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Original Research Article

COMPREHENSIVE MONITORING OF CHANGES IN THE GEOMETRIC STRUCTURE OF A HISTORIC BUILDING THE "SALA BHP" IN GDAŃSK

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A b s t r a c t

The article presents selected results of the analysis of the comprehensive monitoring of the historical building of the "Sala BHP" in Gdansk. The necessity of monitoring was caused by scratches on its structural and finishing elements that occurred in the previous period. A preliminarily assumed factor that could cause the expansion of existing damages and the possible formation of new ones was the planned implementation of an investment consisting of the erection of multi-storey buildings on adjacent plots. As part of the preventive work, a comprehensive monitoring of the facility was proposed, consisting of geodetic determination of vertical and horizontal displacements of measurement points, measurement of changes in the width of existing cracks, and control of the height of the water table in piezometers located in the area adjacent to the „Sala BHP" building. As part of the technical condition inspection, the collected data was analyzed, and the measurement data was compared. In the course of the studies, no strong correlations between displacements and individual factors were observed, and thus the preliminary thesis on the direct impact of the investment carried out on the neighboring „Sala BHP" building on the formation of scratches was not confirmed.

To confirm the conclusion that the current technical condition of the structure is a consequence of the typical operation of a building with a flexible structure, and most importantly, the occurring defects and damages do not threaten the safety of its structure and use, an additional analysis of the uniformity of the obtained displacements occurrence was carried out, using the transformation method for the purpose. The method shows the non-uniformity of the occurrence of the displacements of the control point network. The results of the analysis confirmed the previously formulated conclusions.

Keywords: monitoring of building structures, analysis of displacements and deformations, historic buildings

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1. INTRODUCTION

Geodetic monitoring of engineering structures is a comprehensive measurement and interpretation of the results of vertical and horizontal displacements observed at the points of the assumed measurement and control networks. It is performed on communication and hydrotechnical facilities [1,2]. It is also carried out on construction objects landslides caused by, for example, underground and open-pit mining [3].

It is challenging to determine the factors causing geometrical changes in engineering structures. Often, the analysis of the values of the obtained displacements alone is insufficient. Only by comparing them with other factors, usually external, can the causes of these changes be indicated. The interpretation of the obtained monitoring results is complicated and entails decisions on the further use of the area or facility and recommendations for repairing the identified condition. It is worth using the Helmert transformation error to analyze the obtained displacements, an indicator showing the uniformity of the distribution of displacements.

1.1. Literature review

Displacement measurements are carried out to determine changes in objects and their impact on areas and neighboring objects. Identification of deformations and deformations of building structures, based on previously conducted geodetic measurements, allows for the assessment of their technical condition, planning of repairs and modernizations, and quick reaction in the event of noticing changes that may contribute to the failure of the structures [4-6]. Heavily invested urban areas, particularly buildings during construction and subsequent operation, are exposed to displacements. They are subject to the influence of external and internal factors, including operational factors, which may cause changes in the form of subsidence of buildings. Vertical displacements determine their identification [7,8].

Geodetic study of displacements of engineering structures is performed using modern measurement methods, which should complement classical and non-geodetic methods. Such an approach was described in a paper [9], in which the activity of volcanoes and earthquakes and their impact on terrain deformations were analyzed based on GNSS measurement data and leveling measurements. It is essential to combine geodetic and non-geodetic measurements. The paper [10,11] proposes combining geodetic methods with geomorphic surveys to monitor morphological changes in river channels and large and extensive areas. Shults et al. [12] carried out geospatial monitoring of viaducts and pipelines in combination with modern laser scanning and classic total station measurements. Landslide surveys can be successfully carried out with mobile laser scanning to study landslide areas [13]. The work [14,15] presents non-contact methods for measuring deformations resulting from the influence of vibrations on building structures. The authors used the RTS (Robotic Total Station) geodetic instrument and a seismograph. A robotic total station in mirrorless mode is an effective tool for observing processes and collecting geospatial information over long distances in difficult meteorological conditions. It is also crucial for occupational safety [16].

Buildings in urban areas are subject to the influence of external and operational factors during their construction and subsequent operation. They can cause changes in the form of subsidence of buildings, which are determined by determining vertical displacements [7, 8]. Analyses of the factors determining the formation of horizontal and vertical displacements of the historic brick tower are presented in the paper [17]. The authors point to factors that may cause the resulting displacements. These include changes in temperature, humidity, building loads, and ground conditions. They point to the importance of researching historic objects to understand their behavior over time and to be able to undertake appropriate conservation activities to preserve their structural integrity. The analyses presented in the work [18] point to natural factors. They pointed to changes in ground conditions, such as land subsidence, tectonic movements, changes in groundwater levels, and atmospheric factors, such as freeze-thaw cycles. Factors that significantly affect the condition of historic buildings are improperly carried out renovations [19]. In researching the condition of historic buildings, it is also important to choose an appropriate method of measurement data analysis. The study's authors [20] describe the results of research that show the effectiveness of the Helmert transformation method in monitoring displacements and changes in geometric building objects. Certain stages of Helmert's transformation are shown in [21]. The authors presented a method for determining the GNSS coordinates of an inaccessible location of a measuring device.

1.2. Objective and contribution

Based on the analysis of the available literature and research directions, it can be noted that it is essential, but also tricky, to unambiguously indicate the factors harming changes in the geometry of building structures. To identify them, deliberately selected measurement and analytical methods should be used. The most commonly used are relative methods, which refer to determining the change in the position of an object element in a given time interval, in non-constant, own frame of reference, and absolute methods, which study the change in the position of an object element in a specific period, in a fixed frame of reference called the external frame. Often, for a comprehensive study of an object, using both relative and absolute methods is justified. The article's main objective is to show the usefulness of using comprehensive monitoring of a building object and the use of various analytical methods in the direction of interpretation of the obtained data. The considerations were based on monitoring studies of „Sala BHP" building in Gdańsk. The main stages of the analyses and deliberations are as follows:

1. Presentation of the scope of the proposed monitoring of the tested object.
2. Analysis of the obtained results and indication of the influence of the indicated factors that may cause changes in the geometry of the object.
3. Analysis of the non-uniformity of the occurrence of displacements using the error of elevation and situational transformation.

