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Diagnostics and protection methods a residential building in connection with the reconstruction of a road located in its immediate neighborhood - case study

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Abstract

The paper is a case study in the assessment of the technical condition of a residential building showing a significant degree of technical wear and tear, which was located in the impact zone of the road planned for expansion. Due to the commencement of works related to the expansion of the road, a doubt arose whether the road works carried out, in particular on the section along the residential building, would not cause further deterioration of its technical condition, causing a pre-failure condition, failure or leading to a construction disaster. The paper presents a detailed description of the methodology for assessing the technical condition of the residential building in question.

Keywords: object monitoring, construction failures, construction diagnostics, residential building, utility decapitalization, security works, technical condition, road expansion

1 INTRODUCTION

The technical condition of buildings is influenced by both design errors and shortcomings, as well as execution errors and omissions. The way these facilities are used is also important.

The proper assessment of the current technical condition of buildings is one of the most difficult activities in engineering [1]-[14]. The conclusions from the diagnostic activities carried out not only determine the scope of renovation works, which involves incurring very high financial costs, but also very often determine the possibility of

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further operation of the facility in question due to its technical condition [15]-[20]. An engineering-correct assessment of the technical condition makes it possible to clearly determine whether further use of the facility is possible due to the safety of the structure and operational safety. These activities require in-depth engineering knowledge, especially when assessing facilities completed in the past and with a significant degree of technical wear and tear. In these cases, due to the technical solutions used in the past, the elements subject to detailed assessment are masonry structures, in particular those made of ceramic bricks and natural stone. This situation occurs regardless of whether a given object is or not an immovable monument [21]-[22].

When assessing the technical condition of each building, regardless of the period of its implementation, it is necessary to properly recognize not only its structural system, but also assess the impact of external conditions, including dynamic traffic impacts [23]-[26]. An important issue is to correctly take into account both the form and the scope of deformation of the subsoil, in particular in terms of its locally reduced load-bearing capacity [27]-[43] or changes in load-bearing capacity occurring over time. Thermal protection issues are also very important [44]-[48], as well as taking into account the often overlooked impact of natural conditions [49]-[52].

It should not be forgotten that a proper assessment of the technical condition of buildings requires recognition not only of their structural system, location conditions and environmental loads, but also requires knowledge of the technical and technological solutions used during their implementation, which is particularly important in the case of objects implemented in distant years, especially in the case of historic buildings [53].

The aim of the paper is to present the results of the analysis of the technical condition of a residential building located in the immediate vicinity of the road that was to be expanded.

The purpose of the assessment of the technical condition of the residential building was also to determine whether, due to its current technical condition, the safety of the structure and the safety of use of the facility as a whole were ensured.

Moreover, the aim of the study was to state:

- whether the technical condition of the building being the subject of the analysis limited the work related to road expansion,
- whether, due to the current technical condition of the building, it was possible to start operating the expanded road without negative consequences for the building in question.

The scope of the analysis included:

- indication of the scope of work necessary to be carried out in the area of a residential building in order to enable safe operation of the expanded road
- indication of the target scope of work necessary to be carried out in the area of the building in question in order to bring it to the proper technical condition.

Fig. 1: Basement diagram of a residential building:
(**L**): basement part, right side (**R**): part without basement, left side

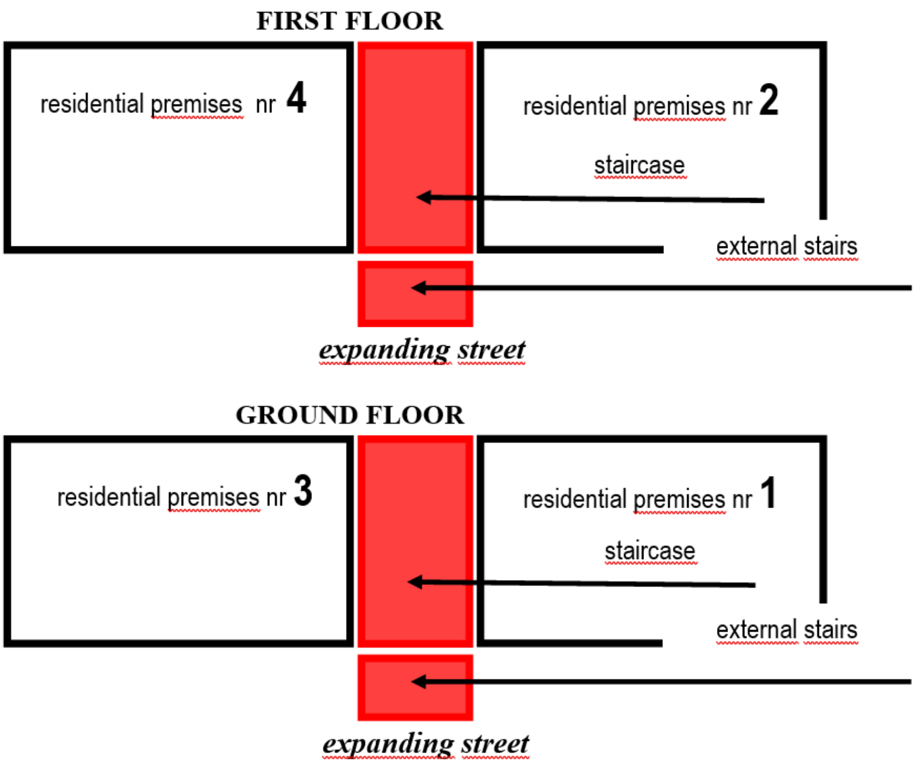


Fig. 2: Functional and utility layout diagram of a residential building

a)

b)

c)

d)

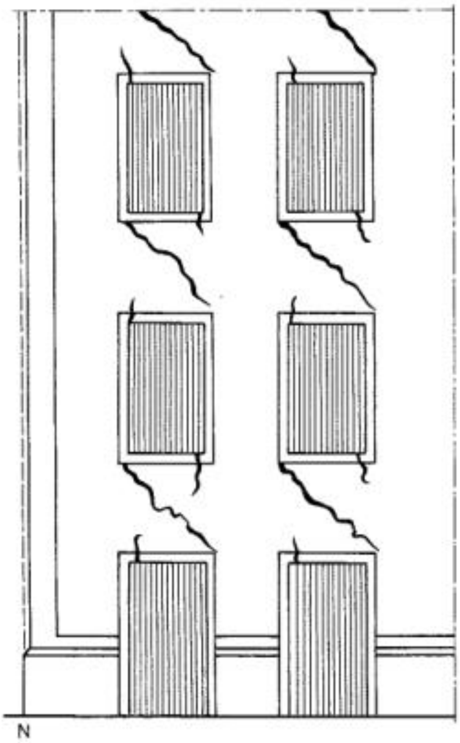
Fig. 3: Location of the outcrops in the residential building: a) view of the building from the street (front elevation), b) internal outcrop (in the basement): O1, external outcrops: c) O2 and d) O3

