSTAINABILITY		10/15
1.1.Place		-/-
Area	124-acre	
Location	The park is cradled by the Rahway River, which serves as a backdrop and a natural buffer from the nearby houses to the north and west. The Rahway River Park forms part of a series of parkways along the Rahway River (Rahway River Parkway), (Fig. 3).	
Surrounding urban pattern	Suburban / urban tissue. Rahway River, Rahway River Cemetery, family houses	
1. 2 Environmental characteristics		6/6
Soil quality	Sufficient for recreational use. No visible traces of pollution [49].	1
Water quality	Sub-optimal, according to the Water Quality Report [50].	1
Air quality	Good, according to the Air Quality index (AQI) [51], good air circulation. The presence of the Rahway River influences the local microclimate.	1
Noise level	Moderate noise nuisance comes from traffic in Saint Georges Street adjacent to the park and slow traffic in Parkway Drive in the park itself.	1
Forms of natural protection	County park, part of the Rahway River Parkway.	1
Green and Blue Infrastructure	It is an important part of the green and blue infrastructure. The park is a part of the Rahway River Parkway – a green belt of parkland along the banks of the Rahway River.	1
1.3.Biodiversity protection		2/4
Parts of open green space not available to visitors	There are no secluded areas for biodiversity protection.	0
Native plants	Planting is a combination of native and non-native species.	1
Native animals	Both native and foreign species were observed.	1
Natural maintenance methods	Data n/a.	0
1.4.Sustainable water management		1/2
Rainwater infiltration	Porous, permeable surfaces. Turf used as walkways.	1
Irrigation with non-potable water	Data n/a.	
1.5.Parks of Second (New) Generation		0/1
	Not observed.	0
1.6.Urban metabolism		1/1
	Waste segregation.	1
1.7.Ecological energy sources		0/1
	Data n/a.	

Table 10. Assessment of Rahway River Park – part 2. *Source: author*

		POINTS
2. ACCESSIBILITY		26/26
2.1.Distance to park		1/1
	Most users drive to the park. Some local residents live within walking distance.	1
2.2.Sidewalk Infrastructure-		5/5
Width of sidewalk	Sufficient for walking.	1
Evenness of surface	Sufficient for walking.	1
Lack of obstructions	Lack of obstructions.	1
Slope	Flat, no significant slope, (Fig. 4).	1
Sufficient drainage	Sufficient.	1
2.3.General conditions of walkways		8/8
Maintenance	The park is well-maintained.	1
Overall aesthetics	Satisfactory.	1
Street art	None.	1
Sufficient seating	Yes, multiple benches.	1
Perceived safety	The park is perceived as a safe place, well-lit and well-maintained. The police cars are circulating in park regularly.	1
Buffering from traffic	Sufficient for safety.	1
Street activities	There are occasional events, both organised and spontaneous.	1
Vacant lots	No, the park is surrounded by the river and residential lots.	1
2.4.Traffic		5/5
Speed	Slow, traffic limits.	1
Volume	Moderate to low.	1
Number and safety of crossings	Numerous possibilities for crossing the street.	1
Stop signs	Yes, with speed limits.	1
On-street parking	yes	1
2.5.User Experience		5/5
Air quality	good	1
Noise level	Moderate, because of the road.	1
Sufficient lighting	Yes, numerous lamps.	1
Sunshine and shadow	Yes. Trees provide shadow.	1
Visibility of nearby buildings	Residential properties and fences on one side of the park, the scenery of the river from other sides.	1
2.6.Public transport		0/1
	There are bus stops near the park, but the bus schedule is not frequent.	
2.7.Sufficient Parking		1/1
	Yes, there are numerous parking spots in the park, as well as along the streets.	1

Table 11. Assessment of Rahway River Park – part 3. *Source: author*

		POINTS
3. AMENITIES		14/15
3.1.Psychological and physical rejuvenation		5/5
Natural Landscapes	Natural borders planted with mature trees give an impression of a pristine natural landscape.	1
Green open space	Extensive grass-covered grounds at the centre of the park.	1
Presence of water	The Rahway River, a reservoir pond.	1
Places to rest in the sun and shade	Multiple places including picnic areas and playgrounds concealed among the trees.	1
Places to rest in silence and solitude	Multiple benches to rest in silence and solitude.	1
3.2.Physical Activity Promotion		3/4
Sports infrastructure	A track & soccer field, a baseball field, four softball pitches, tennis courts, a swimming pool, many loops for running and walking, (Fig. 5).	1
Recreational infrastructure	Recreational infrastructure for all age groups, (Fig. 6).	1
Community gardens	No	0
Addressing the needs of people with disabilities	Pathways are wide and even, the majority of the park area is easy accessible to people with disabilities.	1
3.3.Catering for basic needs		6/6
Safety and security (presence of guards, cleanliness, maintenance, etc.)	Assessed as a safe place.	1
Places to sit and rest	Numerous benches.	1
Shelter	Multiples shelters, including picnic areas with roofed shelters.	1
Restrooms	Yes, two separate units containing restrooms on opposite sides of the park.	1
Drinking water	Yes, drinking fountains, refreshment stands.	1
Food (possibility to buy food in the park or close vicinities)	Snack bar, Food Stands, occasionally food trucks.	1

Table 12. Assessment of Rahway River Park – part 4. *Source: author*

		POINTS
4. DESIGN		19/21
4.1.Architectural design		10/10
Human scale	The entire neighbourhood respects human scale; park interiors are cosy thanks to design and tree canopy. (Fig. 7-8)	1
Architectural variety of urban environment	Single-family individual houses.	1
Focal points and landmarks	Clear landmarks.	1
Structure of interior connections	A clear structure of interior connections.	1
Framed views	Natural frames are created by the trunks and canopy of mature trees.	1
Long vistas (Extent)	Yes, the park offers numerous extensive vistas.	1
Pathways with views	Yes, the path along Parkway Drive provides interesting views.	1
Invisible parts of the scenery (Vistas which engage the imagination)	Yes, numerous designed vistas that engage the imagination, (Fig. 9-10).	1
Possibility to observe other people	Plenty of places to watch the activities of other people from a distance – sport competitions, people running, children playing, etc.	1
Possibility to observe animals	Plenty of places to see wildlife from a distance – wild goose and other birds, squirrels, small animals, colourful insects – e.g., butterflies, etc.	1
4.2.Salutogenic design		4/5
Optimal level of complexity	Yes, the park was designed to offer both legible composition and optimal level of complexity, (Fig. 7-8).	1
Engaging features	There are multiple elements which attract attention, e.g., wildlife, running water in the river, greenery, presence of other users.	1
Controlled Risk	Several elements offer a subjective feeling of overcoming controlled risk, e.g., walking along the river.	1
Mystery/Fascination	no	0
Movement	Flowing river water, shimmering greenery.	1
4.3.Sensory stimuli design		5/6
Sensory stimuli: Sight	Some elements such as colourful leaves in the autumn, flowers in the warm season.	1
Sensory stimuli: Hearing	Sound of water in the river.	1
Sensory stimuli: Smell	Flowers in the warm season.	1
Sensory stimuli: Touch	Trees, water, snow in the cold season.	1
Sensory stimuli: Taste	Refreshment stands, snack bar.	1
Sensory path	no	0

Table 13. Assessment of Rahway River Park – part 5. *Source: author*

		POINTS
5. PLACEMAKING		10/14
5.1.Social Contact Enhancement		2/2
Organization of events	Organized events, sports competition – softball, baseball, etc., cultural events, food truck days, etc.	1
Meeting places for groups	Multiple picnic areas, roofed gazebos with amenities, open green space used for informal gatherings, etc.	1
5.2.Human perception – spiritual & symbolic		2/6
Sacred places	no	0
Works of Art	no	0
Monuments	The Horsehead Copper Monument is located on St. Georges Ave. across the Rahway River Park. Revolutionary War Site Marker – St. Georges Avenue outside Rahway River Park. The Historical Rahway Cemetery located next to Rahway River Park.	1
Culture and connections to the past	A bench with a commemorative plaque is dedicated to the memory of park founder Arthur Rindge Wendell. It can be found in the Rahway River Park facing the lake.	1
Thematic gardens	No	0
Personalisation	No	0
5.3.Community Engagement		6/6
Personalising the architectural process	The authors of the design – Olmsted brothers were well-known landscape architects.	1
Participation of all stakeholders, including inhabitants and users	All stakeholders, including inhabitants and users have a real influence on the design and maintenance of the park.	1
Determining the rules of conduct and self- management	There are information boards with rules of conduct and self-management placed in well-visible places.	1
Space for social contacts	There are inclusive, accessible space for social contacts available to all (picnic areas, roofed gazebos with amenities for reunions, etc.) Park is often used for organising family reunions.	1
– third places	It is a third place for some parkgoers.	1
– fourth places	It is a fourth place for occasional users	1

Fig. 9. Rahway River Park -walking and jogging loop. *Source: author's photography*

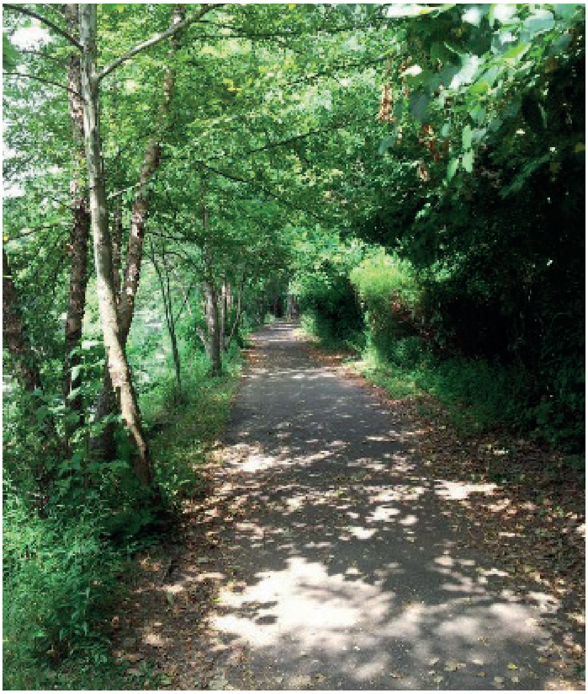

Fig. 10. Rahway River Park - one of the paths. *Source: author's photography*

6. Discussion

Nowadays, city residents need the contact with nature more than ever due to rapid urbanisation and shrinking areas of natural habitats. The results of numerous studies showed that regular visits to urban parks can stimulate the mental and physical regeneration, create social bonds, and facilitate physical activities.

Rahway River Park – built a hundred years ago to promote the health and well-being of Union County inhabitants – scored 86%, that is 79 out of a maximum 91 points. This result indicates that this is a health-promoting place. The universal standard method used in this research has helped to distinguish the material, social, spiritual & symbolic qualities of the park. Addressing the points that were missing, as observed by the author, might help to make the park more welcoming to people who are seeking a spiritual retreat, horticultural therapy sessions, sensory paths, etc.

There are limitations to this Universal Standard, because it is tainted by the subjectivity of perception. For example, section 4. – Design – includes points that require a more subjective assessment. The simplified scale does not allow for the evaluation of the quality and intensity of a given attribute. To mitigate this drawback, the binary assessment used here (0, 1) could be replaced with numerical grades (e.g. 0-10 or 0-100%), which would allow for more precise assessment of given attributes. In the case of more detailed assessments, the problem of subjectivity may be slightly mitigated with more comprehensive descriptions of the assessed attributes.

Previous work addressed the physical activity infrastructure and sustainable solutions assessment, but it did not provide the methods for measurement of therapeutic qualities of POS. This universal standard could be used to evaluate and justify the design choices of public open green spaces (POS). It was developed after scoping literature review and on site observation of over a 100 of POS in various countries in Europe and the USA.

The main identified limitation in its use stems directly from the subjectivity of perception during assessment. While many therapeutic attributes can be assessed objectively, some are more subjective due to the fact that perception of therapeutic landscapes may vary. Therefore, this universal model should not be used as a tool for statistical comparison of therapeutic values of different parks, but rather as an assessment tool. The subjectivity of assessments could be mitigated by providing more detailed descriptions of specific attributes or assessments by a team of researchers.

7. Conclusions

This paper presents a universal standard for health-promoting places. It was developed using an iterative process, after a long-term study of over a hundred public parks and therapeutic gardens located in Europe and the USA. The case study of Rahway River Park demonstrates that the proposed standard can be successfully used to identify the health-promoting qualities of an open green space and to find the areas for improvement.

The universal standard presents a significant advancement in the field of research of urban design and landscape architecture, because it merges an evidence-informed approach with systematic field study. This universal standard is a valuable tool based on research evidence (EBD) and post occupancy evaluation (POE). It could be used to facilitate decision making, justify choices, and incorporate research evidence into urban planning. It could also help in the design of therapeutic POS, as well as support other strategies for urban regeneration.

This universal model should be developed further, for example by including new attributes or determining which of the attributes should become mandatory prerequisites. COVID-19 by forcing social distancing and lockdowns emphasized the need for open urban green spaces. Remote work from home, unemployment, and health insecurity can increase stress level. Open green spaces should provide the opportunity for mental and physical restoration, physical activities, and allow for at least a bit of social contact. Public parks have become a refuge during the time when many sports and recreational facilities were closed. The criteria 2.1 Accessibility, Distance to a park and a question: Is it possible to walk to a park? proved to be the most important during the confinement when it was not possible to use public transport.

As the research was conducted in only a few regions of the Northern Hemisphere, further studies in the wider community may be required, as well as further validation, discussion, and development, in order for it to become a truly universal tool.

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Orginal Article

The role of reliable mining and construction analysis in adjudicating mining damage claims

Wojciech Kocot

Faculty of Mining Surveying and Environmental Engineering;
AGH University of Science and Technology; 30 Mickiewicza Av., 30-059 Krakow, Poland;
wokocot@agh.edu.pl iD *0000-0002-9408-1985*

Abstract: The basis for recognising claims for mining damage to a structure should be a mining and construction analysis, carried out following a detailed visual inspection of the damage and the results of surface deformation measurements. It allows to establish a cause and effect relation between the activity of the mining company and the damage. Unfortunately, there are cases when such an analysis is omitted and the following scheme is used: "since there is damage and the object is located in a mining area, it is mining damage". The problem is illustrated by two court cases where the author acted as an expert witness. Both cases are examples of the so-called pseudo-mining damage and confirm the thesis that the mere image of damage without professional analysis of construction and mining factors may lead to wrong conclusions regarding the causes of the damage.

Keywords: mining damage, mining influences, pseudo-mining damage

1. Introduction

Underground mining exploitation often leads to damage to building structures located on the surface. According to the provisions of the Geological and Mining Law [9], [10], the mining company is obliged to repair the damage caused by its mining operations. On this basis, owners of building structures often make claims to mining companies for repair of damages. However, the basis for recognising such claims should always be a mining and construction analysis, based on the results of surface deformation measurements and detailed visual inspection of the damage. This makes it possible to establish a causal link between the mining plant's activity and the damage. It is necessary, as in many cases the causes of damage are completely different and have nothing to do with the revealed mining influence. Unfortunately, there are cases in which such an analysis is omitted and the following scheme is followed: "since there is damage and the object is located in a mining area, it is a mining damage".

The author was inspired to write this article by numerous court cases in which he acted as an expert witness. Two of them are briefly presented to illustrate the problem.

2. Example one – single-family residential building

2.1. Description of the building structure

This building (Fig. 1) was constructed in stages. In 1953, the oldest part of the building, indicated in Fig. 2 with the letter A, was erected. It is a single-storey building with a usable attic, completely cellared, founded on concrete footings. The basement walls were built of quarry stone and the walls of the ground floor of ceramic brick with cement-lime mortar. The floor above the basement and the ground floor was made of concrete, poured between steel beams, without rims. At the end of the 1960s, a single-storey kitchen and sanitary facility was added to the eastern side of the building at the same level (Fig. 2, letter B). The extension was made without expansion joints, with a connection to the existing part of the building and using its eastern wall. The building was given its final form in 1975, when a staircase (Fig. 2, letter C) and one storey were added. The decision to grant permission for the extension stipulated that the building had to be protected against "category III mining damage". The staircase received its own reinforced concrete footings and masonry basement walls separated from the rest of the building. However, the expansion joint was terminated at the basement floor level. Higher up, staircase C shares a common wall with part A. The walls of the staircase and the entire superstructure of part A were built using self-made cinder blocks. The non-extended part B is used as a terrace. A common, monolithic, cross-reinforced concrete floor above the first floor was made for both parts (A and C). Insulation and an appropriate slope of the ceiling were obtained by laying a layer of granulated slag on it, followed by suprema and cement screed. The roof was covered with layers of roofing paper on bitumen.

Fig. 1. View of the building from the south-east. *Source: author*

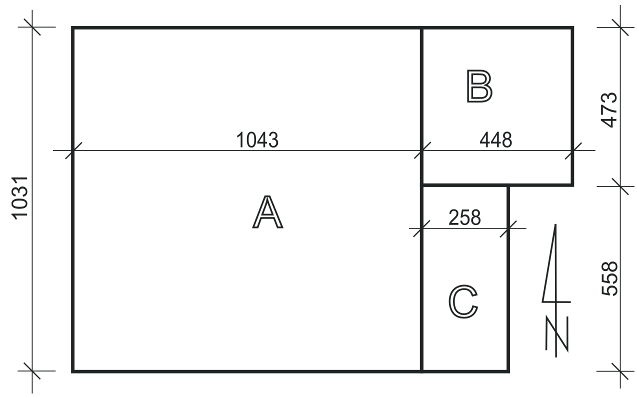

Fig. 2. Individual stages of building erection. *Source: author*

During the expansion of the building, a number of mistakes were made, both in the design and execution of the works. One of the most important errors was the way in which the new parts were connected with the existing ones. The rules of the art of construction recommend in such cases a complete decoupling of the added part. This becomes particularly important when the building is located in a mining area. In the analysed case, in the lower parts of the building (at the basement level) the added staircase was isolated, but the higher parts (the ground floor and the ground floor) were connected with the existing part. This solution makes the building structure very sensitive to the influence of horizontal tensile deformations and curvature of the terrain. The lower parts of the staircase may "move away" from the building, while its upper part remains united with it. This can lead to serious damage in the area of contact. Another design error was the abandonment of the ceiling rim of the superstructure storey. On the other hand, the continuous perimeter ceiling rim above the ground floor was abandoned at the stage of execution works. Although this ring was designed, its absence is proved by the presence of a large window above the entrance to the building (visible in Fig. 1).

