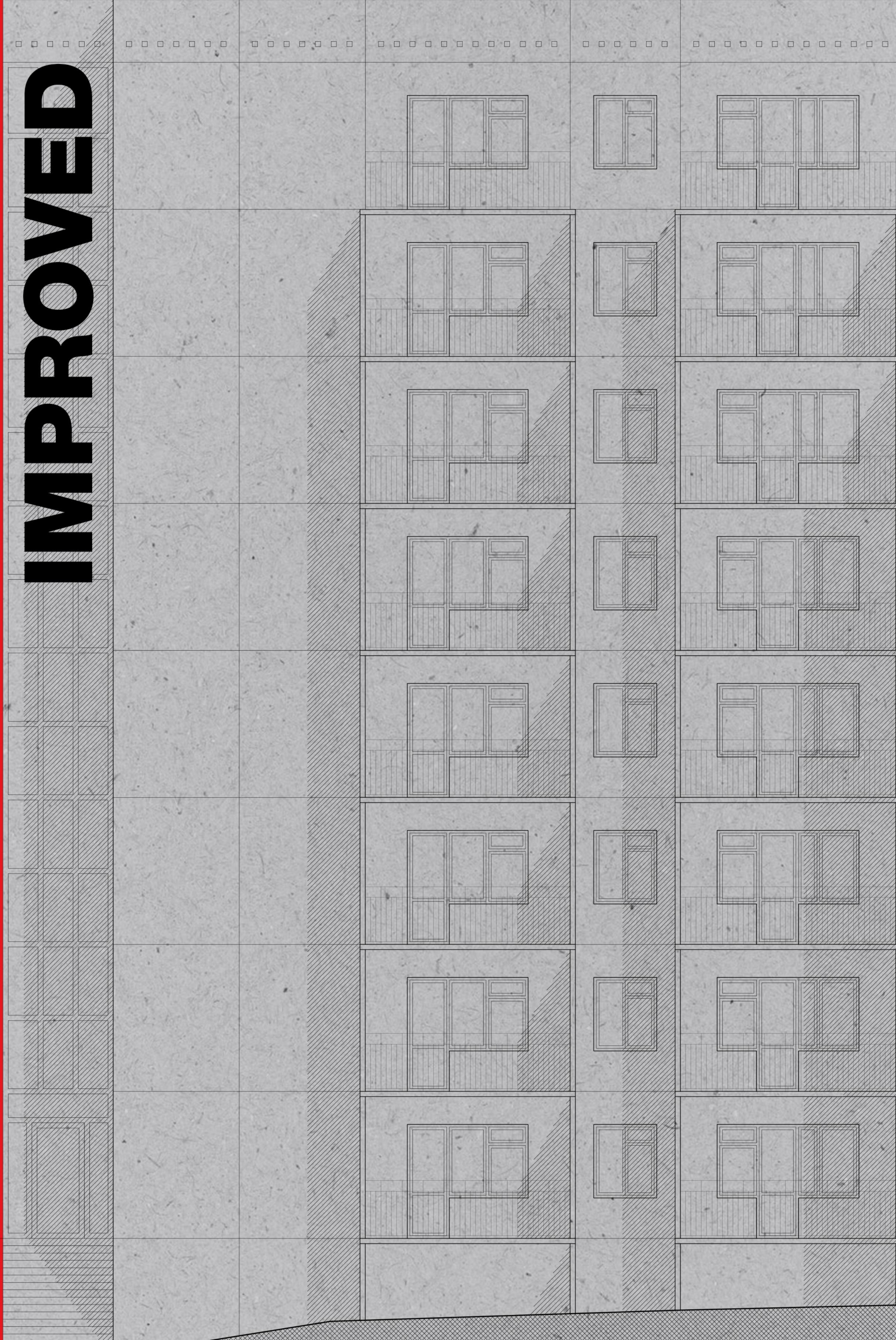
PLATTENBAUS IMPROVED



PLATTENBAUS IMPROVED

Adaptive reuse of LPS-buildings in Poland by increasing occupancy comfort while reducing energy consumption

ENONCE THEORIQUE
DE MASTER EN ARCHITECTURE

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École Polytechnique Fédérale de Lausanne
Lausanne 2022

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I. INTRODUCTION

1. PERSONAL MOTIVATION

The Plattenbaus are undeniably an integral part of both my memories and almost everyone born after 1980 in any town or city of Poland. From the early 2000s I remember the grey, unfriendly residential buildings scattered among the pines in the town where I grew up. A few years later they were renovated and painted in geometric patterns in shades of yellow, beige and orange. This was supposed to improve their perception among residents but, in my opinion, it has turned them into caricatures of themselves.

My foster grandparents lived in one of these orange buildings. I remember the many problems they had to face in their daily lives. The temperature in summer was often too high and in winter too low, hot water for washing had to be heated by a gas boiler hanging in the bathroom and the kitchen was very small. The building, despite 6 floors, did not have a lift and every year climbing the stairs became more and more challenging for them

I also remember that they really liked that flat and that orange block. My grandparents spent a major part of their lives there and never wanted to move out. They were also part of the community that had formed there over the years. Everyone knew everyone, everyone gossiped about everyone and everyone helped everyone. I think that in each of these orange, green, blue or grey blocs scattered across Poland, many such stories have happened.

2. PRESERVATION BY ADAPTIVE REUSE

I believe that the Plattenbau in Poland is worth preserving because it is an integral part of Polish history. It is a legacy of the difficult post-war times and the period of communist rule in Poland. Initially, Plattenbau buildings were a pragmatic response to the struggles of rebuilding the country from the ruins of war. At that time they were for many a symbol of development and hope for a better tomorrow. Despite the fact that they were not and are not without many faults, they provided housing for multitudes of people and are still inhabited by 12 million Poles today.

They are also part of the architectural heritage of Europe and Poland. Their form was influenced by both European modernism and the Russian avant-garde. They are a remnant of a very specific era in the history of architecture and could not have been built under any other circumstances.

However, preservation of Plattenbaus should not be synonymous with treating them as monuments that must remain untouched. Their history should still be alive and the 21st century could be its next chapter. I believe that they should be used to help us to address contemporary problems.

The biggest contemporary problem is anthropogenic climate change. We should introduce solutions to reduce our negative impact, one way of doing this is through adaptive reuse of buildings. Our actions will never be perfect and we will not necessarily succeed in fully stopping what we have caused but we should focus on limiting negative actions and prepare for a drastic change in the conditions in which we will be living. Therefore, I ask the question: When preserving Plattenbaus through adaptive reuse, what are the design interventions necessary to ensure indoor comfort while keeping energy usage to a minimum?

II. BACKGROUND

1. PRESERVATION VALUES

1.1. HISTORICAL VALUES

In order to fully understand the role that prefabricated housing has played in Polish history, it is necessary to go back more than two decades since the construction of the Służewiec Prototype Housing Estate, which was a testing ground for the development of prefabricated housing. During the Second World War Poland, being a largely agricultural and poorly urbanised country, was severely damaged. Cities suffered the most – according to post-war estimates by the Central Statistical Office[1], over 50% of the urban fabric (295 400 buildings) was destroyed or damaged. In Warsaw, 65% of all buildings were completely destroyed, with another 10% damaged to an extent that made it impossible to live in. The western, much larger and more heavily urbanised part of the city was destroyed in 84%[2].

From the beginning of the war, an increased migration of the population, which was mainly caused by the war, could be observed. In 1945, after the signing of the peace treaties, the borders of the country were changed – the eastern border was significantly shifted to the west and coincided more or less with the Curzon Line[3]. In the west and north the post-German Recovered Territories were incorporated into Poland. Many Poles living in the Eastern Borderlands did not want to be citizens of the newly formed Ukraine, Belarus and Lithuania, so they decided to migrate westwards. In such uncertain times, many people decided to move to the cities in search of stability and, above all, work. The cities, though devastated, offered better prospects than the poor and economically backward rural areas.

The war damage, together with the migration of people to the cities, was already enough to cause a housing famine in the cities[4]. It was further deepened by the post-war baby boom – between 1946 and 1950 the population of Poland increased from 23,9 to 25 million. In the following decades the birth rate accelerated even more: in 1960 Poland had 29,7 million inhabitants and 32,6 million in 1970[5].

[1] Halina Dmochowska, ed., 1939-1945 *Pro Memoria*, 1st ed. (Warszawa: Zakład Wydawnictw Statystycznych, 2015).

[2] Marek Getter, "Straty ludzkie i materialne w Powstaniu Warszawskim," *Biuletyn Instytutu Pamięci Narodowej*, 8-9 (2004).

[3] Curzon Line – the proposed demarcation line between the Second Polish Republic and the Soviet Union, the two new states created after World War I, first proposed in 1919. The name comes from the British Foreign Secretary Lord George Curzon, although in fact he was neither the author of the concept nor its supporter. Today the Curzon Line is the eastern border of Poland.

The Stalinist Period

In such circumstances a new government took power. It was a communist totalitarian power, theoretically independent, but in practice strongly reliant on Moscow. One of the first decisions of the new government was the nationalisation of all branches of the economy, including housing. In addition, the authorities began to control most aspects of citizens' lives[6], including the issue of housing. A housing obligation was introduced, which in practice amounted to state control over who should live where. Citizens lost the ability to decide on the properties in which they lived. It was also decided that Poland should be transformed from an agricultural country into an industrialised one.

Given all the challenges ahead of the authorities, it was realised quite quickly that the best and probably only solution to the housing problem would be its far-reaching industrialisation. The solution to this problem could have been heavy prefabrication in the form of the Plattenbau, but politics did not allow it. It was the first but not the only moment in the history of the People's Republic of Poland when architecture was determined by direct decisions of the authorities. The Stalinist doctrine of the time demanded the creation of architecture that was „*national in form and socialist in content*"[7], which was in direct conflict with the minimalist architecture of the Plattenbaus associated with the bourgeois modernism of the 1920s and 1930s.

It was not until Stalin's death in 1953 and, above all, Nikita Khrushchev's condemnation of the Stalinist period in 1955 that the path for the development of prefabricated construction was opened. However, this development will be strongly and directly influenced by political decisions until the very end. They would influence almost every aspect of architecture, from the scale, construction time and size of housing estates to the number of bathrooms and location of windows.

The socialist housing economy was a planned activity of the state to meet housing needs in a manner subordinate to the central plan. Practically the entire economy was centrally planned so that decisions, no matter how important or detailed, were made at the highest level. The housing conditions of millions of people reflected not only the economic and political situation, but also the private convictions of specific decision-makers.

The Gomułka's Era

From 1956 to 1970 the real power as First Secretary of the Central Committee of the Polish Workers' Party was held by Władysław Gomułka[8]. This was a period of a slight thaw and a softening of totalitarian state policy. In practice, however, the housing cooperatives responsible for the construction of new housing estates were fully dependent on state decisions. They could not even decide on such basic issues as the typology of flats or the materials used.

[4] The population within the new borders in 1946 was 23.9 million, 8.1 million less than in 1939. At the same time, population losses were greater than the loss of housing stock, as a result of which, despite the huge war losses, the average population decreased from 2 persons per room in 1939 to 1.7 persons in 1946. In addition, there was a marked decline in the quality of housing which, as a result of the lack of repair and maintenance during the war period, now required urgent repairs.

[5] Renata Bielak, ed., *100 lat Polski w liczbach: 1918-2018*, 1st ed. (Warszawa: Zakład Wydawnictw Statystycznych, 2018).

[6] The degree of control varied depending on the period, but was present until 1989. The most repressive methods were used in this Stalinist period.

[7] Anna Cymer, "*Socrealizm nieoczywisty*," accessed December 15, 2021, culture.pl/pl/artykul/socrealizm-nieoczywisty.

[8] Władysław Gomułka (6 February 1905-1 September 1982) – Polish communist politician, member of the Communist Party of Poland and the Polish Workers' Party, he was the secretary and later the general secretary of the Central Committee. During the formation of communist power in Poland he was the first deputy prime minister (1944-49) and Minister of the Regained Territories (1945-49). He was imprisoned twice for communist activities during the interwar period. Gomulka was an ideological communist and tried to implement all his main ideas without considering their actual performance. The period of Gomulka's rule saw the expansion of heavy industry, the construction of houses and industrial plants, and the increased role of state farms. Initially, Gomulka relaxed the policy of censorship and control of citizens, only to gradually tighten it later.

In 1960 there was a shortage of 1.227 million rooms[9] and the party decided that priority should be given to the expansion of heavy industry, as a result of which there was a shortage of funds for housing construction. Far-reaching savings were needed, which was the real obsession of Władysław Gomułka. The First Secretary sought savings in every possible aspect of people's lives, from restricting coffee imports and ham production to housing standards. The Deputy Prime Minister of the time, Julian Tokarski (actually Wiktor Bożek), a turner by profession and long-time communist activist, was particularly capable in this regard. He became obsessed with maximising savings in the branch of the economy for which he was responsible.

The goal was to reduce costs by an average of 20%, and the tool to achieve this was the Savings Commissions under the chairmanship of the Plenipotentiary for the Example of Economical Housing. Their task was to review architectural designs in search of opportunities to reduce costs. Green areas between blocks of flats and playgrounds were abandoned, distances between buildings were reduced, kitchens were designed without windows, there were no balconies, bicycle storage rooms, cellars, lifts, built-in wardrobes, kitchen equipment, washbasins in bathrooms or even certain doors.

The most extreme example of savings was the „*exemplary-saving*" buildings developed for Gdańsk and propagated by Julian Tokarski. They appealed so much to Wladyslaw Gomulka that he recommended their use throughout Poland. These buildings often consisted only of studios or two-room apartments with a floor space of around 32 m^2. In order to reduce the size of bathrooms, bathtubs were replaced by showers. When designing a housing estate in Poznan, it was decided that bathrooms should not be designed at all within the apartments.