Fig. 4: Distribution of damages to the front wall (northern elevation) in the residential building: a) general view of the front elevation, b) left side (L) (basement part), c) right side (R) (non-basement part)

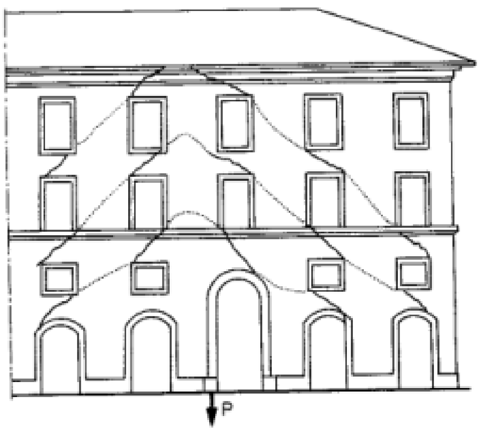
Rys. 2–33. Rysy ściany wskutek nierównomiernego osiadania [124]

Rys. 2–34. Rysy w ścianie od nierównomiernego osiadania (symetryczne) [124]

b)



Rys. 3-11. Rysy spowodowane obniżeniem się narożnika budynku w punkcie *N*



Rys. 3-8. Układ rys powstałych wskutek silnego osiadania gruntu w punkcie P

Fig. 5: The mechanism of damage to external walls caused by uneven settlement according to: a) Mitzel A., Stachurski W., Suwalski J.: Failures of concrete and masonry structures, *Arkady Publishing House*, Warsaw 1973, b) Masłowski E., Spiżewska D.: Strengthening of building structures, *Arkady Publishing House,* Warsaw 2000

2 CHARACTERISTICS OF THE RESIDENTIAL BUILDING

The building was constructed in the early 20th century as a residential building, using traditional technology, with a partial basement, 2-story, with an attic not usable. The building had a longitudinal structure of walls. The external walls of the basement were made of stone, made of pebbles, built on cement and sand mortar with the addition of clay. The thickness of the stone walls was ~70 cm. The internal longitudinal wall at the basement level was made of a brick wall made of solid ceramic bricks, 25 cm thick, built with cement and sand mortar. The external walls of the ground floor were made of solid ceramic bricks, 38 cm thick, with cement and lime mortar. The internal longitudinal wall on the ground floor is made of solid ceramic brick, 25 cm thick, built with cement and lime mortar. On the first floor, all walls, both the external and the internal longitudinal one, were made of solid ceramic brick, 25 cm thick, built on cement and lime mortar. The ceiling above the basement was made of steel beams made of I-beams I140 cm spaced every ~110 cm and filled with a sectional vault made of full ceramic brick with a height of ~15 cm. The ceilings above the ground floor and the first floor were constructed as ceilings on wooden beams, made of beams with cross-section dimensions of 12×26 cm, spaced every ~110 cm. The roof was constructed as a purlin roof, with posts with cross-sectional dimensions of 14×14 cm and intermediate purlins with cross-sectional dimensions of 14×16 cm, stiffened with swords of 14×14 cm. The roof was covered with 2.5 cm thick edged boards. The roof covering was made of thermally weldable felt.

There were 4 independent residential premises in the building: 2 apartments were located on the ground floor and 2 apartments were located on the first floor.

The owners of the building did not have any archival documentation of the facility, nor did they have an architectural inventory of it.

According to the owners' oral statement, no Construction Object Book (KOB) was kept for the building, nor were any Inspections of the technical condition of the building (so-called annual inspections) and Inspections of the technical condition and suitability for use of the building, the aesthetics of the building and its surroundings (so-called 5-year reviews).

Fig. 1 shows a view of the front elevation of a residential building. The part with a basement, including the width of the basement staircase, will be referred to later in the article as the left side (L), while the part without a basement will be referred to as the right side (R).

3 DESCRIPTION OF THE CONDITION OF THE EXISTING RESIDENTIAL BUILDING

On the front, longitudinal wall (northern façade), damage to the brick wall of the longitudinal wall was visible: scratches to the strips under the windows occurred both on the ground floor and on the first floor, in the basement part (L) and in the non-basement part (R). The scope of damage in the basement part was greater: scratches and cracks in the brick strips under the windows were larger. The brick wall of the front wall was not plastered.

There were no significant scratches or cracks visible on the gable and side walls (eastern façade). The wall was plastered with cement and lime plaster. There was an extension (vestibule) attached to the wall, constructed in recent years in a commercial manner. The roof formwork hanging outside the building showed signs of moisture.

On the longitudinal garden wall (southern façade), there were visible scratches in the window arches, as well as in the window sill zones. In practice, scratches in the wall occurred in the area of all window openings.

The gable and side wall (eastern façade) was insulated with expanded polystyrene (styrofoam-EPS), the insulation had a protective layer in the form of thin-layer plaster. There were no visible damages to the insulation made according to the ETICS technology (formerly: BSO, formerly: light method).

The external walls of the basement part were made of stone, made of pebble boulders on a cement-sand mortar with the addition of clay. The thickness of the stone walls was ~70 cm. There was no concrete floor in the basement rooms, it was replaced by packed earth, the so-called threshing floor. The view from the inside of the basement showed cracks in the joints. In the basement zone (near the ground), dampness of the stone wall was visible and palpable, and the joints were wet. The ceiling above the basement was made of steel beams made of I-beams I140 mm spaced every ~110 cm and filled with a sectional vault made of full ceramic brick with a height of ~15 cm. The steel beams showed extensive surface corrosion, locally turning into swelling corrosion. The bricks filling the sectional vaults showed local loosening and chipping of the joints was visible.

Residential premises no. 1 on the ground floor were renovated in recent years. There was a visible crack in the ceiling lining. There were also visible scratches at the ceiling-wall junction in some rooms.

In residential premises No. 3, on the ground floor, extensive plaster scratches were visible, both on the surface of the walls, in particular the partition walls, and at the point where the partition walls meet the external walls. The ceiling lining was scratched, and in some rooms the ceiling was covered with Styrofoam panels.

Apartment no. 2 on the first floor was partially renovated. In the renovated part, scratches were visible where the ceiling meets the walls.

In apartment no. 4, on the first floor, there were visible scratches in the plaster on the walls, especially on the partition walls. Scratches also occurred at the junction between partition walls and external walls. The ceilings were covered with coffers, which made it impossible to assess the degree of scratches on the headliner.

The building's roof was constructed using a purlin-and-tip roof. The roof did not have transverse bracing in the form of pincers in the line of posts supporting the intermediate purlins. The wooden elements showed no visible signs of biological corrosion, and there were no visible signs of larvae or insect feeding.