In conclusion, it should be emphasised that the adopted construction solutions and mistakes made during construction caused that the actual resistance to mining influence of the extended building is far lower than indicated in the permit for extension.

2.2. Damage pattern and probable causes

During the on-site inspection, no damage that could pose a threat to building safety was noticed. However, all damages reported by the Owner were found to exist. The most significant were the following:

- a vertical crack visible on the northern wall, up to 5 mm in diameter, at the junction of the added part B with the main body of the building (Fig. 3),
- a 2 mm crack at the junction of the extended staircase C with the main body of the building,
- vertical and diagonal scratches and cracks up to 1.5 mm in lintels or at the corners of ground floor and basement window openings (e.g. Fig. 4),

- horizontal cracks and fissures in the walls up to 2 mm in size in the area of the reinforced concrete floor slab (e.g. Fig. 5),
- horizontal crack up to 1 mm in size between the ceiling and the wall separating the south-west room from the north-west room and a diagonal crack below (e.g. Fig. 6),
- in the basement, longitudinal cracks in the ceiling plaster, up to 1.5 mm in size, in the course corresponding to the layout of the steel ceiling joists.

The presented image of the damage indicated that its causes should be sought primarily among constructional factors, including those associated with the history of the extension. Thus, the first two described cracks were caused by the separation of the added parts B and C from the main body of the building. When adding a new segment, one should always remember that the ground which is loaded with it will start to settle, while the process of settling under the building erected earlier is already finished. Therefore, an attempt to connect the walls of new segments with the old ones usually results in a spontaneous formation of a "dilation" by the structure. A larger gap opening at the top and a smaller one at the bottom corresponds to smaller settlements of the added block in the immediate vicinity of the existing one, where the ground is already compacted.

Vertical and diagonal cracks in lintels of ground floor and basement window openings were related to the technology of their construction. The appearance of cracks excluded the presence of reinforced concrete or steel lintels in the window part of the wall. Therefore, these were most probably flat brick lintels, particularly prone to cracking near the middle of the span. An additional factor was that the masonry over the windows was overloaded by the storey above. It is worth noting that similar cracks did not occur over the window openings of the first floor, where reinforced concrete lintels were made.

Cracks in the walls along the line of the flat roof slab are typical for the technology used. The cracks are formed mainly as an effect of slag degassing under the influence of frequent changes of humidity and temperature and as a result of thermal work of the flat roof slab. Similar damage is common in buildings with similar roofing throughout the country. The group of damages related to the execution technology also includes the observed cracks in the basement ceiling. All the cracks run along steel bearing beams hidden in concrete, which is typical for this type of construction.

The gap between the first floor interior wall and the ceiling was caused by a construction error. This wall, 25 cm thick, was erected with an offset of approx. 0.6 m from the corresponding wall on the ground floor. As the only support for this wall is the ceiling above the ground floor, the scratches and cracks occurring in it are connected with the deflection of this ceiling.

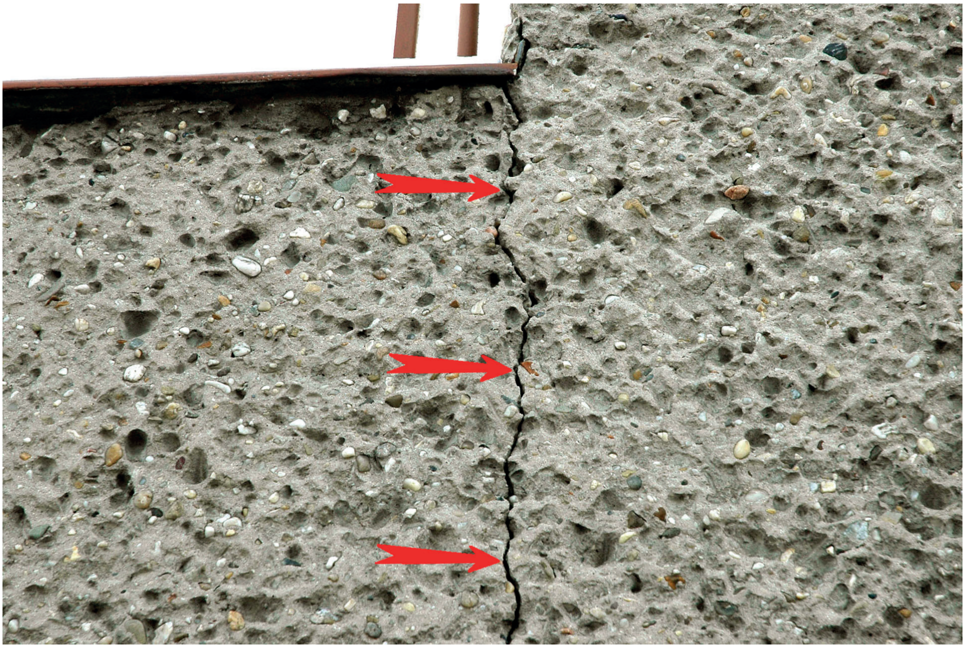

Fig. 3. Fragment of the northern wall – vertical crack at the junction of the extension C with the main body of the building. *Source: author*

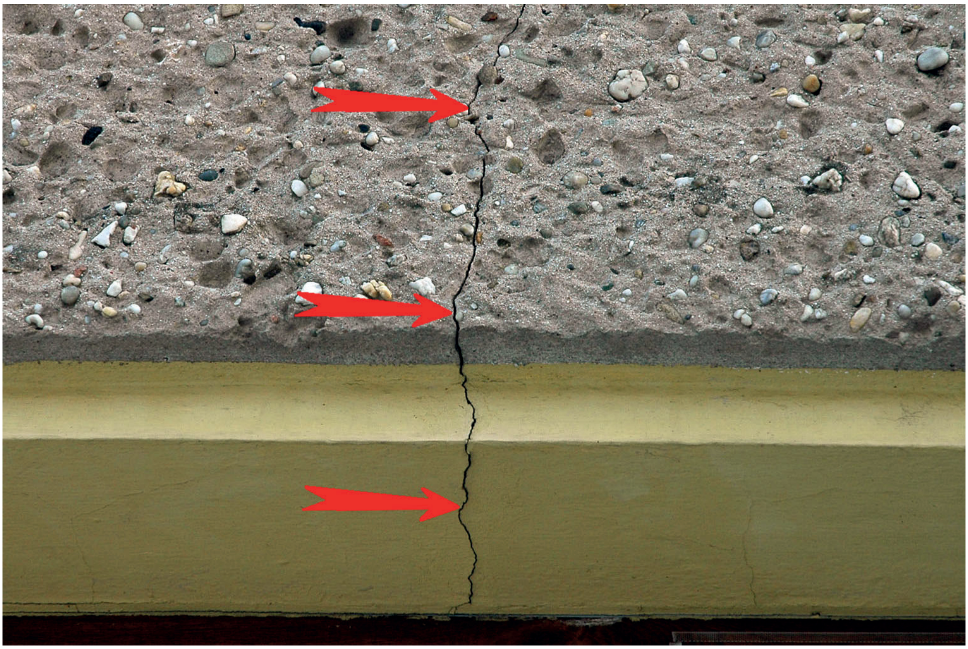

Fig. 4. Fragment of the western wall – vertical crack above ground floor window opening. *Source: author*

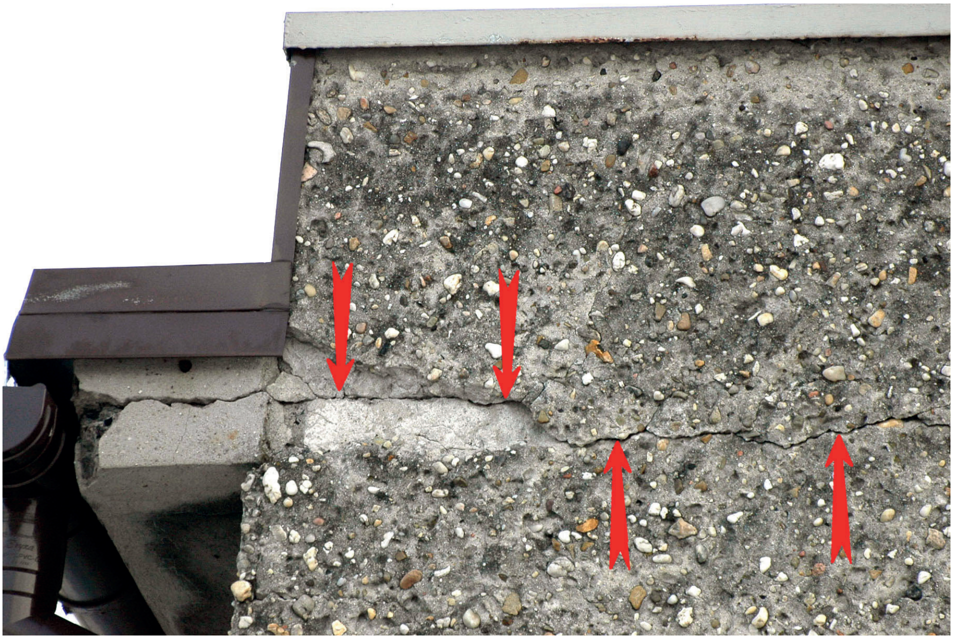

Fig. 5. Fragment of the western wall – visible horizontal cracks along the upper and lower surface of the ceiling slab. *Source: author*

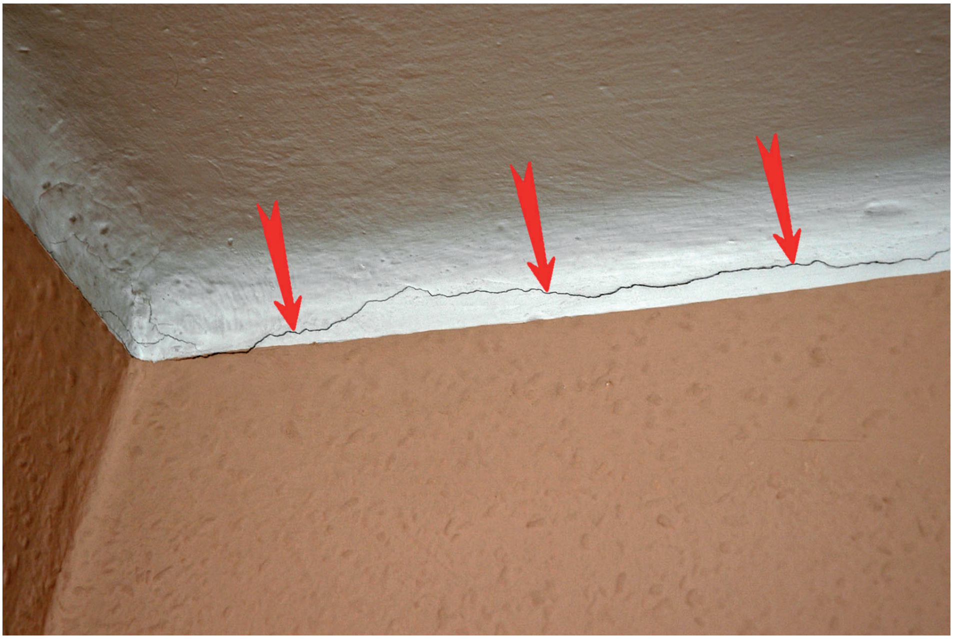

Fig. 6. Gap of up to 1.5 mm between ceiling and first floor interior wall. *Source: author*

2.3. Assessment of mining influences in the building area

The analysis of the influence of continuous deformation showed that mining exploitation was carried out twice in the vicinity of the building in question. The first, at the average depth of 370 m, passed about 400 m to the south of the building, and the second, at the average depth of 540 m, passed about 900 m to the south-east of the building. The ground deformation indices obtained by means of the conducted calculations [1] turned out to be smaller than the limits for the zero category of the mining area. The area characterised by such small deformation indices is practically considered to be free from direct mining influences and therefore not dangerous.

In turn, the influence of discontinuous deformations on the building was excluded. Firstly, because they have not been observed in the analysed area so far, and secondly, because the image of damage which occurs under their influence is completely different from the observed one [3], [4].

Further analysis showed that at the location of the building the mining-induced para-seismic shocks were characterised by zero degree of intensity according to the GSI-GZW_{KW} intensity scale or slightly exceeded it. At this point, it is worth mentioning the descriptive explanation of the degrees of intensity of para-seismic impacts on buildings according to the GSI-GZW_{KW} (e.g. [6], [7]):

- intensity degree 0 means that the parameters of vibrations from shaking are comparable to the level of vibrations caused by the technical usability of the object (e.g. slamming doors) – shaking does not cause any damage to buildings,
- intensity level 1 means that the vibration parameters of shocks are comparable to the seismic background – shocks do not cause damage to buildings. Shocks do not cause damage to buildings. At most, they may cause a small increase in pre-existing damage, e.g. a small increase in the opening of cracks.

Consequently, according to this explanation, there was practically no risk of damage to the building in question as a result of paraseismic tremors of mining origin. Therefore, the tremors could not have caused any damage to the building, but could only have slightly increased the extent of the damage.

In summary, due to the negligible extent of mining impacts, their influence on the damage to the building was practically excluded. At the same time, non-mining causes were identified in all cases.

It was clear at the court hearing to the lawyer representing the Owner that, since the building was located in a mining area and damage had occurred to it, it clearly had to be of mining origin. The author demonstrated to the court the absence of mining impacts capable of causing damage, and at the same time presented to the court the actual causes of the damage. Thus, he proved the absence of a causal link between the activity of the mining company and the damage caused to the building.

3. Example two – an industrial building

3.1. Description of the building structure

The second case concerned an industrial building erected in the early 1980s (Fig. 7). At the end of the 1990s, it changed ownership and was adapted for use by another manufacturing sector. It is a building with a complete basement, consisting of three structurally independent segments separated from each other (Fig. 8):

- segment 1 (western) with axial dimensions of the horizontal projection of 30.0 x 15.0 m,
- segment 2 (central) of similar axial dimensions to the western one,
- segment 3 (eastern) with axial dimensions of the horizontal projection of 15.0 x 15.0 m.

The western segment, the central segment and the first (6 m) field of the eastern segment form the hall-like part of the building, approximately 13 m high. The remaining (eastern) part of segment 3, with axial dimensions of 9.0 x 15.0 m is an 18.5 m high former silo for loose materials, currently not in use). The designed dilatation of all expansion joints is 10 cm.

All segments have a reinforced concrete monolithic zero state. In the case of segments 1 and 2, the load-bearing structure consists of six transverse two-nave frames, longitudinally spaced at 6.0 m, connected to each other by three longitudinal reinforced concrete walls and a ceiling made of TT-type prefabricated reinforced concrete elements. The transverse walls are partly reinforced concrete and partly brick. The first field of segment 3 (under its hall part) has a similar construction as the other two segments. In the remainder of segment 3, the zero state is formed by monolithic reinforced concrete columns, spaced at 4.5 x 3.0 m, adapted to the steel support structure of the silos once placed on them. All three segments were placed on a reinforced concrete foundation grid.

Fig. 7. The industrial building in question – view from the south-west. *Source: author*

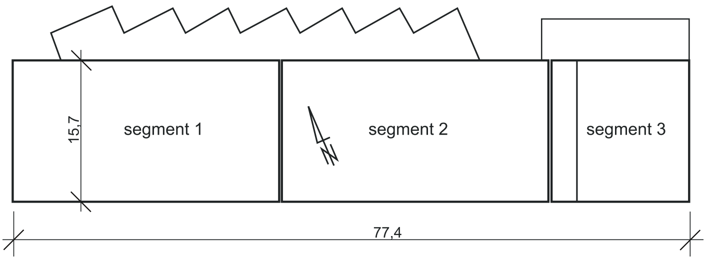

Fig. 8. The industrial building in question – segmentation

The overground part of the building has a steel skeleton load-bearing structure. In the case of segments 1 and 2 it is a two-storey hall with two naves (7.5 + 7.5 m) at the height of the first storey, changing into a single-nave hall (15.0 m) on the second storey. The ceiling of the first storey at the level of +4.20 m was made of TT-type reinforced concrete prefabricated elements supported on steel beams. The roof of the hall is made of reinforced concrete pan slabs with a span of 6.0 m based on trussed roof girders. Stability in the longitudinal direction is provided by steel girders placed in one field of each segment. Lateral stability was achieved by restraining the columns in the ceiling above the basement. The internal cladding of the hall part consists of reinforced concrete prefabricated wall elements and partly of curtain walls made of siporex and ceramic blocks. The enclosure of the former silo consists of filling walls made of siporex blocks.

According to the opinion attached to the court file, the object was to be secured at the stage of construction against mining influences with indicators corresponding to category III of the mining area.

3.2. Damage pattern and probable causes

During the on-site inspection, no damage to the supporting structure of the building was observed. However, all damages reported by the Owner were found. The most significant damages included:

- cracks visible from the outside of the building on the basement walls,
- cracks in the partition walls,
- cracks and chipping of the plaster at the joints of prefabricated reinforced concrete elements of the above-ground walls,
- cracks in the floors.

