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Emergency condition of the ceramic facade of a residential building

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Abstract

The paper presents a description of the technical condition of the ceramic cladding of a residential building, the technical condition of which deteriorated significantly after only a few years of operation. The analysis of the influence of the applied design and working solutions on the façade failure frequency was analyzed. The article presents a conceptual solution to bring the building to the proper technical condition in terms of defects and damage to the facade.

Keywords: elevation, ceramic cladding, emergency condition, renovation, repair works

1 Introduction

The elements influencing the technical condition of a building object are the quality of design documentation, the method of implementation and its operation. Design and execution errors have by far the greatest impact on the safety of the structure, as well as the safety of use of a building. Unwise and unfinished design solutions, relating to both structural and finishing elements, very often contribute to the occurrence of faults and damage, some of which may be the cause of a direct or indirect threat to the safety of the structure, as well as the safety of use [1, 2]. Removing faults and damages in objects that are already in use is difficult, mainly due to the fact that these objects, in particular residential buildings, are operated continuously [18, 19].

The paper is a case study of an existing residential building in which, after a period of three years from the commencement of operation, extensive defects and damage began to occur on the façade surface, including [9]: ceramic cladding burns from the substrate, its falling off and local intense blooms on the façade surface. The occurring faults, damage caused the occurrence of a direct threat to the safety of use of the residential building and resulted in very significant restrictions in its operation.

2 General information

The residential building was implemented in traditional technology, improved as a 4-storey, fully basement building, with a 1-storey underground garage hall. The outer walls were made of small-sized ceramic elements (porous blocks) and monolithic reinforced concrete. The ceilings were made of massive, reinforced concrete. The flat roof was constructed as an inverted roof, and on a part of the projection of the roof, it was constructed as a green roof.

In the period after the commencement of operation, the building was not subject to any reconstruction related to the change of the structural layout. In individual apartments, only works related to the arrangement of apartments were carried out, including a change in their functional and utility layout. During the operation of the building, no changes were made to the manner of use of any of the residential premises.

At the moment of handing over to the use of the building, the surface of the façade made with façade plaster according to ETICS (BSO) technology solutions was 30%, the remaining part of the façade was 70%, it was made as a ceramic cladding glued to the thermal insulation material (polystyrene).

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3 Description of the building facade

Fragments of the facade made in the ETICS (BSO) technology, on which the finishing layer was a facade plaster (textured layer), after three years of operation, did not show any significant defects or damage. On these parts of the façade, there were no visible traces of blistering, delamination and detachment of the texture layer itself, as well as the adhesive (reinforced) layer.