The following article is organized: Chapter 2 describes the monitoring carried out. Chapter 3 presents the monitoring results and the conclusions drawn from them. Chapter 4 contains essential findings and conclusions and indicates further directions for research.

2. RESEARCH OBJECT AND METHODS USED

2.1. Research object

The research subject is the historic building of the „Sala BHP". The facility is located in Gdańsk on the former site of the Gdańsk Shipyard, at 6 Ks. Jerzy Popiełuszki Street (Fig. 1).

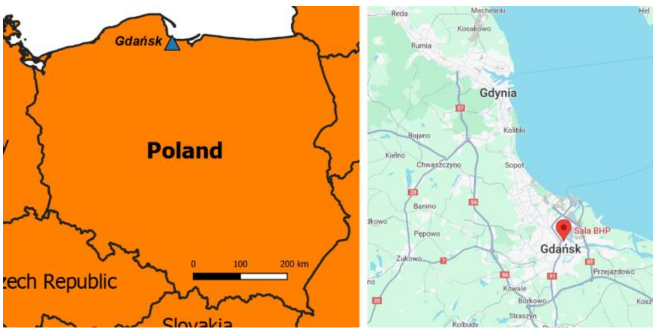

Fig. 1. Research area

The „Sala BHP" building consists of three parts:

A - the main, ground-floor building in which the „Sala BHP" is located,

B - auxiliary, one-storey building in which the bar is located,

C - administrative, multi-storey, with a boiler room added to the main body of the building in 2006 (Fig. 2).

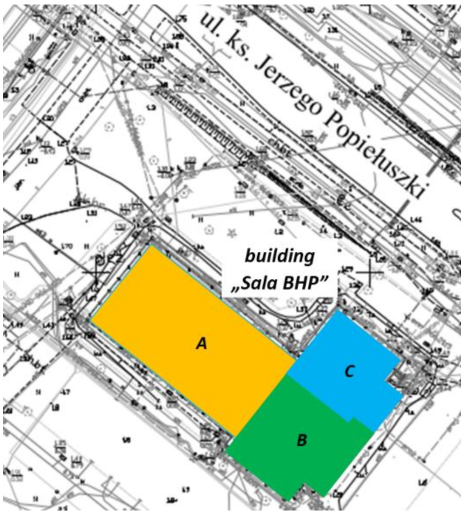

Fig. 2. The „Sala BHP" building in Gdańsk divided into functional parts

The Hall was built at the turn of the 19th and 20th centuries during the reconstruction of the Imperial Shipyard. Initially, it served as a torpedo warehouse and armament assembly plant for Prussia and the Third Reich warships. In the post-war period, the building was used as a warehouse. In 1961, it was adapted for the needs of the Cooperation Department of the Gdańsk Shipyard, and regular employee training was carried out in the building. Since then, the building has been called the „Sala BHP". From the mid-1970s to 1996, the building housed the Company Museum, also known as the Memorial Room, in August 1980. The „Sala BHP" was the meeting place of the Inter-Enterprise Strike Committee (MKS), where on 31 August 1980, one of the August Agreements was signed. In 1996, after the Gdańsk Shipyard went bankrupt, the Company Museum was closed on 6 December 1999. The „Sala BHP" has been entered into the register of monuments of the Provincial Office for the Protection of Monuments. In December 2004, the NSZZ "Solidarność" National Commission became the new owner of the historic building. In 2006-2010, the building in which the „Sala BHP" is located underwent a general revitalization. Since 2011, on behalf of NSZZ Solidarność and the National Commission, the Foundation for the Promotion of Solidarity has managed the Gdańsk Shipyard Health and Safety Hall. In November 2016, the "„Sala BHP"" Museum of the Gdańsk Shipyard was established.

Fig. 3. View of the building from Droga do Wolności Street [google.pl/maps, 2024.03.10]

Fig. 4. View of the building from Ks. Jerzy Popiełuszko Street [google.pl/maps, 2024.03.10]

2.2. Research methods

2.2.1. Measurement methods

The Comprehensive monitoring aimed to assess the size and directions of changes in the location of the structural elements of the monitored building of the „Sala BHP", which could occur during construction works related to the construction of new office and service buildings in the vicinity of the „Sala BHP". The necessity to perform it, among other things, was caused by checking the impact of deep excavations during this investment. The Instruction ITB, Nr 376/2002 [22], regulates protecting objects under the influence of excavations.

The scope of the planned research included cyclical measurements:

- measurement and control network observed using the precision leveling method,
- networks of geodetic disc points controlled by the total station method,
- the width of cracks and cracks on the installed crackmeters,
- the height of the groundwater level in the installed piezometers.

The network of controlled points consisted of 19 points. The network is shown in Figure 5.

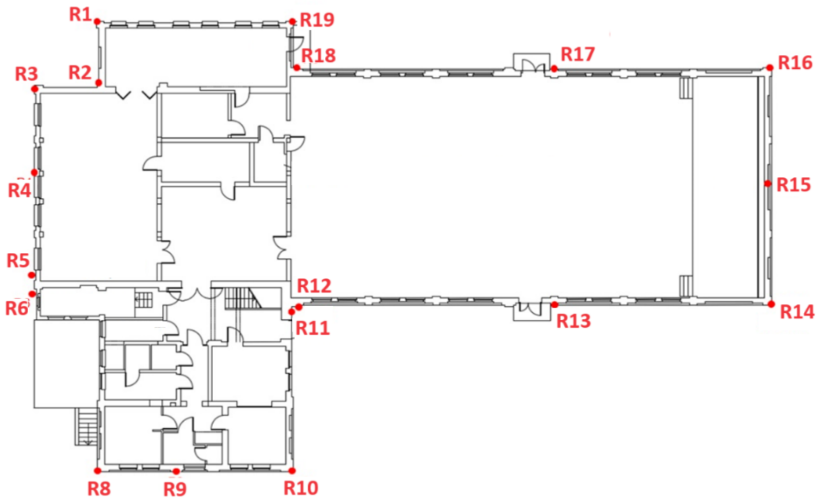

Fig. 5. Sketch of the arrangement of the control points

Classic measuring bench-marks in metal pins were installed (Fig. 6). The bench-marks in the form of stainless steel rods were embedded in the masonry.