At first glance, some of the damage appeared severe. These included numerous cracks visible from the outside on the part of the basement walls protruding above the ground surface. These cracks, mostly horizontal, occurred mainly in the vicinity of window openings and were 2-10 mm wide (e.g. Fig. 9). Larger cracks were sometimes accompanied by a few mm displacement of both parts of the wall in relation to each other in the crack plane. After thorough examination of the cracks, it turned out that only the brick wall pressing the foamed polystyrene insulation layer visible from the outside was cracked. No cracks or even minor scratches were visible anywhere on the reinforced concrete supporting wall on the inside. It should be noted that the ground deformations connected with mining exploitation cannot selectively affect only the finishing layer of the wall without damaging the load-bearing layer. The cause of the damage should therefore be sought among construction defects. In this case, it was a defective foundation of the wall pressing the insulation and the lack of its proper connection with the reinforced concrete basement wall. This diagnosis was further confirmed by the frequently occurring spalling and outward tilting of the part of the wall below the crack (e.g. Fig. 9).

In the southern part of segment 2 there were horizontal cracks in the basement partition walls – 12 cm thick brick (e.g. Fig. 10). The extent of the cracks sometimes exceeded 10 mm, but decreased as they approached the load-bearing walls. According to the information obtained, these walls did not have a proper foundation – they were erected directly on the floor. The floor was laid on a layer of embankment created during the backfilling of foundations. This soil consolidated over time, and with it the floor and the partition walls settled, more in the middle, less in the vicinity of the load-bearing walls. This means that, in this case too, the cause of the damage was a construction defect.

Fig. 9. Fragment of the basement wall of segment 1 – visible cracks in the inter-window pillar from the outside and no damage at this point inside. *Source: author*

Fig. 10. Horizontal cracks in masonry partitions in basements. *Source: author*

On the first floor of segment 1, a crack was observed at the junction between the west gable wall and the internal brick longitudinal wall. This wall is approximately 3 m long and the other end of the wall remains free. The extent of the crack ranged from 0 mm bottom to approximately 8 mm top. This wall was placed directly on one of the precast reinforced concrete beams of the basement floor (spanning 6 m). As there is no wall (longitudinal or transverse) below, the floor beam deflected. The wall resting on it fell down with it, the free end of which coincides with the middle of the beam's span. This caused a crack to appear at the junction of the masonry with the gable wall, with its opening increasing upwards

Similar cracks in appearance and origin are found at the junction of the masonry partition walls of the second storey with the western gable wall (e.g. Fig. 11). The sagging of both ceilings is additionally favoured by their structure. The longitudinally aligned prefabricated elements can work independently to a large extent ("buckling").

Scratches, small cracks and chipped plaster on the joints of prefabricated reinforced concrete elements of the above-ground walls are a separate group. The described damages are characteristic for buildings erected in the skeleton technology, with rigid cladding and are common in similar buildings throughout the country. In this case, the damage to the plaster was additionally increased by rainwater flowing down the façade and leaking from the damaged gutters.

Fig. 11. Cracks at the junction of the masonry partition wall of the second storey with the western gable wall. *Source: author*

Fig. 12. Western fragment of the northern wall of segment 1 – visible cracks and chipping cracks and chipping of plaster at the joints of prefabricated housing elements and dark damp patches. *Source: author*

It should be emphasised that no damage to the load-bearing structure of the building was found. All the described damages concern secondary elements and do not pose a threat to the safety of the building. The technical condition of the building was generally assessed as satisfactory.

3.3. Assessment of mining influences in the building area

Simultaneously with the structural analysis, work was carried out to determine the maximum extent of mining influence that could affect the building in question [2]. This took into account both the possibility of continuous and discontinuous deformations and paraseismic influences.

The analysis of mining data showed that the maximum values of continuous deformation indicators did not exceed those corresponding to mining site category I. These results were verified on the basis of detailed visual inspections and measurements of dilatation gap dilation. Among the indicators of continuous deformations, the most significant for the analysed building are horizontal deformations and curvature of the terrain. In the case of tensile horizontal deformations (accompanied by convex curvature), we can observe distancing of the building segments from each other, resulting in dilation of dilatation joints. In the case of compressive deformations (concave curvature) the segments move closer to each other, at the same time tightening the dilatation joints. The changes in the dilatation joints, calculated on the assumption of indicators characterising the mining area category I ($\varepsilon = 1.5$ mm/m and $R = 20$ km) [8], should amount to approximately ±62 mm on the eastern dilatation and approximately ±46 mm on the western dilatation. However, detailed visual inspection of both dilatations showed virtually no movement on them. For example, the dilatation joint between reinforced concrete walls of the basement, visible in the basement corridor, was bricked up and plastered over several years ago (which is inconsistent with the rules of construction art). The possible appearance of mining influences in this place would have to result either in the creation of a crack of the above-mentioned opening, or in crushing the wall filling the dilatation joint. The visual inspection showed the presence of a crack at the dilatation joint with a delineation of approximately 1 mm (Fig. 13). This means that since the time of masonry work on the dilatation joint in the building, practically no influence of continuous deformation has appeared.

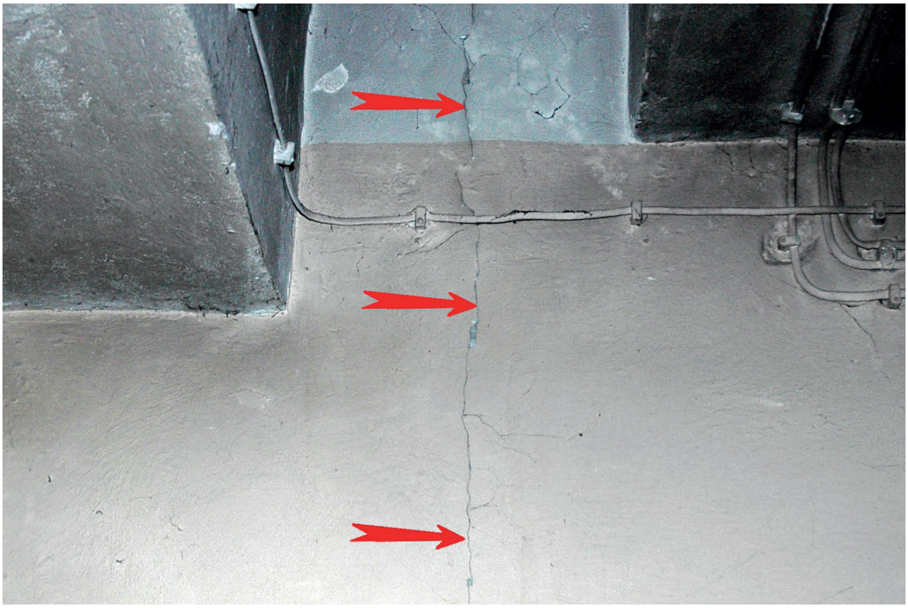

Fig. 13. 1 mm crack at the bricked up and plastered expansion joint between segments 2 and 3 at ground level. *Source: author*

Non-continuous deformation usually takes the form of faults or local sinkholes. The latter may be related to the activation of old shallow gobs after former shallow seams exploitation. The formation of a fault or sinkhole under a structure is usually associated with severe damage to the load-bearing structure (e.g. [3], [4]). The damage is caused by significant irregular settlement of the building fragments in relation to its remaining part. The detailed local inspection did not reveal the presence of any damage which could be caused by the occurrence of discontinuous deformations. Therefore, it should be concluded that no discontinuous deformations occurred under the analysed building, especially that they were not observed in the nearest vicinity of the building either

The potential causes of damage to buildings in mining areas also include paraseismic impacts from mining tremors. However, the list of tremors attached to the court file shows that the maximum amplitude of vibration acceleration that the building could experience did not exceed 30 mm/s2. Meanwhile, shocks which can cause any damage to buildings are assumed to be those whose accelerations are several times higher (e.g. [5], [8]). This information was additionally confirmed during the interview with the Owner, who did not observe any tremors in his building. Therefore, also mining tremors should be excluded as a potential cause of damage.

The analysis shows that construction defects were the main cause of damage in this case. There was also a large group of damages characteristic for the applied construction technology, commonly occurring in building structures regardless of their location. On the other hand, the analysis of mining impacts ruled them out as potential causes of damage. Thus, the existence of a cause-and-effect link between the mining plant's activity and the damage to the building in question was excluded. In the pleading, the Owner's crowning argument was that twice before (in 1989 and then in 1993) the same damage had been recognised by the District Mining Damage Commission as mining damage. This proves that wrongful claims were recognised twice and undue compensation was paid. This was done without proper analysis, acting according to the scheme: "since there is damage and the object is located in a mining area, it is mining damage".

4. Summary and conclusions

The cases presented in the article are examples of the so-called pseudo-mine damage. As a rule, they look similar to damages caused by mining influences, therefore it is easy to make a suggestion and associate their existence with underground mining exploitation. In both cases the main cause of damage was construction defects. There was also a large group of damages characteristic for the applied construction technology, commonly occurring in buildings regardless of their location. On the other hand, the analysis of mining impacts excluded them as potential causes of damage. Thus it was demonstrated that there was no causal link between the mining plant's activity and the damage, and the court cases ended with the dismissal of unjustified claims. It is worth noting that in the second case, exactly the same damage was recognised several years earlier by the Regional Commission for Mining Damages as mining damage, which resulted in wrongful payment of compensation. The Commission acted according to the scheme: "since there is damage and the object is located in a mining area, it is mining damage".

These cases confirm the thesis that the mere picture of damage without professional analysis of construction and mining factors can lead to wrong conclusions and result in unjust rulings.

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Orginal Article

Has the introduction of the possibility to build a single-family house on the basis of notification really improved the development process? The analysis based on the example of the Capital City of Warsaw (Poland)

Sylwia Kołacińska[1], Tomasz Zaborowski[2]

[1] *Department of Architecture and Construction; Bielany District Office of Warsaw Capital City; 29 S. Żeromskiego St., 01-882 Warszawa, Poland; sylwiaw0793@gmail.com*

[2] *Chair of Urban Geography and Spatial Planning; Faculty of Geography and Regional Studies; University of Warsaw; 30 Krakowskie Przedmieście St., 00-927 Warszawa, Poland; t.zaborowski@uw.edu.pl* iD *0000-0001-9656-5169*

Abstract: On 28 June 2015, an amendment to the Construction Law Act (Journal of Laws of 2018, item 1202, as amended) came into force, abolishing a requirement to obtain a building permit to construct or reconstruct a detached single-family residential building, which impact area is limited to the plot or plots on which it was designed, enabling its construction on the basis of a notification. This amendment was intended to simplify the investment process for the construction of single-family houses. This article is a contribution to the verification of this thesis. It analyses data on applications submitted to the Warsaw district offices within the period of 3 years of the amendment of the Construction Law. The data concerning notifications for Bielany and Białołęka districts was then juxtaposed with the data concerning building permits. The number of required formalities, the duration of both procedures, the percentage of positive decisions, and the frequency of using both procedures were compared. The results of the research undermine the thesis that the discussed change in the law has improved the investment process of construction of single-family houses.

Keywords: notification, building permit, facilitation, single-family houses, construction law

1. Introduction

Pursuant to the general rule articulated in Article 28.1 of the Act of 7 July 1994 – Construction Law (hereinafter: Construction Law) [1], construction works may only be commenced on the basis of a decision on the building permit. In Article 29 of the Construction Law [1], the legislator included a catalogue of construction works, the performance of which does not require the building permit – a list of exceptions to the general rule, which according to legal doctrine is of a closed nature [14]. The provisions of Article 29 have been modified several times, as the legislator attempted to expand the catalogue of construction projects exempt from the obligation to obtain the building permit. The last radical change was made in the Act of 20 February 2015 amending the Construction Law and certain other acts [3].

Construction works indicated in Article 29 of the Construction Law [1] should be associated with legal regulations indicated in Article 30, which establishes the institution of the notification. Only the juxtaposition of these regulations provides the complete picture of the administrative formalities that an investor must undertake in order to legally carry out an investment project. Consideration of the notification does not take place by way of an administrative act, but through the so-called tacit consent of an authority, which in fact consists in not taking any action [2].

The competent architecture-construction administration body raises an objection if a notification concerns construction or performance of construction works subject to a requirement of obtaining a building permit, or if the project violates the provisions of the local spatial development plan or other regulations. The term *raises an objection* contained in the Act means that it does not depend on the authority's discretion, but instead they are obliged to raise an objection, if at least one of the prerequisites listed above occurs [2].

On 28 June 2015, the Act of 20 February 2015 amending the Construction Law and certain other acts came into force [3]. In the justification of the proposed act, it was indicated that the existing provisions are overly elaborate and lead to the investment process being too time-consuming [4]. Therefore, the main objective of the amendment was to shorten and simplify the procedure provided for in the Act. The amendment of the legislation was a step towards liberalising the formal requirements for the construction of single-family residential buildings. The main premise of the amending law was the abolition of the requirement to obtain the building permit decision for the construction or reconstruction of single-family residential buildings with an impact area entirely within the plot or plots on which they were designed. From the date of entry into force of the amendment, the investor has the right to choose whether to remain with the current procedure for obtaining a building permit or to make a notification.

According to the legislator, the changes were particularly sought by individual investors, who were pointing out that the complexity of the procedures should be adapted to the type of a building. They were hoping for shortening the duration of the proceedings and simplification of project documentation. In the justification of the draft amending act, it was noted that in 2013, approximately 75,000 decisions on building permits for single-family residential buildings were granted, which accounted for approximately 40% of all building permits issued. It was also pointed out that among the decisions on single-family development, in 40% of them the applicant was the only party to the proceedings [4].

As already mentioned, the exemption from the obligation to obtain the building permit does not mean the abandonment of administrative control. Pursuant to Article 30 Section 1 of the Construction Law [1], a construction project is subject to notification to the competent authority, which must be submitted prior to the intended date of commencement of the works. The replacement of the building permit decision with the institution of notification was the subject of many considerations by the Constitutional Tribunal of Poland. A critical approach was revealed, i. a. in the judgment of 20 April 2011, in which it was indicated that the extension of the scope of application of the notification institution is associated with insufficient influence of state authorities on ensuring public order and the possibility to enforce respect for public interest, as well as with the undermining of protection of property rights of third parties [5].

The slogan – "single-family houses upon notification" – was enthusiastically promoted by the media [6], [7]. According to the Ministry's calculations, investors of as many as 30,000 single-family buildings were to benefit from the new procedure each year [8]. According to the data, in approximately 40% of single-family building cases, there are no other parties than the applicant himself. Therefore, it was assumed that in as many cases, the building permit will be replaced with the notification [8].

2. Literature on the subject

The only scientific publication known to the authors relating to the discussed topic is that of M. Sługocka, and M. Bursztynowicz [4]. The authors are not familiar with other, especially analytical scientific publications on the subject. The discourse so far seems to be limited to the popular and specialist press. The discussed amendment to the Construction Law electrified the public opinion in 2015-2017, i.e. just before and after the change of regulations. Most newspaper articles from 2015 only introduced and discussed the new legislation [6], [7], [9]. Even then, however, the first articles appeared, suggesting a sceptical approach to the apparently favourable legal changes for investors [8]. On 27 February 2015, Dziennik Gazeta Prawna discussed controversies related to unclear rules for determining the area of impact of a facility [10]. In Rzeczpospolita on 3 September 2015, an analysis of the requirements and conditions of both variant legal procedures was presented, suggesting investors to soberly consider their advantages and disadvantages [11]. In retrospect, more and more criticism of the legislation introduced in 2015 can be observed. In an article dated 27 October 2017 [12], the amended provisions regarding the method of determining the area of impact of a facility were considered "unfortunate", while the institution of notification of construction of a single-family house itself was said to be "unpopular".

The subject of notifications was also taken up by Gazeta Wyborcza, where the journalists, a little over six months after implementation of the Act, were attempting to find an answer to the question why Poles do not benefit from such widely advertised simplification of procedures [20]. The issue was also raised in August 2016 in Dziennik Gazeta Prawna. At the time, one of the articles was given the headline: "Collapse of houses on notification" [21]. The editors wrote: "It was supposed to be simpler and faster. However, it turned out that investors do not need such simplifications". When preparing the amendment, it was assumed that about 30 thousand investors would benefit from the simplified procedure within a year; in reality, there were 5 times less of them [21]. In an article published in February 2017, the journalists of Rzeczpospolita also concluded that despite the introduction of the simplified procedure, it is still more popular to build single-family houses with a building permit [22]. The topic also appeared in an article published in November 2018 on the website of Rzeczpospolita with the title “Villa on notification is still a great rarity” [23]. The author, referring to data from the Main Construction Supervision Office, emphasised that investors prefer to build based on a building permit, as this is connected with a lower investment risk [23].

3. Research questions and methods

The aim of the study was to answer the following general research question (GQ): Did the amendment to the provisions of the Construction Law Act, allowing the construction of detached single-family residential buildings based on a notification, contribute to the improvement of the investment process for the erection of single-family residential buildings in the examined period in the Capital City of Warsaw? In order to answer this general question, the following auxiliary questions (AQ) were posed:

AQ1: Are there fewer formalities for the investor to complete in the notification procedure?

AQ2. How many notifications for the construction of detached single-family dwellings were accepted on the territory of the Capital City of Warsaw in the analysed period?

AQ3: What was the most common reason for objections to these notifications?

AQ4: Were investors more likely to use the notification or building permit procedure?

AQ5: Has the duration of the administrative procedure for starting construction work been reduced in real terms?

AQ6: Which procedure – the notification or building permit – was more likely to result in a positive outcome for investors?

The time scope of the study covered the period of three years from the date of entry into force of the Construction Law Amendment Act [3], i.e. 28 June 2015 to 28 June 2018. The substantive and spatial scopes corresponded to the two-stage form of the study. At first, an analysis was performed on the data concerning notifications for the construction of single-family residential buildings, which in the given period were received by all 18 district offices of capital city of Warsaw. On this basis, answers to the auxiliary questions AQ1, AQ2, AQ3 were provided. Then, a comparison was made on the data on notifications versus building permits of two sample districts – Bielany and Białołęka. As a result, it allowed the authors to answer auxiliary questions AQ4, AQ5 and AQ6.

