Difficulties in Operation of Elevations in Large-Panel Buildings

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Abstract. The article presents problems in facade walls operation of large-panel buildings. Examples of irregularities resulting from the initial poor quality of precast elements and assembly errors are presented, as well as problems arising as a result of repeated renovation and modernization works. The problems before and after wall insulation were discussed in greater detail, resulting from leaking joints of precast elements. Biological threats resulting from the influence of algae, lichens and vines on the façade material are presented. The general technical condition of the facade of a selected group of buildings was compared in studies carried out at an interval of 11 years.

1. Introduction
Problems with maintaining the facade of buildings made in large-panel technology are, partly, identical or similar to the problems occurring in traditional structures, and partly there are specific occurring in a given structural technology, in particular resulting from the method of production of precast elements and their assembly.

The main maintaining problems of large-panel buildings often arise from the original poor quality of precast elements and from errors made during assembly. The influence of some of these errors has been reduced by additional work consisting in sealing the joints or insulation of the façade. However, some of the problems are the result of incorrectly carried out renovation or modernization works [1,2], mainly related to the insulation of external walls. Multiple changes in regulations within several years in the minimum insulation of building partitions and changes in the underlying technology make it difficult to assess the technical condition and occurrences of imperfections. Walls insulated with insufficient thickness of the insulation should be insulated again. However, this leads to further technical problems and the need to incur additional costs.

2. Selected maintaining problems
The poor quality of precast elements build in the building facades in the large-panel structure is manifested by exceeding the permissible dimensional deviations (each system allowed for some dimensional differences), mechanical damage, improper hole formation, improper reinforcement anchoring, improper formation of the facade precast elements layers (thickness, insulation displacement). Assembly errors consisted of incorporation of damaged elements, incomplete
arrangement of mortar in horizontal joints, dry assembly without mortar, point support on mortar or wedges, exceeding permissible deviations of assembly (Figure 1).

Figure 1. Sealed connections of precast elements (Piotr Knyziak, 2014)

The problem of the need to strengthening between layers connections in panels and inadequate heat-insulation of exterior walls of large-panel buildings was discussed in many publications (e.g. [2-5]). In practice, the problem of insufficient wall insulation is solved by additional insulation or complete replacement of existing thermal insulation with a new one that meets current requirements for thermal protection of buildings. In some cases, walls made of two layers of concrete (structural and façade) and layers of mineral wool or polystyrene have been additionally insulated twice. During the research of buildings in Warsaw [6, 7], already in 2006, two cases of double insulation were found among 95 buildings assessed. In recent surveys in 2016-2017 it was found that in some, mainly low-insulated buildings made in the 90s of the twentieth century, that is, according to modernized systems, there are still problems with tightness and fungus in corners of rooms located at the gable walls. This problem does not only concern the thermal protection of the building, but can affect the corrosion of the elements fixing the sandwich panels in the nodes.

In typical analyses of heat flow through walls and nodes connecting panels in existing large-panel buildings, the design solutions of walls and nodes are taken into account. They are currently insufficient, so the analyses apply to propose insulation that would meet current requirements. However, the assessment of the condition of prefabricated elements in façade walls is difficult; it is usually limited to a comprehensive inspection. In a few cases, opencast are made in more accessible places on the ground floor level. As research [8,9] indicates, these are places that are beneficial from the information point of view, as the basement level and ground floor level are the most susceptible to corrosion. However, in terms of anchorage connectors and quality of connectors it is impossible to perform extensive testing in a representative number of places.