This aroused considerable opposition from architects including Władysław Skoczek and Józef Sarnecki, engineers from the Residential Construction Institute. After comparing the construction costs of buildings with and without bathrooms in flats, they showed that the variant with shared bathrooms was 4% more expensive than the variant with individual bathrooms, and on top of that, the grouped toilets and bathrooms took up an additional area equal to the size of one flat. By leaving the toilets inside the units, it is therefore possible to design one more apartment on each floor. Fortunately, this proved to be a sufficient argument for the First Secretary, which did not prevent the standards from being significantly reduced.

[9] Beata Chomątowska, *Betonia: Dom dla każdego*, 1st ed. (Wołowiec: Wydawnictwo Czarne, 2018).

Standards were the way in which power influenced architecture from the very beginning. The first one was introduced as early as 1947. The 1959 standard stipulated that one person only needed 11 m^2 of floor space to live. Studio flats should have between 17 m^2 and 20 m^2, in special circumstances 28 m^2, a flat for two people between 24 m^2 and 30 m^2, with a maximum of 36 m^2. For three people, the norm was between 33 m^2 and 38 m^2, with a maximum of 52 m^2. These were some of the lowest norms in the whole of Europe. In the 1960s, the above-mentioned Julian Tokarskim introduced a standard[10], according to which the area for one person should be between 5 and 7 m^2, with the guideline that one should aim for the lower limit of the normative. With this assumption, it was not uncommon for a one-person flat with a kitchen to house a family of at least three.

[10] Chomątowska, *Betonia*.

The Gierek Decade

Another update of the standards took place in 1974. This was during the reign of Edward Gierek[11], which lasted from 1970 to 1980. He was brought to power by workers' strikes resulting from rising food prices, which overthrew Władysław Gomółka. Thanks to multi-million dollar loans, Poland entered a period of prosperity that put an end to the previous government's obsessive austerity. Among the promises that helped consolidate the new First Secretary's power was a declaration that he would provide every Polish family with an independent home. This would require the construction of 7,3 million flats between 1970 and 1990. Plattenbau construction was chosen as the means of fulfilling this promise. Between 1970 and 1980, 70% of multi-family residential buildings were built using this technology. Large housing complexes for tens of thousands of residents were planned (Osiedle Ursynów Północy – 40,000 residents). Up to 290,000 flats were built per year, and between 1970 and 1975 a total of 1 million flats were constructed[12].

[11] Edward Gierek (6 January 1913–29 July 2001) – Polish communist activist, politician, member of the Polish Workers' Party and the Polish United Workers' Party. In 1970 he became the First Secretary of the Central Committee of the Polish United Workers' Party and remained in power until 1980. This period was characterized by rapid economic development of Poland in the first half, only to end in a multi-faceted economic crisis in the second half, which ultimately led to the end of his rule and, in the perspective of the next decade, to the collapse of the socialist system in Poland.

[12] Błażej Ciarkowski, *Odcienie Szarości: Architekci i polityka w PRL-u*, 1st ed. (Łódź: Wydawnictwo Uniwersytetu Łódzkiego, 2017).

The standards from the times of Edward Gierek assumed that the usable floor space of a flat could be, depending on how many people the flat was designed for: M-1 up to 37 m^2, M-2 up to 44 m^2, M-3 up to 63 m^2, M-4 up to 78 m^2, M-5 up to 88 m^2, M6 up to 97 m^2. Any surplus space was also standardised by introducing a permissible increase in the upper limit for technological reasons. The necessity of eliminating the sleeping area from the living room was recognised, and it was considered desirable to have a separate, larger room for the parents. The need for an eating area in the kitchen was noted. It was important to increase the size of the bathroom and WC, the hallway and storage space. Balconies

and loggias began to be included in the design of the buildings and the problem of ventilation became important. The space between the buildings became more important, with plans for green areas, children's play areas and public buildings - local shopping and service centres, community centres, health centres and schools.

In order to raise executive power and fulfil promises, the authorities decided to buy licences, production lines and even entire factories in Western European countries. West Germany in particular was keen to get rid of the ballast of house factories. They were prompted to do so, among other things, by the estimation that „*heavy prefabrication*", when taking into account the costs of the equipment used, was not at all as profitable as it might seem, even if not counting the cost of the house factories that have already been built. In addition, it turned out that it was not possible to simultaneously reduce construction costs and ensure the diversity of the settlements being built.

The housing estates of the Gierek period provided much better living conditions for residents, but at the cost of extreme repetitiveness of the buildings. They often consisted of a very limited number of building types arranged in parallel to each other. Planned green areas and public utility buildings were often not constructed in parallel with the residential buildings. It took many years before these estates were fully completed. The imposed fast pace of construction and the lack of sufficient building culture led to frequent execution errors. This was recognised as early as the beginning of the 1980s, when the first action was taken to repair defects in the Plattenbaus. Many of the defects are still encountered by residents today.

In the second half of the 1970s, problems with repayment of government loans led to an economic crisis, which also affected the construction of new housing estates. The Plattenbau technology was not abandoned, but the scale of planned housing estates was significantly reduced, they were not built as much and as fast.

The Fall of the Plattenbau

The year 1980 brought another huge wave of protests which led to the imposition of martial law and the removal of Edward Gierek from power. Throughout the 1980s the economy did not return to the state of the first half of the 1970s. Housing estates were still being built, mainly with the Plattenbau technology, but on a much smaller scale and with much less impetus.

The year 1989 brought the final end to the Plattenbau. The collapse of the communist system and rapid privatisation of all branches of economy, including housing, made it impossible to continue the projects in which the use of Plattenbau would be justified. This shows how much architecture was linked to the political and economic system. Without it, the Party would not have been able to fulfil its housing promises and the Plattenbau would not have been able to exist without the Party. In every building you can find written information about the political and economic history of Poland – both about the incredible stinginess of comrade Tokarski and about the short but extraordinary time of prosperity at the beginning of the Gierek Decade. It is worth preserving this history written in concrete slabs.

Between 1951 and 1988, the state sector built almost five million flats in Polish cities, around four million of which were in Plattenbau buildings. Even in the record-breaking year 2020, fewer flats were built than were constructed every year in the first half of the 1970s.

1.2. ARCHITECTURAL AND URBAN VALUES

The idea of mass, industrial construction goes back even to pre-modernist times and is directly linked to the development of capitalism. However, the form and approach visible in the Plattenbau has its origins in pre-war modernism. Le Corbusier can be considered its creator, and the document which established the principles which were to govern it – the Athens Charter, signed on a ship sailing from Marseilles to Athens, on which the 4th Congrès Internationaux d'Architecture Moderne took place. Of course, the influence of the heritage of the Russian Avant-garde cannot be overlooked either, especially in the context of building under communism in Poland.

Modernist architecture aimed to improve the lives of ordinary people. This was to be achieved by extracting them from the unhygienic 19th century cities and moving them to comfortable and efficient living machines scattered among the green landscape. It was, in its assumptions, a socialist idea which, at least in theory, focused on the weakest. Modernist concepts were very well known in Poland almost from their inception. Already in the 1930s Polish architects took part in CIAM congresses and they themselves implemented the principles of the Athens Charter[13]. The concept of building blocks and housing estates, developed to a great extent in the second half of the 20th century, did not appear in Poland suddenly. It was processed, partly degenerated, but most of all put into practice on a huge scale.

[13] The most complete embodiment is the pre-war Warsaw housing estate in Rakowiec, designed by Szymon and Helena Syrkus.

From the very beginning, more than a decade before the construction of the first buildings of the Plattenbau, its history was connected with outstanding Polish architects. Already in 1948, during the First Congress of the International Union of Architects, Helena and Szymon Syrkusowie[14] spoke about the necessity of introducing typical designs and prefabrication. At that time, for political reasons, it was not yet possible. The situation changed in the second half of the 1950s and from 1959 on the southern outskirts of Warsaw, in the so-called Southern Industrial District „*Służewiec*" (PDPS), which was already filled with industrial plants, a small housing estate was built, which was turned into a kind of testing ground. This was the so-called Prototype Housing Estate.

Different forms of housing, functional layouts and prefabricated systems were tested there. Contrary to popular opinion, Polish residential buildings were not built only in systems imported from the GDR or USSR. Polish Plattenbau is a collection of many different systems designed by Polish engineers, architects and constructors, which proves the creativity of Polish designers. In a way, they are unique on a European as well as global scale.

The systems tested at the Prototype Housing Estate and elsewhere can be divided into two categories – openness and regionality. Initially, closed systems were used, in which the catalogue of elements and possibilities for their combination was very limited. This significantly increased the repeatability of the typology and the buildings themselves but also allowed for much faster and more efficient production. Each mould had a specific strength and the most optimal solution was to use it in 100%. These systems were among others: Szczecin system, WUF-T, WWP, or the OWT group of systems. Later, at the beginning of the 1970s, open systems based on a modular grid were developed. This allowed, at least in theory, for a significant increase in flexibility, variety and freer shaping of architectural expression. The system of this type was W-70 and its modification Wk-70.

Most of the mentioned systems were general systems, adapted to be used in the whole country. Apart from them there were also regional systems developed taking into consideration local specifics, execution possibilities or ground conditions. The Dąbrowa system was developed especially for the needs of the building industry in Łódź, and the Winogrady system for the needs of the Winogrady housing estate in Poznań. The Fadom system was mainly used in Upper Silesia as it allowed for the construction of housing estates in areas at risk of mining damage.

[14] Helena and Szymon Syrkusowie (Helena – 14 May 1900-19 November 1982; Szymon – 24 June 1983-08 June 1964) – married couple of Polish architects, working together both on projects and theory of architecture. They were among the most important representatives of the Polish architectural scene in the interwar period, representatives of the avant-garde, actively participating in the international life of the avant-garde architecture community (e.g. CIAM). Their work focused primarily on residential architecture, where they explored the possibilities of new forms of habitation and the typification and mass production of housing. Their output includes many private houses and housing estates, as well as many theoretical considerations, including unrealized Plattenbau projects.

Only two of the systems used allowed for relatively free shaping of the architecture of the buildings (W-70/Wk-70 and Szczecin system), but even this was often not used for economic reasons. In the production of prefabricated elements, the aim was to optimize the use of moulds and thus to maximise the repeatability of elements. Despite these limitations, some of the housing estates are characterised by interesting architecture, not devoid of detail and individuality. However, when the situation did not allow for individual solutions, the designers tried to compensate for this with a high urban value.

Due to the nationalisation of land architects and urban planners had large areas at their disposal. Mostly they were located on the outskirts of the cities at that time, although there are also exceptions[15]. Today these areas are located in very attractive, well-developed districts. Vast areas and high buildings allowed for large distances between them. This provides the residents with more privacy and gives the potential for attractive green areas to be created on the estates.

[15] One of the housing estates from that period, admittedly constructed in monolithic technology, was built on the site of the ghetto destroyed during the war, in the very centre of Warsaw.

Along with the design of the housing estates, transport infrastructure and complementary functions were planned – kindergartens, schools, shops, services and health care clinics. The economic crisis meant that the greatest priority was given to the construction of residential buildings, leaving the construction of other elements for later. At first this was very inconvenient for the inhabitants, but with time the functions were supplemented. Nowadays, the housing estates from that period are very good places to live.

Tauzen

The decision to build housing estate "*Osiedle Tysiąclecia*" in Katowice was taken in 1956 and it was initially assumed that this housing estate would house 45 thousand inhabitants. The area was to consist of 5 smaller units – 4 housing estates (Lower, Upper, Central and Western) and a Service Centre. There were also plans for 3 educational centres and 3 service centres. The name referred to the celebration of the millennium of the Polish state. By 1959, when a competition for the design was announced, the planned number of inhabitants was limited to 20,000. The competition was won by a team made up of Henryk Buszko, Aleksandra Franty, Marian Dziewoński and Tadeusz Szewczyk from the Voivodeship General Building Design Studio in Katowice.

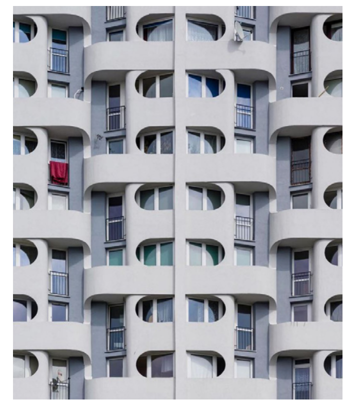
The housing estate, as the architects emphasised many times, was designed like a landscape park. Very large, simple residential

One of the kurydza Tower on "*Osiedle Tysiąclecia*" housing estate

Image from: Beata Chomątowska, *Betonia: Dom dla każdego*. (Wołowiec: Wydawnictwo Czarne, 2018)

buildings were placed on a huge, green area, so that practically from every window one could see the greenery. Vehicle circulation was withdrawn from the housing estate and a network of pedestrian routes was organised, supplemented by the necessary infrastructure (schools, shops). One of the elements of the estate was a lake, where a sailing school functioned. The most characteristic buildings of the "*Osiedle Tysiąclecia*" housing estate are Kukurydze (corncob), referring in their shape to Marina City in Chicago. Today, Katowice's „*Tauzen*" wins in rankings of the best places to live in Silesia.

Manhattan



Façade of one of the buildings on the Manhatan housing estate

Image from: Brtosz Dworski

This housing estate is located at Grunwaldzki Square in Wroclaw. It was designed by Jadwiga Grabowska-Hawrylak in 1967-1970 and completed in 1976-1978. The complex consists of 6 residential towers joined by 3 service pavilions. On the top floors there are common rooms for children, drying rooms and exits to terraces located on the roofs. The most characteristic element of the development is the unusual shape of the residential towers. They were constructed from prefabricated elements of a unique shape developed by the designer.