4. Legal status

During the proceedings for the granting of a building permit, the following parties are involved: an investor and owners, perpetual users or managers of properties located in the area affected by the facility. It is therefore important to determine a building impact area. According to the definition set out in Art. 3, section 20 of the Polish Construction Law Act, the area of influence of a facility is “the area designated in the vicinity of the facility on the basis of separate provisions introducing associated restrictions on the development of the facility, including the development of a given area.” [1]. Such an area should be determined individually for the needs of each specific case and consider the form, structure, and characteristic features of a designed building, as well as the way the land surrounding the planned investment is developed [13]. Therefore, the designer, basing on the regulations, jurisprudence, and own practice, as well as taking into account the development of the adjacent plots, is obliged to decide whether the impact area of a facility is limited to the boundaries of the plot on which it is designed, or not, and then include a note to that effect in the project.

The definition of the area of impact poses certain problems. There are numerous difficulties in applying it in practice as the legislator does not indicate regulations governing the determination of the area of impact of a facility. As early as in 2011, the Constitutional Tribunal in Poland attempted to clarify the issue of the area of impact, concluding that the area of impact is determined by detailed provisions of the law, which set out the restrictions regarding fire protection, noise, environmental protection, technical and construction issues, and in particular the regulations regarding the distance of the facility from the property boundaries, as required by law [5].

There is no doubt that this list includes provisions included in the Regulation of the Minister of Infrastructure of 12 April 2002 on technical requirements to be met by buildings and their location [15], [14]. For example, § 13(1) of this regulation [15] specifies minimum distances of a building with rooms intended for human occupation from other objects, so that it is possible to light the rooms naturally. The jurisprudence repeatedly emphasises the fact that separate regulations do not only include the rules listed in the above-mentioned regulation. These regulations also include rules concerning environmental protection, protection of monuments, nature protection, water law, aviation law, as well as executive directives to the acts [16].

However, one cannot agree with the thesis that if a construction project complies with the technical and construction regulations, it does not have any impact on the surrounding properties. Such an approach would lead to a statement that the impact of a construction object occurs only in a situation where technical and construction regulations are violated. Meanwhile, a decision on a building permit should not be issued for an unlawful investment at all. Consequently, the area of a building's impact cannot be equated with the investor's compliance with the requirements set forth in the technical and construction regulations. It should also be emphasised that the impact area of a facility refers both to the developed and undeveloped land. Restrictions may arise during changes in the manner of development of the adjacent areas. Moreover, the area does not have to include only the plots directly adjacent to the property on which the investment is planned [17]. In fact, single-family detached houses developed in the vicinity of other buildings can always interact to some extent with existing buildings [18].

Table 1 synthesises the differences in the mechanism of building permit and construction notification of a detached single-family residential building. The comparison was made on the basis of the regulations resulting from the Construction Law.

Table 1. Comparison of building permit and notification procedures for a detached single-family residential building. *Source: authors' own study*

Stage	Building permit	Notification
Annexes to the application required by the law	Three copies of the project together with opinions, agreements, permits, and other documents required under separate regulations	
Decision on development conditions (in the absence of a plan)	Required	
Parties of the proceedings	Involvement of parties to proceedings	No need for involvement of parties to proceedings
Completion of the procedure (positive outcome for the investor)	Issuing of a building permit decision	Acceptance of notification by a tacit consent
Completion of the procedure (negative outcome for the investor)	Issuing of a decision to refuse to grant a building permit	Objection by decision
Appeal (positive outcome for the investor)	Appeal against the decision within 14 days	No means of appeal
Appeal (negative outcome for the investor)	Appeal against the decision within 14 days	
Duration of the procedure	Max 65 days*	Max 21 days**
Validity	3 years***	3 years****

* The time limit of 65 days shall not include periods prescribed by law for the performance of specific acts, periods during which proceedings are suspended or periods of delay caused by the fault of a party or by reasons beyond the control of the authority.

** The obligation to remedy the deficiencies in the dossier shall interrupt the time limit.

*** The building permit decision shall expire if construction has not commenced within 3 years from the date on which the decision became final or construction has been interrupted for more than 3 years.

**** If construction works have not commenced before the expiry of 3 years from the deadline specified in the notification for their commencement, they may commence after a new notification has been submitted.

The data presented above enables us to answer the auxiliary research question AQ1 posed at the beginning: are there fewer formalities to be fulfilled by an investor in the notification procedure? The answer is no. When planning the construction of a residential building based on a notification, the investor is obliged to provide the same architectural documentation as for a building permit. In both cases, for the areas where local land-use plans [*miejscowy plan zagospodarowania przestrzennego*] have not been adopted, an ad-hoc, auxiliary planning permit [*decyzja o warunkach zabudowy*] is also required. The number and type of attachments required by the architectural and construction administration depends, among others, on the location of an investment or its designation in the applicable local land-use plan. For example, if a planned building is to be erected on an agricultural plot, it will always be necessary to present the position of the competent authority on excluding this land from agricultural production [3].

5. Results of the study

5.1. Analysis of construction notifications for single-family dwellings

From 28 June 2015 (entry into force of the Act of 20 February 2015 amending the Construction Law and certain other acts [3]) until 28 June 2018, all 18 districts of the capital city of Warsaw received 537 construction notifications for single-family residential buildings, (Table 1) [1].

Table 2. Number and completion of the notification procedure for detached single-family residential buildings in individual districts of the Capital City of Warsaw in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

District	Number of notifi-cations	Tacit consent	Objection	Notification withdrawn
Bemowo	10	3	3	4
Białołęka	110	55	20	35
Bielany	16	8	7	1
Mokotów	16	6	10	0
Ochota	0	0	0	0
Praga-Południe	2	1	1	0
Praga-Północ	0	0	0	0
Rembertów	29	21	7	1
Śródmieście	0	0	0	0
Targówek	19	9	6	4
Ursus	9	4	3	2
Ursynów	45	14	22	9
Wawer	181	70	86	25
Wesoła	23	14	5	4
Wilanów	44	26	4	14
Włochy	28	19	7	2
Wola	3	1	2	0
Żoliborz	2	0	1	1
Total	537	251	178	102

Fig. 1 presents the spatial distribution of notifications on the map of Warsaw with division into districts.

[1] The data were collected independently.

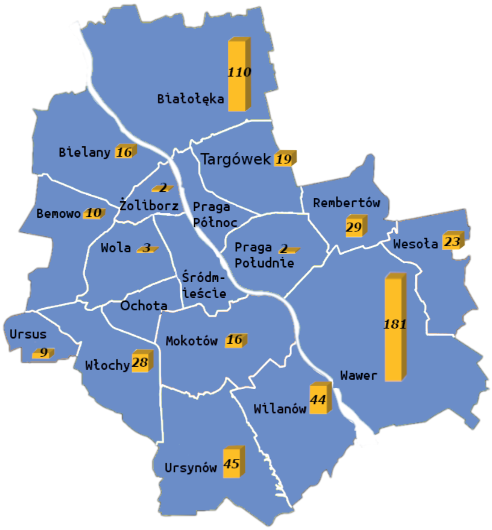

Fig. 1. Number of notifications of detached single-family residential buildings in individual districts of the Capital City of Warsaw in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

Fig. 2 and Table 2 present the outcome of processing of construction notifications of detached single-family residential buildings in the period from 28 June 2015 to 28 June 2018 by districts of the capital city of Warsaw.

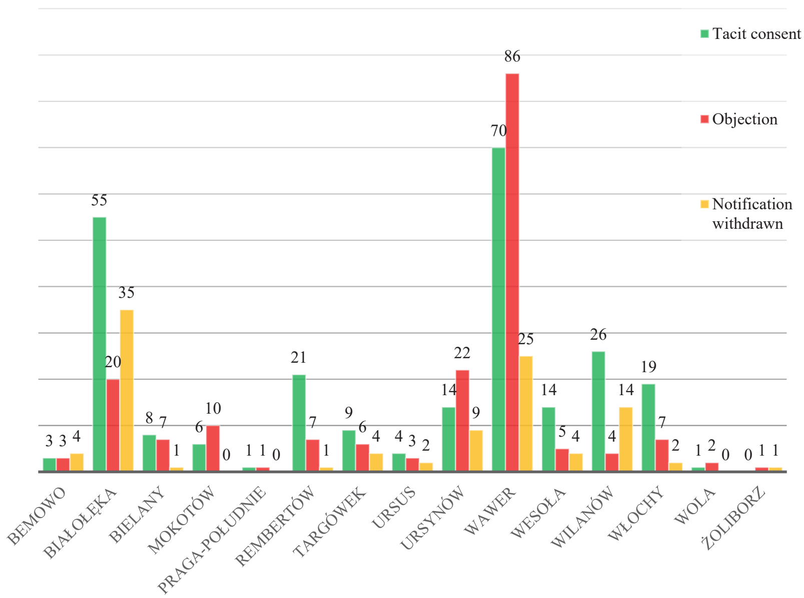

Fig. 2. Number of accepted notifications, withdrawn notifications, and objections to notifications of construction of detached single-family residential buildings in individual districts of the Capital City of Warsaw in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

The way of completing of the notification procedure in the whole city is shown in Table 3 and Fig. 3.

Table 3. Number of accepted notifications, withdrawn notifications, and objections to notifications of construction of detached single-family residential buildings in the capital city of Warsaw in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

Completion of the procedure of notification	Number
Objection	184
Withdrawn	102
Tacit consent	251

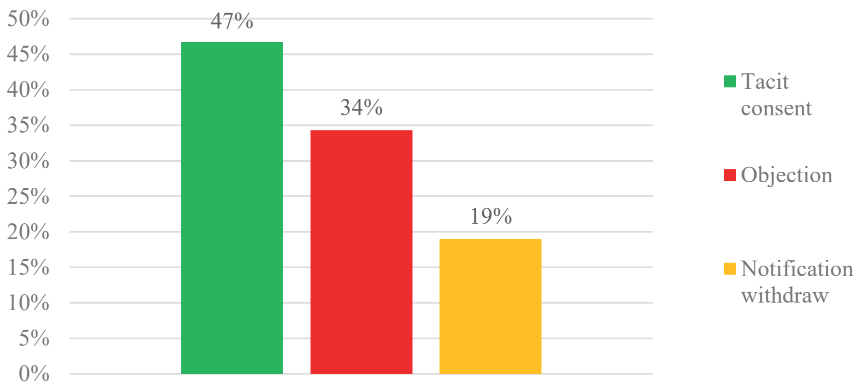

Fig. 3. Percentage of accepted notifications, withdrawn notifications, and objections to notifications of construction of detached single-family dwellings in the capital city of Warsaw between 28 June 2015 and 28 June 2018. *Source: authors' own study*

5.2. Analysis of objections to construction notifications of single-family residential buildings

Since accepted notifications for the construction of detached single-family dwellings accounted for less than 50% of all applications submitted, this subsection focuses on identifying the reasons for objections. In order to obtain the answer, almost all objection decisions issued by individual districts between 28 June 2015 and 28 June 2018 were analysed, i.e. 148 objection decisions (out of 184 issued). The exception is the district of Wawer, where out of 86 decisions issued, it was possible to access only 50 of them.

There is no single, discernible trend concerning the reasons for objections issued by individual district offices of the Capital City of Warsaw. Among 4 out of 15 districts: Białołęka, Mokotów, Rembertów, Wawer, the most frequent reason was the impact area of a designed facility extending beyond the boundary of an development plot. The districts of Praga-Południe, Ursus and Wola submitted objections only due to the lack of timely completion of missing information indicated in the decision (Fig. 4).

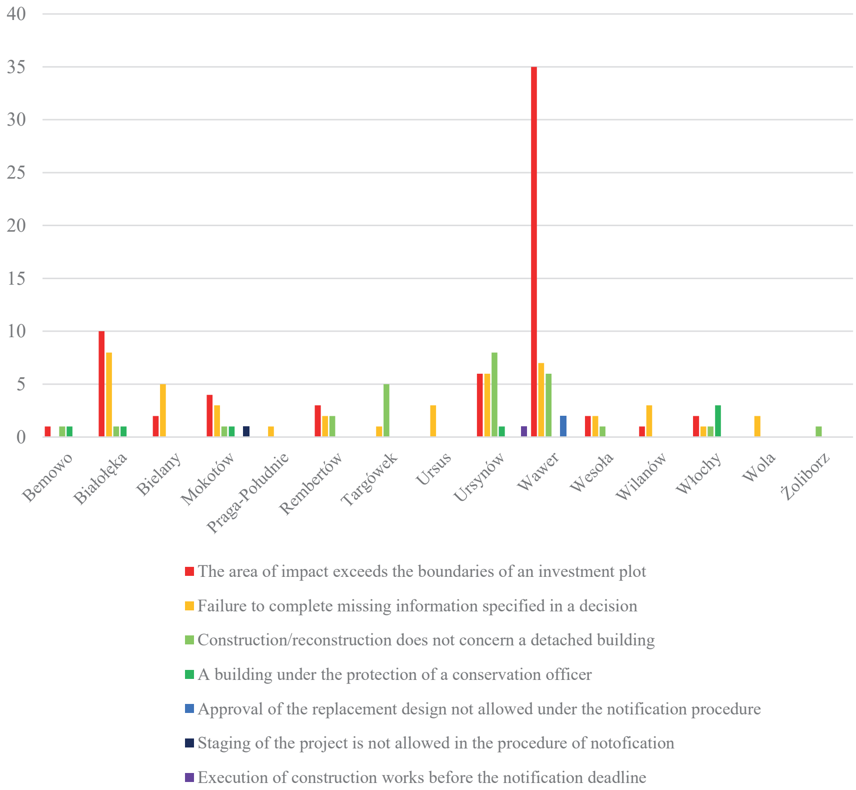

Fig. 4. Reasons for objections to notifications for detached single-family dwellings submitted between 28 June 2015 and 28 June 2018 in individual districts of the City of Warsaw. *Source: authors' own study*

Table 4 summarises the reasons for objections to notifications in the whole city.

Table 4. Reasons for objections to notifications of detached single-family residential buildings submitted between 28 June 2015 and 28 June 2018 in the Capital City of Warsaw. *Source: authors' own study*

Reason for objection	Number
Construction/reconstruction does not concern a detached building	27
A building under the protection of a conservation officer	7
Staging of the project is not allowed in the procedure of notification	1
Failure to complete missing information specified in a decision	44
The area of impact exceeds the boundaries of an investment plot	66
Execution of construction works before the notification deadline	1
Approval of the replacement design not allowed under the notification procedure	2
Total	148

The presented data enable answering the auxiliary research question AQ3: what was the most frequent reason for filing objections to notifications? The most common reason for objections to notifications of construction of detached single-family residential buildings in the period from 28 June 2015 to 28 June 2018 in the capital city of Warsaw was the impact zone of a designed building exceeding the boundaries of an investment plot. In 44% of the decisions subject to examination, an architecture and construction administration body (after analysing an investment project presented in the design) disagreed with a designer, finding that the area of impact of the building was not enclosed within the boundaries of a plot on which it was designed. A large share among analysed objections were also those, which were issued due to failure to remedy indicated irregularities within the time specified by the administrative body (Fig. 5). It is worth noting that such a situation occurs, if after checking the application submitted together with the architecture-construction design, the authority finds a violation of regulations. In such case, the authority calls on the investor to remove the irregularities, adjusting the deadline to the nature and scope of the listed deficiencies. In the notification procedure, the provisions on general administrative proceedings do not apply, so if there are difficulties in submitting the required documentation, the investor cannot request a suspension of the proceedings.

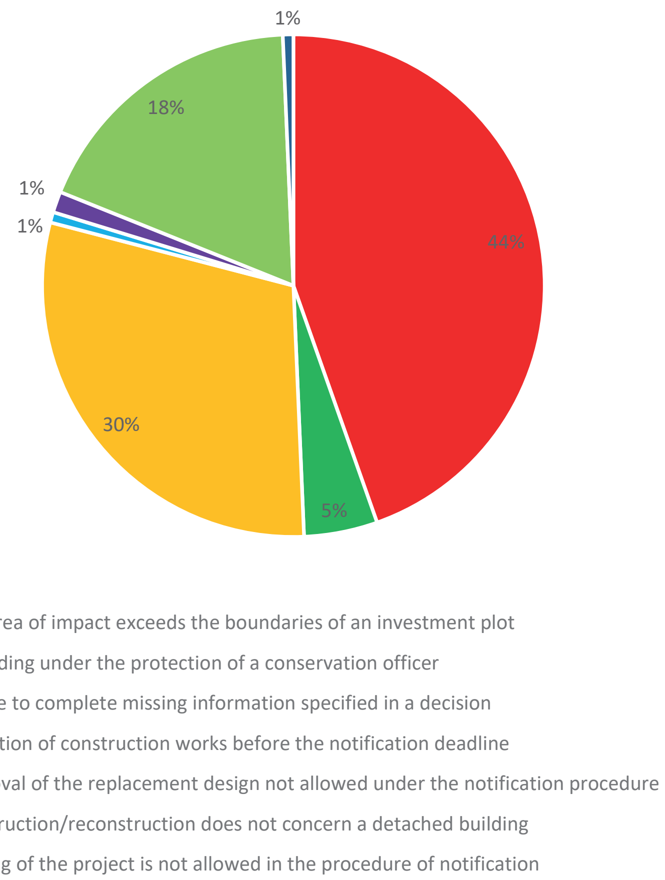

Fig. 5. Reasons for objections to notifications of detached single-family residential buildings submitted between 28 June 2015 and 28 June 2018 in the Capital City of Warsaw (in %). *Source: authors' own study*

5.3. Comparison of construction notifications and building permits in selected districts

To give more accurate picture of the scale and possible benefits of using the notification procedure for construction of detached single-family dwellings, a comparison was made of the data in relation to building permits. The comparison was made for two districts: the left-bank Bielany district and the right-bank Białołęka district (Fig. 6), for the period from 28 June 2015 to 28 June 2018. Data for the period of 1 January 2016 – 28 June 2018 are taken from the search engine of the Main Construction Supervision Office [19]. Data for the period from 28 June 2015 to 31 December 2016 were obtained directly from the Bielany and Białołęka district offices.