The ceiling on wooden beams above the first floor did not have a wooden floor made of boards, made of tongue-and-groove boards or as a floor made of edged boards, only OSB boards were laid on part of the floor plan. The space between the wooden ceiling beams was filled with plaster, locally insulated with a layer of mineral wool.

The roof covering was made of thermally weldable felt placed on a sheathing made of edged boards. The chimney shafts leading above the roof slope were renovated, some were plastered while replacing the roofing felt, some were rebuilt with clinker bricks. The roofing felt did not have any bumpers, the so-called catch basins draining rainwater from the chimney shafts.

4 ANALYSIS OF THE TECHNICAL CONDITION OF THE RESIDENTIAL BUILDING IN THE ASPECT OF ROAD IMPLEMENTATION

There were no visible defects or damages in the building, the morphology of which would indicate that their cause may be the current or past negative impact of motor vehicle (car) traffic on the surrounding roads, including the street along which the building in question was located.

In the facility as a whole, no damage typical of vibrations caused by the movement of motor vehicles (scratches and cracks with a typical X or ½ X morphology) was found. There were no noticeable vibrations of the ground around the building caused by construction works directly related to the expansion of the road - no measurement of vibrations of the ground around the building was carried out, and no measurements of vibrations of the structure of the facility itself were made: taking into account the location conditions and the current technical condition, it was considered that dynamic measurements were completely unnecessary.

The issue of damage in terms of cracks and scratches in the front wall on the northern facade and scratches on the garden wall on the southern facade is discussed later in this article.

In the past period, no trees with significant trunk or crown size were removed from the area adjacent to the facility covered by the study, and no new tall trees and shrubs were planted.

Therefore, there were no grounds to conclude that the root system of the tree stand had ever or will have in the future a significant impact on the occurrence of defects and/or damage to the foundations of the building in question, as well as to formulate the thesis that the roots of the tree stand have contributed or will contribute in the future to disturbances in soil and water conditions in the area of the building as a whole, in accordance with the mechanism described in [49]-[52].

Fundations

Based on the excavations made, it was determined that the building is founded on stone walls that do not have any offsets.

In order to identify the foundation method, 3 excavations were made (Fig. 3):

- on the left side (L) (in the basement part): internal excavation O1, from the side of the basement room,
- on the right side (R) (in the part without a basement): external excavations O2 and O3, from the outside of the building.

In the basement part (L), the thickness of the stone wall, built on cement and sand mortar with the addition of clay in the part buried in the ground and on cement and sand mortar in the part above ground level, was ~70 cm. The thickness of the stone wall measured in the excavations made in the part without a basement (R) was from 60 to 70 cm and was similar to the thickness of the wall in the basement part (L). The decision was not made to make any open-pits on the garden elevation (south) and side elevations (east and west). For the purposes of further analysis, it was assumed that the same construction solutions were used along these walls. In the basement part (L), there is no concrete floor in the rooms, the floor was made of compacted earth, the so-called threshing floor, in some rooms ceramic bricks were laid flat on the ground. The stone wall was founded on a layer of mortar ~8 cm thick. The foundation level was at a depth of ~12 cm below the level of compacted earth in the basement. The level of the threshing floor was variable, locally it was visible lowering, which meant that the stone wall was practically founded at the level of compacted earth in the basement. Since the ground level around the building was ~150 cm above the level of the stone wall foundation, it could be assumed that in the part sunk into the ground the wall was below the ground frost zone, assuming, in accordance with the requirements of the no longer applicable, but commonly used in engineering practice, standard PN-B-03020 Direct foundation of structures. Requirements and calculations, the depth of the frost zone in the building location is 100 cm below ground level. In the part without a basement (R), the stone wall was founded on a layer of mortar ~6 cm thick. The foundation level was at a depth of ~15 cm below the ground level around the building, i.e. in the ground frost zone.

The applied solution, i.e. a partial basement of the building, contributed to its uneven settlement, especially when the part without a basement was located in the ground freezing zone.

Vertical partitions (walls)

Based on the macroscopic assessment, the mortar used to build the stone wall at the basement level was determined to be grades M2 to M3 (fm=2 to 3 MPa). This assessment only concerned the part of the wall that was not intensively damp. In the floor zone (at the dirt floor), the joints were damp and their strength was reduced.

Based on the macroscopic assessment, the brick built into the walls at the level of all storeys was assessed as grades 75 to 100 (fb=7.5 to 10 MPa), while the mortar was determined to be grades M1 to M3 (fm=1 to 3 MPa).

In the front wall on the northern elevation, where the brick was not protected with plaster, erosive mortar defects were visible

The load-bearing capacity of the building's walls was not analyzed. The thermal insulation, fire protection (in terms of the ZL hazard category and fire resistance class) and acoustic properties of vertical partitions such as walls were also not subjected to detailed analysis. Mass moisture measurements (Um) were also omitted. The above issues were not crucial for making a decision on how to secure the walls of the building in question in connection with the road expansion being implemented.

Scratches and cracks were visible on the front (northern) elevation (Fig. 4). Scratches were also visible on the garden (southern) elevation. The morphology of the above damage, especially that visible on the unplastered brick wall, i.e. on the front elevation, indicated that they were the result of uneven settlement of the building as a consequence of its partial basement. A similar picture of damage can be found in the literature on the subject (Fig. 5): in the case of the building in question, the analogy to the examples from the literature is that, similarly to Fig. 5, damage to the wall is visible, i.e. its cracks above the window arches that are tilted to the right, in the basement part (L) and to the left in the part without a basement (R). The inclination of the cracks is consistent in terms of direction with the place of change in stiffness caused by the partial basement. The foundation of the part without a basement (R) in the ground freezing zone additionally contributed to the formation of damage to the wall - this method of foundation results in damage to the front elevation tilted to the right: in the winter, the corner of the building was uplifted upwards, and in the summer it settled excessively, which resulted in the formation of diagonal cracks tilted to the right. Unquestionably, the lack of tie beams between floors and the probable lack of frontal and side anchoring of the ceiling beams contributed to the extension of the damage to the wall. In practice, it was impossible to estimate quantitatively to what extent the previous traffic on the street contributed to the damage to the building's walls. Certainly, vibrations from moving vehicles had a negative effect, especially since the analyzed building had no foundations, which made it even more sensitive to vibrations from road traffic, propagating through the ground and affecting its structures - however, it was impossible to assess quantitatively the impact of traffic on the technical condition of the walls in practice.

Inter-storey ceilings

At the level above the basement, the ceiling was constructed as on steel beams with the spaces between I140 I-beams filled with brick segmental vaults spaced ~110 cm apart.