Fig. 6. View of the mounted bench-marks

In order to determine vertical displacements, 6 reference points were stabilized. Their location is shown in Fig. 7.

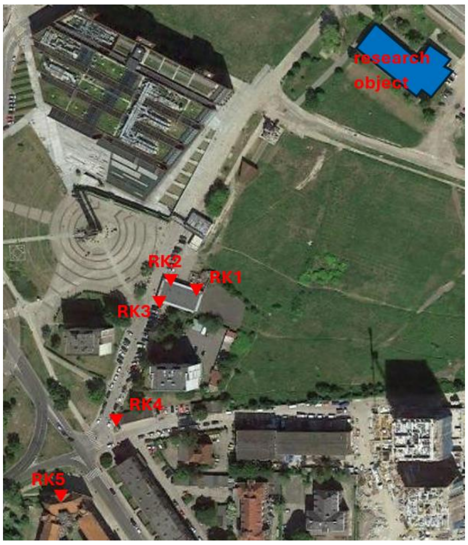

Fig. 7. Sketch of the location of reference points

Precise geometric leveling was used to measure vertical displacements. It involves measuring the difference in height between two points (A, B) on which leveling rods are placed and a leveling section in the middle of the measured point [23-26]. After taking readings on the leveling rod, the height difference in classic leveling is calculated as:

$$\Delta h_{A-B} = R_A - R_B \tag{2.1}$$

where:

$\Delta h_{A\text{-}B}$ - height difference between points A end B,

R_A, R_B - readings on the leveling rods at points A and B, respectively.

The measurement was carried out with a precision level DNA03 from Leica and the use of an invar leveling rod in the measurements. The device provided a measurement accuracy of 0.3mm per kilometer of double leveling. The vertical displacements of network points are calculated through strict adjustment using the least squares method.

There are 18 target plates mounted on the facade of the facility. The angular-linear method was used to measure them, determining their position in the XY plane system. A sketch of the network is shown in Fig. 8.

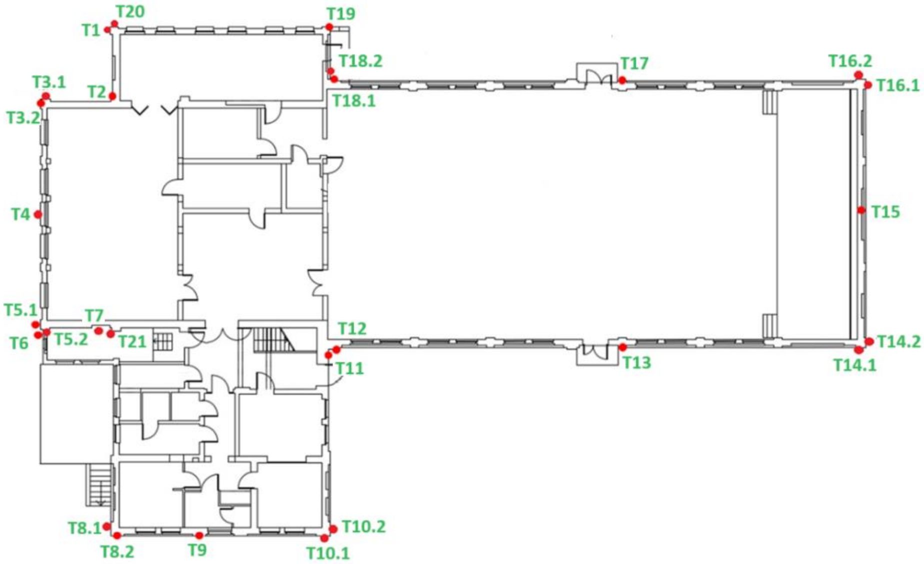

Fig. 8. Sketch of the arrangement of target plates

In the places shown in Fig. 8, on the wall, target discs were mounted on the outer surface of the wall (Fig. 9).

Fig. 9. View of the mounted target plate

To determine horizontal displacements, 14 reference points in the form of reflective target discs and measuring prisms were stabilized during the initial phase of the study. Their location is shown in Fig. 10.

Fig. 10. Sketch of the location of horizontal network reference points

Their coordinates were determined in the calculation process of the first measurement series. The measurement of the target plate network was performed using the irregular angular-linear network measurement method. It was carried out from the measurement control points with an electronic total station TS30 from Leica. It allows precise measurement of angles with an accuracy of 0.5" and distances with an accuracy of 0.6mm. Calculations were based on strict alignment of the assumed angle-linear network using the GEONET application from AlgoRes-Soft. The analysis of the obtained results allowed for:
- quantitative assessment of changes (displacements) of the monitored building at selected measurement points,
- obtaining information on the mutual movements of monitored points,
- assessment of the impact of displacements of monitored points on the technical condition of the building.
Crackmeters were installed on the building's structural and finishing elements, where scratches were observed (Fig. 11).