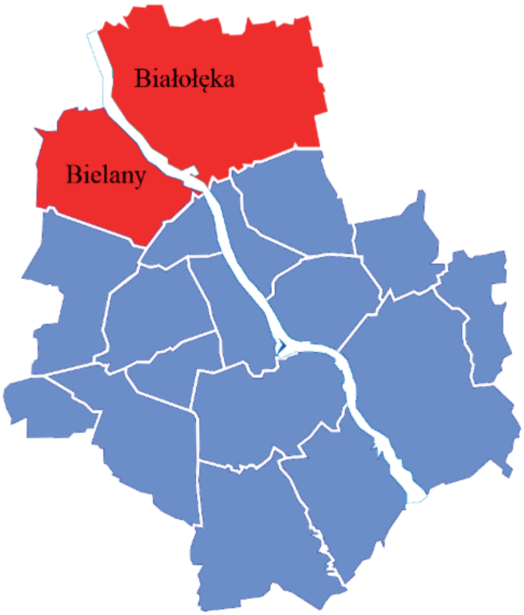

Fig. 6. Location of Bielany and Białołęka districts within the area of the Capital City of Warsaw. Source: authors' own study

In Bielany district, during the same time investors used the notification procedure much less frequently than the traditional building permit procedure. During the period of 3 years, the district office received only 16 notifications regarding construction of single-family residential buildings, while the number of applications for a building permit was almost 7 times higher, i.e. 108 (Fig. 7).

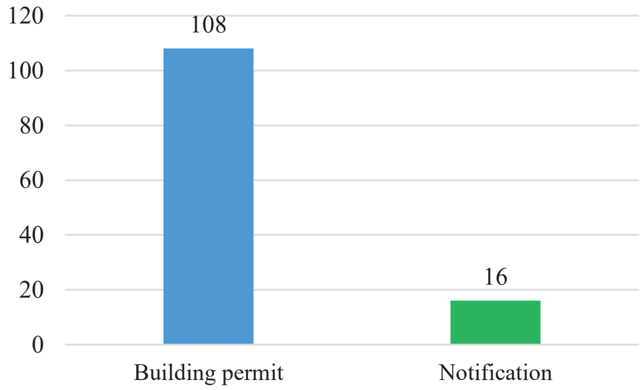

Fig. 7. Comparison of the number of notifications and applications for building permits for construction of detached single-family residential buildings in Bielany district between 28 June 2015 and 28 June 2018.
Source: authors' own study

In the analysed period in Białołęka district there is also a noticeable difference in the number of notifications and applications for building permits for construction of detached single-family houses. During the period of 3 years, as many as 338 investors used the building permit procedure, while only 110 used the notification procedure (Fig. 8).

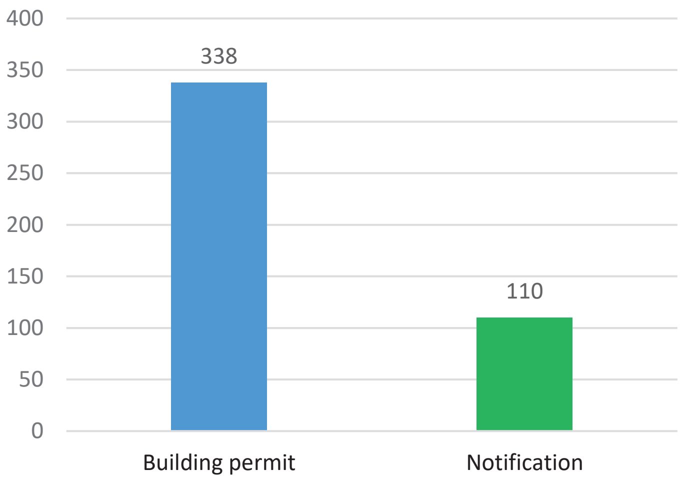

Fig. 8. Comparison of the number of notifications and building permits for construction of detached single-family residential buildings in Białołęka district between 28 June 2015 and 28 June 2018.
Source: authors' own study

Based on the data presented, it is possible to conclude that in both districts there is a tendency to carry out developments based on a building permit (auxiliary question AQ4).

5.4. Duration of procedure in Bielany and Białołęka districts of Warsaw

Another aspect analysed was the duration of procedures. The regulations explicitly indicate impassable time limits, however, in specific situations they may be extended or shortened. In the period of 3 years that was studied, the legal regulations concerning processing of notifications were subject to changes. From June 2015 to January 2017, a deadline of 30 days applied. Since January 2017, the period has been shortened and, to date, the notification must be processed in no more than 21 days.

The proceedings concerning a building permit cannot last longer than 65 days, however, this period does not include deadlines stipulated by law to perform certain actions, periods when proceedings are suspended, and periods of delays caused by a fault of a party or reasons beyond the control of the authority. Such situations include, among the others, the time from the moment of imposing on the investor, by way of a decision, the obligation to complete the construction designs to the moment of submitting the corrected documentation.

In order to provide a clear picture of the duration of both procedures in Bielany and Białołęka districts, the periods were divided as follows: from 1 to 30 days, from 31 to 60 days, from 61 to 90 days, and more than 91 days. For the purpose of research only the data related to the situation when the investor receives a positive decision for himself, i.e. the application is accepted with a tacit consent or a building permit is issued, were included. The results of the research illustrate how long the procedure allowing for commencement of construction works based on a notification and a building permit actually took.

In the analysed period almost all applications in Bielany district were examined in less than 30 days. Only one application received the tacit approval after a period of two months, which was probably due to the obligation on the investor to supplement the irregularities in the project documentation submitted with the application, or formal deficiencies in the application itself (Fig. 9).

Proceedings for granting a building permit in Bielany district, which ended with a positive decision in less than 30 days, accounted for only 5%. Comparatively most applications were processed within a period between 31 and 60 days. The longest, i.e., more than three months, took the proceedings concerning 21% of the permits (Fig. 9).

The data presented shows that investors in Bielany district who opted for the notification procedure in the period between 28 June 2015 and 28 June 2018 were able to start construction much faster than investors who have decided to apply for building permit.

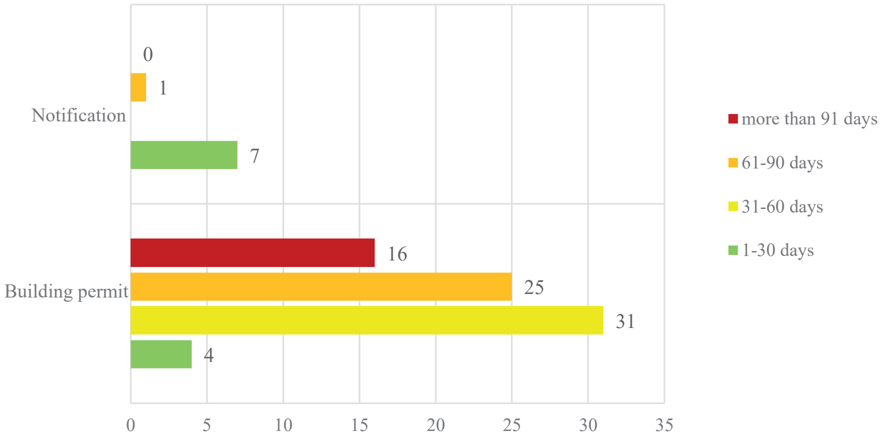

Fig. 9. Duration of the procedure for accepting notifications and obtaining building permits for detached single-family residential buildings in Bielany district in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

Unlike in Bielany district, in Białołęka district notifications were most often processed within one to two months. In the period not exceeding 30 days, only 14% of the applications received tacit approval (Fig. 10). In most cases investors in Białołęka were obliged to complete missing elements in the notification or irregularities in the architectural documentation, which resulted in lengthening the procedure.

As in the case of notifications, investors in Białołęka had to wait longer to obtain a building permit than those in Bielany. Only 4% of applicants obtained a building permit in less than one month, 26% of them waited more than a month, and 32% more than 2 months (Fig. 10). Comparatively most investors received a building permit only after about 3 months. The prolongation of the proceedings could be caused by the necessity to fill in irregularities, obtaining exclusion of land from agricultural production, periods of suspension of proceedings or e.g. the obligation to agree the investment with a conservator of monuments.

The presented data show that in Białołęka district, investors choosing the notification procedure could most often start construction work after 31-60 days from submission of the application. When choosing the traditional form of the building permit, most investors had to wait more than 60 days. In summary, in the period between 28 June 2015 and 28 June 2018, the more favourable (in terms of waiting time) procedure for Białołęka investors was the construction notification.

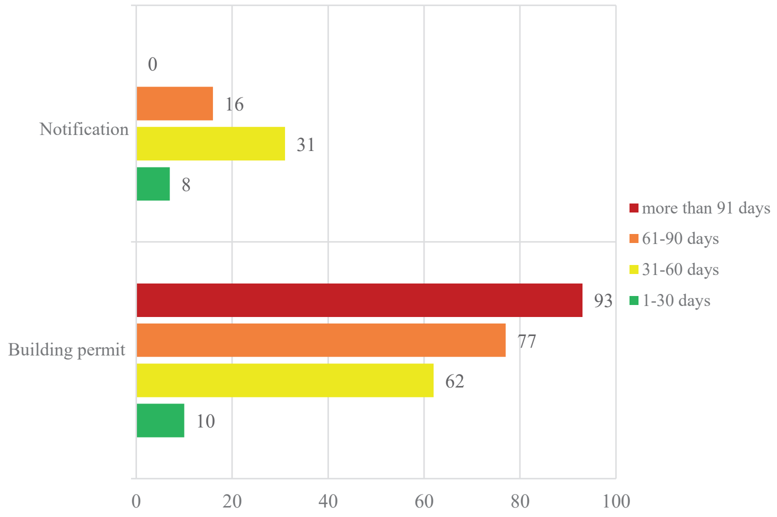

Fig. 10. Duration of the procedure for accepting notifications and obtaining building permits for detached single-family residential buildings in Białołęka district in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

Based on the above data, it is possible to answer the auxiliary research question AQ5 in such a way that, within the examined scope, the construction notification procedure enabled faster commencement of construction of detached single-family residential buildings.

5.5. The outcome of the procedure in Bielany and Białołęka districts

According to the current regulations, the notification procedure may end with a tacit consent of the authority, filing of an objection by way of a decision or withdrawal (marked on the charts (Fig. 11 and 12) and in the tables 5 and 6 as "other"). In the case of the building permit, the situation is slightly more complicated as we are dealing here with administrative proceedings, regulated not only by the provisions of the Construction Law [1], but above all, by the Code of Administrative Procedure [24]. In the analysed data the following possibilities were noted: issuance of the positive decision, issuance of the negative decision, and (marked on the charts (Fig. 11 and 12) and in the Tables 5 and 6 as "other") leaving the application unconsidered, issuance of a discontinuance decision, and suspension of proceedings. The data presented in the form of the following Tables 5 and 6 and charts (Fig. 11 and 12) allow for obtaining information which of the procedures more often ended with a positive resolution for the investors.

Table 5. Completion of construction notification procedures and proceedings to obtain building permits for detached single-family residential buildings in Bielany district in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

Building permit		Notification	
Positive decision	76	Tacit consent	8
Negative decision	8	Objection	7
Other	24	Other	1
Total	108	Total	16

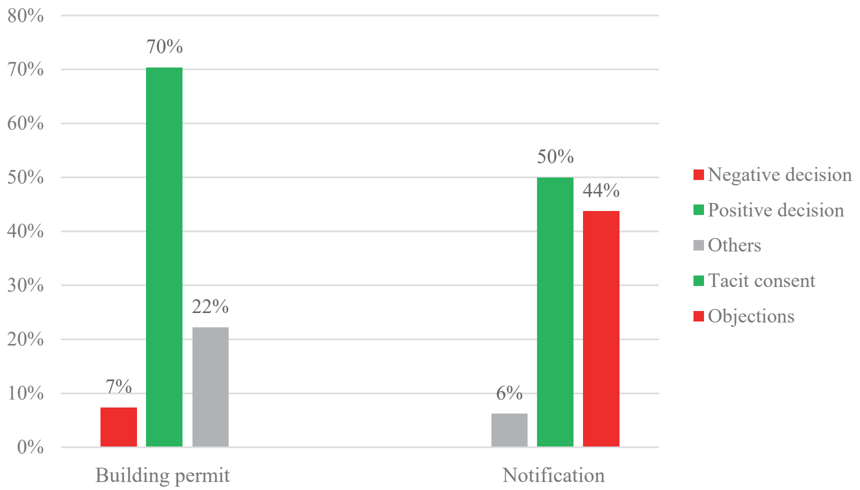

Fig. 11. Outcome of proceedings of construction notifications and proceedings to obtain building permits for detached single-family residential buildings in Bielany district in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

In the Bielany district, only half of the notifications for the construction of detached single-family residential buildings received by the office between 28 June 2015 and 28 June 2018 were accepted by a tacit consent. Objections were raised against 44% of the notifications. Proceedings for obtaining a building permit in Bielany district resulted in a positive decision in 70% of the cases. Only 7% of investors received a negative decision (Fig. 11).

Having compared the above data, it can be concluded that in Bielany district investors who decided to build a detached single-family house based on a building permit were more often granted a positive decision than in case of submitting a construction notification.

Table 6. Completion of procedures for construction notifications and proceedings for obtaining building permits for detached single-family residential buildings in Białołęka district in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

Building permit		Notification	
Positive decision	242	Tacit consent	55
Negative decision	19	Objection	20
Other	77	Other	35
Total	338	Total	110

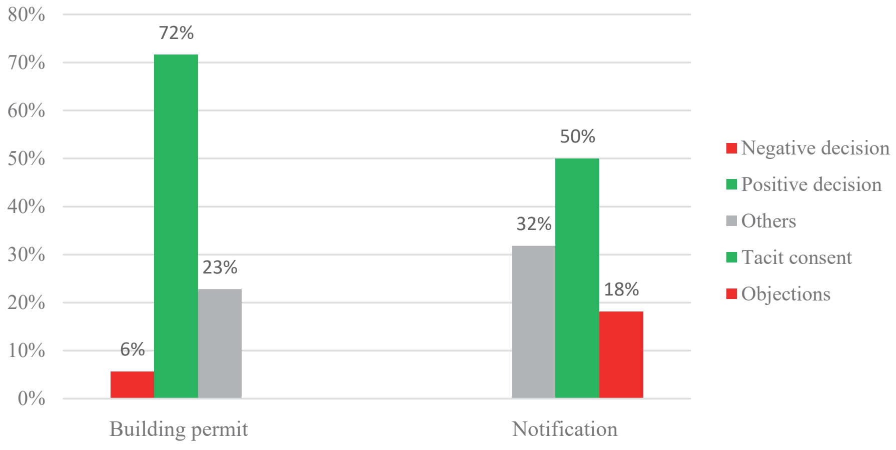

Fig. 12. Outcome of proceedings to obtain permits for the construction of detached single-family residential buildings in Białołęka district in the period from 28 June 2015 to 28 June 2018. *Source: authors' own study*

In Białołęka district (similarly to Bielany district) the procedure of submitting notifications on construction of detached single-family houses in the analysed period resulted in a tacit consent of the authority only in 50% of the cases. Objections were received by 18% of investors. The proceedings to obtain a building permit in Białołęka district resulted in a positive decision in 72% of the cases. Only 6% of investors received a negative decision (Fig. 12).

The collected data allow the conclusion that both in Bielany and Białołęka districts the building permit procedure much more often concluded with a positive decision for the investor (auxiliary question AQ6).

5. Summary and conclusion

Basing on the conducted research, it can be concluded that among the analysed indicators, the only benefit brought to investors by the amendment to the provisions of the Construction Law of 20 February 2015 [3], was the possibility of faster commencement of construction of detached single-family residential buildings (AQ5), which, however, due to the low interest in the procedure (AQ4) and the low rate of positive outcome (AQ2), provided advantages to a negligible group of investors. The amendment did not result in a reduction of the required formalities (AQ1). Expectations that the simplified notification procedure would be used to large numbers turned out to be unjustified. Investors, who had already decided to submit notifications in the area of the capital city of Warsaw, obtained silent consent only in 47% of the cases. Therefore, most of them, after receiving a decision on objection or withdrawal of notification, were forced to reapply, which obviously involved loss of time, contrary to assumptions of the amended act in this scope.

In both surveyed Warsaw districts, the investors used the notification procedure much less frequently than the traditional building permit procedure (AQ4). In Bielany district, only 16 notifications were submitted while the number of applications for building permits was as high as 108. In Białołęka district, 338 investors used the building permit procedure, while only 110 made use of notifications.

In the analysed districts, positive decisions were much more frequent among investors who decided to go for the building permit procedure (AQ6). In both Bielany and Białołęka districts, only 50% of the submitted notifications received a tacit approval of an architecture-construction administrative body, while about 70% of those applying for a building permit obtained a positive decision. The most common reason for objection to a notification for the construction of detached single-family residential buildings in the period from 28 June 2015 to 28 June 2018 in the area of the capital city of Warsaw was the area of impact of the designed building exceeding the boundaries of a development plot.