The steel elements showed extensive surface corrosion along their entire length. Locally, especially in the wall zones, the lower flanges were damaged by intumescent corrosion. During the inspection, no advanced pitting corrosion was found, which led to the loss of the lower flanges.

The bricks of the segmental vaults showed mechanical damage, some of them were cracked. During the inspection, no bricks were found to be falling out of the vaults. On the side of the basement rooms, the brick vaults in most cases did not have a plaster coating, and the plaster on the bottom of the vaults in several rooms was scalded.

In the ceiling level above the basement on the outside of the walls, there was no visible frontal and side anchoring of steel ceiling beams.

Despite the extensive degradation of the ceiling above the basement, no excessive deflection of the steel ceiling beams was found. There were also no signs of ceiling overload in the form of collapses and collapses of the brick segmental vaults.

The ceilings above the ground floor and the first floor were constructed as a ceiling on wooden beams. The spacing of the ceiling beams in the ceiling above the first floor was ~110 cm. The ceilings showed deflection of the ceiling, which in most rooms was covered with polystyrene cassettes. In some rooms, the ceilings were covered with plasterboards, which made it impossible to assess the actual deflection of the ceilings. No collapses of the ceiling above the ground floor or the first floor were found in any of the rooms subject to inspection. Visually, the range of the occurring deflection of the ceilings built up with cassettes corresponded to typical deflection of rheological origin.

At the level of the ceiling above the ground floor and above the first floor on the outside of the walls, there was no visible frontal and lateral anchoring of the wooden ceiling beams.

It was decided not to perform verification of the tangential and strength calculations of the inter-storey ceilings because their load-bearing capacity was not directly related to the main objective of the analysis of the technical condition of the building, i.e. its ultimate protection in connection with the ongoing road expansion.

Chimney shafts

The brick chimney shafts in the building area were tight, there were no external signs of leaks. In some residential premises, the plaster on the chimney shafts was cracked. The extent of plaster damage on the shafts was similar to the plaster damage on the partition walls and the soffit. In the part extending above the roof slope, the chimney shafts were renovated during work related to the replacement of the roofing felt.

Wooden roof

The steep wooden roof was made as a massive carpentry roof of the purlin type. There was no visible deformation of the roof surface from the outside. The roof covering was replaced in previous years with new ones made of thermo-weldable roofing felt.

In the view from the inside of the usable attic, there were also no visible signs of roof structure deformation, the structural elements did not show excessive deflection. The wooden elements did not show signs of larvae or insects feeding, and there were no visible signs of biological corrosion of parts of the wooden elements under the roof covering.

The roof covering elements visible from the outside showed signs of dampness, which was a consequence of the previous leak in the roof covering.

Joinery (windows and doors)

The window joinery in some of the rooms of the residential premises was replaced with modern PVC profiles. In some of the rooms, the built-in joinery was still original and secondary, wooden, intensively depreciated.

The door joinery in the rooms of the residential premises was also partially replaced, but in some of the rooms the previously built-in joinery still remained.

Pipe and cable installations

In the building in question, the following industry installations: pipes (central heating, water supply, sewage) and wires (electrical installation) were technically efficient.

The installations were implemented according to the construction standards in force in previous years.

The degree of technical efficiency of the above installations corresponded to the period of their use.

5 ANALYSIS OF THE TECHNICAL CONDITION OF THE RESIDENTIAL BUILDING IN THE ASPECT OF ROAD IMPLEMENTATION

Due to the scope of the damage and taking into account the ongoing and planned road expansion, the renovation and repair works of the building in question had to be carried out in a **STAGE** system:

STAGE 1 - to be carried out at the moment, enabling inspection of the technical condition of the building, during works related to the expansion of the road on the section along the building:

- start conducting geodetic monitoring of the building. The proposed location of target plates, benchmarks and feeler gauges is shown in Fig. 6,
- during installation of target plates and feeler gauges, care should be taken not to attach them to the plaster but directly to the wall,
- geodetic measurements should be carried out at the following time intervals:
  - ❖ reading "0": immediately after installation,
  - ❖ for a month after the installation of the elements: every week,
  - ❖ after a month: every 2 weeks,
  - ❖ during the period of construction works related to the reconstruction of the road in the area of the building: every week,
  - ❖ when the works related to the reconstruction of the road are completely completed: every month for 6 months,
- after the completion of **STAGE 2** works, the feeler gauges may be destroyed. In such case, geodetic measurements should be limited to measurements of benchmarks and target plates, which are recommended to be carried out for a year at monthly intervals.

FRONT ELEVATION (NORTH)

Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

SIDE ELEVATION (EASTERN)

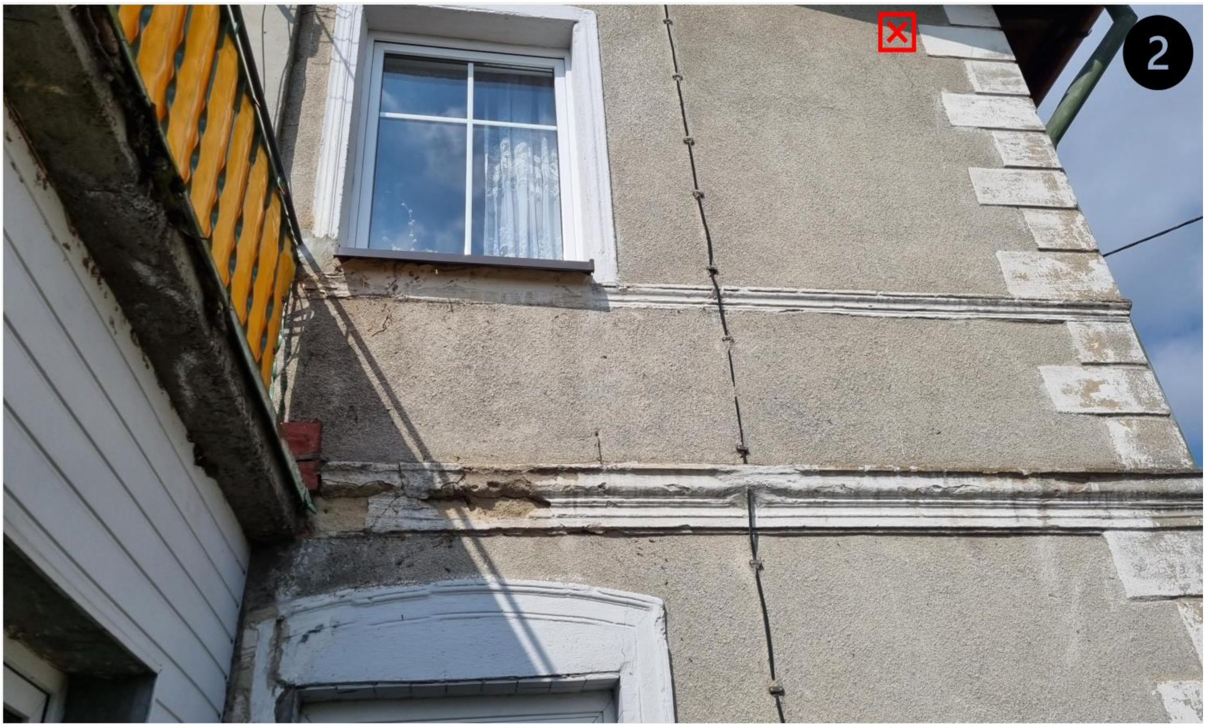


Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

SIDE ELEVATION (EASTERN)

Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

GARDEN ELEVATION (SOUTH)

Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

GARDEN ELEVATION (SOUTH)

Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

GARDEN ELEVATION (SOUTH)

Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

SIDE ELEVATION (WEST)

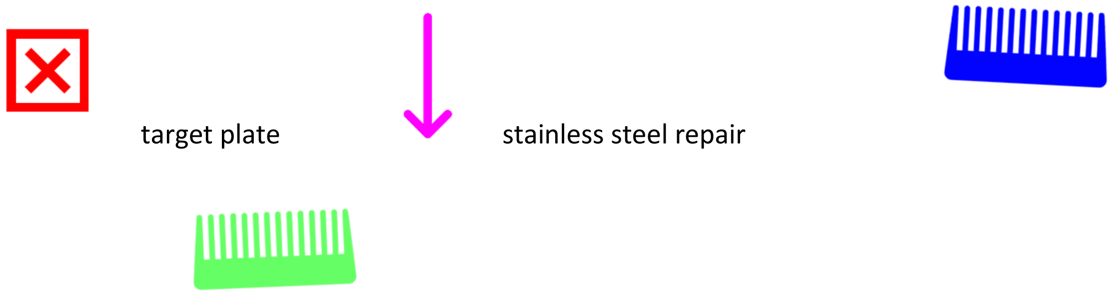


Fig. 6: Proposed location of target plates, benchmarks and feeler gauges on the external walls of a residential building: 1) front elevation (north), 2) side elevation (east), 3) garden elevation (south), 4) side elevation (west)

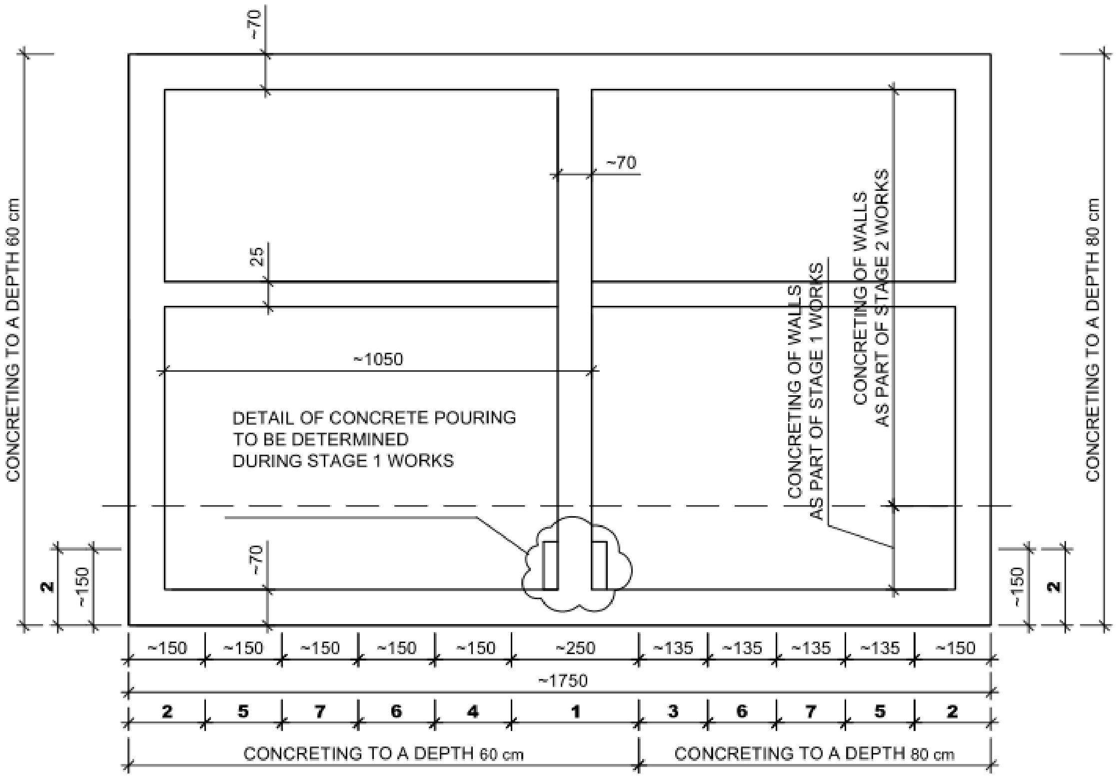


Fig. 7: The sequence of reinforcement of the front, longitudinal wall (northern elevation) in a residential building: a) general view of the front elevation, b) left side (L) (basement part), c) right side (R) (non-basement part)