In many cases, the execution of sandwich panels in prefabrication plants was subject to a number of disadvantages, and the acceptable tolerances of their assembly were exceeded. Laying the insulation and filling the precast elements joints with supplemental concrete was also not done precisely enough. A large number of large-panels made at different times in the prefabrication plant prevents generalization of results of samples taken from the structure. The abnormalities are indicated by cracks of large-panel joints, including slab joints in façades, manifested by plaster cracks appearing after renovations, as well as by fungi occurring in the corners of rooms. These irregularities are not checked prior to thermal insulation. In most cases, additional sealing of joints is not performed, and the insulation layers do not constitute a full protection against water vapour diffusion. As a result, nodes after insulation are moistened with condensed water vapour transported from inside the building, and reinforcement of joints in places of incomplete filling with complementary concrete can corrode intensively.
The publication [10] considers the heat flow in the external walls made of precast panels in the Wk-70 system in two versions - the supporting wall and curtain wall. The flow of heat flux through plate joints was taken into account, in particular cases of not filled or not completely filled of these joints with a concrete mix. The results indicate that the thermal insulation in the places where the joints are not fully embedded can be significantly lower. Steam bridges form in the joints, which cause condensation of water vapour under the plaster layer or under the insulation layer. Moisture in the joint area increases the heat transfer coefficient, and thus also the heat loss, which intensifies the condensation process. A significant amount of condensed water in empty vertical joint flows down to the horizontal joint and causes its dampness with similar effects. Condensed water vapour in the winter in joints and gaps between styrofoam panels, due to variable freezing-thawing cycles, leads to destruction of the layers of wall structure. The result can be cracks in the plaster and the interior destruction of concrete and steel in the joint area (Figure 2).

![Figure 2. Damage to façade (Piotr Knyziak, 2014)](image)

The analysis of heat flow along with the assessment of the possibility of condensation in connection with design and implementation errors may explain at least some of the symptoms of damage visible on the façade. In some buildings, the problem of condensation is clearly exposed as the condensation of water vapour at the outlets of the openings in the ventilated roof (Figure 3).

![Figure 3. Condensation of water vapor at outlets of openings in roof (Piotr Knyziak, 2014)](image)

Considering both non-insulated and post-insulated facades, the effects of biological aggression should also be taken into account. From the outside, some of the sandwich panels and joints were the subject of aggression resulting from growing on the walls of climbing plants, most often vines. These plants were planted in order to quickly provide housing estates with attractive greenery, which was supposed to improve their perception by residents. In practice, however, the climbing plants with their roots growing out of the shoots along the entire length penetrated each encountered joint and scratch. Under the thick cover of the leaves, the humid conditions and lack of ventilation dominated for a long time. The combination of chemical and biological aggression with decomposing organic particles,
penetrating the roots and moisture shaped environmental conditions aggressive to the wall material. Attempts to destroy expanded climbers lead to the destruction of the biologically active mass, but the complete removal of the vines with their roots is practically impossible (Figure 4).

Figure 4. Growth of elevation by vines and traces of them (Piotr Knyziak, 2016)

Insulation of multi-family buildings in a wider scope was initiated in 1982. These works were subsidized by the government. Until 1997, these were subsidies whose main purpose was to eliminate technological defects resulting from insufficient system solutions and assembly errors. In the initial period of applying additional insulations, the thickness of the applied insulation of walls was low, about 5-6 cm, that is 2÷3 times smaller than the current ones resulting from the requirements of thermal protection of buildings. In addition, insulation inside the panels or in the nodes of the structure cannot be taken into account in sensitive places because it is either missing or compacted or wet. A similar problem resulting from moisture in insulation was noticed in the study of energy-efficient buildings [11], where irregularities were found in 80% of the 138 examined buildings resulting from moistening of the thermal insulation insufficiently protected from weather conditions.

It was considered that insulation would eliminate the impact of technological defects and by increasing the insulation parameters of the wall would prevent freezing. Used in many cases, the dry method or insulation from fibre-cement boards, do not allow the addition of another layer of thermal insulation. It is necessary to disassemble the original insulation layer. Depending on the insulation parameters of the used material, the currently typical thickness of the insulation of external walls is 14-16 cm. It is good when the applied thermal insulation thickness takes into account another (according to the regulation [12]) change in the $U_c$ (max) heat transfer coefficient from currently required for residential buildings at 0.23 W / (m$^2$K) to the value required from December 31 2020 at the level of 0.20 W / (m$^2$K).