The project involved making the outer layers of the prefabricated elements from white concrete. The walls by the balconies were to be finished with exotic wood and planted with vegetation. The roofs of the service pavilions were also to be planted with vegetation to give the whole a Mediterranean atmosphere. During implementation, the project was simplified in order to reduce costs. The prefabricated elements were finished in plain grey concrete, the exotic wood was replaced by clinker bricks, and no plants were planted.

Ursynów Północny

The Ursynów Północny housing estate was built at the time of the greatest development and mass popularity of the Plattenbau in Poland. At that time estates for tens of thousands of inhabitants were designed, which for economic reasons were architecturally and urbanistically very standardised. One housing estate occupies an exceptional position in this systematics – Ursynów Północny in Warsaw. The project was created as part of an architectural competition in 1971; soon afterwards it was slightly modified, when after the death of the main designer, Ludwik Borawski, this role was taken over by Marek Budzyński[16]. Although it was built in Plattenbau construction system, the estate has

[16] Marek Budzyński (born 7 April 1939) – Polish architect and urban planner, designing mainly public utility buildings. His work is characterized by a distinctive style combining monumentalism and pompous classicism, rich in symbolism and ecological motifs. His most recognizable projects include: Ursynów Północny housing estate, The University of Warsaw Library and The Supreme Court building in Warsaw.

a unique character of an intimate, full of greenery, exceptionally friendly space to live in. The badly associated name „*blocks of flats*" (often used for describing poorly designed estates with lack of space and greenery) does not suit Ursynów – the buildings, diversified in terms of their dimensions, were designed in such a way as to create the impression of a friendly neighbourhood settlement. In 1975 in the magazine „*Architektura*" Marek Budzyński wrote:

„*Ursynów cannot become a bedroom community, it must be a new vital part of Warsaw. [...] We want Ursynów to be not only an anonymous unit of account for planners, but a city district with its own face.*"[17]

[17] Stowarzyszenie Architektów Polskich Architektura 1975, 1-2 (1975).

The buildings were initially designed in the W-70 system modified by the authors and called W-70PP. However, the authorities did not agree to this modification, so the Szczecin system was adopted for implementation. The capacity of the local house factory operating in this system was not sufficient so some of the buildings were adapted to the W-70 system.

Façade of the W-70 system building

Image from: Brtosz Dworski

W-70/Wk-70

„*System Otwarty Budownictwa Mieszkaniowego*" (Open Housing System) is the most popular system of the Plattenbau construction and the only open system (other open systems were developed for frame constructions). 35,9% of all the Plattenbau buildings in Poland are built in this system[18]. It was the result of a national competition in 1968 to develop a construction and assembly system that was to become the basis for the construction industry. The winning work was developed by a team led by Maria and Kazimierz Piechotkowie[19]. It enabled the construction of buildings up to 15 storeys high.

In its principles, the system was supposed to combine the advantages of heavy prefabrication with the possibility of relatively free shaping of the architectural expression and details. The number of prefabricated elements was theoretically unlimited and allowed great creative freedom. Maria Piechotkowa wrote: „*The way of using the system and the architectural detail of the building depends on the needs and on the willingness, skills and creative invention of the authors and designers of specific realizations*". Many times these possibilities were not used for financial reasons, the maximal use of moulds was pursued, thus unusual and unique architectural details were avoided and repetitive buildings were designed.

[18] Teresa Taczanowska and Anna Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych*, 1st ed. (Warszawa: Dom Wydawczy MEDIUM; Dom Wydawniczy MEDIUM, 2012).

[19] Maria and Kazimierz Piechotkowie (Maria – 12 July 1920–28 November 2020; Kazimierz - 20 November 1919–6 March 2010) – married couple of Polish architects, took active part in the uprising fights during World War II. After completing their architectural studies, they worked in the field of historic preservation and reconstruction, they were involved in the reconstruction of Warsaw destroyed after the war, they also researched and documented wooden synagogues in Poland. In the 1940s and 1950s they focused primarily on residential architecture, designing numerous housing developments, often using prefabricated elements. After retiring, they once again focused on Jewish religious architecture, publishing books that now belong to the canon of literature on Jewish cultural heritage.

The system was based on a 60 × 60 cm modular grid. The basic construction solution was a transverse structure of load-bearing walls, but it was also possible to use mixed or even longitudinal structures. In the W-70 system the basic elements were: unidirectionally reinforced 22 cm thick hollow core floor slabs, 15 cm thick internal walls for residential storeys and 20 cm thick for basement walls; external multi-layer walls were 27 cm or 40 cm thick, made of expanded concrete. Typical floor spans (load-bearing wall spacings) were: 240, 360, 480 and 600 cm. The height of residential storeys was 280 cm. Internal walls were made of large-size slabs of lightweight materials or gypsum boards. Assembly was carried out as forced-assembly.

The catalogues included typologies of centrally typified elements – identical elements produced in stationary or field production plants all over the country. The system included the possibility of using additional elements taking into account the needs of a region (regional typification) and produced for the needs of a single housing estate (local typification).

In the middle of 70's the decision was made to buy factories of houses in West Germany and to use them for production of prefabricated elements of W-70 system. However it was not possible to produce hollow core slabs, therefore the Wk-70 system without this type of elements was developed. In this variation additional ceiling span (300 cm) and additional storey height (330 cm) were introduced, hollow core floor slabs were replaced with 16 cm thick solid slabs, external walls made of expanded concrete were no longer used.

Façade of the OWT-67 system building

Image from: Brtosz Dworski

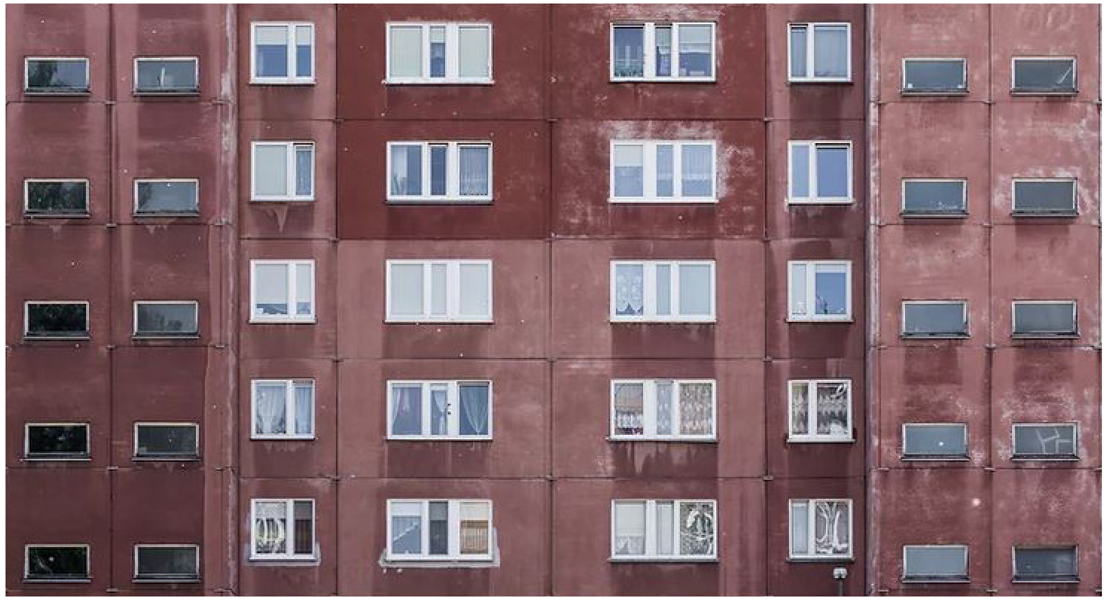
OWT-67

The OWT-67 system ("*Oszczędnościowy Wielkopłytowy-Typowy*" – Plattenbau Economical-Typical) was developed in 1962 by the Office for Typical Designs and Urban Construction Studies in Warsaw. It gave origin to a group of OWT systems, which are variants and modifications of the original system. It is the second most popular group of systems after W-70/Wk-70. It allowed for the construction of residential buildings with 5, 11 or 16 storeys.

The OW-T system was based on a grid measuring 540 × 480 cm with a complement of 540 × 540 cm for living areas and 270 × 480 for circulation routes in 5-storey buildings (circulation routes in 11-storey buildings had a 480 × 540 cm grid). The storey height was 270 cm. The primary structural system was a longitudinal-transverse system involving internal walls, external walls and cross-reinforced concrete floors.

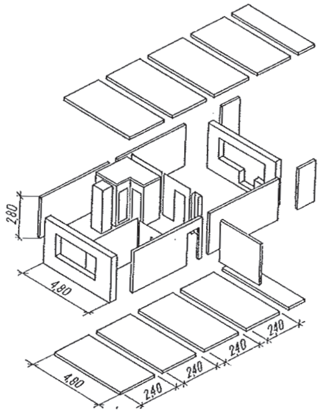
The material solution of the system: internal walls and ceilings – 14 cm thick reinforced concrete slabs, external three-layer walls 16 cm thick (longitudinal walls) or 24 cm thick (gable walls) with a 5 cm thick polystyrene insulation layer (the difference in thickness resulted from a different thickness of the reinforced concrete bearing layer – 6 or 14 cm respectively).

In 1975 the variant marked OWT-75 was developed, increasing not only the size of typical flats, but also the height of a storey up to 280 cm. A modular grid of 120 × 120 cm was also used, with the depth of the housing tract – 480 cm, and with widths of: 240, 360, 480, 600 cm (where the width of 240 cm was used as a supplementary). The thickness of ceilings was also increased to 16 cm, of internal walls to 15 cm and of external longitudinal walls to 19 cm.



Façade of the Szczecin system building

Image from: Brtosz Dworski



Elements of Szczecin system

Image from: Eugeniusz Pilszka, *Systemy budownictwa mieszkalniowego i ogólnego.* (Warszawa: Arkady, 1974.)

Szczecin system

This system was developed in the same year (1968) and as part of the same competition as W-70. It was used in 13.7% of all the Plattenbau buildings constructed in Poland[20]. The name refers to the city in which the design office responsible for the system „*Miastoprojekt – Szczecin*" was located. The first buildings constructed with the use of this system were constructed in the same city.

In the Szczecin system 140 typical elements were designed, on the basis of which 16 layouts of flats of types from M-1 (for one person) to M-7 (for seven persons) were created. Using these layouts, it was possible to develop building segments of 5 and 11 storeys. It was still a closed system, but thanks to the principle of freely combining segments, it was possible to obtain a variety of housing structures and flexible urban layouts.

The basic units were based on a 480 × 480 cm and 480 × 240 cm grid, and later elements of 480 × 155 cm and 240 × 155 cm were also added. The basic spacing of the load-bearing walls was 480 cm, and the transverse arrangement of the walls was the basis for shaping the layout of the building. The floor slabs, unidirectionally reinforced, were 14 cm thick, the internal load-bearing wall slabs were 15 cm thick, and the

[20] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*

partition wall slabs were 5 cm thick. The external walls made of expanded concrete had two thicknesses: 40cm for the load-bearing walls and 36cm for the curtain walls. Sanitary facilities, stairwells, lift shafts etc., as well as basement walls, were also prefabricated. Initially, the forced-assembly method was used, but due to technological problems and lack of sufficient accuracy, it was later changed to the free-assembly method. This is the system with the highest concrete usage rate of all systems found in Poland.

Façade of the WUF-T system building

Image from: Brtosz Dworski

WUF-T

The WUF-T system ("*Warszawska Uniwersalna Forma-Typowa*" – Warsaw Universal Form-Typical) was developed by the Office of Typical Designs and Urban Construction Studies in Warsaw in 1967. It accounts for 2,5% of the Plattenbau buildings in Poland[21]. It allowed for the construction of 5 and 11 storey buildings.

[21] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*

The system was based on a modular grid. Tracts were designed with a depth of 480 cm and the spacing of the transverse walls was: 300, 450, 600, 750 and exceptionally 900 cm. The slabs used in this system were 14 cm thick, and the external walls, apart from the 14 cm thick load-bearing layer, also consisted of 5 cm thick polystyrene insulation and a 6 cm thick concrete outer layer. The height of the residential floors was 270 cm. The floor slabs were cross reinforced with the possibility of supporting them on two, three or four edges.

Over time, new variations were developed, designated successively: WUF-T/65, WUF-T/72 and WUF-75. For the WUF-T/67 variant two flats were provided on each storey, in the later WUF-T/72 variant three flats on each floor. In 1974, after the introduction of new housing standards (the size of typical flats was increased), another variant of the WUF-T system was developed – WUF-75, which was still intended for the construction of 5- and 11-storey buildings.

1.3. CULTURAL VALUES

The Plattenbau has been a culturally significant element from the very beginning. It was at the centre of society's collective consciousness as it embodied the promise of something new – a new man and a new life. Of course, this was the result of a strong propaganda message from the authorities of the time. The rebuilding after war damage, and later the construction of new housing estates, was a constant feature of government propaganda newsreels. They showed a socialist state that cared for its citizens, regardless of the social class they represented. The new intelligentsia could live in harmony with the proletariat pulled out of the dark basements of tenement houses and backward villages. The Plattenbau estates were a dream place to live and the optimism associated with them prevailed from the early 1960s to the late 1970s.

This optimism was not destroyed by the numerous problems, shortcomings and absurdities of the system. It took a long time to get a flat and the process was not transparent. When one did manage to get one's own flat, it was sometimes full of defects, and for years no road, shop or bus stop was built next to the blocks. This is reflected in films and TV series from the late 1960s and 1970s. In the 1969's movie „*Człowiek z M3*" (Man from M3), Leon Jeannot laughs at the absurdities of the communist bureaucracy and housing allocation system. A young doctor is given the opportunity to live in the titular M3, but only if he is married (single people were not entitled to bigger flats) – he only has 30 days to find a partner. The series "*Czterdziestolatek*" (Forty-year-old'), directed by Jerzy Gruza and broadcast between 1975 and 1978, tells the story of the adventures of the main character – the 40-year-old engineer Karwowski. He is a representative of the new intelligentsia and can be described as a representative of the reborn middle class. Both stories are humorous and sarcastic in their portrayal of the absurdities of everyday life, particularly in the context of housing, but their overall tone is positive – living in the Plattenbau is a status symbol and, despite many inconveniences, ensures happiness and stability.