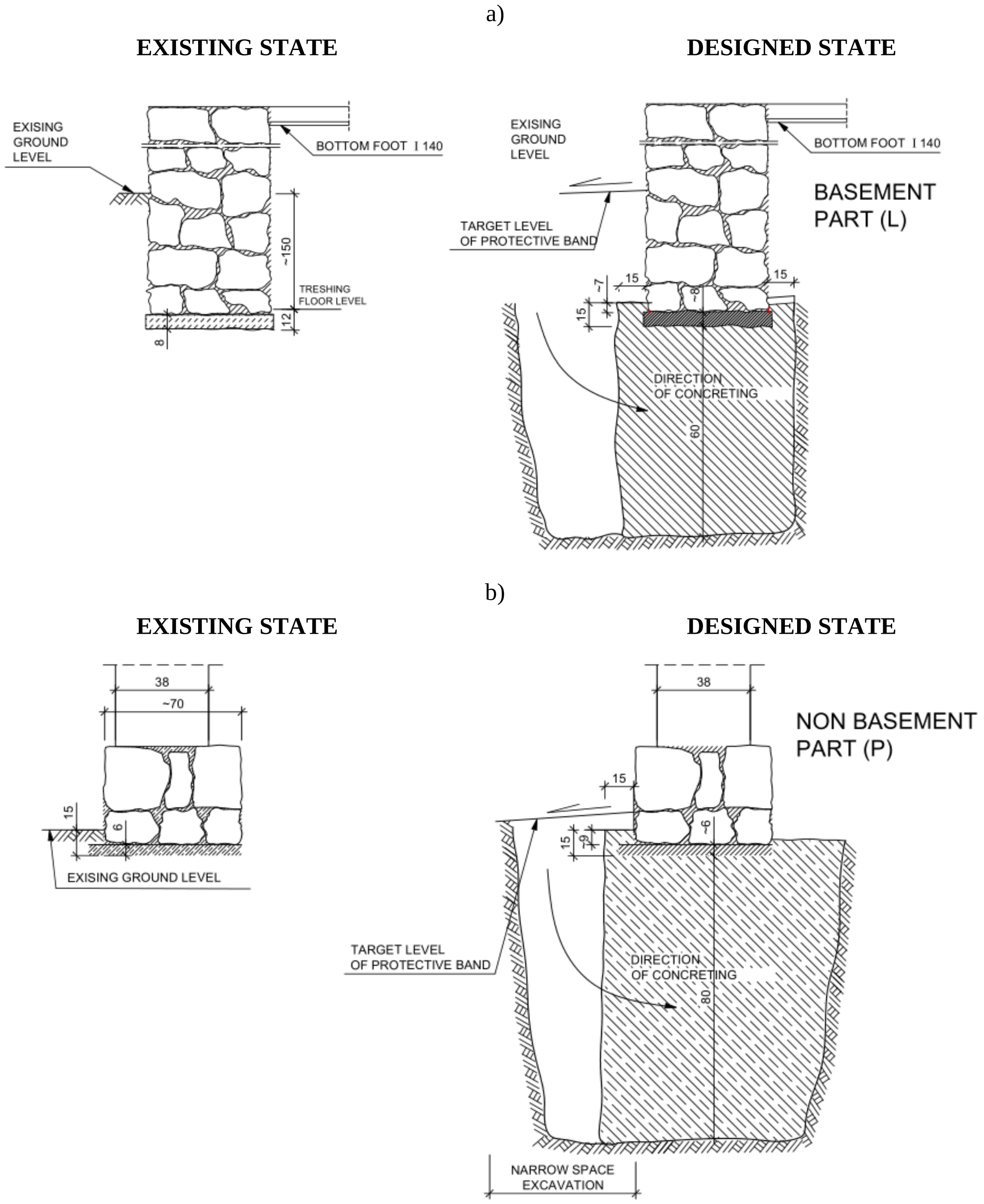


Fig. 8: Details of reinforcement of the front, longitudinal wall (northern elevation) in a residential building: a) left side (L) (basement part), c) right side (R) (non-basement part)

<u>STAGE 2</u> - to be implemented as part 1 of the major renovation of the building, enabling preliminary reinforcement of the imperfect foundation of the building:

- dismantle the entrance stairs to the building from the street side,
- perform sub-concreting of the front, longitudinal wall (northern elevation) according to the concept of solutions presented in Fig. 7 and Fig. 8,
- sub-concreting of the left side (L) (basement part) should be performed from the outside of the building with a control excavation of the wall foundation from the basement side in order to check whether the concrete introduced under the stone wall tightly fills the space under the wall across its entire width,
- sub-concreting of the right side (R) (non-basement part) should be performed from the outside of the building, paying particular attention to ensuring that the concrete is distributed across the entire width,

- sub-concreting at the place of change in the depth of the stone wall foundation, i.e. at the connection of parts L and P, should be performed from the outside of the building, maintaining far-reaching care in filling the space under the stone wall with concrete,
- as part of the works related to strengthening the front wall, strengthen parts of the gable and side walls (eastern elevation and western elevation) - the scope of reinforcement in accordance with the solution presented in Fig. 7,
- fill the joints of the stone wall from the outside and inside using cement mortar - it is recommended to use a system-based packaged (bagged) mortar characterized by low shrinkage,
- after completing the works related to strengthening the front wall, reconstruct the entrance stairs from the street side.

STAGE 3 - to be implemented after the completion of STAGE 2 works (part 2 of the major renovation of the building) in order to protect the building structure from deterioration of its technical condition:

- reinforce the walls:
  - ❖ gable, side (eastern elevation),
  - ❖ garden, longitudinal (southern elevation),
  - ❖ gable, side (western elevation),
  - ❖ internal longitudinal

According to technological solutions, as in the case of the front, longitudinal wall (northern elevation),

- fill the joints of the stone wall from the outside and inside using cement mortar - use a system-based packaged (bagged) mortar characterized by low shrinkage, similarly to the works carried out under **STAGE 2**,
- after the completion of works related to the reinforcement of the walls, the damage occurring in the form of cracks and scratches should be secured:
  - ❖ groove the cracks in the wall visible from the outside along the entire height of the building,
  - ❖ prepared grooves blow out with compressed air, clean and remove dust,
  - ❖ fill (close) the grooves with a fast-setting (fast-acting), swelling mortar used to seal point water outflows,
  - ❖ seal the secured grooves by using pressure injection (gluing) using mineral material for injection fillings,
  - ❖ cracks found during repair work, visible on the outside should be repaired by using pressure injection (gluing):
    - ➢ scratches with a gap width of more than 1 mm should be repaired using cement suspension,
    - ➢ scratches with a gap width of up to 1 mm should be repaired using epoxy-based duramer resin,
- wall scratches visible from the inside of the building should be repaired according to the solutions for damage with a gap width of more than 1 mm and up to 1 mm, after preparing the crack by chiseling off the plaster, widening it, chamfering it, and then blowing it out with compressed air, cleaning and dust removal,
- the scope of wall repair works described above should be applied to walls repaired as part of **STAGE 3** works, as well as previously as part of **STAGE 2** works.

STAGE 4 – to be implemented as part of the planned periodic renovations:

- start successive renovation works including:
  - ❖ renovation of the ceiling above the basement (anti-corrosion protection or local replacement of corroded steel ceiling beams, replacement and repair of the brick filling of the segmental vaults, plastering of the brick vaults),
  - ❖ construction of a concrete floor in the basement (insulated, on a substructure made of “lean” concrete),
  - ❖ construction of efficient gravity ventilation, with the possibility of supporting it with mechanical ventilation in the basement rooms,
  - ❖ renovation works related to the replacement of scalded and cracked plasters on the walls and ceilings in the residential premises and on the staircase,

- insulation of the garden wall, longitudinal wall (south elevation), gable wall, side wall (east elevation) and increasing the existing insulation on the gable wall, side (western elevation) - the ETICS (BSO) technology should be used as a solution,
- the issue of insulation of the front, longitudinal wall (northern elevation) currently not plastered and presenting the original brick layout should be consulted with the appropriate local conservation administration body,
- reprofiling of the area around the building, making protective concrete bands around the building, profiled with a slope towards the outside "from the building".

6 Conclusions

The degree of decapitalization of the residential building covered by the analysis, both its structural and finishing elements, negatively exceeded the technical condition appropriate to the period of use - the building as a whole was in a state of far-reaching operational decapitalization.

