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Comparison and analysis of construction defects on the example of two multifamily residential buildings

Porównanie i analiza usterek budowlanych na przykładzie dwóch wielorodzinnych budynków mieszkalnych

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Streszczenie. Celem artykułu jest przedstawienie liczby, rodzaju i lokalizacji usterek budowlanych na podstawie analizy protokołów odbioru dwóch wielorodzinnych budynków mieszkalnych. Dokonano przeglądu literatury oraz przedstawiono analizę statystyczną najczęściej występujących usterek, biorąc pod uwagę różne kryteria. Najwięcej usterek zgłoszonych przez inspektorów dotyczyło rys na ścianach i parapetach oraz zarysowań szyb okiennych.
Słowa kluczowe: budynki wielorodzinne; mieszkania; stan deweloperski; usterki budowlane; analiza porównawcza.

Abstract. The aim of the articleis to present the number, type and location of defects on the basis of ananalysis of acceptance reports from two multifamily residential buildings. The article reviews the literature and presents a statistical analysis of the most common defects, taking into account various criteria. The greatest number of defects reported by the inspectors concerned scratches on walls and window sills as well as scratches on window panes.
Keywords: multifamily buildings; apartments; shell and core by developer; defects; comparative analysis.

According to the Statistics Poland, between January and December 2021, developers completed 234,900 apartments (6,4% more than a year ago) with a total floor area of 21.8 million m^2, 11.3% more than in 2020. In 2021, the average floor area per apartment in residental buildings was 52.6 m^2. Between January and December 2021, developers received permits for 341,200 new residential units and started construction of 277,400 apartments. As can be seen in Figure 1, between 2018 and 2022, there is an increase in the number of completed apartments, the number of apartments for which construction permits have been issued or notifications have been made with a construction project, and the number of apartments for which construction has begun [1].

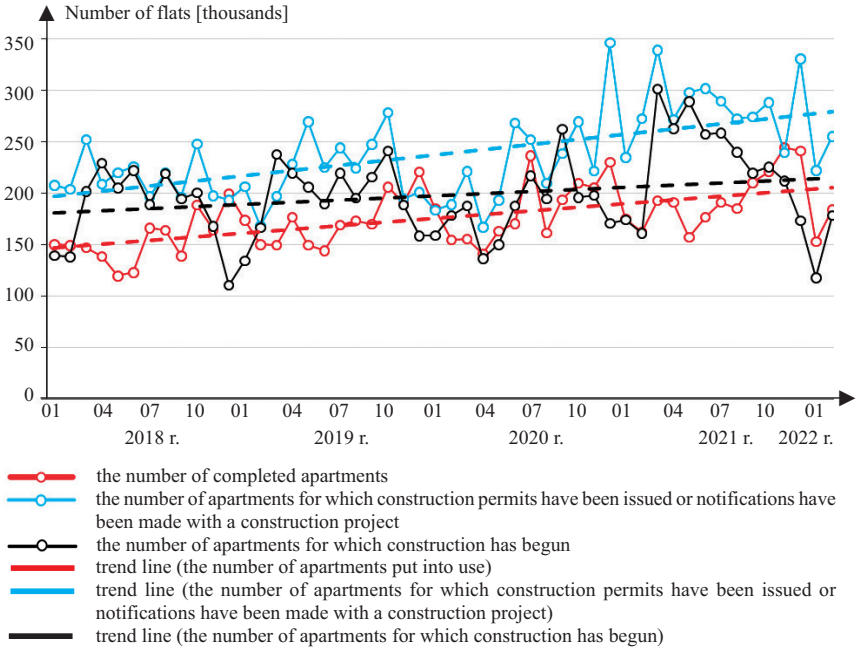

Fig. 1. Apartment construction traffic in Poland *source: Statistics Poland [1]*

As the number of apartments completed increases, so does the number of residential unit inspections, during which thousands of construction defects and flaws are discovered. The purchaser of an apartment expects the developer to receive an apartment free of any defect, which is why it is the subject of many disputes between the investor and the construction contractor. However, some of the claims of apartment buyers are unfounded – it is impossible to make a building completely free of construction defects and defects. Slight unevenness, dirt, stains, small losses, scratches, etc. are inevitable. Each construction site is different from all others, so there are different defects in each building constructed (even by the same contractor). The aim of this paper is to analyze the available scientific literature and to investigate the number, type and location of construction defects

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in two multifamily residential buildings located in two different housing estates in Krakow. Additionally, this paper compares the detected construction defects to search for the relationship between two construction objects.