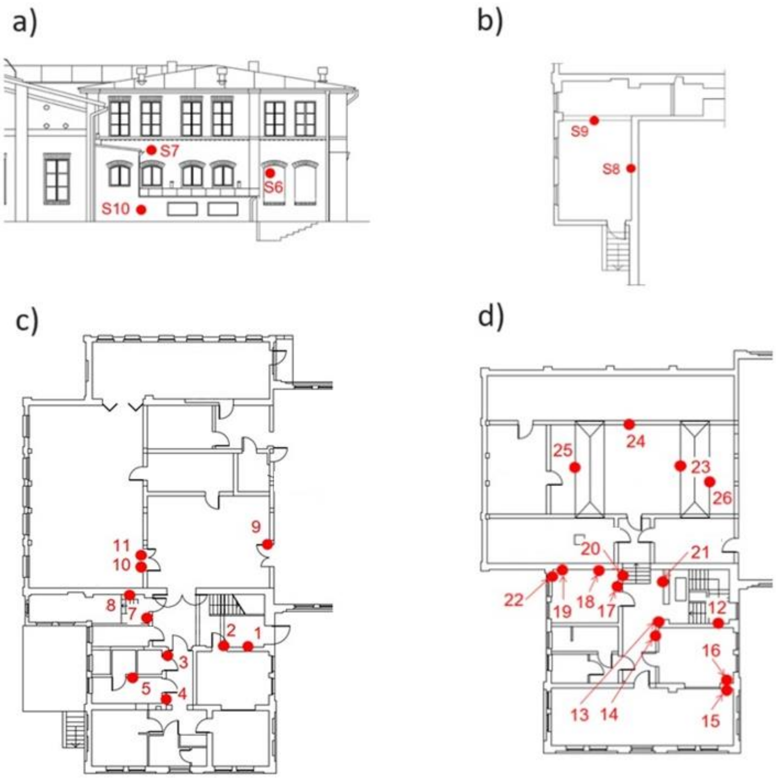

Fig. 11. Location of crackmeters: a) eastern elevation, b) boiler room, c) ground floor, d) first floor

The crackmeters were installed on the building's structural elements (walls) and finishing elements at various heights (floors). The measurements made it possible to assess changes in the opening width of monitored scratches and cracks (building geometry) in different seasons of the year and the impact of these changes on the technical condition of the monitored building. An example view of the installed crackmeters is shown in Fig. 12.

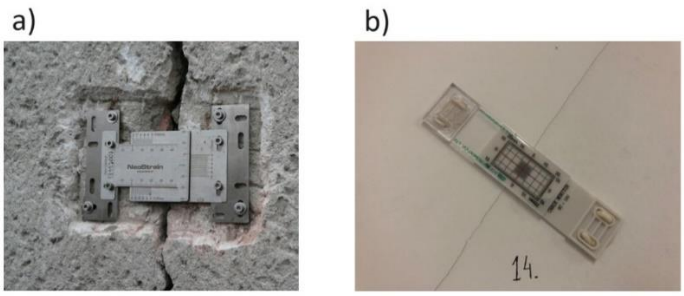

Fig. 12. View of the installed crackmeters: a) inside the facility, b) outside the facility

A network of piezometers was installed in the vicinity of the tested facility. A hole was drilled in each place, and a plastic pipe was inserted into each. Their location is shown in Fig. 13.

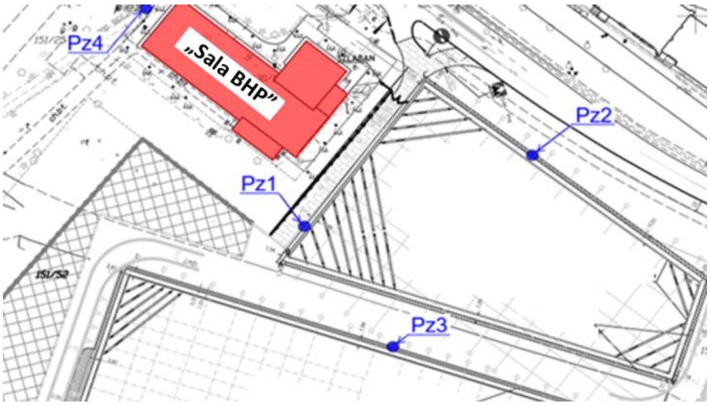

Fig. 13. Piezometers location

2.2.2. Analysis methods

The results obtained from the measurements and preliminary calculations allowed for:

- determination of vertical and horizontal movements of the network of controlled signs installed in the facility,
- determination of changes in the width of the opening of monitored scratches and cracks,
- determining changes in hydrogeological conditions near the building.

For further analyses, using the Stacja Meteo Gdańsk portal, the sum of precipitation falling in the two weeks preceding each measurement series was determined. Using the Pearson`` linear correlation coefficient, the dependences of the obtained vertical and horizontal displacements on the sum of precipitation were examined. The coefficient determines the strength of the relationship between the variables. Mathematically, the correlation coefficient between the variables x and y is defined by the correlation:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{2.2}$$

where:

x – vertical or horizontal displacement,
y – sum of rainfall.

Correlation coefficient ranges from -1 to 1. The following assessments of the strength of the relationship are adopted for the coefficient:

$r < 0.2$ - no correlation,
from 0.2 to 0.4 - weak correlation,
from 0.4 to 0.7 - moderate correlation,
from 0.7 to 0.9 - quite strong correlation,
$r > 0.9$ - very strong correlation.

The correlation coefficient values between the analyzed variables were considered in the result analysis. Further analyses determined the uniformity of the distribution of vertical and horizontal displacements. For the purpose, the facility was divided into zones (Fig. 14, Fig. 15).