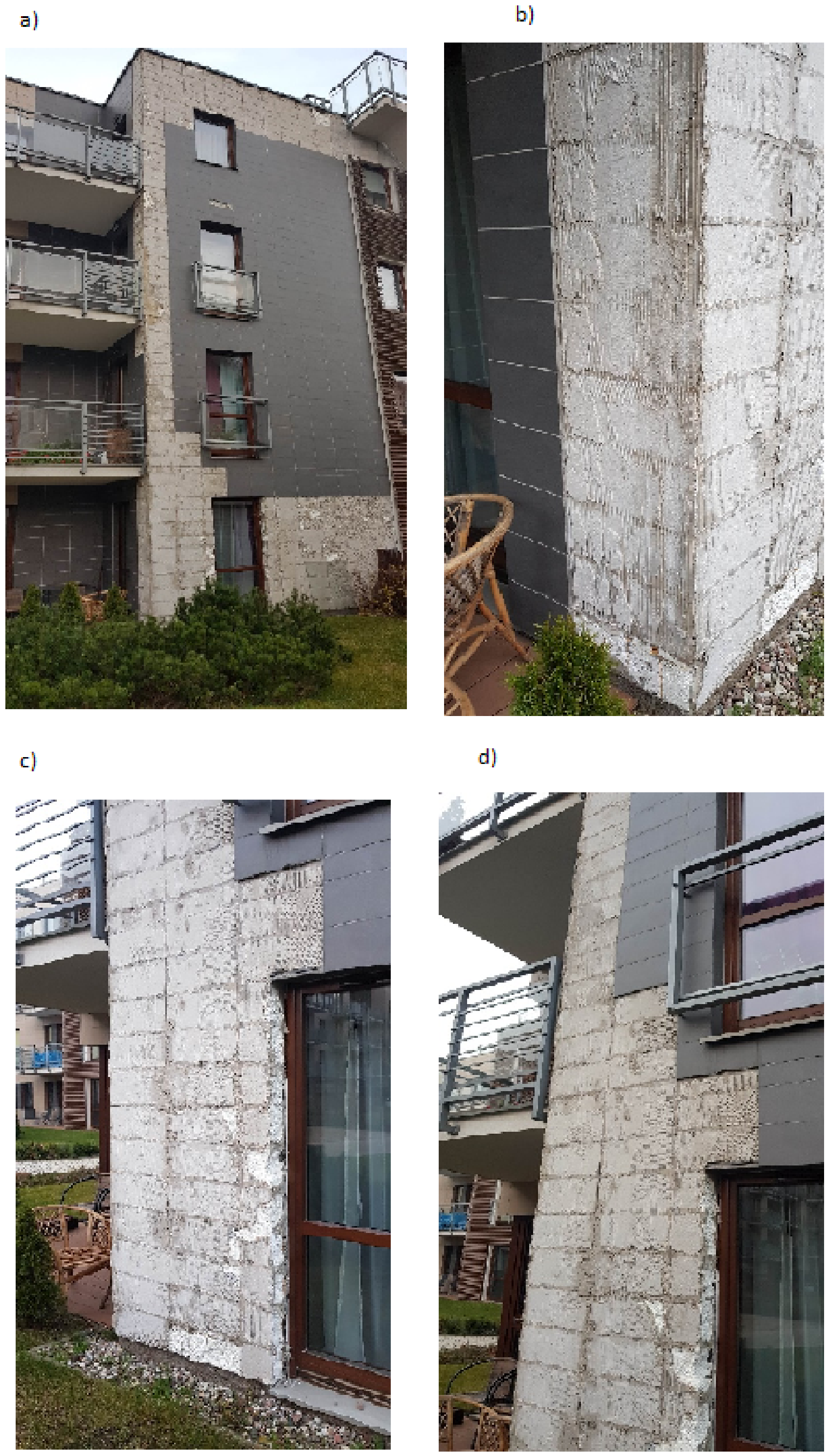

Figure 1. Damaged ceramic cladding a), b), c) and d) of the building facade

On the façade fragments made of ceramic tiles, extensive blooms were visible, occurring at the joints between individual ceramic tiles. About 50% of the façade surface made with the use of ceramic cladding had damage in the form of its detachment from the substrate, i.e. from the adhesive layer, made on a heat-insulating material such as polystyrene. These damages occur over the entire height of the building, at the height of 4 above-ground storeys (Fig. 1).

Roof parapets along the fragments of external walls with facades made of ceramic tiles showed leaks in the form of leaks in the places of joining individual sheets of metal, which resulted in leaks, both on the facade surface and into the intermediate layers, between the wall and the thermal insulation material.

4 Analysis of the building facade condition

Based on the analysis of the archival design documentation made available for inspection, it was found that no detailed calculations were made for the building, the so-called seasonal heat demand in terms of compliance with the requirements of standards [11, 15, 16]. The parameters of the heat transfer coefficient U for external partitions (external walls) were only adopted in an estimate so that the requirements specified in [17] were met.

As part of the assessment of the technical condition of the façade, a detailed computational analysis of the correctness of the adoption of the external layers of vertical partitions in terms of thermal protection of the building was not carried out - it was assumed that the structure of the partitions was adopted by the Designer in a layer system ensuring compliance with the requirements of detailed regulations in the field of thermal protection and thus ensuring proper thermal and humidity comfort for people staying in the building in question for permanent residence.

Based on the estimated (qualitative) assessment, it can be assumed that the thicknesses of thermal insulation materials taken over at the design stage can be considered correct, enabling the fulfillment of detailed requirements for external partitions, included, among others, in [17].

It should be noted that due to the thermal insulation technology of external walls adopted in the archival design documentation and implemented according to ETICS (External Thermal Insulation Composite System) technology solutions [7, 8] (formerly: building insulation by BSO (Bezspoinowy System Ocieplania), formerly :light method, formerly: light - wet method), the facades constructed in the area of the building should meet the requirements set out in [5] and [6].

[5] and [6] (being an extension and supplement to [5]) are the so-called technical literature containing executive recommendations applicable during the construction works related to the execution of the facades of the buildings covered by the study. It should be stated that the ITB (Instytut techniki Budowlanej) Instructions are documents defining quality requirements, commonly used in construction, and like other publications of the ITB, they are considered in the engineering community as superior documents (in terms of quality requirements) in relation to other studies and literature items.