Basing on the results of the conducted research, it can be concluded that the amendment to the provisions of the Construction Law Act, coming into force on 28 June 2015, which involves enabling construction of detached single-family residential buildings on the basis of the notification, has not contributed to the improvement of the development process on the territory of the Capital City of Warsaw (GQ). Therefore, the results of this study provide a significant premise for the conclusion that the assumed objectives of the amendment to the Construction Law made on 20 February 2015 have not been achieved [3].

References

[1] *The Act of 7 July 1994, The Construction Law*, Warszawa, Journal of Laws 2018, item 1202 as amended.

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Orginal Article

Forgotten shelters of Kłodzko Land. On architecture inspired by the local building tradition

Jacek Suchodolski

Chair of Architecture and Visual Arts; Faculty of Architecture; Wrocław University of Science and Technology; ul. B. Prusa 53/55, Wrocław, Poland;
jacek.suchodolski@pwr.edu.pl *0000-0002-4767-6169*

Abstract: The article addresses the problem of the decline in the number of tourist facilities with outstanding features of regional architecture, built before 1945 in Kłodzko Land. Their destruction is an irreparable loss for the cultural heritage of the described region. Usually designed in the spirit of the local building tradition – born out of centuries of experience of the people living here – hostels, inns and taverns were a characteristic, regional distinguishing feature of the landscape of Kłodzko Land. Meanwhile, the new architecture of objects related to tourism, built after the end of the Second World War, most often does not refer to the characteristic forms and structures of local buildings. The article stresses the need to put an end to the often deliberate practice of destroying old pre-war buildings and to draw the attention of architects working today to the importance of continuing local, regional forms in the emerging tourist facilities.

Keywords: architecture, shelters, Kłodzko Land

1. Introduction

Kłodzko Land, partially covering the areas of the Central and Eastern Sudetes, is certainly one of the most diverse and interesting regions in the Sudetes in terms of tourist attractiveness. The reasons for that are its history, a significant number of architectural monuments, including wooden buildings in the regional style, and the landscape diversified by the ranges of the Stołowe, Orlické, Bystrzyckie, Bardzkie, Bialskie and Golden Mountains, as well as the Śnieżnik Mountains, the Kłodzko Valley and the Upper Nysa Rift. What nature created here in the form of an undoubtedly attractive landscape has been used by man for centuries, i.a. in tourism: in developing new maps, setting out hiking trails, buildings shelters, inns and viewpoints.

The second half of the nineteenth century brought a lot of investments in the Sudetes, related to the expansion of railway routes and roadways accompanying the mining and textile industry emerging here, as well as glassworks, porcelain factories and other types of production. This had a major impact on the development of tourism, which also became one of the profitable branches of the economy. A more important and clearly visible element of tourism development, which also constitutes a form of its architectural expression, were the emerging shelters and other tourist facilities, more and more of which were built on mountain slopes and in valleys in the Sudetes, and thus in Kłodzko Land, providing travellers with accommodation and rest.

Unfortunately, the period of development of these lands and the expansion of tourist facilities in the Sudetes was interrupted in 1945, after the borders were changed. Lower Silesia became a part of Poland, and settlers from various parts of the former Commonwealth of Poland came to replace the current German population; however, they were not usually familiar with the specificity of farming in the mountains. To make matters worse, Poland found itself in the zone of Soviet influence, which meant that a command-and-distribution economy was established, which is a denial of logical and established principles in economics. Moreover, uncertainty prevailed among settlers whether the decision to annex the Western Territories to Poland would last or not. It was often used by the authorities as leverage in the event of social unrest. All these factors did not favour stabilisation, especially in the initial period after the end of World War II. As a consequence, many tourist and leisure facilities were devastated and liquidated, including those with significant value of the architectural and regional features they represented.

2. Aim of the study

The aim of the study is to restore and preserve the memory about those tourist shelters which had an interesting regional form and constituted an important part of the cultural landscape of Kłodzko Land before 1945. These buildings should become an inspiration for contemporary architects in order to restore the cultural continuity of this region and to create new architecture, enriched with traditional elements. The current article presents and publicises this problem in an attempt to halt the process of degradation, which consists in decapitalising and then demolishing the objects from before 1945. It should be the task of institutions established for this purpose, mainly the Provincial Heritage Monuments Protection Office in Wrocław, because these objects are often valuable examples of old, unique work of local builders. The above-mentioned examples are only a fragment of what was irretrievably lost in Kłodzko Land after the end of the war and in later years. This problem concerns the entire range of the Sudetes on the Polish side of these mountains.

3. Tourist and sport resorts in Kłodzko Land

Over the past centuries, three main centres of tourism and winter sports were formed in Kłodzko Land, in which most of the buildings with recreational and tourist functions were concentrated, including shelters, mountain inns and taverns. These include the Śnieżnik Mountains, whose name is derived from the highest mountain in the former Kłodzko County –1425 m above sea level – along with summer resorts and famous winter resorts such as Międzygórze and Sienna with the ski resort in Czarna Góra, and Jodłów, Potoczek or Goworów [18], situated slightly away from Śnieżnik. The following one is Masyw Orlicy – 1084 m, located in the Orlické Mountains – with Zieleniec, Kozia Hala, Graniczna and Podgórze, which are now parts of Duszniki-Zdrój [17]. The third mountain massif, whose first ascent, in 1790, is one of the earliest known, [13], [19], is Szczeliniec Wielki (919 m) located in the Stołowe Mountains, with the adjacent Karłów, Karłówko and Pasterka.

In addition to the main resorts, there were also smaller ones, in which tourist and recreational architecture was constructed, including well-known buildings [15]. Among others, towns on the Dzika Orlica River should be mentioned here: Lasówka, Piaskowice, Mostowice, Rudawa, Poniatów, Niemiów and Lesica. Sudeten huts with an interesting regional form [17], [24], [25] were also located in Spalona, Wójtowice, Młoty, Biała Woda in the Bystrzyckie Mountains or the Puchaczowska Pass separating the Śnieżnik Mountains from the Krowiarki Mountains. Before 1945, in the above-mentioned resorts and individual towns, as well as in particularly attractive places, such as passes or summits in the mountains, mountain shelters, hotels and mountain inns formed a well-organised system of to urist and recreational facilities, which suffered significant degradation after the Second World War. Places that used to be densely populated became deserted; where buildings once stood, hills covered with grass and trees are now seen – these can be easily identified and stimulate the viewer's imagination even stronger. Out of 56 shelters in Kłodzko Land (Fig. 1) which existed before 1945, as many as 43 are no longer in operation and only thirteen have a tourist function. After the war, only three new facilities of this type were built [4], [13], [16], [25].

4. Regional architecture as a source of inspiration for the form and architectural details of shelters and inns in Kłodzko Land

As in the neighbouring ranges of the Sudetes on the Silesian and Czech sides, characteristic features of the local wooden architecture also developed over the centuries in Kłodzko Land. The fact that the Kłodzko County used to belong to the Czech Crown for many centuries is also apparent in the form of its wooden architecture, largely resembling its Czech versions [1], [9], [13], [23]. The most common object of regional origin on both sides of the border is a one-storey building with a log structure of wooden walls and a steep gable roof with a slope of 45-55 degrees. At first roofs were covered with straw or reed thatch, then with wood shingles, less often with phyllite slate. Even before the First World War, in some buildings sheet metal was nailed to shingle roofing through intermediary ridge beams as an external covering, which increased fire resistance, but changed the character of the whole [9], [23] (Fig. 2).

Fig. 1. Location of shelters in Kłodzko Land (points: green – new shelters, built after 1945; black – non-existent shelters, shelters that perform a different function; red – shelters in operation today, built after 1945; lines: red – Polish and Czechia state border; rose – poviat (district) border). *Author's study*

Fig. 2. The village of Młoty in the Bystrzyckie Mountains. A rural residential building with log walls, a gabled roof covered with sheet metal, with a slope of 45 degrees. *Photo by Jacek Suchodolski 2005*

Among the varieties of regional architecture, there are also single-storey wooden houses with an attic storeroom, i.e. a single-storey extension in the form of a dormer (extending beyond the perimeter of the building), supported on posts. Known in Polish as wyżka, pięterko or ryzalit wejściowy, it was originally used for storing hay, and over time it became an additional living space for holidaymakers visiting these areas [23] (Fig. 3).

Buildings in the region had gable roofs or roofs with a mansard structure. Buildings with log walls and mansard roofs are also a distinctive group among wooden architecture. Larger in volume, they often had the above-mentioned attic storerooms and served as taverns, shelters and inns. These roofs were mostly covered with diamond-shaped eternit or sheet metal tiles (Fig. 4).

Fig. 3. Pstrążna – an open-air museum of wooden buildings. The so-called Zajazd (Inn) moved from Szalejów Dolny (probably built in the first half of the nineteenth century). The modest form of a single-storey house with log walls is diversified by an attic storeroom, i.e. an extension protruding beyond the eaves, supported on posts, in which there were rooms for tourists. *Photo by Jacek Suchodolski 2015*

Fig. 4. Orlica shelter in Zieleniec, built in 1878. The building with log walls, covered from the outside with vertically-laid boards and with a mansard roof with dormers, also has an attic storeroom in the form of an extension, supported by the masonry walls of the ground floor. There was a second tavern near Orlica (*Gasthaus zur Mense*), of a similar shape and structure, but it was pulled down in the 1960s. *Photo by Jacek Suchodolski 2009*

An important distinguishing feature of the regional architecture is also the architectural detail which gives it a distinct character and a kind of charm. The most characteristic elements include the arrangement of boards on the side and gable walls, the size and form of window openings and the shape of their trims, door lintels, types of structural joints in the walls and the most common types of roofing. It should be emphasised here that the main feature of regional houses were their proportions – the height of the walls of the ground floor in relation to the height of the roof (ranging from 1:2 or 1:2.5 to 1:3). Buildings intended for tourist purposes, put up in the mountains in the described region, were characterised by form and detail mostly based on regional motifs, and houses that were designed in isolation from local tradition were rare [9], [23].

5. Non-existent tourist facilities with regional features

The places where the largest number of tourism-related facilities, i.e. inns and shelters, ceased to exist after 1945, certainly include Zieleniec (*Grunwald*) in the Orlické Mountains, which is currently a part of Duszniki-Zdrój. Initially a poor mountain village, founded in 1719, over time it became one of the better known winter resorts with excellent conditions for skiing, as well as for hiking and cycling in the summer, thanks to extensive routes on the Polish and Czech side of the border [14], [25], [26]. Even before the First World War, when it was inhabited by almost 900 people, it boasted many well-known shelters and inns located on the slopes of Šerlich and Orlica, forming small complexes of buildings, scattered over the mountainous terrain. The most famous ones, now non-existent, were *Hindenburgbaude*, *Hohe Mense – Baude*, *Gasthaus zur Mense* (later called *Ritterbaude*) and *Berghof Rübartsch* (formerly called *Reinerzer "Ski – Hütte"*), or *Mensehorst am Goldenen Stolen*. Also in the central part of Zieleniec there was an inn that gained the rank of a shelter – *Grunwaldbaude*, whose name was changed in the 1930s to *Adlerbaude*. In 1948, *Hindenburgbaude*, built in 1928, ceased to exist. The author of this successful project was Konrad Goebel, a member of GGV and the architect of the city of Kłodzko. GGV was also the investor. Located at an altitude of 975 m above sea level, at the foot of Orlica, it was characterised by a compact form, inspired by regional architecture. Wood was the basic building material here, both for construction and finishing – apart from the basement walls and fragments of the ground floor made of stone. The skilful combination of the texture of wooden walls with stone elements in the entrance area emphasised the regional character of the building. The huge, steep, gable roof with pediments, covered with shingles, certainly stood out in the body of the shelter. The plan for the functions of the shelter also deserved praise, especially its ground floor with rooms intended for guests, where the designer managed to create interiors with an individual character. Decorated in a regional style with wooden carvings, they gave a sense of solidity and security. There was a fuel dispenser next to the shelter, as it could be accessed by car. Unfortunately, this building burned down in November 1948, probably as a result of a boiler room failure [14], [22] (Figs. 5-7).

Fig. 5. Zieleniec (*Grunwald*). *Hindenburgbaude* shelter. North-east façade. The interwar period. *Source: Jacek Suchodolski's collection*

Fig. 6. Zieleniec. Hindenburgbaude shelter. North-west façade. The interwar period. *Source: the collection of the Museum of Kłodzko Land in Kłodzko*

Fig. 7. Zieleniec. *Hindenburgbaude* shelter. The interior of the dining room. The interwar period. *Source: the collection of the Museum of Kłodzko Land in Kłodzko*

This shelter, as it should be emphasised once again, was one of the most beautiful in the Sudetes, alongside *Samotnia* (*Kleine Teichbaude*) on Mały Staw in the Karkonosze, and *Lucyna* (*Max Müllerbaude*) in the Owl Mountains, which makes its loss even more severe. The second shelter – *Hohe Mense-Baude* (1084 m) – was built gradually, thanks to the efforts of its owner Heinrich Rübartsch, just below the summit of Orlica, at the Austrian-Prussian border. It was characterised by a simple form, and it consisted of two buildings with log and masonry construction, covered with steep gable roofs, with a wooden observation tower next to it (Fig. 8). They provided rest and accommodation for 10 people in bedrooms and 25 places in a shared room. The main advantage of this place, it seems, was the surrounding nature as well as peace and quiet, which was so valued – especially at the end of his life – by Heinrich Rübartsch, the precursor of skiing in Zieleniec, who contributed to the development and significance of this place in the Sudetes as a tourist resort. When he left the world of the living in 1930, he left behind an equally valuable thing: a memory of a person who never refused to help anyone, sometimes in extreme mountain conditions [24], [26].

Fig. 8. Zieleniec. *Hohe Mensee-Baude* shelter. The interwar period. *Source: www.ansichtskarten.de*

The first shelter building was constructed in 1883, the second in the first years of the twentieth century. The shelter was demolished in the 1940s. The next building, *Gasthaus zur Mense* (872 m above sea level), is also associated with Rübartsch, because this was where he began his work as an innkeeper. Located opposite the main entrance to the church, the *Gasthaus* building was one of the oldest in Zieleniec (apart from the wooden church demolished at the beginning of the twentieth century), and its form referred to the regional tradition of wooden architecture of Kłodzko Land. It offered 35 beds in 15 rooms. *Gasthaus* changed its name to *Ritterbaude* after it was taken over by a new owner. This one-storey building, covered with a mansard roof with a pediment and an attic storeroom, was one of many objects of this type found on the Kłodzko-Orlické border, as well as in other parts of the region. To a large extent, it resembled the *Orlica* shelter from 1878 – which still stands next to it – in terms of form and detail, but it was probably older. Rübartsch eventually left *Gasthaus zur Mense* in 1903, when he moved permanently to his *Hohe Mense-Baude* shelter at the top of Orlica. After the war, the inn building fulfilled auxiliary functions for some time as *Orlica III*. *Gasthaus zur Mense* was demolished in the 1960s [24]. Another shelter – *Berghof Rübartsch* (975 m above sea level) – situated on steeply sloping ground, was a relatively small facility, but had visible regional influences in its architecture. It provided 25 beds. The original name of this Orlické hut on the slope of Šerlich Mountain was *Reinerzer "Ski Hütte"*. After 1945, the building ceased to exist

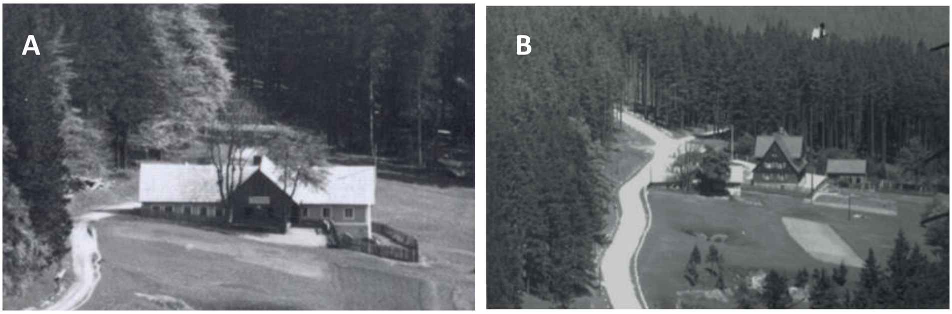

Fig. 9. *Mensehorst am Goldenen Stollen* shelter: (A) – the first building from 1927, (B) the shelter after its expansion (after 1936). *Source: Andrzej Wziątek's collection*

Mensehorst am goldenen Stollen youth hostel, located about two kilometres from Zieleniec, by the Orlicka Road, was built in 1927 as a small one-storey building with a steep gable roof (Fig. 8A). It had 23 rooms with 40 beds. In 1936, a second, also one-storey building (Fig. 8B) was erected on the plot of the existing facility, with architecture reminiscent with its form of border guard buildings in many Sudeten towns along the border (e.g. in Szklarska Poręba, on the Okraj Pass, in Jarkowice, Pasterka, Zieleniec, Lasówka, Rudawa, Lesica, Międzylesie). In the 1960s, *Mensehorst am Goldenen Stollen* was demolished.