The research conducted in Warsaw shows that most buildings have already been insulated (Table 1). On some of the buildings, the works were carried out twice or even three times (separately, different parts of the façade or double insulated, usually the gable walls). On one of this buildings curtain walls were insulated three times ([1985, 2004, 2014]) on three buildings, the gable walls were also insulated three times ([1984, 2001, 2012] [1985, 2004, 2014]; [1990, 2005, 2009]). So many works, the use of various materials and various system solutions lead to difficulties in the current assessment of the elevation. In the future, they can also lead to problems with the durability of the insulations and risks resulting from the smaller safety stocks of the more weighted façades.

Low number of buildings in Warsaw made of large-panels remain still uninsulated. Mainly these are buildings put into use in the 90s of the twentieth century. Built from modernized system precast elements, they are characterized by better insulation. Non-insulated buildings assessed during inspections are characterized by relatively good assembly quality, leakages occur sporadically, locally between single plates and not in the line of many plates.
Collected by the author (1) information suggests that the state of thermal insulation of large-panel buildings in the whole country is not as satisfactory anymore. Higher rates of thermal insulation concern large cities, where a better-paid society can allocate more funds for investments. In smaller towns and settlements, next to former socialist farms remain without proper insulation.

Table 1. Scope of insulation of group of buildings, condition in 2016-17, Warsaw

| The scope of insulation                                      | number of buildings |
|--------------------------------------------------------------|---------------------|
| A1 lack of insulation                                         | 12                  |
| A2 the insulation was made for the first time (can only be on the gable walls) | 62                  |
| A3 incomplete first insulation was completed                 | 21                  |
| A4 insulation was performed with a second layer, at least on part of the façade | 15                  |

Repeated insulation is due in part to the lack of sufficient funds for one-time insulation of the entire building, and in part results from changing standards and technical standard requirements. Primary insulation, often only 5 cm thick compared to the currently used thickness of 16 cm insulation, is considered insufficient. Too thin layers of insulation do not sufficiently reduce the heat flow through the wall and thus costs of current maintenance of the building, they also do not prevent moisture condensation and fungus growth in corners of rooms (in particular at the gable walls). In the research in 2005-06 buildings with insulated gable walls (walls at the ends of the building, without windows) were found 54 and with insulated curtain walls (with windows) there were 38 of them. In the surveys in 2016-2017 buildings with insulated gable walls were found 98 and with insulated curtain walls there were 94. The implementation of façade insulation on subsequent buildings improved the results of assessments of the technical condition of the building’s façade [13] (Figure 5).

Figure 5. Comparison of facade technical condition evaluation in 2005-06 and 2016-17

Figure 6. View of wall with exfoliating mineral thin-layer plaster covered with silicone paint (Marcin Kanoniczak, 2017)
Poor quality of products used for finishing works, including adhesive mortar for making the reinforced layer, plastering mortar and façade paint may cause damage to the façade (Figure 6). Carrying out works during improper weather conditions - during rain, strong wind or high temperature (the last two factors may cause e.g. loss of mixing water), as well as the failure to use appropriate technological breaks between particular stages of works, may result in exfoliating of the surface layer already in the initial period of façade operation.

As thin-coat plasters on the layer of insulation made of foamed polystyrene or mineral wool, they are most commonly used mineral plaster, mainly due to the low price of the materials needed to make them. Due to the high pH of about 12, they have a potentially good resistance to the aggression of algae, fungi and mould. In addition, their important feature is high vapour permeability. They require a surface finish with a paint coating, but thanks to this, interesting colour solutions of the façade are possible (Figure 7). Paint coatings, especially silicone, provide good protection against moistening of internal insulation layers during rain. In addition, during the rainfall, the self-washing effect occurs.

![Figure 7. Elevations with interesting colour solutions (Piotr Knyziak, 2016)](image1)

![Figure 8. Uneven algae aggression (Piotr Knyziak, 2016)](image2)

In spite of applying the façade finish with potentially beneficial properties, the inspections revealed the problem of algae overgrowth. Observations lead to the conclusion that the overgrowth process in particular intensifies in the proximity of trees and shrubs (Figure 8).