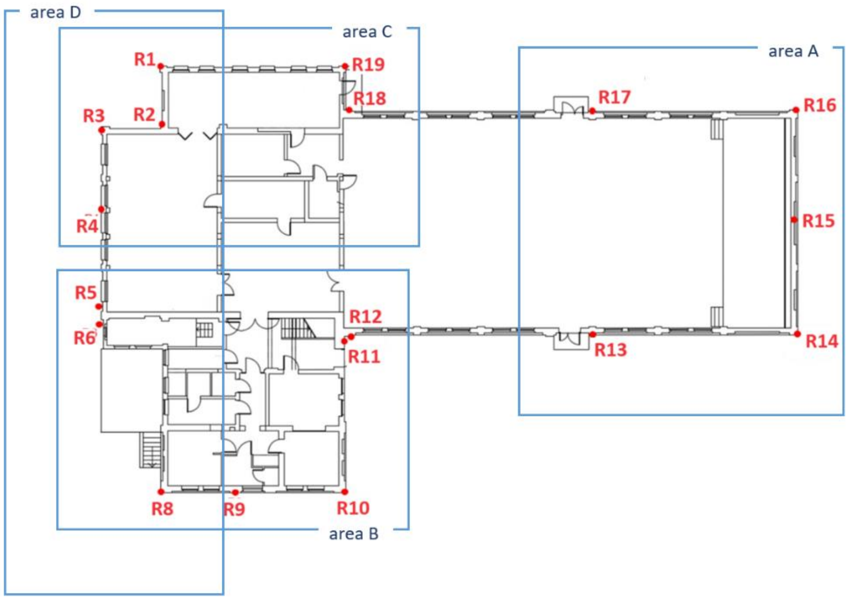

Fig. 14. Distribution of zones in the analysis of vertical displacements

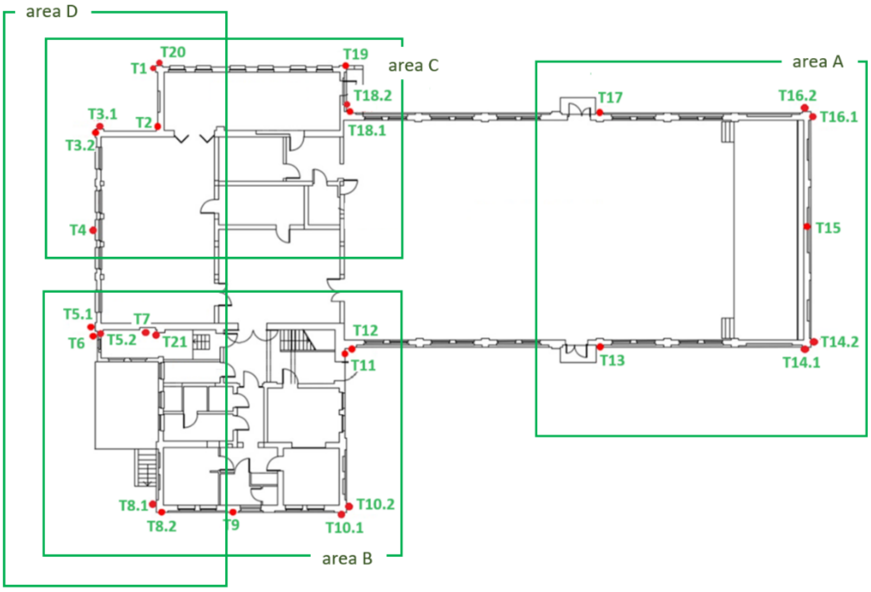

Fig. 15. Distribution of zones in the analysis of horizontal displacements

The analysis used the transformation method limited to determining the transformation errors. Calculations were performed for all control measurement series compared to series 0. The numerical value of transformation error can be interpreted as an indicator of the uniformity of displacements. Below are the procedures for calculating the transformation error.

Procedure for calculating the height transformation error:

1) Calculation of average heights for the controlled (primary) and zero (secondary) epochs:

$$h_B = \frac{\sum h_i}{n}, \quad H_B = \frac{\sum H_i}{n} \tag{2.3}$$

2) Calculation of the height shift of the controlled epoch relative to the zero epoch:

$$\Delta H = H_B - h_B \tag{2.4}$$

3) Calculation of the transformed heights of the controlled era:

$$H_i^T = h_i + \Delta H \tag{2.5}$$

4) Calculation of adjustment deviations and average adjustment error:

$$V_H = H_i - H_i^T \tag{2.6}$$

$$M_{dost} = \sqrt{\frac{\sum V_H^2}{n-1}} \tag{2.7}$$

Procedure for calculating the plane transformation error:

1) Calculating the poles for the controlled epoch (primary) and the zero epoch (secondary):

$$x_B = \frac{\sum x_i}{n}, \; y_B = \frac{\sum y_i}{n} \qquad X_B = \frac{\sum X_i}{n}, \; Y_B = \frac{\sum Y_i}{n} \tag{2.8}$$

2) Calculate the increments of the coordinates of the connecting points relative to the pole for both measurement epochs.

- controlled epoch: $\Delta x_{Bi} = x_i - x_B, \; \Delta y_{Bi} = y_i - y_B$
- epoch 0: $\Delta X_{Bi} = X_i - X$, $\Delta Y_{Bi} = Y_i - Y_B$ (2.9)

3) Calculation of transformation coefficients u, v:

$$u = \frac{\sum(\Delta x_{Bi} \cdot \Delta Y_{Bi} - \Delta y_{Bi} \cdot \Delta X_{Bi})}{\sum(\Delta x_{Bi}^2 + \Delta y_{Bi}^2)} \qquad v = \frac{\sum(\Delta x_{Bi} \cdot \Delta X_{Bi} + \Delta y_{Bi} \cdot \Delta Y_{Bi})}{\sum(\Delta x_{Bi}^2 + \Delta y_{Bi}^2)} \tag{2.10}$$

4) Calculation of the coordinates of the connective points of the controlled epoch in epoch 0 after the transformation:

$$X_i^T = X_B - \Delta y_{Bi} \cdot u + \Delta x_{Bi} \cdot v \qquad Y_i^T = Y_B + \Delta x_{Bi} \cdot u + \Delta y_{Bi} \cdot v \tag{2.11}$$

5) Calculation of adjustment deviations and average adjustment error:

$$V_{X_i} = X_i - X_i^T \qquad V_{Y_i} = Y_i - Y_i^T \tag{2.12}$$

$$M_{dost} = \sqrt{\frac{\sum V_X^2 + \sum V_Y^2}{n}} \tag{2.13}$$

3. RESULTS AND DISCUSSION

After installing the measurement points (bench-marks, discs, and crackmeters), a zero measurement and 11 control measurements were made. The measurement schedule is shown in Table 1.

Table 1. Measurement schedule

Number of the measurement epoch	Date of measurement
0	23.12.2021
1	24.01.2022
2	28.02.2022
3	31.03.2022
4	06.05.2022
5	24.06.2022
6	26.08.2022
7	26.10.2022
8	29.12.2022
9	01.03.2023
10	30.03.2023
11	28.04.2023

The results of displacements of controlled bench-marks R1-R19 were obtained based on periodically performed precision leveling measurements. Displacement calculations for each of the measurement series were preceded by checks on the stability of the set of reference points. The checking proved correct. The graphical results are shown in Fig. 16.