Fig. 10. Zieleniec. In the foreground, on the right, the *Grunwaldbaude* shelter, later known as *Adlerbaude*. A characteristic element in the body of the shelter was the observation porch. The interwar period. *Source: Andrzej Wziątek's collection*

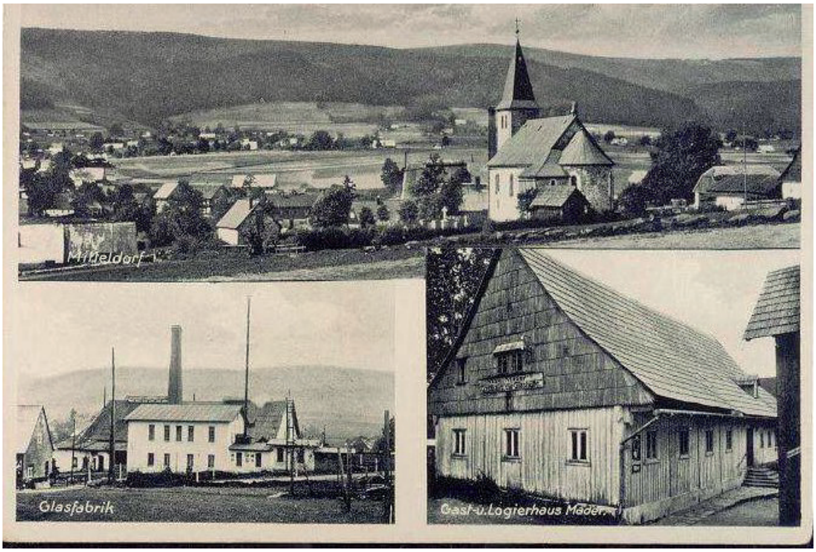

Fig. 11. Lasówka (*Kaiserswalde*). Three-field postcard, the interwar period. Bottom right corner: *Max Mader Gasthaus*. This object, which had probably been built in the mid-nineteenth century, ceased to exist in 1954. *Source: www.klodzkikatek.pl*

The last shelter in Zieleniec from this group, located in the central part of the town, which no longer exists today, was *Grunwaldbaude* (900 m above sea level), called *Adlerbaude* since 1934. It had 16 beds. Initially, it was an inn, which then became a shelter (Fig. 10). A porch was added in the 1930s, enlarging this object and giving it a tourist character. The architecture of this Sudeten hut, though it did include some regional elements in its architectural details, did not stand out as anything special. However, the volume of this object was adapted to the surrounding buildings and did not cause visible disharmony, which, unfortunately, is now often seen in the expanding Zieleniec. After the war, in the 1950s, *Adlerbaude* was renamed *Janosikowa Hala*, which was then taken over by the Wrocław University of Physical Education and demolished. All the above-mentioned shelters – perhaps the last one the least – had a common quality: namely, their architecture was strongly saturated with local and regional features, which, together with their location in the mountainous terrain (which made them harmoniously fit in with the surrounding landscape), made the panorama of Zieleniec uncluttered and clear. In the neighbouring Lasówka (*Kaiserswalde*), known before the war for a crystal glassworks and a glass cutting plant, *Max Mader Gasthaus* (Fig. 11) shelter/inn – a one-storey, wooden building situated next to the church – was demolished in the 1950s. Its form and detail clearly attested to its regional origins, which were evident in such features as a steep gable roof covered with shingles, log walls of the ground floor, covered with vertically-laid boards, and the gable wall covered with shingles. Small window openings with trims represented the modest architectural details of Mader's *Gasthaus*. As befits the regional Sudeten structures, the ratio of the height of the ground floor walls to the roof height was 1:2. [25] (Fig. 11).

Fig. 12. Lasówka (*Kaiserswalde*), *Erlitztalbaude* shelter, the interwar period. *Source: Jacek Suchodolski's collection*

Fig. 13. Lasówka (*Kaiserswalde*). Former *Erlitztalbaude* shelter, now a residential building. The metal sheet on the roof was nailed to the original shingle covering through ridge beams. *Photo by Jacek Suchodolski 2005*

The second shelter, *Erlitztalbaude* (Fig. 11, 12), located near the Mostowy Stream, which also has a classic, regional form, has survived to our times, becoming a residential building after 1945. Initially, it housed the *Stumpfgasthaus* inn, and in the 1930s it became a shelter. A characteristic element in the body of the building is the raised roof slope (*Frakdach*), intended to provide larger cubic capacity in the attic. This was often used in facilities intended for tourist and leisure purposes. This building – like the previous one – represents one of the varieties of the local regional architecture, whose main features include log walls of the ground floor, covered with vertically-laid boards, a steep gable roof and small window openings with trims. The proportions of the ground floor walls to the roof height are 1:2. The places from which several inns and shelters also disappeared after 1945 and to which the tourist industry has not returned since were the Waldhufendorf-type village of Lesica (*Freiwalde*) on the Jelonik stream and the nearby settlement Czerwony Strumień (*Rothflössel*), located on the stream of the same name, which is, as the former, a tributary of the Dzika Orlica. The hamlet of Lesica, *Hirschenhäuser*, was characterised by particular landscape values, and it had two inns in the second half of the nineteenth century. One of them was transformed into *Hirschenhaus* shelter (650 m above sea level) with a wooden structure. Above the ground floor with a log wall there was a high, steep roof covered with shingles, which also protected the gable wall against atmospheric influences. The building was representative of one of the varieties of regional construction, often found in Kłodzko Land. After 1945, the shelter ceased to exist. Regional features were also visible in the case of the facility located in Czerwony Strumień, namely *Gruppenbaude* shelter (which was an SS resort during the war), whose ruins are located at the foot of Bochniak Mountain[1]. Among the well-known shelters with regional architectural features which have not survived to our times, *Baude Carl Rast* (680 m above sea level) can be mentioned, located near the also non-existent today waterfalls Pośny in the Table Mountains, in Karłówek (*Klein Karlsberg*), which disappeared after the war. The inn functioning here was transformed into a shelter in the mid-nineteenth century, and then expanded in the first years of the twentieth century. In two wooden buildings, one of which had an attic storeroom, there were 14 beds. After the war, when Pośna waterfalls ceased to exist, which was caused by the creation of the artificial lake in Radków, the shelter fell into ruin. As in other mountain ranges in the tourist county of the Sudetes, there were also buildings in the Table Mountains that until 1945 served as shelters, such as *Rabenkoppenbaude* (721 m above sea level) in Dańczów, characterised by a classic regional form. After the war they became private residential buildings [25]. In the village of Biała Woda (*Weisswasser*), located near the Puchaczówka Pass, by the road connecting Bystrzyca Kłodzka, Lądek and Stronie Śląskie, a youth hostel *Jugendherberge Weisswasser* was built with over 100 beds; its architecture was modelled on regional motifs. After 1945, the shelter ceased to exist. A little above the pass, on the northern slope of Czarna Góra, by the road mentioned above, in the first half of the nineteenth century there was an inn called *Puhu Wirtshaus*, transformed at the beginning of the twentieth century into the *Puhu-Baude* shelter (899 m above sea level). (Fig. 14).

[1] Its ruins are marked on the tourist map: *Góry Bystrzyckie, Góry Orlickie*, scale 1:35 000, Wydawnictwo Compas, Cracow, catalogue number: 1473/2019 [7].

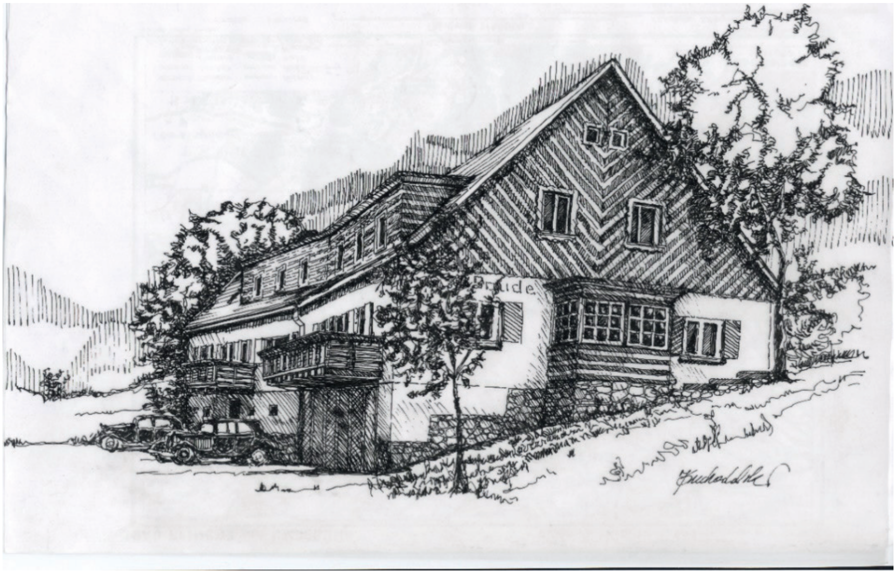

Fig. 14. The Puchaczówka Pass (899 m above sea level) separating the Śnieżnik Mountains from the Krowiarki Mountains. The *Puhu-Baude* shelter, the interwar period. *Drawing by Jacek Suchodolski* [17]

Along with the change of the inn into a shelter, it was expanded and its architecture was given a regional form. It had 17 beds in 14 rooms and a shared room. The wooden-brick building gained a compact body with a steep, gable roof with a long dormer. The gable walls were covered with boards arranged in a herringbone pattern, and the ground floor windows were fitted with shutters, which clearly referred to regional motifs. The interior of the shelter was in a rustic style, which was emphasised by the beam structure of the wooden ceiling. Similarly, tables and chairs were made of wood, and it was all complemented by a large tiled stove. White areas between the ceiling beams were covered with floral motifs. Porcelain plates decorated with local motifs hung on the walls, and under the ceiling there was a wooden candelabrum depicting a group of musicians, reminiscent in its form of the works of woodcarvers from the Cieplice school of crafts[2]. This shelter, which was very popular before the war, ceased to exist after 1945. Near Puhu-Baude, another small shelter was built in the interwar years – Schwarze-Berg-Häusel (900 m above sea level), located on the slope of Czarna Góra. An alpine garden was founded around it, the remains of which are still visible today. The building was crowned with a characteristic steep gable roof, giving it a somewhat "fairy-tale" character. Like the neighbouring shelter, Domek Czarnogórski was pulled down after 1945

2 In the School of Wood Carving in Cieplice near Jelenia Góra (*Holzschnitzschule Bad Warmbrunn*), founded in 1902, which educated both sculptors-artists and craftsmen, a characteristic style was born, inspired by the local folk tradition as well as that of south Tyrol. The school was animated by Cirillo Dell'Antonio (a teacher and later the principal of the school in Cieplice in 1920-1940). The works of the graduates of the school could be found throughout the Sudetes, often in the form of stylised images of groups of people that decorated information boards, signposts or the interiors of shelters [20].

6. Conclusion

The examples of non-existent shelters in Kłodzko Land described here reflect only a small scale of the problem which was and still is the devastation of the cultural environment after 1945 in these areas as well as in other parts of the Sudetes. Unfortunately, it is especially visible on the Silesian, i.e. Polish side of these mountains. The listed non-existent objects, distinguished by their regional architecture, were an inseparable component of the mountain landscape, currently very incomplete and often further damaged by the foreign form and an inadequate scale of the buildings being erected today, which does not contribute to restoring the cultural continuity of the region. Therefore, it is indispensable to provide professional and systematic conservation care and legal protection over the still existing wooden buildings of regional character, including tourist and recreational facilities, as well as compliance with the provisions contained in detailed land use plans. This has become exceptionally important in recent years, as the volume and form of buildings under construction that serve tourist functions are a contradiction of tradition and often common sense (examples are the *Gołębiewski Hotel* in Karpacz or the *Infinity* apartment building in Zieleniec, which is under construction, intended for around 1,000 people). Similar facilities are planned and if these intentions are not stopped by public opinion and competent authorities, the degradation process will deepen. According to the author, in order to restore former splendour and uniqueness to the cultural landscape of Kłodzko Land, one should consider recreating some former shelters and inns in their original locations. This would apply to objects with special aesthetic and regional values of their architecture, i.e. some of those referred to in the article. As it has already been stated, new facilities should incorporate solutions inspired by the local building tradition in their form and structure. Examples of such an approach are residential buildings and those with a tourist function, designed in Alpine areas in Germany, Austria, Switzerland or Italy. Thanks to the use of mainly wood and stone and modest architectural details, the buildings fit in well with the surrounding landscape, at the same time being a contemporary, creative complement to it and its continuation, i.e. they meet the assumptions that should also be implemented in the Kłodzko Region and other parts of the Sudetes in terms of shaping architecture.

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Orginal Article

Granulation of porous materials with phase change material (PCM)

Tomasz Bień

Faculty of Geology, Geophysics and Environmental Protection; AGH University of Science and Technology;
Al. Adama Mickiewicza 30, 30-059 Kraków;
Biko-Serwis sp. z o.o. sp.k., ul. Zakładowa 13, 26-052 Nowiny;
tomasz.bien@op.pl *0000-0001-9568-0288*

Abstract: The paper describes the research on the method of production of granulated phase-change materials (PCM) used in construction industry for the accumulation of thermal energy. As mineral materials for the granules preparation zeolite from fly ash Na-P1 and natural diatomite dust were used which were impregnated with paraffinic filtration waste and granulated using a combined granulation method. Obtained granules were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), nitrogen adsorption/desorption isotherm, and differential scanning calorimetry (DSC). Mechanical strength of the materials was determined in a "drop strength" test. Performed analyses revealed that mineral composition and micromorphology of the diatomite and zeolite granules were varied, with zeolite granules having higher mechanical strength.

Keywords: PCM, granulation, zeolite, heat capacity

1. Introduction

Phase Change Materials (PCM) are an element of intelligent building materials, textiles and energy accumulators that absorb or release lateral heat depending on changing environmental conditions. This feature results from the absorption or emission of heat during the transformation from solid to liquid phase and vice versa, hence the heat capacity and phase change hysteresis are extremely important parameters of these materials [1]–[3].

The main function of PCM in construction industry is to minimize the heat flux between the inside of buildings and the outside environment, thus reducing the energy consumption needed to maintain a constant temperature, which significantly increases the interest in materials containing PCM. The reduction of energy consumption in the operation of buildings is one of the most important challenges of the building materials industry, also related to the requirement to reduce emission of CO_2 [4], [5].

The most commonly used in construction industry PCM substances are saturated hydrocarbons of various chain lengths (so-called paraffin waxes), including:

- lanolin (CAS 8006-54-0), with solidification temperature 38 °C and melting temperature 42 °C,
- eikosan (CAS 112-95-8), with solidification temperature 30.6 °C and melting temperature 36.1 °C,
- octadecane (CAS 112-95-5), with solidification temperature 25.4 °C and melting temperature 28.2 °C,
- heptadecane (CAS 629-78-7), with solidification temperature 21,5 °C and melting temperature 22.5 °C,
- hectadecane (CAS 544-76-3), with solidification temperature 16.2 °C and melting temperature 18.5 °C.

Mixtures of these hydrocarbons are also used to extend the temperature range of the phase transition. Due to the low melting points of the mentioned substances, they are closed in microcapsules or granules before introducing them to the target structure [6], [7].

In the granulation process, the comminuted material particles change their size to form groups called granules. The size of the granulated particles is usually in the range from 1 to 10 mm, depending on the production methods, additives used and, above all, their subsequent use. One of the granulation methods is agglomeration. The condition for the formation of a durable agglomerate is the occurrence of sufficiently large forces connecting the grains. Rumpf divided the bonding mechanisms between grains into 5 categories [8]:

1. Permanent bridges, formed at elevated temperatures at the grain junction, as a result of the diffusion of molecules from one grain to another.
2. The forces of adhesion and cohesion occurring in binding substances, which do not allow the free movement of the grains. The highly viscous substances thus form bonds similar to those appearing in solid bridges.
3. Forms of closed mechanical bonds occurring in materials with a fibrous or lamellar structure, as well as in the case of grains, which, undergoing deformation, cause mutual blocking.
4. Capillary pressure forces in loosely arranged grains. These forces in the capillary spaces can form strong bonds, which, however, disappear when the liquid evaporates and there are no other bonding mechanisms.
5. Attractive forces acting between the grains, such as Van der Waals forces, electrostatic or magnetic, which cause the grains to fuse together when they come close enough. These forces clearly increase when the grain size is reduced.

In practice, these categories are combined in the agglomeration process. Bonding of mineral matrix particles with fillers uses the mechanisms described in point 1–3.

So far, a number of attempts have been made to enclose PCM materials in mineral matrix. Sterczyńska et al. [9] used octamethylcyclotetrasiloxane (OMCTS) in the mesoporous Al-SBA-15 structures. Ramakrishnan et al. [10] used commercial PCM paraffin blends in the intramolecular spaces of expanded perlite, using vacuum during saturation. In turn, Sololciak et al. [11] used commercial paraffins RT42 encapsulated in expanded graphite.

On the other hand, there are commercial PCM microgranules encased in polymeric shells (eg Micronal from BASF), which however exhibit a volume change during the phase change and hence their use in building materials such as flooring, mortar and plaster is limited. A more advantageous solution is to use granules made of mineral matrices soaked in PCM, in which the phase change material remains in a liquid state. Apart from expanded perlite, such structures are characteristic, for example, for diatomite and zeolites.

The basic limitation of PCM application in construction is their liquid form, which forces the use of polymer microcapsules or granules. Due to a thin polymer coating around phase-change substances, PCM microcapsules expand in temperature, which affects the risk of cracking in building materials that use them [12]. Granules using three-dimensional mineral matrix are a much more advantageous alternative because the compensation takes place inside the pores. So far, however, there is little experience in developing a technology enabling the industrial production of PCM granules based on mineral matrix, especially those using waste substrates [9], [13]. This work covers research on the granulation technology of two types of matrices soaked in PCM and a comparison of their properties – natural diatomite and synthetic zeolite made from waste coal fly ash.

2. Materials and methods

2.1. Materials

Two matrix mineral bases were used for granulated PCM preparation: natural diatomite dust (GD) and synthetic Na-P1 zeolite (GZ), obtained as a result of the hydrothermal reaction of fly ash. Fly ash from coal combustion, characterized by the appropriate ratio of SiO_2 to Al_2O_3, was subjected to a NaOH solution at elevated temperature according to the procedure described by Kunecki et al [14]. The post-reaction product was then washed and filtered. The Na-P1 zeolite dust prepared in this way was one of the bases for impregnation with the phase change material. The second base was a natural milled diatomite with a fraction of 0-200 µm.