Literature review

K. Zima and S. Biel developed a definition of construction defect [2]. According to the authors of the publication, a construction defect is any unfavorable property of a building or lack thereof, hindering its intended use or reducing its aesthetics or the comfort of its users, which is not an unacceptable change compared to its intended state.

Forcada, Macarulla and Love [3] analyzed 2,351 defects detected during building acceptance by clients of four different developers, with a total of seven residential projects in Spain. The defects were classified in terms of their location, subcontractors, and the component affected. The most commonly detected defects included improper grouting and painting of walls, incorrect installation of toilets, uneven floors and walls, and cracks. According to the authors of the publication, identifying the location and element on which defects have been detected, and linking them to specific construction companies can support quality control and supervision of subcontractors, which will translate into a reduction of defects and defects in construction facilities.

Milion, Alves, Paliari [4] examined the effect of construction defects and defects on buyer satisfaction in the residential construction sector. According to the authors, flaws and defects do not significantly affect customer satisfaction. The buyers' dissatisfaction was caused by the occurrence of several defects or defects in one item, poor contact between the construction company and the customer after the claim was filed, and the occurrence of defects or defects that disrupted the functioning of the item.

In [5] the defects reported by housing cooperative representatives and identifies relationships between building characteristics, developer/contractor size, and defect type. Based on the survey, it was indicated that building quality may be one of the main causes of energy gaps. The most serious defects reported by Swedish cooperatives are defects in the building envelope, including facades, window frames and balconies. According to the authors, the size of the development company and the location of the building have a significant impact on construction defects.

In [6] the main factors influencing the occurrence of defects in the design of residential buildings in the Gaza Strip were identified and ranked. In order to provide the analysis, a survey was conducted identifying 3 major design errors: ignored or incorrectly performed soil analysis, missing or unqualified drawing supervision, and conflicts between architectural and construction drawings. To minimize errors, the authors recommend the use of a quality assurance/quality control (QA/QC) program during design, which includes providing the construction contractor with simple and legible drawings.

In [7] defects in low-rise residential buildings in Australia were analyzed. The authors analyzed two residential buildings. In the first case, the most common defects included cracks in the walls and the separation of plaster from the substrate. In the second building, there were, e.g. deviations in the level of the ceilings, deviations in the vertical plane of the walls, and cracks in the plaster.

S. Dubas and P. Nowotarski [8] presented differences between the list of defects detected during apartment acceptance and the list of construction defects entered in the protocol of apartment acceptance. In the first case, 6 defects were detected, two of which were not entered into the protocol. The first was the deviation of the level of the screed in the bathroom by 7 mm compared to the one specified in the project, but the customer said that the defect will not affect the arrangement of the apartment. The second defect was a scratched exterior window sill, the developer company could not hand over the apartment with this defect to the client, therefore it agreed to omit the defect from the protocol. In the second case, 12 defects were detected and 3 were entered in the acceptance protocol. 9 defects were not entered because the developer undertook to repair 8 defects outside the acceptance protocol, while 1 defect was considered insignificant by the client – it was the difference in the area of the apartment by 2.44 m^2. In the third case, there were two acceptance protocols (official and unofficial). During the initial acceptance of the apartment, 21 defects were identified in an unofficial acceptance report. The developer did not want to lose its good reputation, so it committed to repairing the defects before performing the final acceptance of the apartment. The second protocol identified 5 defects, the absence of a right angle between the walls was omitted.