As part of the assessment of the technical condition of the ceramic cladding of the facade, the compliance of the thermal insulation of the building with the requirements set out in [5] and detailed in [6] was not analyzed in terms of: the type and structure of the thermal insulation material, the thickness of the thermal insulation material, the application of glue on the thermal insulation boards, evenness surface, surface and edge deviations from the vertical and horizontal directions, the thermal insulation surface deviation from the plane and the edge deviation from the straight line in the vertical and horizontal directions, deviations of the intersecting planes from the angle provided for in the design documentation, plinth solutions, starting strip, facade mesh structure, continuity of the facade mesh, reinforcement of the corners of openings, thickness of the reinforced layer, reinforcement of the reinforced layer.

The subject of the analysis was only the assessment of the technical condition of the ceramic cladding of the building facade.

Based on the analysis of the available design documentation that, in accordance with the design solutions, the ceramic elements were to be made as 7 mm thick boards - the completed condition was consistent with the design condition, both in terms of the thickness of the facing tiles and their dimensions.

The developed project envisaged the execution of façade fragments with ceramic cladding according to the system solution in the BAUMIT EPS-P technology. As the User and the Building Administrator did not have a complete set of acceptance documents, including as-built documentation, in the further part of the analysis it was assumed that this system was implemented in the area of the building.

a)

b)

c)

Figure 2. Details of thermal insulation (substrate) a), b) and c) for the ceramic cladding of the building facade

The available technical literature indicates that facades with ceramic cladding should be made in accordance with the following recommendations [3, 4, 10]:

- boards of thermal insulation material should be, in addition to gluing to the substrate, also pinned with pins with a galvanized steel pin - in the excavations made, the use of this type of pins was found (+),
- the recommended number of dowels should be 8 pieces / m2 - in the excavated pits the number of dowels is basically compliant with the technological requirements (+),
- the pins should be fixed in the first layer of the facade mesh and then covered with the second (top) layer of the mesh with glue - in the outcrops, the use of a double facade mesh and fixing the pins according to the technological requirements (+) was found. The thickness of the glue allows the facade mesh to be fully covered (Fig. 2),
- tiles should be attached to the substrate with C2 cement glue according to [12] - due to the lack of a complete set of acceptance documents, it was not possible to assess what type of glue was used to lay the ceramic cladding,
- tiles should be laid so-called combined method, i.e. when laying the adhesive both on the substrate and on the tile using a notched trowel - in the excavations made, tiles were laid using the combined method (+),

- tiles should be grouted using cement mortars of CG2 type with reduced water absorption (W) according to [13] - due to the lack of a complete set of acceptance documents, it was impossible to assess what type of grout was used for grouting,
- the width of the joints should be from 6 to 20 mm - in the case of facades covered by the assessment, the width of the joints was 6 mm, which is in line with the technological requirements (+),
- pointing should be carried out after the adhesive has dried completely, i.e. 24 - 48 hours after fixing the ceramic tiles - due to the lack of the Construction Log, it was not possible to determine when they were grouted,
- cladding tiles should be frost-resistant tiles, produced by pressing or drawing, belonging to groups BIa, BIb or AI according to [14], the maximum absorption of the tiles should not exceed 3%, and their weight should not exceed 40 kg/m2 - due to the lack of a complete set of acceptance documents, it is not possible to assess the parameters of the built-in ceramic tiles,
- facing tiles should be in light, pastel colors - significant parts of the facades of the buildings covered by the study were made in dark colors, which is a discrepancy with the technological requirements (-). It should be noted that there is a similarity to the requirements for thermal insulation systems: [5] recommends the use of bright facade plasters, while [6] even requires that the facade colors should be kept in pastel colors. According to the recommendations in [6], the HBW diffused light reflection coefficient for the colors intended for use on darker parts of the facade should be higher than 30. According to the current state, there is no information on the HBW characteristics of dark cladding tiles (-),
- the surface of the cladding should be divided into technological fields with an area of 4m2, with a maximum side length of 3 m, preferably with a shape similar to a square, or a rectangle with a side ratio of 2:1 - in the case of the façades covered by the analysis, the dilatation of the ceramic cladding was not used, which made it impossible their deformability (-),
- cladding works should be carried out in dry weather, in the temperature range from + 5^{o}C to + 35^{o}C, while avoiding direct sunlight, precipitation and strong wind - due to the lack of the Construction Log, it was impossible to assess the weather conditions in which the works were carried out cladding.