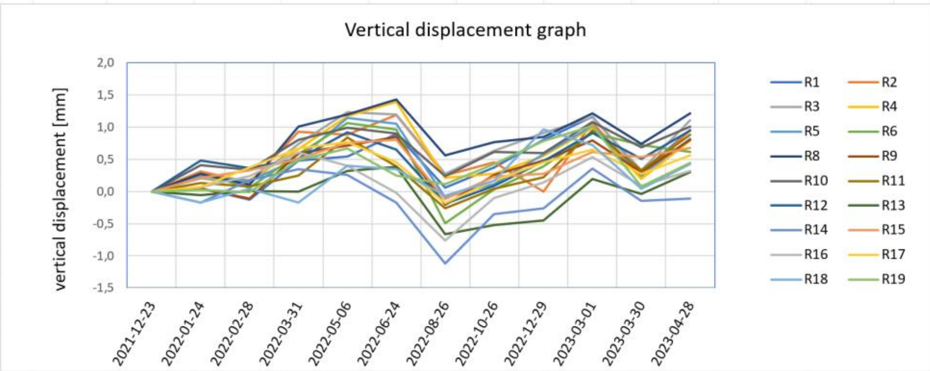

Fig. 16. The vertical displacements of the control points R1- R19

The values of measured vertical displacements of controlled bench-marks mounted on the walls of the monitored facility ranged from -1.12 mm (R14) to +1.43 mm (R8). The average errors of the determined vertical displacements, in most of the measurement series, did not exceed 0.35mm. The exception was the series of 2022.10.26, for which the average error slightly exceeded 0.50mm. These

values are lower than the Serviceability Limit State (SLS) recommended by the Building Research Institute (ITB).
The results of horizontal displacements of the shields mounted on the object are shown in the charts Fig. 17 and Fig. 18.

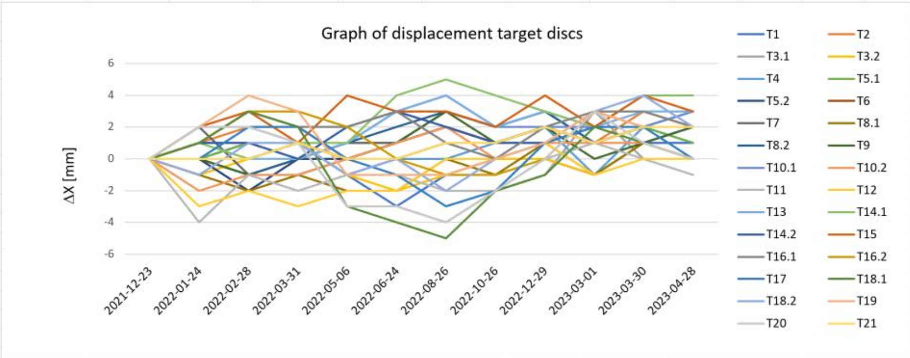

Fig. 17. Horizontal displacements of the discs in the X direction

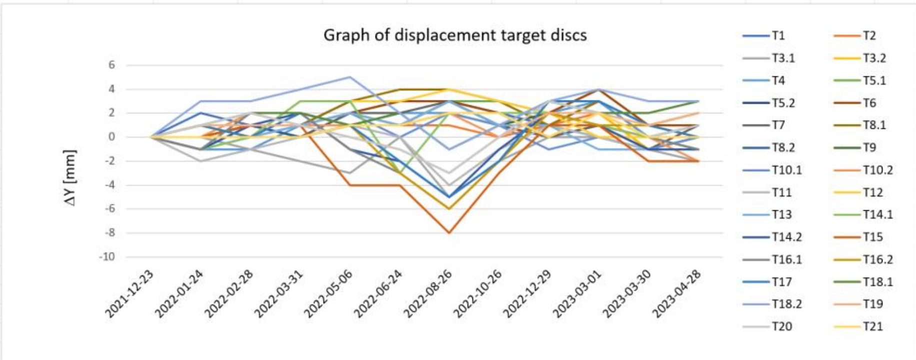

Fig. 18. Horizontal displacements of the discs in the Y direction

The maximum horizontal displacement was recorded for the T15 disc in the Y direction and amounted to -8 mm. In the alignment process, errors in the position of the points of the controlled network in relation to the reference points were determined. The values of these errors were a maximum of 1.5mm. According to the currently applicable standard [9], the values of horizontal displacements are permissible in the case of brick buildings, which are considered up to 20 mm on each floor and up to 50 mm along the entire height of the wall.

During the study of changes in crack width, two parameters were determined:

ΔU - change in the crack opening width, where the + sign means an increase in the crack opening,

ΔV - mutual shift of the crack edge along its length, where the + sign means the right edge of the crack is moved up. The results are graphically presented in Fig. 19 - Fig. 22.

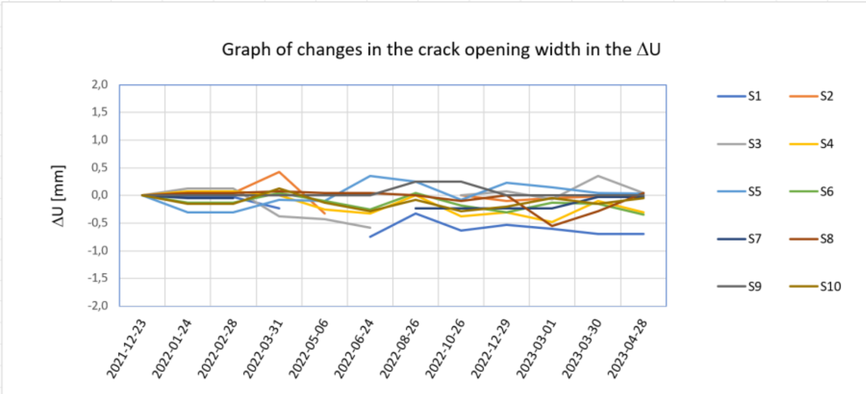

Fig. 19. Changes in the crack opening width in the ΔU direction for crackmeters S1-S10