Two films from the 1970s differ significantly from this positive image of the Plattenbau. In Krzysztof Zanussi's 1971 film "*Za ścianą*" (Behind the Wall), the multi-family building becomes a place of alienation and lack of understanding. The protagonists squeezed into small apartments inside a huge building are very crowded, but at the same time they are very lonely and unable to break down the barriers that separate them. In „*Paciorki jednego różańca*" (Beads of One Rosary) from 1979, Kazimierz Kutz tells the story of an old miner who is forcibly relocated from his old mining estate to a new building made in Plattenbau technology.

The modernistic buildings are not a promise of a new, better life for him, but rather the end of everything he knew, loved and understood. It becomes a place without history and without roots – a place of alienation.

Everything changes drastically at the beginning of the 1980s. The imposition of martial law and the economic crisis, which has been dragging on since the second half of the 1970s, lead to a decade of pessimism. The 1980s seems to be a lost decade. This is reflected in the culture, including the perception of housing estates from the Plattenbau. They are shown as a place without privacy, without individuality, full of depressing schematisation of life. The protagonists of Krzysztof Kieślowski's films "*Krótki film o miłości*" (A Short Film About Love) from 1988 and "*Dekalog*" (The Decalogue) from 1989 feel an overwhelming loneliness. There is no physical escape from the blocks and the dramas that take place in them, only resignation or escapism remains. The same feelings are also visible in the music. The first punk rock bands – T.Love, Brygada Kryzys, Dezerter – emerged in the basements and drying rooms of the of the Plattenbau residential buildings. Their music expresses the feeling of lack of perspectives, anxiety and overwhelming inhuman scale of architecture, in which they have to live every day.

In contrast to this pessimistic image stands the iconic comedy series „*Alternatywy 4*" (Alternatives 4) from 1983. The master of Polish comedy – Stanisław Bareja made a microcosm of Polish society of the 1980s out of a Plattenbau residential building. The block and its inhabitants become a reflection of the hierarchical social system of late communism. Bareja shows the authorities (in the form of the caretaker), who know everything and try to control everything, and people who unite across class divisions in opposition to these authorities. Despite the same genre, „*Alternatywy 4*" lacks the same positive overtones as "*Człowiek z M3*" or "*Czterdziestolatek*" – it is rather a satire on the communist system.

The year 1989 brought another dramatic change in the image of the Plattenbau in culture. With the fall of communism, it became a symbol of a difficult past, in which only those whose lives had failed were stuck – everyone who was able tried to escape it. Those who remained were either representatives of the margins of society, excluded people or lost intellectuals who were incapable of achieving social advancement allowing them to move out. This is evident in two films by Marek Koterski – "*Nic śmiesznego*" (Nothing Funny) from 1995 and "*Dzień świra*" (Day of the Wacko) from 2002 – where the figure of a sensitive, neurotic intellectual is juxtaposed with oppressive architecture and its oppressive inhabitants. Plattenbau housing estates are hostile places, devoid of a sense of community and understanding for others.

The Plattenbau buildings of the 1990s also gave rise to the subculture of „*Blokers*"[22] – young hooligans deprived of perspectives, sense of life and sense of subjectivity. In the 1990s they spent their time on the benches between the blocks drinking alcohol, taking drugs and starting brawls. They were surrounded by depressing ugliness and greyness, and their lives were marked by violence and injustice passed down from generation to generation. This image of the housing estates is shown in the film "*Cześć Tereska*" (Hi, Tereska) from 2001, directed by Robert Gliński.

[22] Blokers – a term coined in the late 1990s by photojournalist Maria Zbąska, and popularised in the press to describe frustrated young people with no prospects, for whom the bench in front of the building is the centre of social life, often abusing alcohol and marijuana.

The Plattenbau housing estates were also the birthplace of the Polish hip-hop scene in the 1990s and early 2000s, which was linked to the Blokers community. Music was a way for them to gain identity through talking about their everyday life. The setting for almost every music video was the Plattenbau housing estates from which they originated and where they lived.

The 2010s brought a more complex and gracious view of the Plattenbau. It ceased to be perceived only as a place cursed and devoid of individuality. In 2012's "*Jesteś bogiem*" (You Are God), the story of the hip-hop group Paktofonika, founded in 1998, is told. The lack of prospects, so strongly associated with the image of communist housing estates, became an impulse for the creation of music. The Plattenbau was reclaimed for culture, from a rejected place it became a space with potential for creating culture. In 2017, Karolina Breguła filmed the opera "*Wieża*" (The Tower), in which she narrates through the voice of the inhabitants their everyday life in the Plattenbau.

The Plattenbau housing estates have been an important part of Polish culture for 50 years. They have been both the leitmotif, background and main character of many works. Their reception has changed dynamically – from a symbol of hope, through a cursed place, to, quite simply, remnants of the previous system. The current public perception of these housing estates allows us to perceive them more positively and to notice their more complex image. As a result, more and more people appreciate their importance and feel that they should be protected.

1.4. SCALE

„*Quantity has a Quality All Its Own*" – a quote attributed according to various sources to Napoleon Bonaparte and by others to Joseph Stalin describes well one of the values possessed by the Plattenbau. On the surface, it might seem that a large number of buildings with many defects will cause problems to grow even larger. However, in many respects the opposite is true.

More than 12 million people in Poland, which accounts for around one third of the population, live in multi-family buildings built during the Communist period. The vast majority of buildings constructed during this period were built in one of a dozen prefabrication systems, 80% of them in the Plattenbau system[23]. It is estimated that there are about 60,000 buildings constructed using this technology[24]. Currently, there is still a shortage of almost 2 million flats in Poland. This is a problem that for 30 years has not been solved either by the market or by public investment at local and central level.

[23] Apart from the Plattenbau, other prefabrication systems existed. In large block systems, e.g. Cegła Żerańska, the basic structural elements were smaller than the whole wall or floor slab. This is considered an intermediate form between traditional and Plattenbau technology. There were also frame prefabrication systems such as Rama H. A small number of buildings were also constructed using monolithic or traditional technology.

[24] Andrzej Basista, *Betonowe dziedzictwo: Architektura w Polsce czasów komunizmu*, 1st ed. (Warszawa - Kraków: Wydawnictwo Naukowe PWN, 2001).

Not every citizen can afford to build a single-family home in a suburb or small town. Despite the limited scale, this causes massive urban sprawl and overloads outdated infrastructure. Developers investing in single multifamily buildings and entire housing estates, thanks to overly favourable laws, apply solutions of very low urban, architectural and material quality, but nevertheless they are still unable to satisfy the existing housing famine, especially in large cities.

Authorities at all levels ignore the problem of housing shortage, absurdly high purchase and rental prices. Attempts to launch a nationwide social housing programme have been a failure. By the end of 2019, 100 000 flats were to be built, by the beginning of 2021 just over 11 000 had been completed and a further 14 000 are under construction[25]. This represents only 25% of the target number. Due to the lack of legal tools, it is almost impossible for cooperatives founded by private individuals to obtain loans, which makes it very difficult to develop social housing, as is the case, for example, in Switzerland.

[25] mb, "*Miało być 100 tysięcy Mieszkań plus, jest dużo mniej. Liderem województwo śląskie*", TVN24 Biznes, accessed November 21, 2021, tvn24.pl/biznes/nieruchomosci/mieszkanie-plus-ile-mieszkan-jest-w-budowie-ile-mieszkan-wybudowano--dane-mrpit-5040156.

In such a situation, the demolition in the short term of about 4 000 000, i.e. 20% of all dwellings in Poland, would lead to a deepening of the pathology of the housing market. It would not be possible for anyone to meet the demand for housing, which would further accelerate price increases. The year 2020 saw the largest number of flats completed since 1989 – 220 000. Assuming such a pace of construction of new flats, it would take almost 20 years just to replace the Plattenbau construction.

Solving the housing hunger problem at current levels would require another 9 years.

If it is not possible to replace the Plattenbau quickly with new buildings, it should be presumed that they will be exploited for at least another few decades – possibly to the end of their structural endurance. Given the age of the Plattenbau buildings and the limited number of comprehensive renovations to date, maintenance, repair and comfort issues for those living in this type of building will need to be addressed in the near term. In this situation, scale, combined with the most important feature of the Plattenbau construction – repeatability – is also of value. Once problems have been defined, and above all, once solutions have been developed, they can be implemented much more easily and quickly in consecutive buildings.

2. ADAPTIVE REUSE AND CLIMATE CHANGE

2.1. CHANGE OF USER COMFORT

The consequences of inevitable climate change will be part of our future and will have a major impact on many aspects of our lives. They will certainly have a strong impact on the conditions in which we will live and it is necessary to prepare our homes for the upcoming changes as well. From the very beginning of its history, the home has been first and foremost a shelter, a place that provides a sense of security. Although over the millennia many other meanings and roles have developed around it, safety has remained at its core. To ensure this safety, it is necessary to take care of the climate resistance of buildings and the comfort of users.

Since the preservation of the Plattenbau in Poland for at least the next few decades is not only a matter of protecting the historical and cultural values it carries, but also a pragmatic necessity dictated by the housing situation, the problem of user comfort should be considered. Even under current climatic conditions it is not sufficient and the conditions that will prevail at the end of the life cycle of the Plattenbau buildings must also be taken into account. It is necessary to make them habitable and as resistant as possible to the upcoming changes.

The main threat to user comfort, which used to occur much less frequently and was not taken into account during designing, is high temperatures in summer. Summers in Poland are getting warmer and warmer – in the last 30 years the average number of hot days (the highest

temperature in a day above 30⁰C) has increased by about 5 days. The average temperature in the summer months of June to August also increased by about 3⁰C. Considering the moderate scenario of further climate change (RCP4.5) published by the Intergovernmental Panel on Climate Change, the number of hot days (highest daily temperature above 25⁰C) will increase from 35 days to 44 days, and the number of extremely hot days (highest daily temperature above 30⁰C) will double in 2100 compared to the current decade, although the length of heat waves will increase slightly. In a scenario close to the current pathway (RCP 8.5), more significant increases in summer temperatures are projected. Over the horizon to 2100, the number of hot days will increase from 35 to about 65 days, the number of hot days will triple, and heat waves will be longer and more frequent. The number of tropical nights will also increase in the second half of the century[26].

[26] Instytut Ochrony Środowiska – Państwowy Instytut Badawczy, "*Jak zmienia się lato w Polsce?*", Instytut Ochrony Środowiska – Państwowy Instytut Badawczy, accessed November 14, 2021, klimada2.ios.gov.pl/jak-zmienia-sie-lato-w-polsce/.

These changes will not only reduce the users' comfort but may even pose a direct threat to their health and lives. Addressing this problem will require comprehensive and thoughtful interventions, during which it will also be possible to respond to other, but not less important, aspects of user comfort such as acoustic, visual and air comfort, which also require intervention and improvement.

2.2. REDUCTION OF NEGATIVE IMPACT

According to various estimates[27], construction accounts for about 39% of all greenhouse gas emissions. Additionally, it is expected that these emissions will double by 2050, mainly due to newly constructed buildings. In this situation, it is necessary to plan project activities very carefully and pay attention to the consequences of our decisions.

[27] Preservation Green Lab, "*The Greenest Building: Quantifying the Environmental Value of Building Reuse*" (National Trust for Historic Preservation, Washington, D.C., 2011).

Emissions generated by construction can be divided into two basic categories. First is day-to-day energy use-known as the „*operational carbon emissions*" that comes from powering lighting, heating, and cooling. Globally, building operations account for about 28 % of emissions annually. Second is the amount of carbon generated through manufacturing building materials, transporting materials to construction sites, and the actual construction process – what's known as the „*embodied carbon of a building*", which accounts for about one quarter of a building's total lifecycle carbon emissions. Globally, the embodied carbon of a buildings account for about 11 % of emissions.

Newly designed buildings generally generate significantly lower operational carbon emissions. They have better thermal insulation, energy efficient lighting, advanced glazing and many certified energy efficient systems to ensure comfort and low energy consumption. However, producing all the materials needed, transporting them to the site, the construction process and manufacturing and installing the systems generates huge amounts of embodied carbon of a building. It takes between 10 and 80 years before a new, energy-efficient building offsets the negative impact on climate change created during the construction process[28]. This depends on the level of energy efficiency and the materials used, which even with the same properties and price can have extremely different climate costs. The construction industry also accounts for 36% of global plastic production. Another activity that is inextricably linked to the construction of new buildings is the demolition of existing ones. This is a process that not only causes emissions but also generates an enormous amount of waste.

In such circumstances it seems reasonable to reuse buildings in order to economize on the embodied carbon of a building. Research[29] confirms that the reuse of buildings almost always has a positive effect in terms of saving emissions. What is important in this respect is a properly managed refurbishment that reduces current energy consumption without significantly increasing emissions associated with the manufacture of materials, equipment and the refurbishment process itself. In this context, Plattenbau buildings have a very high potential to make a positive contribution to reducing emissions and thus slowing down the oncoming climate catastrophe.

[28] Preservation Green Lab, "*The Greenest Building: Quantifying the Environmental Value of Building Reuse*".

[29] Preservation Green Lab, "*Untapped Potential: Strategies for Revitalization and Reuse*" (National Trust for Historic Preservation, Washington, D.C., 2017).

III. METHODOLOGY

The research part is divided into three basic categories: structural condition of buildings, energy consumption and user comfort. Studying these three categories will allow to build a comprehensive picture of the condition of the Plattenbau buildings in Poland, define the problems and determine the direction of changes aimed at improving the comfort of users while minimising energy consumption.