In the case of damage to the ceramic cladding of the building façade, it was most likely a consequence of using too little water added to the adhesive, which resulted in its drying too quickly instead of the spread of bonding over time. Carrying out cladding works in the period when the wind was probably periodically blowing, which resulted in exceeding the so-called open time and resulted in the glue drying out, and consequently accelerated setting start contributed to the tiles being scorched by the glue layer. Likewise, the probable performance of works in the period of periodic increased insolation had a negative effect on the adhesion of the adhesive to the substrate and to the tiles. In addition, the implementation of the cladding fragments on the thickened adhesive layer led to excessive shrinkage and loss of adhesion. Leaks in the attic's plinth also contributed to the degradation of the cladding.

Local efflorescence on the ceramic cladding of the building façade resulted from the occurrence of local leaks in the attic roofing, which could result in the penetration of rainwater into the façade finishing layers, which by gravitation resulted in leaching of calcium compounds. In addition, the locally increased diffusion of water vapor transported to the outside leaches calcium compounds from cement mortars, and the limited transport surface, which is a grout, also made as cement-based mortar, contributes to the formation of efflorescence [20].

5 Concept of the scope of repair work

In the event of damage to the ceramic cladding of the building facade, the proposed scope of repair work included:

- disassembly of the damaged ceramic cladding on the entire surface of all facades of the building,
- re-profiling the substrate: gluing an additional layer of facade mesh in places of damage, additional pinning of the thermal insulation material (polystyrene), making a new layer of glue on the entire surface,
- reconstruction of all facades of the building using the facade plaster,
- checking the tightness of flashings and flashing, especially in the area of parapets, taking into account the possibility of their complete replacement.

a)

b)

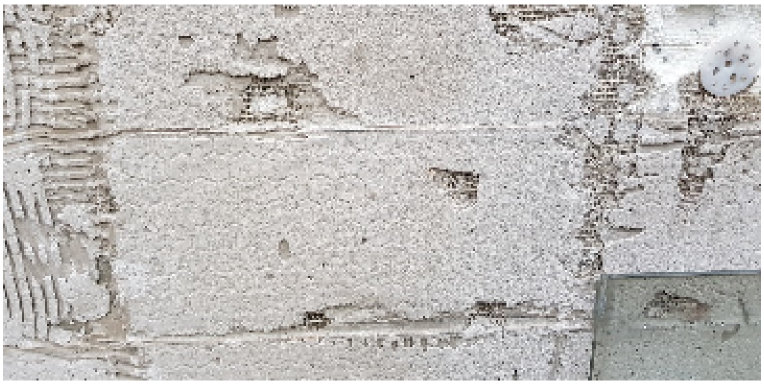

Figure 3. Mechanism a), b) (method of detaching) the ceramic cladding of the building facade

6 Conclusions

The direct causes of damage to the building facade were: a) design imperfections and b) errors in execution.

The design imperfections include:

- the adoption in the design documentation of the concept of making significant parts of the facade in the form of a ceramic cladding made by gluing on a substrate made of heat-insulating material, which generated a high probability of manufacturing errors already at the design stage, and in the event of a defect, it significantly increased the possibility of a real threat to safety in use,
- designing a dark-colored ceramic cladding on a large surface of the facade, which contributed to the absorption of solar radiation by the ceramic elements, heating of the ceramic cladding, and consequently increased deformation of the cladding elements,
- failure to include design details in the design documentation, including concerning the arrangement of expansion gaps and detailed recommendations regarding material parameters and quality requirements for the execution of ceramic cladding or references to specific literature items where these recommendations are included.

The implementation errors include:

- no documented objection to the facade design solutions adopted in the design documentation,
- probable use of too little water added to the glue, which resulted in its drying too quickly instead of the delayed setting,
- execution of cladding works in the period when the wind was probably periodically blowing, which resulted in

exceeding the so-called open time and contributed to the drying of the adhesive, and consequently an accelerated start of bonding,

- probable carrying out of works in the period of periodic increased insolation, as a result of which the glued cladding tiles would heat up, which significantly disturbed the adhesive bonding process,
- local implementation of the cladding on a thickened adhesive layer, which led to excessive shrinkage and loss of adhesion,
- the occurrence of local leaks in the sheet metal flashing in the area of the attics, along the width of the external walls, where the façades were made as a ceramic cladding, which resulted in the penetration of rainwater into the finishing layers of these façade fragments, which water, flowing by gravity, washed out calcium compounds, and as a result of increased local diffusion intensification water vapor, which was transported outside through the joints, leaching calcium compounds from cement mortars, including the cement-based mortar filling the joints.

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