After initial technological trials, the paraffinic filtration waste (CAS 64742-67-2) was qualified as PCM used for tests. This filtrate was selected due to the melting point, oscillating around 30 °C, and the low cost of obtaining it, which is of key importance for the future possible implementation of the PCM granulate production technology. The filtrate is currently used industrially for the production of paraffin emulsions, anti-caking agents for fertilizers and for impregnation of chipboards in the furniture industry.

2.2. Granulation procedure

The technological tests included granulation of bulk materials (matrices) in a wax with a temperature of 70-80 °C, sprayed together with cooling water. In order to obtain the appropriate mechanical strength, a small amount of cement was used in the final stage of pelleting. Then, the granules were dried in a low temperature microwave oven and aged for 2-3 days.

The samples were prepared with following equipment in R&D test center of Biko-Serwis, Polish producer of granulation equipment:

– fluid bed vibration granulator,

– disc granulator,

– pin granulator,

– high shear granulator.

Despite the pre-selected vibro-fluid technology, other methods resulted in better results in during the tests, due to the expected particle size. The vibro-fluid method allowed for the obtained particles of 1-2 mm in size, which did not allow to enclose a sufficient amount of paraffins inside the granule structure and to cover it with a layer of strengthening cement crust. It was desired to obtain 6-8 mm granules, which were produced using the other tested methods. The best results were achieved by combining two technologies:

– pelleting with the pin granulator, where hot paraffin was added to the base material with cooling water,
– thin cement coating with disc granulator.

Such selection of methods resulted in the shortest sample preparation time, amounting to 3-5 minutes, and the highest proportion of the desired fraction, which was over 80%.

2.3. Characterization methods

In order to fully characterize PCM granules, a number of phase, chemical and textural research methods were used.

X-ray phase analysis (XRD) was performed with the powder method using a Panalytical X'pertPRO MPD X-ray diffractometer with a PW 3020 goniometer. A Cu copper lamp (Cu_{Ka} = 1.54178 Å) was used as the source of the X-ray emission. X'Pert Highscore software was used to process the diffraction data. The identification of the mineral phases was based on the PDF-2 release 2010 database formalized by JCPDS-ICDD.

The morphology and chemical composition in the grain micro-area of the main mineral components of the studied materials was determined using the Quanta 250 FEG Scanning Electron Microscope by FEI.

The textural research included the determination of the most important surface and volume parameters. The texture study was performed on the ASAP 2020 specific surface analyzer from Micromeritics Instrument Corporation on the basis of nitrogen vapor adsorption and desorption isotherms at liquid nitrogen temperature (-194.85 °C). The measurement was carried out in the range of relative pressures p / p_0 ranging from $1.5 \cdot 10^{-7}$ to 0.99.

Differential Scanning Calorimetry was performed using Perkin-Elmer DSC 7 apparatus. By recording the rate of change (0.1-200) °/min in steps of 0.1 °/min.

The mechanical strength of the obtained granules was determined in a test called "drop strength". It best simulates the conditions related to handling and transport that the tested granules may be subjected to. A triple drop of 20 randomly selected granules from each sample was made from a height of 2 m onto a steel plate. Then the broken and crushed mass was screened through a sieve. The size of the screen was chosen such that the mesh size was about 2/3 of the average calculated from the two maximum granule dimensions measured in mutually perpendicular directions. The drop resistance of the granules was determined on the basis of the formula:

$$K = \frac{m_z}{m} \cdot 100\% \tag{1}$$

where: K – the drop resistance of granules, m_z – average weight of pellets after drop, m – average weight of pellets before drop.

3. Results and discussion

The phase analysis showed that the dominant crystalline phase in the zeolite granulate (GZ) is the zeolite with the structure type NaP1 (Fig. 1). It was recognized by characteristic interplanar distances d_{hkl} = 7.10; 5.01; 4.10; 3.18 Å. The second important component is mullite recognized at d_{hkl} = 5.38; 42; 3.39; 2.21 Å. An important sub-component is also calcite recognized by characteristic interplanar distances d_{hkl} = 3.86; 3.04; 2.49; 2.28 Å. The mineral composition is completed by quartz recognized at d_{hkl} = 4.25; 3.34; 2.46; 2.28 Å.

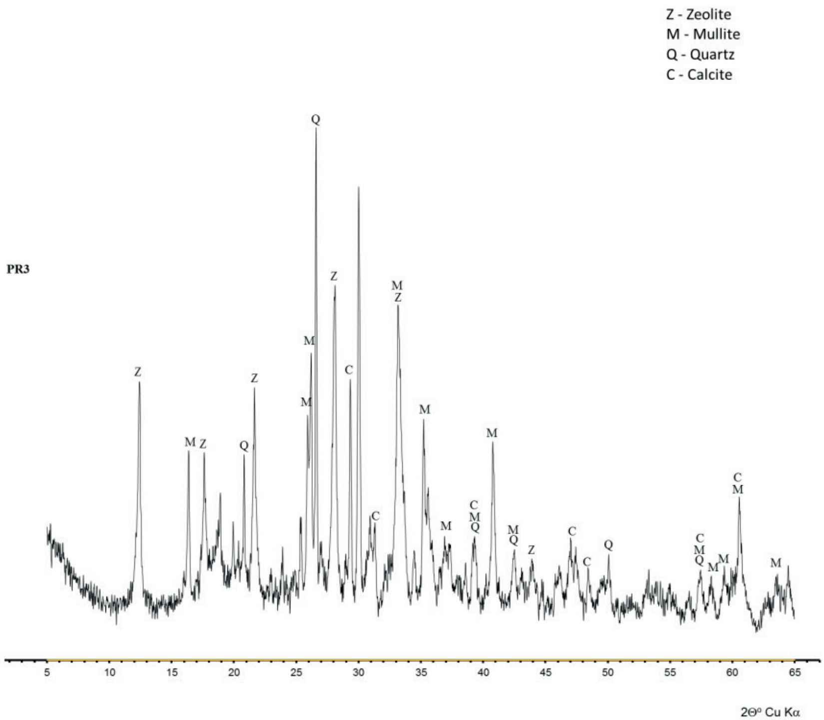

Fig. 1. Phase composition of the GZ sample

Figure 2 shows the XRD patterns of diatomite granulate (GD). In the sample, the dominant crystal phases are Ca_2Al [(Si, Al) $_2O_7$] and cristobalite. The presence of gehlenite is confirmed by the strongest reflections with interplanar distances d_{hkl} = 5.46; 5.08; 2.85 Å. Crystobalite was recognized by d_{hkl} = 4.05; 3.13; 2.48 Å. The sample also shows a clear elevation of the background in the angular range of 15-25 2theta, which proves the presence of amorphous silica. The mineral composition is complemented by quartz recognized by the characteristic interplanar distances d_{hkl} = 4.25; 3.34; 2.46; 2.28 Å.

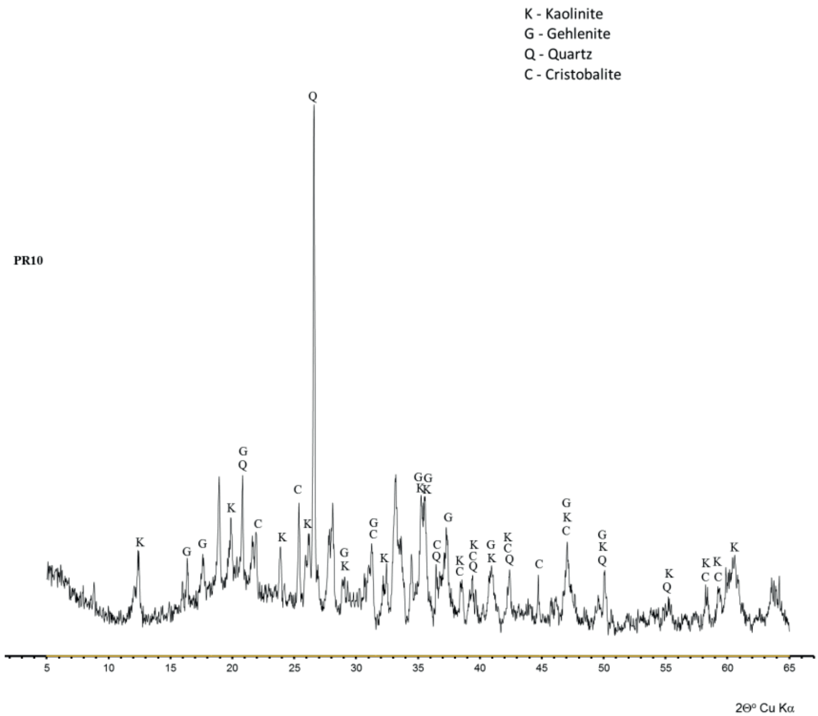

Fig. 2. Phase composition of the GD sample

The presence of zeolite as the main mineral component confirms the presence in microscopic images of spherical plate aggregates with a size of up to 10 μm (Fig. 3). The microscopic observations clearly show the presence of unreacted fragments of fly ash in the form of spheres with smooth surfaces, made of mullite and aluminosilicate glaze, which is confirmed by XRD tests. The zeolite-based granulate sample also shows a significant pore content in its internal structure.

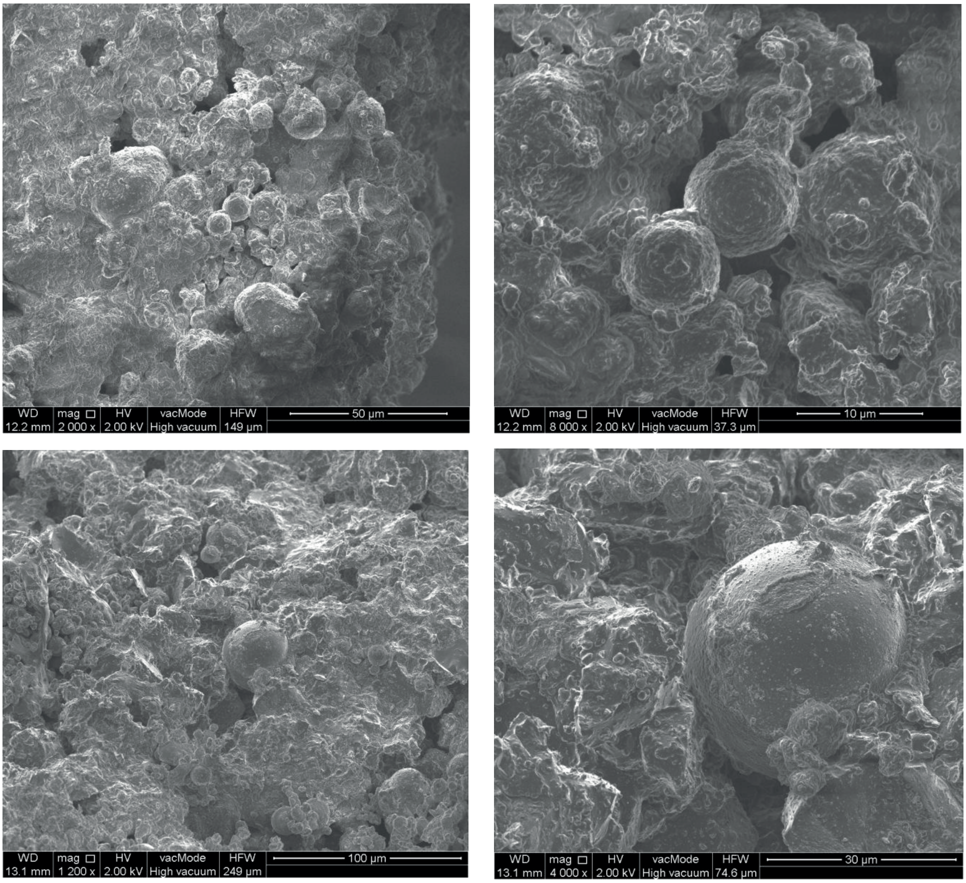

Fig. 3. SEM images of the GZ sample

In the images made with electron microscopy (Fig. 4), the fractures of the diatomite granulate sample showed almost no pores. The microscopic observations clearly show that the main minerals present in this granulate are embedded with an amorphous substance (wax), which masks their morphology and prevents phase recognition using the SEM technique.

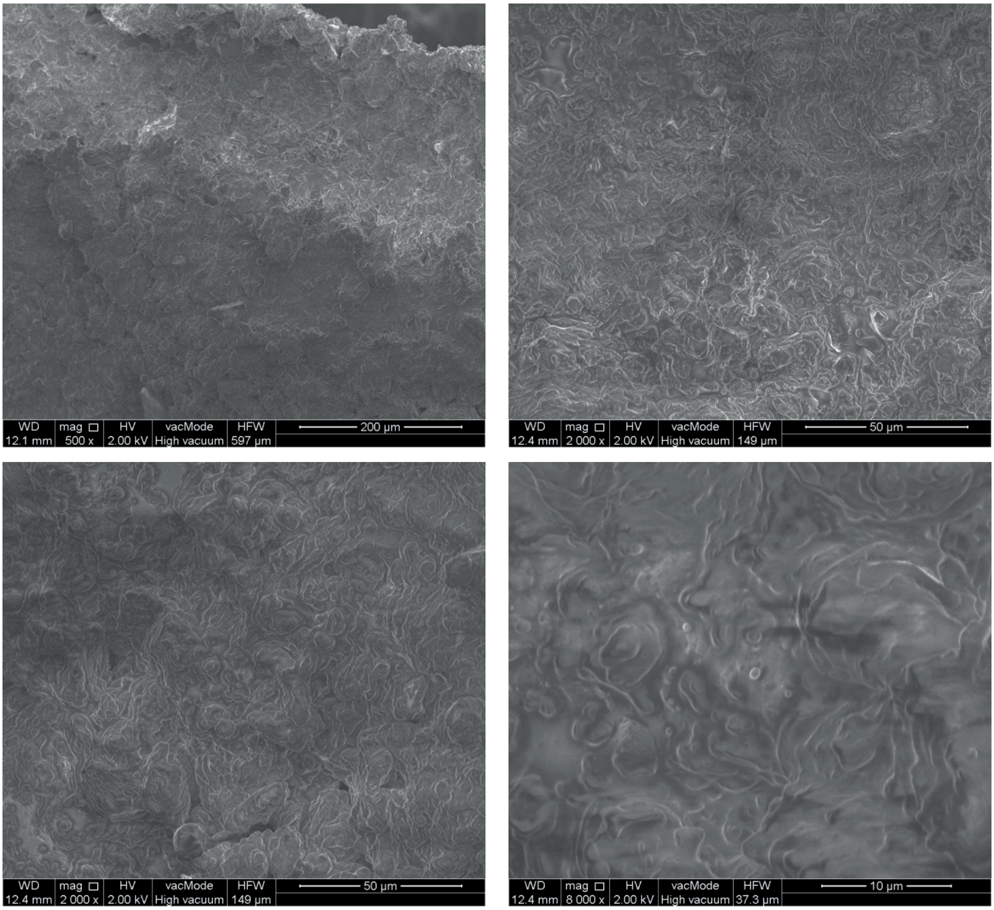

Fig. 4. SEM images of the GD sample

The nitrogen adsorption/desorption analyses performed allowed for the calculation of the specific surface area of the granules tested. The results of these determinations using BET and Langmuir theories are presented in Table 1.

Table 1. Scpecific surface area of PCM granules

Sample	BET Surface Area [m²/g]	Langmuir Surface Area [m²/g]
GZ	0.7581	1.3346
GD	0.3878	0.7484

The studied granules represent materials with low specific surface area. Slightly higher specific surface area parameters were obtained using the Langmuir equation to determine this parameter. The GZ granules obtained from Na-P1 zeolite had the highest surface area.

Table 2 shows the results of the research on the heat capacity of PCM granules obtained from DSC analysis.

In the course of the research, it was found that increasing the working temperature for the samples causes an increase in the energy output, which is directly related to the materials used for their production.

Table 2. The heat capacity of PCM granules

Sample	cp /0°C [J/(g*K)]	cp /30°C [J/(g*K)]
GZ	30.59	-31.83
GD	28.91	-27.23

According to the data presented in the test report, granules with zeolite and diatomite are characterized by a greater difference in the value of specific heat in the temperature range of 0-30 °C. This may indicate their greater energy storage potential. For the sample based on the zeolite matrix, the heat capacity was 62.42 kJ/kg, for the diatomite matrix it was 56.14 kJ/kg. Obtained heat capacities are higher than those for the commercially available Rubitherm GR granules, which have a heat capacity of 55-57 kJ/kg. Table 3 shows the results of the mechanical strength tests for PCM granules.

Table 3. Mechanical strength of PCM granules

PCM granules	Average diameter of granules [mm]	Diameter of screen [mm]	m [g]	m_z [g]	K [%]
GZ	6	4	1.65	0.635	38.48
GD	18	12	65.41	20.58	31.46

Based of the drop resistance of the granules K values it can be stated that zeolite granules exhibit higher mechanical strength that diatomite granules and can be used in construction industry more preferably. Presumably, the higher porosity of the zeolite causes better adhesion of the wax to the mineral surface resulting in increased cohesion and better mechanical performance of the obtained PCM composites.

4. Conclusions

Since the main parameter of PCM materials used in the construction industry is high heat capacity in the range of 0-30 °C with sufficient mechanical strength, it was found that the best material base (matrix) will be zeolites, while the technology of granules production: pin granulator with coating with disc. This is indicated by the better obtained values of heat capacity, as well as the greater share of granules with sizes in the range of 4-7 mm.

The use of waste material, which is fly ash from coal combustion, as a raw material for zeolite synthesis, along with the low cost of the PCM material used in the tests, has a positive effect on the possibility of using the technology in industrial production. The use of ashes is part of the circular economy and will reduce greenhouse gas emissions associated with the extraction of raw materials from natural sources. The use of waste materials to create a matrix and residue wax as a phase-change filling allowed to create assumptions for an economically viable technology for the production of PCM granules with better parameters than those currently available on the market.

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