The analysis of structural condition will provide answers to questions such as: is the existing housing stock in Plattenbau buildings habitable, what are the structural problems and what is the expected life span of the buildings, particularly their structure. The research will be based on original historical materials on how the Plattenbau buildings were designed, scientific studies investigating the structural condition of the buildings and a report resulting from analyses conducted by the Building Research Institue on behalf of the Polish Ministry of Investment and Development.

The analysis of energy consumption aims at defining what is the energy consumption of the Plattenbau buildings in relation to their condition and the degree of modernization carried out as well as identifying the potential for energy consumption reduction. The study is based on available materials on energy consumption in residential buildings, including the Plattenbau buildings and methods of increasing energy efficiency.

The analysis of user comfort is divided into four main categories: acoustic comfort, air comfort, visual and luminous comfort and thermal comfort. Due to the large differences in weather conditions between summer and winter, the analysis of thermal comfort will be split into an analysis of thermal comfort in summer and winter. This study will define the current comfort of the users, the primary and secondary causes of this condition and will allow to define what steps should be taken in order to improve the current conditions. The evaluation of the current level of comfort of users will be based on available scientific papers containing simulations and measurements of parameters describing the comfort of users. The identification of the causes will be based on an analysis of historical material on prefabrication methods and on subsequent analyses of the construction and operation of large panel buildings.

IV. DEVELOPMENT

1. STRUCTURAL CONDITION

In the 2010s, the public began to take interest in the previously neglected issue of large panel buildings. Concerns were raised that the technical condition of buildings constructed using this technology was very poor and that all residents were living in the shadow of a nationwide building disaster. These fears were well entrenched and stemmed from real factors such as poor quality of installation work, defects in workmanship, the use of poor-quality materials and products (finishes and plumbing), and the expiry of the "*expected life span of the buildings*". Some suggest that fuelling such fears has been particularly to the advantage of private developers, who were keen to exploit the sites left after the demolished Plattenbau housing estates, since many of these are now located close to city centres and have much better developed infrastructure, particularly transport, than most newly built estates.

In its principles, the Plattenbau buildings were supposed to be the fastest and most efficient way of solving the increasing housing shortage. However, it was not intended to be a particularly long-lived solution; according to initial design intentions they were to be operational for a period of about 40 years in the case of less complex closed regional systems or 70 years in the case of more advanced ones[1]. The latter group included, among others, the Szczecin system and WWP systems and the open W-70/Wk-70 system. These assumptions were confirmed by tests carried out by the Building Research Institute in 1970 during the installation of buildings in the systems: WWP, W-70 and Szczecin system[2].

Taking into account that mass production of the Plattenbau buildings started in the 1960s, and its greatest development took place in 1970s and 1980s, now the oldest buildings are about to reach the end of their above mentioned period of exploitation. The situation is slightly better for the 1970s and 1980s buildings with more advanced systems, which are supposed to reach their predicted lifespan in 2040 and 2050.

In order to address the doubts and determine in what condition the Plattenbau buildings are, the Polish Ministry of Investment and Development commissioned in 2015 the Building Research Institute to conduct research aimed at „*Assessing the safety and durability of Plattenbau buildings*", the result of which is „*Plattenbau Buildings. Structural condition report.*"[3] This study lasted from 2016 to 2018 and covered about 300 buildings built in different Plattenbau systems – both central systems and selected regional systems. The study concluded that the overall structural health of the buildings is good – it should (assuming

[1] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*

[2] Teresa Taczanowska, "*Ocena techniczno-ekonomiczna montażu wymuszonego na przykładzie budynków wielkopłytowych*" (Politechnika Warszawska, 1974).

[3] Jarosław Szulc, "*Budownictwo wielkopłytowe – Raport o stanie technicznym*" (Instytut Techniki Budowlanej, Warszawa, 2018).

proper maintenance and testing) last another 100 years. It was also noted that the expected lifespan of between 40 and 70 years is not synonymous with structural durability.

This is confirmed by the instructions for use and maintenance of prefabricated buildings which were developed in the 1970s. According to a 1972 study by the Central Research and Design Centre for Construction in Warsaw, the structural durability of a building constructed in the above-mentioned W-70 system was predicted to be at least 100 years. The durability of other elements, such as roofing and flashings was estimated at 10-20 years, while the sealing of joints at 5-15 years[4].

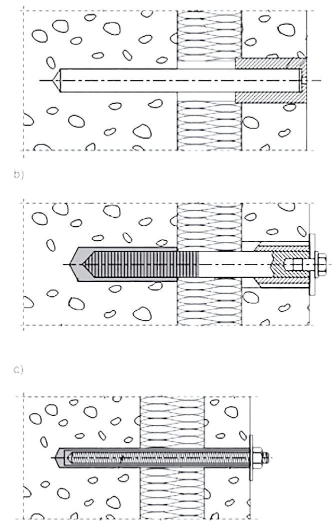
Similar results were obtained from earlier research carried out in 2002 and 2004 by the Institute of Construction Technology and from a conference of experts in Cedzyna in 2004. In both cases the life span of the Plattenbau structure was determined to be about 80 years. It is worth noting that the conclusions presented then did not take into account the thermal modernisation works which have been carried out over the last 20 years. Thanks to these measures, the influence of atmospheric conditions, in particular humidity and frost on the hangers in the three-layer walls and on the junctions, which are the most structurally vulnerable elements, was significantly reduced. As a result, the structural lifespan of the Plattenbau buildings is determined to be at least 100 years from the moment of construction and with proper maintenance it can be even 100 years from the end of the 2010s. Despite relatively optimistic predictions, it cannot be said that this construction is not free of structural problems. These occur most frequently in the two previously mentioned elements: the hangers of the finishing layer of three-layer walls and in the junctions of the elements.

[4] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*

Mounting anchors (Hangers)

The element identified as the most vulnerable to failure are the steel anchors connecting the finishing layer to the construction layer in three-layer façade walls. These walls consist of a structural layer which is 14 to 16 cm thick (depending on the system), a 5 or 6 cm thick insulation layer and a 6 cm thick finishing layer suspended on steel mounting anchors. The connection between the outer layer and the load-bearing part is particularly exposed to dampness and frost, for which reason it was originally intended that corrosion-resistant steels would be used for the fasteners. However, due to a lack of suitable steel, ordinary steel without any corrosion protection coating was often used.

Broken mounting anchor



Methods of integrating the finishing layer with the load-bearing layer

[5] Zbigniew Dzierżewicz, "*Utrzymanie i kontrola okresowa budynków wielkopłytowych w systemach OWT, W-70 i Wk-70 zrealizowanych w woj. lubelskim (Lublin, Chełm, Zamość i Biała Podlaska) w świetle wymagań Prawa budowlanego, rozporządzeń wykonawczych oraz wytycznych ITB stan prawny 1 stycznia 2010 r. opracowanie i realizacja*", unpublished manuscript.

A solution to limit the negative effects of frost penetration and condensation in the vicinity of the mounting anchor is to re-insulate the façade. It is executed by adding a layer of several centimetres of foamed polystyrene or mineral wool on top of the existing finishing layer. However, very often execution errors occur during this type of procedure. The insulation layer is not mounted directly to the load-bearing layer of the prefabricated element. Instead, it is anchored in the finishing layer, which puts additional strain on the mounting anchors, which are often in poor condition. The reason for such errors is the use of too short anchors, their length is recommended by the manufacturers of the thermal insulation system, but it does not work in the case of Plattenbau buildings.

Conducted researches[5] of the condition of three-layer prefabricated façade elements have shown also other problems resulting from non-observance of regulations valid at that time:

Element	In accordance with the regulations	Not in accordance with the regulations
Finishing layer thickness (required thickness 6 cm)	6,8 cm on average (from 4,9 to 8,7 cm)	
Mineral wool thickness (required thickness 6 cm)	3,8 cm on average (from 2,5 to 5,1 cm)	
Quality of concrete of the finishing layer	90%	10%
Occurrence of concrete plugs not acceptable	58%	42%
Mounting anchors steel grade fixing of the finishing layer in the structural layer	10%	90%
Mounting anchors spacing and verticality: by design displacement of mounting anchors inclination of the mounting anchors from the plumb line	 79% 46% 88%	 21% 54% 12%
Anchorage of mounting anchors each mounting anchor should be anchored with a steel rod with a diameter of 8 mm and a length of at least 30 cm	41%	59%
Positioning of the reinforcement mesh and diameter of the rods in the finishing layer according to the design	70%	30%
Corrosion of mounting anchors due to lack of proper cover	none	33,3%

In addition, other defects of prefabricated façade elements such as cracks and too high water absorption of the concrete can also be observed.

The above-mentioned report shows that irregularities in the execution of external walls do not pose a direct threat to the integrity of the building. However, it is necessary to constantly monitor their condition. The most beneficial solution is the secondary integration of the finishing layer with the load-bearing layer of the prefabricated element by means of additional anchors, which ensures better stability of the latter and reduces the issue of hanger malfunction. To date, no case of a major façade failure has been identified in a Plattenbau building.

Joints

The structural layout of Plattenbau buildings is provided by rigid transverse and longitudinal walls. They are treated as cantilevers restrained in the monolithic underground part of the building or, less frequently, in the ground. In addition, the external walls, due to their significant stiffness to deformation in their own plane, counteract the torsion of the structural system of the building when bending and therefore, when designing, it was presumed that under the influence of wind pressure the sections of the system move in parallel.

From the structural point of view, the basic element distinguishing Plattenbau buildings from monolithic ones is the occurrence of joints between the prefabricated elements, which are much more exposed to the risk of cracking. The individual plates were joined by means of welds and then by concrete. The durability of the construction joints is reduced if these operations have not been carried out accurately. This may lead to a reduction in resistance or, in the case of insufficient steel bar covering, to more frequent corrosion. This may be exacerbated by dampness caused by leaks, freezing of walls and inadequate ventilation of rooms. According to a study[6], in 11% of the cases there were deficiencies in the reinforcement and in 4% there were defects in the execution of the reinforcement and the installation pitches. It is also noticeable that the concrete cover falls off and tears appear in the joint lines of prefabricated elements.

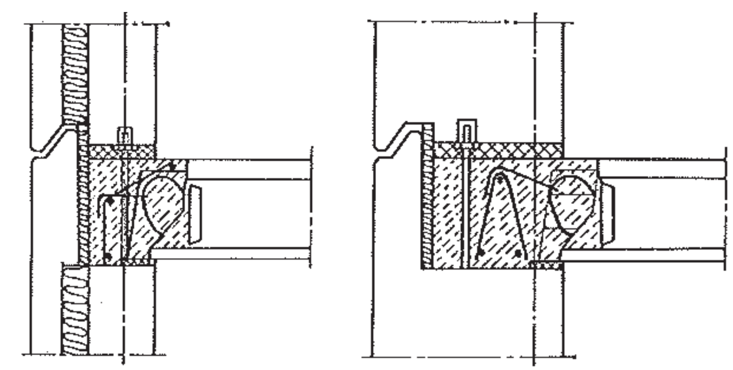
From the conducted research, including the ITB report, it results that the state of prefabricated elements joints is good, the occurring defects do not threaten the stability of the structure and the integrity of the buildings. However, it is necessary to periodically verify their condition and remove any problems that may occur. When assessing the technical condition of a building structure, one should also assess the protection of the structure against the effects of exceptional loads (e.g., impact of a heavy object on the building or explosion in its premises). This is due to the fact that Plattenbau structures, due to their lower degree of monolithization, have a limited capacity to redistribute internal forces.

[6] Leonard Runkiewicz, Jarosław Szulc, and Jan Sieczkowski, "*Uprzemysłowione budownictwo mieszkaniowe. Dawne i obecne wymagania oraz oczekiwania*". Builder 2021, no. 9 (2021).

Visible cracking on joints

Past experience of failures and catastrophes (gas explosions and destruction of part of the walls) indicates that the structures of Plattenbau buildings, given their lifespan, were designed correctly. An important problem for the assessment of durability may be linked to incorrect execution of prefabricated elements and their assembly, which in the period of construction of Plattenbau buildings significantly differed from the standards that should have been met.

In addition to the more serious defects related to the structural elements, other less important defects can also be observed: leaks at the junctions between balconies and loggias and the building wall, dampness and mould growth, rust stains on the surface of reinforced concrete elements, concrete deterioration, signs of degradation of the roofing and drainage system.



Detail of joints between slab and load-bearing external wall

Image from: Eugeniusz Pilszka, *Systemy budownictwa mieszkalniowego i ogólnego.* (Warszawa: Arkady, 1974.)

Technology and installation errors

In order to better understand the construction and finishes problems encountered in Plattenbau buildings, it is also necessary to look at the issue of execution and assembly errors in the context of the technology used. The primary reason for the high incidence of execution and assembly errors was a change in building technology. Traditional technologies were provided with experienced builders and educated site managers. Even building design engineers were not fully aware of the differences introduced by the transition from cast-in-place concrete and brickwork to assembling prefabricated elements. In particular, the issue of the accumulation of errors, which very quickly exceeded the assumed tolerances. This was especially evident in the first projects of the early 1960s.

From analyses of moment of occurrence and frequency of errors based on the W-70/Wk-70 system it is concluded that in the phase of[7]:

1. design – no significant structural faults were found, with the exception of the Wk-70 system, in which actual tolerances in the production and assembly of elements were not taken into account;

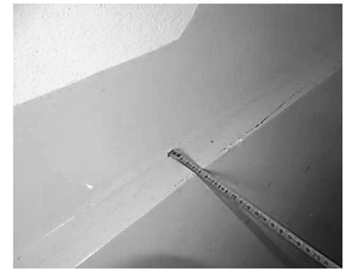
2. production of large-panel elements – the following errors were determined:
- shortages of reinforcement of prefabricated elements, hangers, assembly details, lack of stabilisation of reinforcement in mould – 11%
- bad quality of concrete – 5%
- faulty concrete compaction and care defects – 2%
- damage to precast elements – 10-30%;

3. transport and storage – damages of elements in approx. 60% were determined;

4. assembly – defects were found in the form of:
- assembly deviations and faulty rectification – 17%,
- faulty execution of reinforcement and assembly welds – 4%,
- inappropriate thickness of mortar in „*underfloors*" – 12%,
- installation of facilities in poor weather conditions – 13%.