The direct causes of the current technical condition of the building covered by the analysis as a whole were:

- imperfections of the technical solutions used during its implementation,
- long-term use of the building,
- no major renovation of the facility has been carried out so far,
- lack of regular periodic renovations.

Due to the current technical condition, the residential building that was the subject of the analysis as a whole was in a condition that did not pose a direct threat to the safety of the structure and the safety of use.

However, the building required renovation and repair work. Failure to start them could have led to a pre-failure condition in the building in question.

The current technical condition of the residential building that was the subject of the analysis did not limit the work related to further expansion of the road, in particular on the section along the building in question.

Bibliography

[1] Baranowski W.: *Zużycie obiektów budowlanych*. Wydawnictwo Warszawskiego Centrum Postępu Techniczno-Organizacyjnego Budownictwa, Ośrodek Szkolenia WACETOB sp. z o.o., Warszawa, 2000.

[2] Baryłka A., Baryłka J.: *Diagnostyka techniczna obiektu budowlanego*. Budownictwo i Prawo, Warszawa, 19-22, 4, 2015.

[3] Halicka A.: *Ocena istniejących konstrukcji budowlanych według normy ISO 13822-2010*. V Ogólnopolska Konferencja Problemy techniczno-prawne utrzymania obiektów budowlanych. Warszawa, 2019.

[4] Substyk M.: *Utrzymanie i kontrola okresowa obiektów budowlanych*. Wydawnictwo ODDK, Warszawa, 2012.

[5] Szer J., Jeruzal J., Szer I., Filipowicz P.: *Kontrole okresowe budynków – zalecenia, wymagania i problemy*. Wydawnictwo Politechniki Łódzkiej, Łódź, 2020.

[6] Drobiec Ł.: *Przyczyny awarii i katastrof obiektów zabytkowych*. XXX Konferencja Naukowo-Techniczna Awarie Budowlane-2022, 33-52, Szczecin - Międzyzdroje, 2022.

[7] Majewski T., Niedostatkiewicz M.: Monitoring of a historic sacral building on an example Basilica St. Nicholas in Gdańsk. *Inżynieria Bezpieczeństwa Obiektów Antropogenicznych*, 3, 30-42, Warszawa 2024, https://doi.org/10.37105/iboa.179.

[8] Niedostatkiewicz M.: *Building modernization located in the conservation protection zone in the aspect of technical conditions*. Inżynieria Bezpieczeństwa Obiektów Antropogenicznych, 1, 58-74, Warszawa, 2022, https://doi.org/10.37105/iboa.133.

[9] Niedostatkiewicz M., Majewski T.: *Assessment of technical conditions in adapting a historic warehouse's space functionality*. Modern Engineering, 4, 7-37, Warszawa 2023.

[10] Niedostatkiewicz M., Majewski T.: *Bunker demolition located in a conservation protection zone in the light of technical, national defense, functional-utility and economic conditions*. Inżynieria Bezpieczeństwa Obiektów Antropogenicznych, 4, 1-11, Warszawa, 2022, https://doi.org/10.37105/iboa.155.

[11] Niedostatkiewicz M., Majewski T.: *Demolition of the cereal elevator buildinglocated in the conservation protection zonein the aspect of technical, functional-utility and economic conditions*. Inżynieria Bezpieczeństwa Obiektów Antropogenicznych, 3, 55-65, Warszawa, 2022, https://doi.org/10.37105/iboa.151.

[12] Niedostatkiewicz M., Majewski T., Baryłka A.: *Renovation works in buildings in the area of former defensive fortifications*. Inżynieria Bezpieczeństwa Obiektów Antropogenicznych, 1, 1-21, Warszawa, 2023, https://doi.org/10.37105/iboa.164.

[13] Podolski B., Bober W.: *Zagrożenia bezpieczeństwa w kwalifikowanych do remontu budynkach starej zabudowy*. VII Konferencja Naukowo-Techniczna Problemy Remontowe w Budownictwie Ogólnym, Wrocław-Szklarska Poręba, 231-236, 1996.

[14] Radziszewska-Zielina E., Fedorczuk-Cisak M., Steidl T.: *Wybrane aspekty diagnostyki i remontu sakralnych obiektów zabytkowych*. XXX Konferencja Naukowo-Techniczna Awarie Budowlane-2022, 243-254, Szczecin - Międzyzdroje, 2022.

[15] Masłowski E., Spiżewska D.: *Wzmacnianie konstrukcji budowlanych*. Wydawnictwo Arkady, Warszawa, 2000.

[16] Mitzel A., Stachurski W., Suwalski J.: *Awarie konstrukcji betonowych i murowych*. Wydawnictwo Arkady, 1982.

[17] Niedostatkiewicz M.: *Dachy, stropodachy, tarasy. Remonty i wzmacnianie*. Polskie Centrum Budownictwa Difin i Muller sp. z o.o., 1-178, Warszawa 2016.

[18] Niedostatkiewicz M.: *Prace remontowo-naprawcze w obiektach zabytkowych. Wybrane przykłady*. Wydawnictwo Bernardinum, 1-299, Pelplin 2023.

[19] Ściślewski Z.: *Trwałość konstrukcji żelbetowych*. Wydawnictwo ITB, Warszawa, 1995.

[20] Thierry J., Zaleski S: *Remonty budynków i wzmacnianie konstrukcji*. Wydawnictwo Arkady, Warszawa, 1982.

[21] Niedostatkiewicz M., Majewski T.: *Badania wytrzymałości historycznych murów ceglanych.* XXXVIII Ogólnopolska Konferencja Warsztat Pracy Projektant Konstrukcji WPPK-2024, tom 1, 175-214, Wisła 2024.

[22] Stawiska N., Stawiski B.: *Rewaloryzacja murów w obiektach zabytkowych.* Wiadomości Konserwatorskie, 11, 18-22, Kraków, 2005.

[23] Kawecki J., Stypuła K.: *Diagnozy a posteriori wpływów drgań drogowych na budynki.* XXIV Konferencja Naukowo-Techniczna Awarie Budowlane-2009, 539-546, Szczecin-Międzyzdroje 2009.

[24] Kawecki J., Stypuła K.: *Jeszcze raz o błędach w diagnozach dotyczących oceny wpływów dynamicznych na budynki oraz ludzi w budynkach*. XXVI Konferencja Naukowo-Techniczna Awarie Budowlane-2013, Szczecin-Międzyzdroje 2013.

[25] Kawecki J., Tatara T.: *Procedury uwzględniania wpływu drgań komunikacyjnych na budynki eksploatowane.* Inżynieria i Budownictwo, 3-4, 132-144, Warszawa 2023.