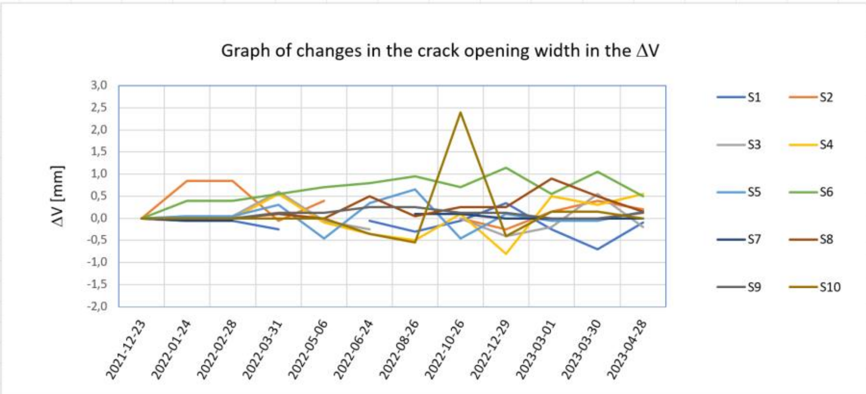

Fig. 20. Changes in the crack opening width in the ΔV for crackmeters S1-S10

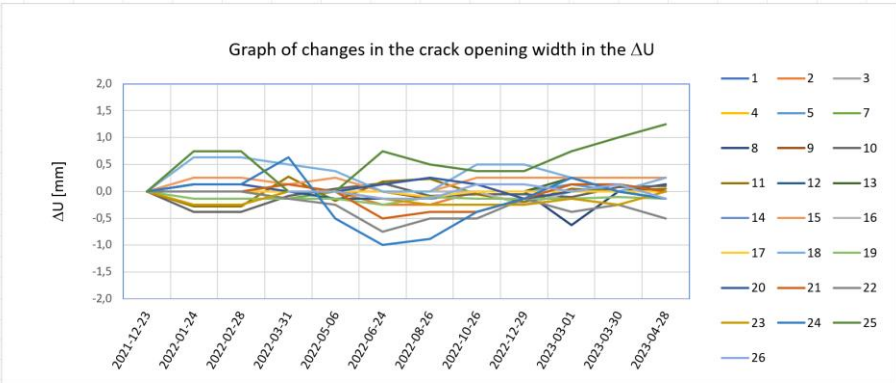

Fig. 21. Changes in the crack opening width in the ΔU direction for crackmeters 1-26

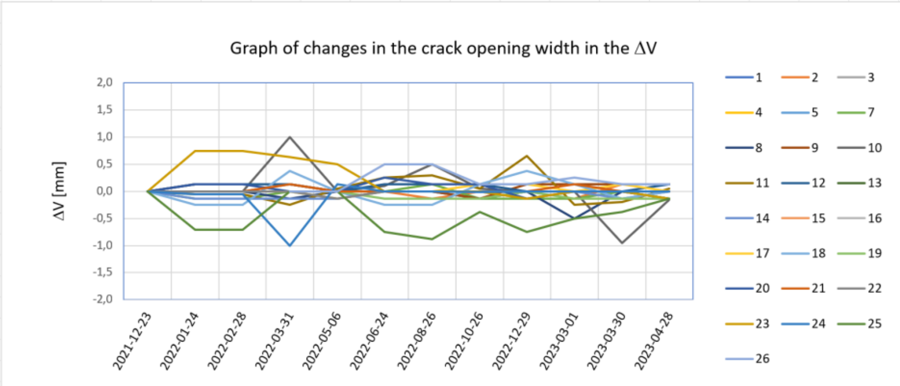

Fig. 22. Changes in the crack opening width in the ΔV for crackmeters 1-26

The extreme values of the opening width on the mounted crackmeters were:
- for direction ΔU:
min ΔU = -1.00 mm - crackmeter no. 24,
max ΔU = +1.25 mm – crackmeter no. 25,
- for direction ΔV:
min ΔV = -1.63 mm – crackmeter no. 25,
max ΔV = +2.40 mm – crackmeter no. S10.

It was found that changes in the width of monitored cracks located on the walls of the building's facade are caused by changes in atmospheric conditions: ambient temperature, humidity, and sunlight. Significant changes in the readings of the S10 crack gauge means that the crack above the lintel is active, and therefore it is recommended to check the lintel's stress and propose ways to strengthen it.

The results of groundwater level readings are shown in Fig. 23.

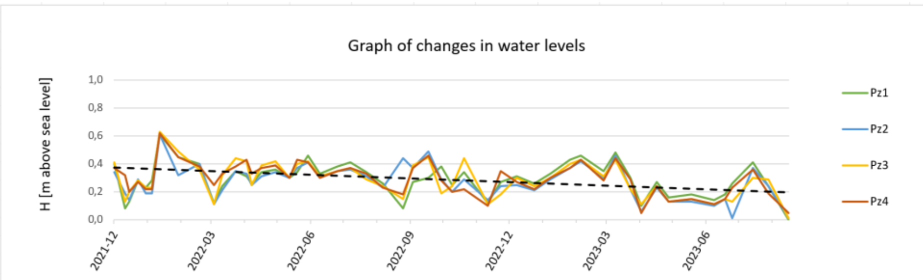

Fig. 23. Graph of changes in water levels in monitored piezometers

Fig. 23 shows the linear regression of changes in the height of the groundwater table in the monitored piezometers as a dashed line. A decreasing trend in the groundwater level near the building was observed in all monitored piezometers.

In the analysis of the conducted research, it was decided to check the strength of rainfall's impact on the obtained displacement values. Increased rainfall can lead to changes in groundwater levels, which can cause land subsidence, potentially affecting buildings. Precipitation can intensify the subsidence of the

building by saturating the soil, reducing its bearing capacity, and leading to increased deformation of the foundations. These analyses will allow for a decision on the further direction of research.
The Stacja Meteo Gdańsk portal was used to analyze the dependence of the influence of rainfall on the values of the obtained displacements. For further analysis, using the Stacja Meteo Gdańsk website, the sum of precipitation falling in the two weeks preceding each of the measurement series was determined. The values of the determined rainfall sums are presented in Table 2.