Due to similar manufacturing conditions, it can be assumed that the structure of execution errors was similar for other systems. The quality of the designs was high, as they were developed in large design offices and were subject to detailed verification. The principle of prefabrication was almost unchanged since the early 1960s. Battery moulds were used for the production of internal walls and ceilings. These consisted of vertically aligned moulds of fixed thickness, separated by heating walls. These walls were connected to steam generators which heated the moulds, significantly accelerating the maturation of the concrete. The dimensions and shape of the edges were moulded by means of inserts placed at the bottom and in the bottom of the vertical sides. Concreting was done from above. The exception to this were the channel ceilings in the W-70 system, which were made flat. The external walls, both the layered and solid ones, were also made flat. This was due to the more complicated finishing of the external surface, which would be difficult to achieve in a vertical form. It was only during demoulding that they were turned by 75 degrees in order to reduce the occurrence of stresses.

[7] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*



Assembly errors, no common wall axis.

Research[8] shows that the largest systematic error was in the height of the precast wall panels. External wall slabs made flat have too large dimensions. This is due to hinge loosening with mould usage. Internal walls, made in vertical battery moulds are mostly too low. This could be due to the concrete not being poured to the correct height or shrinkage during accelerated maturation. There was a similar problem with the precast floor slabs, which were also made vertically.

As the precast elements were not delivered to the construction site in the order of assembly and they had to be stored directly on the construction sites. Very often this storage was not carried out in the correct manner, and in addition, it was often necessary to move the precast units in order to unblock access to those that were needed at a particular point in the assembly.

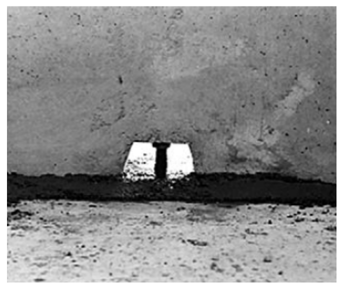
The assembly could take place in the free-assembly method (this concerned, among others, the group of early OWT systems, and later the Szczecin system) or in the forced-assembly method (WWP and W-70/Wk-70 systems). In the free-assembly method a geodetic team was responsible for determining the wall axes. Initially they were marked on the lower part of the building and later moved to each successive floor. The accuracy of the installation depended to a large extent on the precision of the construction crew and the geodetic team. This provided greater freedom and easier adaptation in the event of accuracy problems. Often deviations that could be hidden in the thickness of the wall support joints were not corrected because it was too time-consuming. This resulted in the floor slabs being installed at an incorrect level, and the floor slabs themselves were also not indifferent in the tolerance chain.

[8] Norbert Nitsche, "Moglichkeiten der Hohenfixierung un Plattenbau," *Bauzeitung*, no. 3 (1970).

In addition, the walls were not always vertical and properly aligned on top of each other, which led to poorer transmission of vertical forces and the occurrence of eccentricities.

With such a lack of accuracy in assembly, deviations increased with each successive storey. For example, the height of the flats could increase by as much as 10-20 mm, which might seem to benefit the residents, but the threshold at the balcony, which was designed to be 70 mm high, became too low, causing rainwater to leak into the building. The increased height of the storey also had a negative effect on the staircases. Stair treads had to be supported at an angle, which resulted in poorer stability and also increased the chance of slipping from steps that were not perfectly horizontal.

The forced-assembly method theoretically provided greater accuracy and was intended to eliminate such errors. The prefabricated wall units had the rectification bolts (at the top) and bushings (at the bottom) aligned. During assembly, the element hanging from the crane was clipped onto the protruding bolts, and mounting struts set into special holes in the ceiling were attached to it. The slab was then released from the crane and aligned using turnbuckles located in the struts. This provided a constant level geometrically and dimensionally related to the design, which prevented the walls from increasing in height or becoming out of verticality.



Forced-assembly detail

Image from: Eugeniusz Pilszka, *Systemy budownictwa mieszkalniowego i ogólnego.* (Warszawa: Arkady, 1974.)

This method was only suitable if the execution errors were within the specified tolerances. In such a case the best results were obtained by the forced-assembly method on rectification bolts. The most important factor was the correct installation and stabilisation of the bolts and bushings in the precast element. When the errors in the production of precast elements were too high it was more economical to use free-assembly with full geodetic support.

On the basis of studies carried out over the last 30 years, it can be concluded that manufacturing and assembly errors are not so large and serious as to threaten the structural safety of the buildings. However, they do have a direct impact on aspects related to user comfort and convenience[9][10].

[9] Taczanowska, "Ocena techniczno-ekonomiczna montażu wymuszonego na przykładzie budynków wielkopłytowych".

[10] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*

Adaptability of the typology

During the process of modernisation of Plattenbau buildings, it may be advisable to make openings in the load-bearing walls – for example in order to modify the typology of apartments or to introduce commercial services to the first floor of the building. Depending on the needs, the width of the openings can range from 0,9 m for new internal doors, to as wide as possible when enlarging open space, such as opening a kitchen onto a living room. There is also a need to adapt existing door openings to the requirements of people with disabilities.

Apart from the width of openings, their location in the projection (distance from perpendicular walls) has a significant impact on the safety of the large-panel building structure after introducing new openings in load-bearing walls. Walls perpendicular to the wall with designed new openings have two basic functions. The first of them is cooperation in load transfer, i.e. taking over part of the load from the ceiling directly above the walls in question and cooperation in taking over the compressive forces from the storey above. The second one is the function of stiffening of the considered wall strand. The first of the mentioned functions is performed only by load-bearing walls. When considering the second function of perpendicular walls, i.e. the role of stiffening walls, it is acceptable to take into account the load-bearing layer of the curtain wall.

According to the conducted research[11], this is quite a difficult issue, requiring individual calculations almost every time. Taking into account the cooperation of the supporting layer of the curtain wall depends, among other things, on the quality and stiffness of the joints. Moreover, it should be noted that the load-bearing wall, in which a new opening is designed, may also act as a stiffening wall. By making the opening, the perpendicular wall can be deprived of stiffening. If the lintel zone above the new opening is not reinforced, the low tensile strength of the concrete may be critical in determining the allowable width of the opening. In addition to the effects of new openings in load-bearing walls, the effect of new openings on the stiffness of the structural system due to horizontal forces, e.g. wind, must also be taken into account. This effect is even more important the greater the width of the designed openings and the fewer walls that contribute to the stiffening system in the direction parallel to the wall with openings.

[11] Wiesław Ligęza, "Synteza zagadnień technicznych w rewitalizacji budynków wielkopłytowych," *Przegląd budowlany* 2015, no. 6 (2015).

2. ENERGY CONSUMPTION

Energy and heating costs in Poland constitute as much as 55% of property maintenance costs. In this respect it is the second most expensive country in the European Union. This is also reflected in the costs of providing municipal services. Charges for central heating and hot water constitute 63.4% of total costs. Households are in third place, after industry (30%) and transport (29%), in terms of the volume of energy consumption in Poland[12]. In addition, energy consumption of the Polish economy is about 3 times higher than that of the most developed European countries and about 2 times higher than the European average. In such circumstances, saving energy is not only reasonable and important from the ecological point of view, but also necessary from the economic point of view.

[12] Anna Ostańska, *Wielka płyta: Analiza skuteczności podwyższania efektywności energetycznej: termomodernizacja, termografia, wytyczne naprawcze*. 1st ed. (Warszawa: Wydawnictwo Naukowe PWN, 2016).

Therefore, it is not surprising that the reduction of energy consumption is the basic criterion for the current renovation of the Plattenbau buildings. It has its justification in the costs – maintenance of an average apartment in the Plattenbau block of apartments is 27% more expensive (calculated per unit of area) than maintenance of an apartment in a new building. One of the biggest components of these costs is heating. In all residential buildings in Poland heating and ventilation constitutes as much as 71,5% of energy consumption. In the case of large panel buildings, due to lower insulation of walls, it is even more. In extreme cases the cost of thermal energy in the Plattenbau buildings is twice as high as the cost of energy in the buildings built after 2010.

A standard building, which meets the Polish standards, consumes between 90 and 120 kWh/(m^2a). For an energy efficient building it is between 50 and 80 kWh/(m^2a), and for a low energy building less than 50 kWh/(m^2a). In comparison, an unrenovated Plattenbau building built before 1970 uses on average between 320 and 380 kWh/(m^2a), built between 1971 and 1978 uses between 240 and 290 kWh/(m^2a), and built between 1979 and 1988 uses 160 – 200 kWh/(m^2a)[13]. This value is the total energy consumption, in which thermal energy is only a component. Nowadays these values are probably lower, because more energy efficient lighting and appliances are in use. In Poland, there are still about 50 000 buildings in which thermomodernisation measures have not been carried out (data as of 2016)[14].

[13] Ostańska, *Wielka płyta.*

[14] Szulc, "Budownictwo wielkopłytowe – Raport o stanie technicznym"

So far, the thermomodernisations carried out mostly consisted of replacing windows and insulating the walls with a layer of styrofoam 6 cm thick. Often it was not decided to insulate the roof, the building plinth and the ceiling between the basement and the first floor. The ventilation system was not interfered with either. This type of treatment allowed to reduce energy consumption for heating by about 25-30%. Savings of 50% can be achieved in the case of a thorough thermomodernisation consisting of insulation of walls with a layer of at least 12 cm of styrofoam, replacement of windows and insulation of the roof. This allows to achieve energy consumption similar to that of a modern, standard residential building.

Additional savings are possible in the case of replacement of the installation with one with lower heat losses, installation of thermostats controlling heating, thanks to which overheating of buildings will be eliminated. In the case of buildings that are not supplied from the municipal heating network, energy efficiency can be improved by installing boilers with higher efficiency. Another element that works in favor of the Plattenbau is the form of the buildings, which are characterized by a relatively small surface of external partitions in relation to the volume.

3. USER COMFORT

3.1. ACOUSTIC

Lack of acoustic comfort, which manifests itself primarily in hearing all the noises from neighbors' apartments, is a situation commonly associated with living in high-rise buildings. It is visible both in works of popular culture and in everyday opinions of ordinary people. It is so common and annoying that it is a topic very often discussed on Internet forums for people planning to buy or rent an apartment in a Plattenbau building. Opinions expressed there, however, are not explicit, which may suggest both that the occurrence of this problem is not the rule and that the expectations and feelings of individual people can be very different.

Despite the widespread concern about poor acoustic comfort in Plattenbau buildings, this topic is not often discussed in studies and research articles. As a result, the amount of available material is quite limited. The work in which the field research was conducted is *„Diagnostics and retrofitting of Plattenbau buildings."*[15] This research was carried out in a residential, multi-family, eleven-storey building made in WUF-T technology located in Krakow. As a point of reference, the requirements of the PN-B-02151-3:2015[16] standard in effect in Poland were adopted.

[15] Kinga Zębala, "Izolacyjność akustyczna przegród wewnętrznych w budynku z wielkiej płyty," [Sound insulation of internal barriers in a prefabricated large wall panel system building] *Izolacje* 22, no. 1 (2017).

[16] KT 253, Akustyki Architektonicznej, *Akustyka budowlana - Ochrona przed hałasem w budynkach - Część 3: Wymagania dotyczące izolacyjności akustycznej przegród w budynkach i elementów budowlanych* (2015), PN-B-02151-3:2015.

At the outset, it is worth noting that in comparison with the European standard ISO/TS 19488:2021[17], the requirements of the Polish standard PN-B-02151-3:2015 are not demanding. The minimum requirements of the Polish standard are between the limiting requirements of class D and C of the ISO/TS standard. Disturbance by intruding noise can be expected more than occasionally, even in case of considerate behaviour of neighbours, adjusted to these conditions.

In the studied building, the air sound insulation of walls between apartments was between 54 dB and 55 dB. This is a result that meets the requirements of PN-B-02151-3:2015, according to which the minimum air sound insulation for vertical partitions between apartments is 50 dB and corresponds to class B according to ISO/TS 19488:2021.

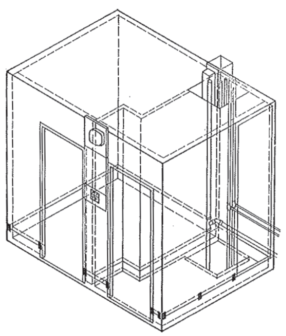
The results of the air sound insulation measurements for the ceilings were less clear. In one of the tested apartments, it was 49 dB, while in the other it was 59 dB. The Polish norm predicts that this index should not be lower than 51dB. According to the European norm, this is class D and A, respectively.

The results of measurements of impact sound transmission for ceilings are even less clear. In the case of room ceilings, the result was 55 dB, which is the maximum value provided for in the Polish standard and corresponds to class C of the ISO/TS standard. However, for ceilings in the hallways it was as high as 80 dB and 83 dB for bathroom ceilings, which corresponds to class F of the ISO standard. According to the Polish standard it should not exceed 57 dB.