[26] Wilde K., Rucka M., Chróścielewski J., Niedostatkiewicz M.: *Rozwiązanie przegrody wibroizolacyjnej w budynku zabytkowym narażonym na drgania wywołane ruchem kołowym i szynowym.* Inżynieria Morska i Geotechnika, 5, 408-411, Gdańsk 2013.

[27] Bjurstrom H., Ryden N.: *Detecting the thickness mode frequency in a concrete plate using backward wave propagation.* J. Acoust. Soc. Am., 139 (2), 649-657, 2016.

[28] Borowczyk M., Frankowski Z.: *Polowe badania gruntu lekką sondą stożkową.* Inżynieria i Budownictwo, 3/1974, Warszawa, 1974.

[29] Borowczyk M., Frankowski Z.: *Problemy interpretacji wyników sondowań dynamicznych w gruntach niespoistych.* Inżynieria i Budownictwo, 7-8/1985, Warszawa, 1985.

[30] Conyers L.B. 2015. *Analysis and interpretation of GPR datasets for integrated archaeological mapping: Multiple GPR datasets for integrated archaeological mapping*. Journal of Near-surface Geophysics, 31, 1, 2241-2262.

[31] Dahlin T. & Zhou B. 2006 - *Multiple-gradient array measurements for multichannel 2D resistivity imaging, Near Surface Geophysics,* : Vol 4, No 2, April 2006 pp. 113 – 123.

[32] Ganji V., Gucunski N., Nazarian S.: *Automated inversion procedure for spectral analysis of surface waves. J. Geotech. Engrg., ASCE,* 124, 8, 757-770, 1998.

[33] Godlewski T.: *Metody określania sztywności gruntów w badaniach geotechnicznych.* Wydawnictwo Instytutu Techniki Budowlanej, Warszawa, 2015.

[34] Jarzyna J., Bała M., Zorski T.: *Metody geofizyki otworowej: pomiary i interpretacja*, Wydawnictwo AGH, Kraków, 1997.

[35] Kwiecień S.: *Geotechniczne przyczyny awarii budowlanych i metody ich zapobiegania*. XXXVIII Ogólnopolska Konferencja Warsztat Pracy Projektant Konstrukcji WPPK-2024, tom 3, 1-40, Wisła 2024.

[36] Leucci G., Negri S., Carrozzo M.T.: *Ground penetrating radar (GPR): an application for evaluating the state of maintenance of the building coating annals of geophysics,* 46, 3, 2003.

[37] Loke, M.H., Kiflu, H., Wilkinson, P.B., Harro, D. and Kruse, S., 2015. *Optimized arrays for 2-D resistivity surveys with combined surface and buried arrays.* Near Surface Geophysics, 13, 505517.

[38] Majewski T., Popielski P., Niedostatkiewicz M., Mieszkowski R.: *Diagnostyka podłoża gruntowego i fundamentów zabytkowego kościoła w stanie awarii.* XXXVI Ogólnopolska Konferencja Warsztat Pracy Projektanta Konstrukcji WPPK-2022, t. II, 1-40,Wisła, 2022.

[39] Niedostatkiewicz M., Majewski T., Popielski P.: *Bazylika pw. Św Mikołaja w Gdańsku – przykład monitoringu i diagnostyki zabytkowych obiektów kubaturowych.* XVII Konferencja Naukowo-Techniczna Warsztat Pracy Rzeczoznawcy Budowlanego 2022, 1-40, Cedzyna, 2022.

[40] Popielski P., Bednarz B., Majewski T., Niedostatkiewicz M.: *Settlement of a historic building due to seepage-induced soil deformation*. Archives of Civil Engineering, 65 – 82, Warszawa, 2023, https://dx.doi.org/10.24425/ace.2023.145253.

[41] Popielski P., Majewski T., Bednarz B., Niedostatkiewicz M.: *Deformacje filtracyjne i ich oddziaływanie na osiadanie podłoża na przykładzie zabytkowego obiektu sakralnego.* Materiały Budowlane, 10, 2-6, Warszawa, 2022. 10.15199/33.2022.10.

[42] Sikora Z.: *Sondowanie statyczne: metody i zastosowanie w geoinżynierii.* Wydawnictwo Naukowo - Techniczne, Warszawa, 2006.

[43] Xia J., Miller R.D., Park C.D.: *Advantages of calculating shear-wave velocity from surface waves with higher modes.* Soc. Expl. Geophys., 1295-1298, 2004.

[44] Instrukcja ITB nr 334/96: *Ocieplanie ścian zewnętrznych metodą „lekką”.* Wydawnictwo Instytutu Techniki Budowlanej, Warszawa 1996.

[45] Instrukcja ITB nr 334/02: *Bezspoinowy system ocieplania ścian zewnętrznych budynków*. Wydawnictwo Instytutu Techniki Budowlanej, Warszawa 2002.

[46] Instrukcja ITB nr 418/06: *Warunki techniczne wykonania i odbioru robót budowlanych, część C: Zabezpieczenia i izolacje, zeszyt 8: Bezspoinowy system ocieplania ścian zewnętrznych budynków.* Wydawnictwo Instytutu Techniki Budowlanej, Warszawa 2006.

[47] Instrukcja ITB nr 447/09: *Złożone systemy ocieplania ścian zewnętrznych budynków (ETICS). Zasady projektowania i wykonywania*. Wydawnictwo Instytutu Techniki Budowlanej, Warszawa 2009.

[48] Instrukcja ITB: *Warunki techniczne wykonania i odbioru robót budowlanych, część C: Zabezpieczenia i izolacje, zeszyt 8: Złożone systemy ocieplania ścian zewnętrznych budynków (ETICS) z zastosowaniem styropianu lub wełny mineralnej i wypraw tynkarskich.* Wydawnictwo Instytutu Techniki Budowlanej, Warszawa 2019.

[49] Jeż J.: *Drzewa a stateczność budowli posadowionych na gruntach pęczniejących*. Przegląd Budowlany, Warszawa, 2-3/90, 1990,

[50] Jeż J.: *Przyrodnicze aspekty bezpiecznego budownictwa*. Wydawnictwo Politechniki Poznańskiej, Poznań, 1998,

[51] Jeż J., Suwalski J.: *Wpływ nieprawidłowego zadrzewienia osiedla na rysowanie się ścian budynków*. VII Konferencja Naukowo-Techniczna Problemy Remontowe w Budownictwie Ogólnym, Wocław-Szklarska Poręba, 221-229, 1996,

[52] Jeż J., Wojtasik A.: *Wpływ drzew na awarię budynku posadowionego na gruncie pęczniejącym*. *Inżynieria i Budownictwo*, Warszawa, 7/89, 1989.

[53] Tajchman J., Jurecki A.: *Historia technik budowlanych. Fundamenty, rusztowania, mury, więźby, sklepienia.* Wydawnictwo PWN, Warszawa 2020.