It was observed that the facades of buildings located in the proximity of trees, especially clusters of birches are more often and intensively covered with algae. Other species of trees and shrubs favor the growth of algae to a lesser extent. Intensification of the aggression process occurs on the northern walls, only in some cases results from improper protection of the facade, then the process progresses on each of the façades, including the south one (the most sunlight is reaching). Partly in observed cases of algae overgrowth of the façade indicates executive errors. This is especially visible in the case of "lamb" type plaster (Table 2). Algae aggression occurs from various sides of the building and at
various elevation levels (Table 3). An important factor in this case is also the ability to protect against algal growth or loss of this ability by materials of the surface layer (plaster, paint). Antigone additives effect by several years. This time is given by the producers. In Figure 8, intense aggression occurs especially in vertical zones between the windows, where anti-algae additives may have been rinsed out with rainwater flowing down the façade. The use of paints to obtain a non-absorbable and washable façade surface during rain is an effective protection against such situations.

More susceptible to overgrowing are facades with "horizontal bark-beetle" plaster structure, i.e. with rubbing causing horizontal furrows. Application in a manner conducive to the accumulation of pollutants facilitates the accumulation of seeds, pollen, dust and moisture occurring in the lower parts of the elevation at which the bushes and trees grow.

Table 2. Structure type of plaster applied to façade

| The structure type                  | number of buildings |
|------------------------------------|---------------------|
| B1 lack of insulation              | 12                  |
| B2 horizontal "bark-beetle"        | 24                  |
| B3 vertical "bark-beetle"          | 1                   |
| B4 "lamb"                          | 72                  |
| B5 other                           | 1                   |

Table 3. Occurrence of algae on facade

| Occurrence of algae on the façade                                             | number of buildings |
|-------------------------------------------------------------------------------|---------------------|
| C1 do not occur                                                               | 67                  |
| C2 small area or only in the lower parts of the façade, especially close to the ground | 14                  |
| C3 occurrence mainly on the north elevation of the building                   | 18                  |
| C4 small surface area, occurrence from various sides of the building and on different elevation levels | 2                   |
| C5 small surface area, occurrence from various sides of the building and on different elevation levels | 7                   |
| C6 extremely intense, at least on one, almost the entire wall of the façade   | 2                   |

The reason of biological corrosion is the development of microorganisms on the surface. The substrate can be practically any type of material. If there are favourable humidity conditions above 60% and the temperature is between 0 °C and 35 °C and the pH of the material is close to neutral, then biological aggression can develop even on a ceramic or stone substrate. The most popular form of aggression is the development of algae, because these can, in the dried form, survive the unfavourable conditions on the façade. Algae do not damage the substrate, on which they grow; substances for the development are contained in the air. Fungi are more dangerous aggression, because they use substances contained in the substrate and spreading their shreds destroy the material. Renewing the façade should always be preceded by thorough cleaning of the surface from impurities and control of the disposal of fungi and algae colonies.

In most of the assessed buildings and other buildings located in the examined estates prior to insulation, reinforcement of joints in sandwich facade panels was not made (only in 5 buildings out of 110 analysed strengthening between layers connections was made). On some buildings in the housing estates disassembly works of previous heavy versions of insulation and then re-insulation using the
ETICS method were carried out. Information was obtained on three cases of buildings from the analysed housing estates (not only from among the assessed buildings) the occurrence of the wind breakage of the insulation on large façade surfaces. Works consisting in the exchange of insulation, re-insulation, drilling holes for anchors strengthening the connection of plate layers, in none of the buildings in the studied estates have led to failure of external facade panels. Especially drilling under the anchors could be the cause of problems, because they involve a violation of the structure of the panels and vibrations. Particular attention was paid to this, because in one of the housing estates after the experiments with strengthening the joints of layers in the facade panels of the first building, the strengthening of the joints of layers was completely abandoned due to problems with the fragility of concrete in prefabricates.

3. Conclusions

Inspections on buildings have shown good overall condition of the analysed buildings. Has not been noticed visible signs which would be point of any security risk for the main building structure [14]. However, owners of apartments in buildings are struggling with many problems. Some of these problems arise from the original imperfections of the buildings, including the precast elements from which they were built. In many cases, problems arise from the operation process and renovation and modernization works carried out repeatedly, to a different extent and at different quality levels. In the case of façade walls, this applies mainly to the diversity of exterior insulation systems, multiple and in some cases incorrect application.

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