The result of the measurement of acoustic insulation of walls in the analysed building is satisfactory. The inter-apartment walls in buildings constructed in WUF-T technology were made of 14 cm thick reinforced concrete. The internal structural walls in the systems were formed in an analogical way: W-70/Wk-70 (15cm), Szczecin System (15cm), OWT-67 (14cm), WWP (14cm). In their principles they meet the requirements concerning acoustic insulation. Too low acoustic comfort is a result of workmanship mistakes made during the installation of elements on the building site. The basic and common problem occurring in Plattenbau buildings is insufficient accuracy of joints between elements. Local weakening of acoustic insulation of walls is also caused by the lack or improper filling of holes and technological passages. The problematic element are also the ducts for electrical installations. The group of acoustic problems which occur in some buildings also includes the lack of proper acoustic insulation of technical rooms in relation to the adjacent apartments (e.g., lack of dilatation between the apartment and the elevator shaft or transformer station).

[17] KT 253, Akustyki Architektonicznej, *Akustyka budowlana - Ochrona przed hałasem w budynkach - Część 3: Wymagania dotyczące izolacyjności akustycznej przegród w budynkach i elementów budowlanych* (2015), PN-B-02151-3:2015.

The results of measurements of the air sound insulation for ceilings are directly conditioned by the WUF-T system. In this system, the pipes with cold and hot water were not run-in built-up shafts but only in exposed casing pipes. In one of the investigated apartments, the installations were re-cased with gypsum-cardboard panels, which clearly improved acoustic insulation (49 dB vs. 59 dB). In almost every system of Plattenbau construction, regardless of the solutions used, sanitary units generate problems with airborne sound penetration. In systems: W-70/Wk-70, Szczecin System and WWP, the sanitary section was designed and prefabricated as a single, ready-to-install element. Sanitary installations were run in a collective duct serving all cabins in a given riser, which caused and still causes the transfer of air sounds between apartments connected to the same duct.



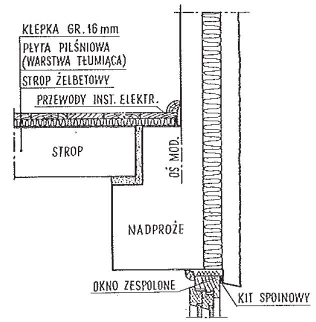
Sanitary cabin, Szczecin system

Image from: Eugeniusz Pilszka, *Systemy budownictwa mieszkalniowego i ogólnego.* (Warszawa: Arkady, 1974.)

An additional problem is vibration of sanitary cabins by sanitary devices and installation wires attached to them. In the W-70/Wk-70 and Szczecin system attempts were made to reduce this by using shock absorbing dividers when mounting devices and wires to the cabin walls. The cabin itself was placed on a layer of damping material. These solutions are correct in their principles, however, taking into consideration numerous workmanship errors and far-reaching deficiencies and material savings, they were not applied at all or in an incorrect way. Also due to the lack of proper assembly accuracy, gaps were created between the prefabricated elements which has a negative impact on the airborne sound insulation of the ceilings.

In the above-mentioned study one can also notice very unfavourable results of measurements of impact sound permeability, especially in hallways and bathrooms. In the WUF-T system, the ceilings are constructed from prefabricated uniform 14 cm thick reinforced concrete. The same type of slabs was also used in the systems: Szczecin system, OWT-67 and WWP. As shown by the research on the Szczecin system carried out during the design and initial implementation of this technology, floating floors had to be used to obtain sufficient insulation against impact sounds. This was not the case because the OWT-67 system used only a fiberboard damping layer by default. In the case of the investigated apartments, floating floors were used, but in the hallway and bathroom they are made in an incorrect way. This is due to the secondary location of the floor finishing layer without expansion joints from the walls. Due to savings and time of execution, in some buildings despite the system recommendations, the use of floating floors was resigned from.

It is worth mentioning that in the W-70 system the use of 22 cm thick hollow core slabs in the floors was suggested. It was found that this solution provides better acoustic properties than a monolithic slab at the same weight per 1 m^2. This solution would provide sufficient insulation from impact sounds without the need to use floating floors, but only a damping layer the same as in the OWT-67 system. In 1972, it was decided to purchase several factories for the production of the W-70 system. They were characterized by better production efficiency than those previously used, but were not adapted to the production of hollow-core slabs. For this reason, it was decided to introduce modification of the system – Wk-70. In this system uniform floor slabs with thickness of 16 cm were used, resulted in necessity of application of floating floors.



Detail of joint between ceiling and wall, OWT-67 system

Image from: Eugeniusz Pilszka, *Systemy budownictwa mieszkalniowego i ogólnego.* (Warszawa: Arkady, 1974.)

There is lack of research describing the problem of acoustic insulation of external walls and therefore problems with acoustic comfort caused by outside noise. The impact of thermomodernisation on the change of acoustic comfort is described in the paper „*Measurements of acoustic insulation of selected external walls in a high-rise building before and after thermal insulation*"[18]. The research was realized on the example of one residential, multi-family building made in WUFT technology. The assessment index of sound insulation specific for external solid walls was 50 dB before thermal insulation, after thermal insulation 47 dB. In the case of walls with windows, this index increased from 35 db to 36 dB. These data show that the acoustic insulation of external walls is not high but it is not sufficient for drawing clear conclusions, especially that external acoustic conditions resulting from the location of Plattenbau buildings are very different.

[18] Kinga Zębala, "Pomiar izolacyjności akustycznej wybranych ścian zewnętrznych w budynku wielkopłytowym przed i po dociepleniu," [Measurements of acoustic insulation in the selected external walls of large panel building before and after thermal modernization] *Czasopismo Inżynierii Lądowej*, Środowiska i Architektury, 2016.

3.2. LIGHT

The problem of light comfort in Plattenbau buildings is a subject which is not very often discussed in Polish scientific papers. The lack of interest in this subject can be also seen in the very liberal regulations in polish norms regarding luminosity and lighting time. The first law specifying the minimum requirements of illumination came into force in Poland in 1928. Apart from the generally formulated necessity to ensure access to the sun, the maximum height of a building bordering a street was determined to be equal to the width of that street. The height of buildings inside the quarters could reach 1,5 of the distance between buildings[19]. The vast majority of the existing buildings in the cities were still 19th century tenement houses, in which the lack of access to sunlight was an everyday occurrence.

[19] Katarzyna Warzocha, "Naturalne światło w budownictwie mieszkaniowym początku XXI wieku. Standard czy luksus?," [Natural light in city housing of the XXI century. Is this a standard or luxury?] *Środowisko Mieszkaniowe*, no. 18 (2017).

The war damage significantly changed the situation, huge areas of the cities were destroyed, reconstruction and housing development was necessary. The change in the political and economic system put the needs of the proletariat at the forefront, and extensive nationalisation gave the state access to vast areas of land that could be used for housing. The first post-war law specifying requirements for the illumination of buildings was established in 1961. It defined the minimum angle of incidence of light – 27 degrees. In practice, this meant that the minimum distance between buildings was twice their height[20]. Moreover, the regulation forbade designing flats with only northern exposure and flats for 3 people and more with only one-sided window exposure.

[20] Małgorzata Bartnicka, "Wczoraj, dziś i jutro w promieniach słonecznych," *Czasopismo Techniczne. Architektura*, 2010.

During the peak of the development of Plattenbau buildings in the 1970s and 1980s, there were two changes in the regulations on light exposure. In 1974, a minimum sunlight duration for dwellings equal to 3 hours on equinox days was introduced. This applied to one room in two-room flats and to two rooms in larger flats. The minimum distance between buildings was reduced to 1,8 of their height[21]. This distance was reduced again in 1980 and was equal to the height of the buildings[22].

[21] Bartnicka, "Wczoraj, dziś i jutro w promieniach słonecznych".

[22] Warzocha, "Naturalne światło w budownictwie mieszkaniowym początku XXI wieku. Standard czy luksus?".

In practice, however, the distances between buildings were much greater. This was dictated both by architectural and urban planning considerations, as well as technological ones. Plattenbau buildings were built on state-owned land, which was usually very vast and easily accessible. This made possible the design of buildings with considerable distances between them, thanks to which the architects ensured greater intimacy and more light into the interiors. This was a direct reflection of the modernist ideas, which gave rise to the Plattenbau buildings. Also, the method of assembling the buildings required appropriate distances between the individual building lines. Prefabricated elements were transported by trucks (or sometimes even by narrow-gauge railway), which required provision of adequately wide access roads and manoeuvring yards. The precast elements would then have to be unloaded and stored. From the storage area they were moved by cranes and overhead cranes. All this required a large amount of space that could not be built on. In addition, the most optimal alignment of the buildings, from an assembly point of view, was to place them in parallel.

These factors were reflected in the minimum distances between buildings in the housing estates built at that time. At the housing estate "*Osiedle Tysiąclecia*" in Katowice (arch. H. Buszko and A. Franta; year of construction: 1961) they are 50 m, with buildings 20 m high[23]. With 16-storey buildings under 50 m high, it is 82 m. In the Lipiński Street housing estate in Krakow (year of construction: 1984-1985), the smallest distance between parallel buildings is 30,80 m, with a building height of 16,20 m. In addition, the neighbouring buildings, which are oriented north-south, have been offset from each other along the north-south axis, further increasing the level of light in the flats. Also the typical depth of the rooms rarely exceeded 5 m, in the most common OWT system[24] the depth of the flats did not exceed 4,8 m, in another very popular system W-70/Wk-70 it was usually 3,6 or 4,2 m[25], which with a relatively large area of glazing, often exceeding 40% of the façade area, enabled very good lighting.

The lack of any shading elements is an important issue for the light comfort in the Plattenbau buildings. Before 1971 balconies or loggias were rarely used due to the cost savings. During the whole period of construction of the Plattenbaus buildings no shading elements such as overhangs or cornices were used. There was a belief that the more light the better. The problem of glare was not taken into account as well as the problem of overheating resulting from too much heat gain. Certainly other climatic conditions also had an influence – there were fewer extremely high temperatures in summer so the problem of overheating was not as significant. Another element that worsened the lighting comfort in the buildings were windowless kitchens, which were common in buildings constructed between 1961 and 1970. As in the case of the lack of balconies, this was the result of far-reaching austerity measures introduced by Władysław Gomułka and Julian Tokarski. From the early 1970s until the end of the construction of Plattenbau buildings, this type of solution did not occur.

[23] Filip Springer, *Źle urodzone: Reportaże o architekturze PRL-u* (Kraków: Wydawnictwo Karakter, 2012).

[24] Actually a group of systems, due to frequent modifications and regional versions.

[25] Eugeniusz Pilszka, ed., *Systemy budownictwa mieszkalniowego i ogólnego*, 2nd ed. (Warszawa: Arkady, 1974) Witold Ciołek.

The current legislation in force since 2002 requires a minimum distance between buildings equal to their height, but this only applies to buildings under 35 m. For taller buildings, the minimum distance is still 35 m. These requirements apply to obscuration only within a field of vision of 60 degrees set for the windows of the room. In addition, the distances may be halved for downtown buildings. The minimum time of daylighting for living spaces is 3 hours on equinox days, between 7:00 a.m. and 5:00 p.m. The requirement applies to one room in a multi-room dwelling. In downtown complementary developments, the minimum time is 1,5 hours, while for single-room dwellings there is no required sunshine time.

Confronting the requirements according to which the Plattenbau buildings were designed with the current requirements of the Polish law shows how much more daylight there is in the Plattenbau buildings. However, this undoubted advantage sometimes turns into a big problem which requires a solution.

3.3. AIR

At the time of construction, Plattenbau buildings were characterised by a very poorly airtight envelope. This was due to leaky windows and leaks in the joints between prefabricated external walls. This resulted in large heat losses in winter and increased the problem of freezing. However, given the not very strict requirements for room ventilation at the time, this ensured a sufficient number of air exchanges.

Since the 1990s, modernisation measures have been carried out to improve the thermal insulation of external walls. These measures consist of replacing windows and adding an external insulation layer. During modernisation, the condition of the joints between panels and the condition of the panels themselves are only occasionally analysed. Sometimes actions are carried out to seal joints between panels, but the effects of these actions are rarely verified by appropriate measurements. This is mainly due to the lack of requirements in Polish law for the verification of airtightness of buildings. They are required only in the case of issuing Passive House Certification, and for obvious reasons this is a situation which does not occur in the case of Plattenbau buildings. Polish regulations only stipulate that in a residential building, non-transparent external partitions, joints between partitions and parts of partitions, and connections between windows and reveals must be designed and constructed to achieve complete air-tightness.

All thermomodernisation measures, in particular the replacement of the windows, lead to a significant increase in the airtightness of the envelope. The exact influence of such actions was examined in a pilot study[26] carried out on the basis of two flats, in two buildings constructed in the W-70 technology. The n50 index, determining the number of air exchanges per hour, which occurs at a pressure difference of 50 Pa, was examined in it. According to recommendations, the required maximum value of the n50 index for buildings with gravitational ventilation should be less than 3,0 [1/h]. In the first of the investigated buildings, no thermal insulation of walls was carried out, only windows were replaced and joints were resealed. The second building underwent full thermal modernisation of external walls with windows replacement, however the joints were not resealed.

[26] Katarzyna Nowak and Katarzyna Nowak-Dzieszko, "Szczelność budynków wielkopłytowych przed i po termomodernizacji - wymóg czy dobrowolność," *Przegląd budowlany* 2015, no. 6 (2015).

The results of measurements with the ventilation ducts closed, intended to check the tightness of the envelope, showed the result of 2,195 [1/h] for the first building, and 1,777 [1/h] for the second building. Both results meet the norms currently required in Poland. Full thermal modernisation brings better results in increasing the airtightness of external walls than sealing the joints without performing any thermal insulation works. Despite earlier resealing of system joints, ensuring full airtightness was not achieved. The results of measurements without duct sealing, which are supposed to investigate the total number of air exchanges in the flat, indicated 5,757 [1/h] and 5,405 [1/h] respectively. These results are much higher than those required by the Polish law. It can be assumed that if there is a sufficiently large pressure difference between the inside and outside of the building, very good ventilation occurs. On the other hand, due to the limited scope of the study, it is difficult to unequivocally state how representative it is.