J. Czupajłło [9] described numerous defects in construction and finishing work discovered at construction sites and the causes of each defect, and suggested several methods for correcting each defect. Czupajłło described defects he encountered at every stage of construction – starting with improper soil compaction and ending with performance defects related to noise abatement. Similar to J. Czupajłło, R. Oswald and R. Abel [10], as well as J. Hinks and G. Cook [11], discussed defects, defects, and other irregularities often found during acceptance of new sites.

Based on the acceptance protocols and research carried out by E. Plebankiewicz, K. Zima, J. Malara and S. Biel [12], it can be noticed that the average number of defects in a flat increases with the increase of the flat area.

Study methodology

The author's analysis was based on housing acceptance protocols. These acceptances were carried out by the investor inspectors between 2017 and 2019. The buildings surveyed are multifamily residential buildings located in Krakow.The first (Building A) is a residential building consisting of 15 floors and divided into three staircases. The building is designed with 172 apartments with a total area of over 8000 m^2. The second facility (Building B) is a 10-story multifamily residential building. The building was divided into 3 staircases, where 179 apartments with a total usable area of 9000 m^2 were designed.

The apartments that were sold by the developer in the analyzed buildings were in the so-called "shell and core condition". Shell and core condition is a standard of apartment finishing, which allows the buyer to start finishing works immediately after its acceptance. The state of apartment finishing at the time of its acceptance should be strictly described in the developer's agreement.

Analysis of defects in multifamily residential buildings

Inspectors found a total of 3265 building defects – Building A had 1945 defects and Building B had 1320 defects identified. Figure 2 shows the 10 most common construction defects in the analyzed apartments.

Comparing the analyzed buildings, it can be seen that despite the work being performed by different construction companies, the percentage ratio of the vast majority of construction defects is similar. Cracks in the walls and lack of right angles between walls are the exceptions. Based on Figure 2, we can see that almost 30% defects in Building B were related to cracks on the walls, while there was less than 10% of those in Building A. In addition, in Building A, about 9% of the defects were related to the lack of right angles between walls, while in Building B, only 0.2% were related to the lack of right angles between walls. This can be explained by the fact that plastering works in staircases were carried out by different subcontractors, as well as by the higher proportion of reinforced concrete walls on lower storeys, and the successive increase of the ratio of masonry walls to reinforced concrete walls on higher storeys. In the analyzed buildings, the most frequent defects concerned plastering works (27.9%), painting works (10.3%) and window joinery (9.9%). A summary of the remaining work is presented in Figure 3.

Figure 4 shows the 10 building elements with the most construction defects. Most defects were found on walls (35.4%), railings (10.8%) and windows (9.7%). Figure 5 shows the rooms where the most building defects were identified. When analyzing Building A and Building B, one can see the similarity in the number of building defects per room, by function. During the