Table 2. The sum of two weeks of rainfall preceding the measurement epoch

No. of the measurement epoch	Measurement date	Total rainfall [mm]
1	24.01.2022	3.2
2	28.02.2022	17.3
3	31.03.2022	0.5
4	06.05.2022	1.4
5	24.06.2022	10.3
6	26.08.2022	26.8
7	26.10.2022	6.8
8	29.12.2022	16.2
9	01.03.2023	14.4
10	30.03.2023	5.9
11	28.04.2023	5.3

The vertical displacements of each of the controlled points obtained for each measurement series were compared with the values of the sum of precipitation. The strength of the relationship between these variables was determined by calculating the values of the Pearson correlation coefficient, which are presented in Table 3.

Table 3. Correlation coefficient values for vertical displacements

No. of bench-mark	Pearson's linear correlation coefficient	No. of bench-mark	Pearson's linear correlation coefficient
R1	-0.15	R11	-0.43
R2	-0.34	R12	-0.54
R3	-0.28	R13	-0.52
R4	-0.26	R14	-0.59
R5	-0.36	R15	-0.58
R6	-0.60	R16	-0.63
R8	-0.30	R17	-0.50
R9	-0.48	R18	0.18
R10	-0.51	R19	-0.09

The correlation coefficient values were also determined for the resultant horizontal displacements of each of the measuring discs. These values are presented in Table 4.

Table 4. Correlation coefficient values for horizontal displacements

No. of measuring disc	Pearson's linear correlation coefficient	No. of measuring disc	Pearson's linear correlation coefficient
T1	0.19	T11	0.19
T2	0.03	T12	0.03
T3.1	0.45	T13	0.44
T3.2	0.29	T14.1	0.10
T4	0.45	T14.2	0.62
T5.1	0.52	T15	0.55
T5.2	0.50	T16.1	0.86
T6	0.63	T16.2	0.67
T7	0.54	T17	0.74
T8.1	0.36	T18.1	0.69
T8.2	0.70	T18.2	-0.33
T9	0.64	T19	0.43
T10.1	0.38	T20	0.77
T10.2	0.61	T21	0.28

The correlation coefficient analysis shows a weak or moderate dependence of the obtained horizontal and vertical displacements on the amount of precipitation. However, it is worth considering this factor when further analyzing the technical condition of the examined object.
Further analyses included checking the uniformity of vertical and horizontal displacements. These analyses were based on the calculated error of the horizontal and height transformations. For this purpose, each set of bench-marks and measuring targets was divided into four zones (Fig. 7 and 8). The values of the indicator were determined for each zone and each type of displacement. Table 5 presents the values of the indicator for the high-rise network in individual zones.

Table 5. Height transformation error [mm]

Zone	Measurement series										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
A	0.14	0.14	0.27	0.25	0.39	0.42	0.32	0.37	0.19	0.27	0.30
B	0.14	0.15	0.22	0.16	0.30	0.33	0.28	0.18	0.13	0.20	0.17
C	0.16	0.10	0.35	0.31	0.44	0.12	0.14	0.14	0.15	0.11	0.26
D	0.10	0.11	0.18	0.24	0.21	0.31	0.23	0.19	0.13	0.20	0.18

Transformation error values were also determined for horizontal displacements in individual zones. These values are presented in Table 6.

Table 6. Horizontal (situational) transformation error [mm]

Zone	Measurement series										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
A	0.92	2.10	2.41	2.02	3.68	5.35	2.30	2.89	2.61	2.91	2.55
B	1.34	1.91	1.01	1.31	1.49	1.99	1.47	1.51	1.94	1.17	1.04
C	1.45	2.32	1.96	1.93	2.24	2.30	0.73	1.78	2.88	1.88	1.59
D	0.62	1.24	1.05	1.74	2.29	2.61	1.63	2.11	2.14	1.65	1.90

Analyzing the obtained indicator values, one can notice its increased value for zone A. The relationship occurs in both the height transformation error and the horizontal transformation error. Slightly higher values of this indicator in zone A indicate a more uneven distribution of displacements. The obtained displacement values are at a level that does not threaten the facility's use, but their unevenness may cause scratches on the walls both outside and inside the facility. With higher values of this indicator, conducting a more detailed analysis would be recommended.

4. CONCLUSIONS

The article presents the results of monitoring the historical building of the Health and Safety Hall in Gdańsk, which was carried out to find the cause of scratches in its structural elements. The impact of the investment involving the construction of multi-story buildings on adjacent plots was indicated as a factor that may cause more profound damage and create new ones. The monitoring of the facility consisted of determining vertical and horizontal displacements, measuring changes in the width of existing cracks, and controlling the height of the water table in piezometers located in the area adjacent to the “Sala BHP” building. To confirm the conclusion that the current technical condition of the facility is a consequence of the typical operation of a building with a flexible structure, and most importantly, the occurring faults and damages do not threaten the safety of its structure and use, an additional analysis of the uniformity of the obtained displacements was carried out, using the transformation method. The method shows the uneven distribution of the results of displacements of the network of controlled points in a simple way.

The obtained results allow the following conclusions to be formulated:

1. The values of measured vertical displacements of controlled bench-marks mounted on the walls of the monitored facility, ranging from -1.12 mm to +1.43 mm, are lower than the Serviceability Limit State (SLS) recommended by the Building Research Institute.
2. The maximum value of horizontal displacements was -8mm, within the permissible limit according to the currently applicable standard [26].
3. The correlation coefficient analysis showed a weak or moderate dependence of the obtained horizontal and vertical displacements on the amount of precipitation. It is worth considering this factor when further analyzing the technical condition of the examined object.
4. An increased value of the transformation error for zone A was noticed, occurring in both the height transformation error and the horizontal transformation. Slightly higher values of indicator in zone A indicate a more uneven distribution of displacements. Although vertical and horizontal displacements are acceptable and do not threaten the facility's use, their uneven occurrence may cause scratches on the

walls both outside and inside the facility. With higher values of this indicator, it would be recommended to continue research to investigate the phenomenon of scratch formation.
5. No strong dependencies between displacements and individual factors were observed during the analyses. Thus, the initial thesis about the direct impact of the investment carried out in the neighboring building on the formation of scratches in the "Sala BHP" building was not confirmed.

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