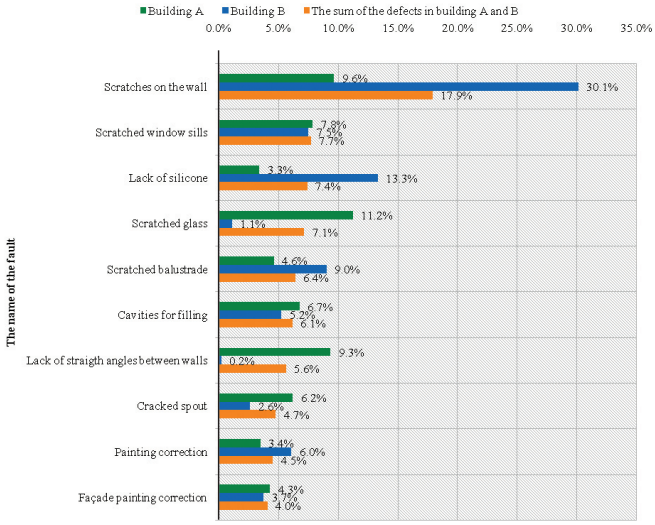

Fig. 2. The most frequent defects in buildings

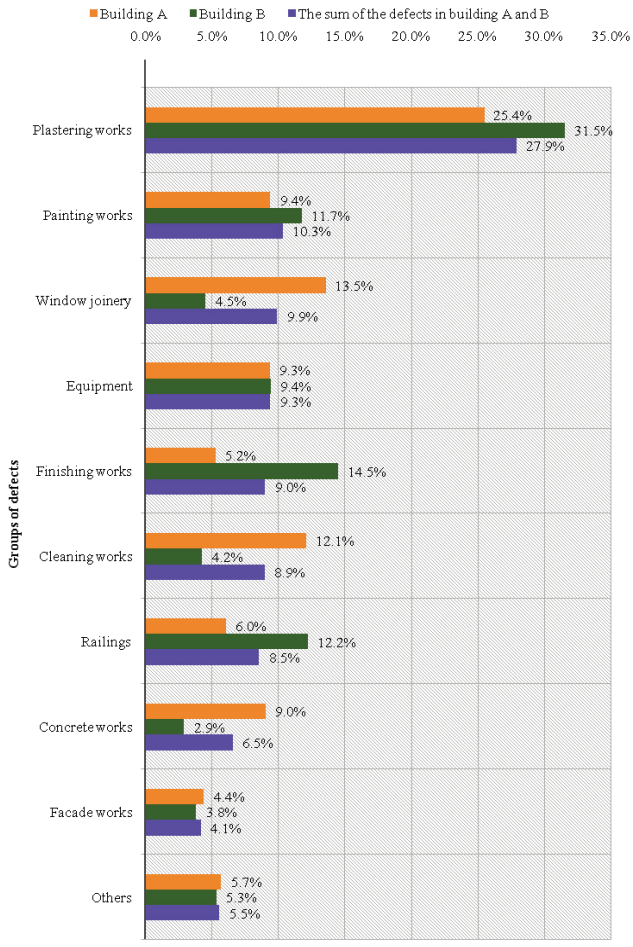

Fig. 3. Most common construction defects (breakdown by the type of construction work)

inspections carried out by the investor inspectors, it can be noted that most defects were detected in living rooms and living rooms with an kitchenette (23.4%), balconies, loggias, terraces and gardens (20.4%), sleeping rooms (20.3%), and halls (18.8%).

After the main construction work is done in the apartments, many construction companies move to the apartment or adjacent balconies, terraces and loggias to complete the remaining construction work (e.g., to install sockets and switches, adjust windows, make ordered corrections, install railings, etc.). In addition, the living room and the room with an kitchenette are the largest rooms in each apartment, and as the area increases, the average number of defects per room also increases [12]. During the acceptance inspections of living rooms and rooms with partial kitchens, the investor's supervision inspectors most often detected: cracks on the walls and screeds, scratched window woodwork, lack of right angles between the walls, scratched outer sills and corrections in the paint of the walls.

Defects on balconies, loggias and terraces account for about 20% of all defects detected. The most frequently detected defects included: scratched and dirty railings and flashings/roof work, defects in the facade requiring paint repair, lack of silicone tightness at balcony doors and plinths, as well as chipped paint on balustrades.

When analyzing the construction defects in the surveyed residential buildings, it can be seen that a significant portion of the defects were located in the bedrooms. This group

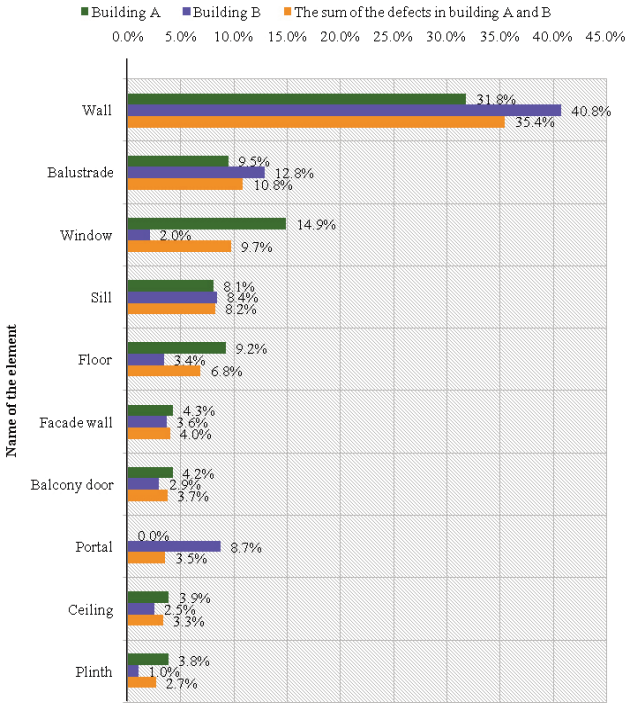

Fig. 4. Elements of the building on which defects appeared most frequently

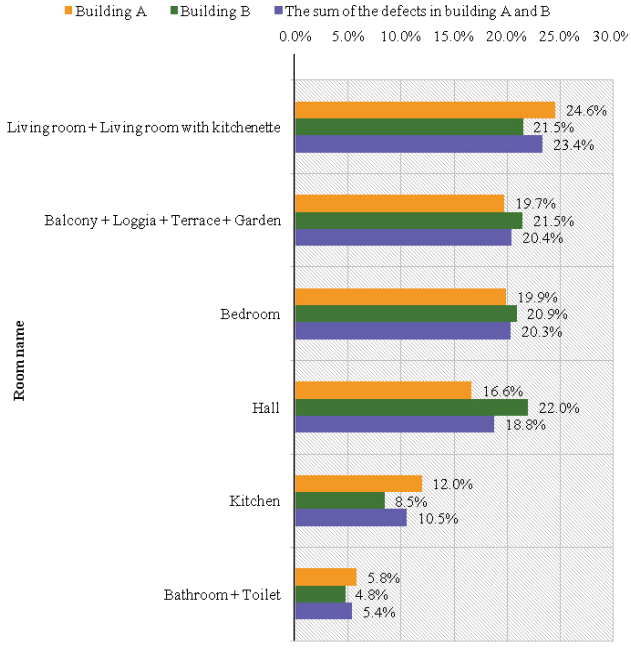

Fig. 5. Breakdown of construction defects by location

includes rooms, which were intended to be bedrooms in the architectural concept, however nothing stands in the way of future users changing the use of these rooms, for example for a study. Bedrooms constitute a significant portion of an apartment's floor area, therefore – as in the case of living rooms (with or without an annex) – the total area of these rooms has a definite impact on the defects. In the bedrooms, the building inspectors most often detected cracks on the walls, window woodwork and window sills, lack of right angles between walls and defects requiring paint touch-ups. As we can see, the types of defects are very similar to the defects found in living rooms and living rooms with partial kitchens.

In each of the cases reviewed, a significant proportion of the building defects identified were identified in the hallway. In the corridors, the most frequently detected defects included: lack of continuity of silicone around the entrance door and electrical box, gaps in the wall to be filled (resulting from, among others, hitting the wall with a ladder), scratches on the walls and screeds, as well as dirt on the walls and door handles.

Summary

Studies of the Central Statistical Office indicate that the number of flats put into use has increased in recent years. Hundreds or thousands of construction defects are detected during the commissioning of multi-family residential buildings. This issue is discussed in foreign scientific literature in many publications, while in the Polish literature there are few publications dealing with the analysis of construction faults in buildings in Poland. Most of the building defects were located on the walls (scratches, poorly made plaster). Therefore, inspectors carrying out acceptance of residential premises should pay particular attention to the walls. In the next publication, the significance of construction defects will be analyzed and the impact of the location and sides of the world on the type and nature of defects will be checked. In addition, the two analyzed buildings will be compared in order to find similarities and relationships in the occurrence of building defects.

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