Flats in the Plattenbau buildings do not have individual ventilation ducts. Every second flat in the vertical duct is connected to the same duct, which may negatively influence the air draft and thus the ventilation efficiency. In the description of the quoted research, it was not specified whether the access to the ventilation shaft for the remaining flats was closed for the time of the research. If so, this would lead to results that have no reflection in reality.

It is also worth noting that the cross-sections of prefabricated ventilation ducts in industrialised housing were not designed with regard to the position and size of the rooms. Dwellings were ventilated through the kitchen and bathroom, which means that significant areas of rooms are not ventilated adequately. The difference is particularly noticeable when the building is airtight. Then rooms other than the bathroom and kitchen are deprived of direct access to fresh air. With insufficient air exchange through windows and ventilation ducts, moisture from the rooms condenses on the inside surface of the external walls and causes mould growth. Too small number of air exchanges combined with old heating installation without thermostats may cause overheating of the rooms in winter.

Another element that negatively affects the efficiency of ventilation and thus the level of air comfort are the interventions of residents. In one housing estate in Lublin, it has been found that residents „*enlarged*" their bathrooms by demolishing the core of ventilation blocks or connected to the ducts of their neighbours. The patency tests of the ventilation ducts carried out in the same housing estate showed the deposit of debris in the ducts, which significantly worsened the air flow[27].

[27] Taczanowska and Ostańska, *Dokładność realizacji a potrzeba modernizacji budynków wielkopłytowych.*

Air pollution

Due to the mass production of prefabricated buildings in the early 1970s, there was a change in the building and finishing materials used. The more traditional materials were replaced by plastics, adhesives, paints and asbestos products with unknown effects on human health. Of course, the law stated that the impact and safety of new products had to be tested, but in practice these provisions were not observed.

The result was significant indoor air pollution, as determined in tests conducted by the Building Research Institute, caused by the installation of materials, mainly finishing materials, emitting harmful chemical substances. These included in particular: phenol and formaldehyde – mainly from plasterboards, parquets and insulation products, organic solvents – hydrocarbons and their chlorinated derivatives, alcohols, ethers present in paints, varnishes, putties, impregnates, pastes, unreacted monomers contained in plastics (vinyl chloride, styrene, acrylonitrile) and others.

Today, many years after the buildings were constructed, most of the dangerous volatile compounds have been emitted from the premises. Problems of this type usually arise in the course of renovations, during which previously built-up construction products are exposed (tar insulation, sound insulation saturated with Xylamite)[28].

[28] Oprac. zbior., "Diagnostyka i modernizacja budynków wielkopłytowych (cz. 2)," *Przegląd budowlany* 2014, no. 9 (2014).

The „*new, durable, non-combustible and inexpensive material – asbestos*"[29] was also widely used in Plattenbau constructions. In the W-70/Wk-70, Szczecin system, WWP systems, it was used in cladding and

[29] Andrzej Obminski, *Ocena stanu i mozliwosci bezpiecznego uzytkowania wyrobow zawierajacych azbest, Instrukcje, Wytyczne, Poradniki* nr 491/2014 (Warszawa: Instytut Techniki Budowlanej, 2014).

façade panels, in the OWT system in pillars between windows and in the WUF-T system, pipes covering sewage ducts were made of asbestos cement. Asbestos fines enter the respiratory system and can cause cancer. It was banned in 1998 and since then there have been extensive efforts to remove it from buildings. Its presence has been significantly minimised, but there are still places where it has not been removed.

Indoor air quality also depends on the presence of biological pollutants. In the case of large panel buildings, these are mainly moulds that develop as a result of moisture. Dampness can be caused either by inadequate insulation of the envelope or by lack of ventilation, which can occur after the envelope is insulated.

3.4. THERMAL

Summer

In public perception, the issue of thermal comfort in summer and in particular the problem of overheating in buildings is not considered important. As a result, this topic is not widely discussed in scientific papers and, consequently, also during the design and implementation of modernisation works. One of the few researches concerning this topic was carried out within the scope of the study „*Influence of the thermal insulation of a large-panel building on the thermal comfort of dwellings*"[30] and later developed within the scope of the study „*Analysis of the influence of thermomodernization on the heat loss by penetration and thermal comfort of a building*"[31]. In this study, a computer model of an existing building constructed in the W-70 system was used. It is located in Krakow and was commissioned in 1974. As part of the work, simulations were carried out for average climatic conditions between 15 May and 15 September. The results were then partly confronted with measurements on site. The tests were performed according to the international standard PN-EN ISO 7730[32]. The upper temperature limit within thermal comfort was set at 25°C. Two methods for assessing thermal comfort were used in the simulations and studies:

1. PMV (PredictedMeanVote) – predicts the average rating by a large group of users defining their impressions on a seven -point rating scale:
+ 3 – hot;
+ 2 – warm;
+ 1 – fairly warm;
0 – indifferent;
(-1) – fairly cool;
(-2) – cool;
(-3) – cold.
PMV should be between – 0.5 < PMV < +0,5;

2. PPD (Predicted Percentage of Dissatisfied) – describes the predicted percentage of people who are dissatisfied with the prevailing conditions.

[30] Katarzyna Nowak-Dzieszko, Małgorzata Rojewska-Warchał, and Jacek Dębowski, "Wpływ docieplenia budynku wielkopłytowego na komfort cieplny lokali mieszkaniowych," *Czasopismo Inżynierii Lądowej, Środowiska i Architektury* 2015, no. 2 (2015).

[31] Katarzyna Nowak-Dzieszko and Małgorzata Rojewska-Warchał, "Analiza wpływu termomodernizacji na straty ciepła przez przenikanie i komfort cieplny budynku," *Przegląd budowlany* 2015, no. 6 (2015).

[32] KT 158, Bezpieczeństwa Maszyn i Urządzeń Technicznych oraz Ergonomii, Ergonomia środowiska termicznego - *Analityczne wyznaczanie i interpretacja komfortu termicznego z zastosowaniem obliczania wskaźników PMV i PPD oraz kryteriów miejscowego komfortu termicznego* (2006), PN-EN ISO 7730:2006.

The W-70 system used prefabricated façade panels consisting of 3 layers: 15 cm of structural layer, 6 cm of thermal insulation from mineral wool or polystyrene and an external 6 cm thick finishing layer. According to the design, the partition wall had the heat transfer coefficient U=0,75 [W/m²K], but in practice it could be higher. In this system, the following external walls were also used: 42 cm or 36 cm thick single-layer expanded clay concrete walls; 24 cm thick single-layer cellular concrete walls or multi-layer curtain walls consisting of 3 layers, 8 cm of construction layer, 6 cm of mineral wool or polystyrene thermal insulation and 6 cm thick external finishing layer. When the building was commissioned, the minimum heat transfer coefficient for the walls was 1,15 [W/m²K], but the building was designed in accordance with requirements introduced in 1982.

Analogous layer compositions were also used in other prefabrication systems, but did not necessarily have the same thermal insulation properties. In the case of the Szczecin system, the external curtain walls had a U-value of 1,05 (kcal/hm²°C), which is equal to 1,22 (W/m²K). The exterior structural walls had a U-value of U=1,07 (kcal/hm²°C) – 1,24 (W/m²K). This corresponds to the minimum requirements before 1982.

The results of the simulation showed that before thermomodernisation, thermal comfort in the analysed period was not sufficient, and its level depended on the orientation of the flat in relation to the directions of the world. This is most evident when comparing a flat located on the north-eastern side with a flat located on the south-western side. In the first one, there were 2081 hours out of thermal comfort, in the second 2120 hours, of which during 350 hours the temperature exceeded 32°C.

Simulation of the thermal comfort of the building after thermomodernisation showed that in the flats the number of hours out of comfort increased to 2526 for the north-east flat and 2553 for the south-west flat. The number of hours in which the temperature exceeded 32 degrees increased to over 600. In all analysed flats the number of hours out of comfort increased. It is worth noting that the simulation assumed an air exchange of 70 m³/hour in the kitchen and 50 m³/hour in the bathroom. Such values may not be achieved in real conditions. This is due both to the characteristics of gravitational ventilation, which works more efficiently the bigger the temperature difference between the inside and the outside (for proper air flow direction, a higher inside temperature is necessary), and to the poor condition and obstruction of ventilation ducts.

These results were confronted with actual measurements in the building, which took place between 29 July and 31 July. During the analysed period, the daily outdoor temperature exceeded 30 °C. The operative temperature exceeded 25 °C throughout the measurement period, the highest recorded temperature being 29,17 °C. These conditions persisted also at night.

The reason for overheating of the Plattenbau buildings is the relatively large surface area of glazing. For the analysed building, the percentage share of glazing on particular façades amounts respectively: northern façade – 8 %; southern façade – 40 %; eastern façade – 26 %; and western façade – 26 %. This is not an isolated case, in the typical façades of the most popular set of OWT systems included in book "*Systemy budownictwa mieszkalniowego i ogólnego*" (Residential and general building systems)[33], the area of glazing exceeds 40%.

Another study[34] focusing on a more detailed analysis of thermal comfort in summer in a building constructed in the W-70 system shows that the most unfavourable conditions in terms of thermal comfort occur in a room located on the south-eastern side. A room in the same flat located in the east has 50% fewer hours with a temperature exceeding 32°C. Apart from the location in relation to the cardinal directions, these rooms have also different glazing surfaces – a room from the south has 25% more glazing and 50% less surface area.

It is worth noting that the Plattenbau buildings are lacking any shading elements. Before 1971 balconies and loggias were very rarely designed. Even later designed buildings are deprived of overhangs, cornices, shutters or roller blinds.

The situation is not improved by thermomodernisation measures. They increase the airtightness of the envelope, which worsens ventilation and leads to higher temperatures in summer. Solar heat gain coefficient (SHGC) is not taken into account when replacing windows. This approach is economically justified, glazing with better parameters is expensive and the most important indicator is the price and reduction of heat loss in winter, but it severely compromises user comfort.

[33] Pilszka, *Systemy budownictwa mieszkalniowego i ogólnego.*

[34] Katarzyna Nowak-Dzieszko and Małgorzata Rojewska-Warchał, "Analiza warunków mikroklimatu w lokalu mieszkalnym budynku wielkopłytowego w systemie W-70," [Analysis of microclimate conditions in the dwelling of large panel W70 building] *Czasopismo Inżynierii Lądowej, Środowiska i Architektury* 2015, z. 62, nr 3/I (2015).

Winter

Shortly after the construction of the Plattenbau buildings, it was noticed that there was a problem with too low temperatures in winter. Already in 1976, a state commission was established to check whether the buildings were constructed according to documentation. The analyses revealed many execution and assembly errors, including problems with thermal insulation and thermal bridges. The most drastic example of the consequences of these errors was during the winter of the century at the turn of 1978 and 1979. At the coldest moment, problems with thermal insulation were compounded by failures in the district heating system. This experience resulted a decade later in the first thermomodernization actions in the Plattenbau Buildings.

According to the design specifications (valid in the period of erecting the Plattenbau buildings), single-layer walls were to be characterised by heat transfer coefficients of about 1,2 W/(m^{2}K), and three-layer walls – about 0,7 W/(m^{2}K). Investigations have shown that the actual values are 0,3-0,5 W/(m^{2}K) higher in single-layer partitions and 0,2 W/(m^{2}K) higher in three-layer partitions[35]. The main reasons for the deterioration of the insulating properties were due to the use of higher density concrete and various errors in the execution or damage to the thermal insulation layers.

The values given do not take into account the influence of thermal bridges at junctions and construction joints. The places with the lowest insulating properties were the joints of gable and longitudinal walls with the ceiling above the basement, vertical joints of walls with loggia walls and balcony slabs, vertical joints of gable and longitudinal walls, where no thermal insulation was used or only 2 cm thick polystyrene inserts were mounted. The additions to the wall heat transfer coefficient resulting from taking into account the influence of thermal bridges in various Plattenbau systems are about 0,2-0,3 W/(m^2/K)[36]. This means that the walls of nonthermally modernised Plattenbau buildings have a heat transfer coefficient of between 1,2 W/(m^{2}K) (for single-layer walls) and 1,7 W/(m^{2}K) (for three-layer walls). These values are far from the contemporary heat transfer coefficient requirements of 0,2 W/(m^{2}K) for walls.

Low thermal insulation of junctions and structural joints results not only in increased heat loss, but also in low values of the internal temperature of the partition surface. Previous research has shown that in Plattenbau buildings these phenomena occur mainly in the above-mentioned corner joints of partitions and at window and balcony door frames.

[35] Jarosław Szulc, "Możliwości techniczne napraw lub wzmocnienia budynków z wielkiej płyty," [Technical capacities of repairs or reinforcement of panel buildings] *Izolacje*, no. 2 (2019).

[36] Katarzyna Nowak-Dzieszko, Małgorzata Rojewska-Warchał, and Jacek Dębowski, "Wpływ mostków termicznych w istniejących i modernizowanych budynkach systemowych W70," *Przegląd budowlany* 2015, no. 6 (2015).

In these places, the dimensionless value of the surface temperature ranges from about 0,66 to 0,70, i.e., lower than the minimum permissible values in residential buildings, which in the current regulations are assumed to be equal to 0,72[37]. In rooms where the ventilation intensity is not adjusted to the moisture emission by the tenants, this generally leads to the occurrence of surface condensation and the development of mould. High heat losses are also caused by poor roof insulation. Maintaining an operating temperature that provides comfort to occupants is problematic mainly due to the cost of energy required for heating, but is technically feasible.

Due to the above-mentioned problems and to increasingly higher requirements concerning thermal properties of partition walls and windows, thermomodernisation is the most common modernisation measure in the case of Plattenbau buildings. Nowadays, this applies both to buildings which have not been modernised since their construction and those in which interventions were undertaken in the 1990s and at the beginning of the 2000s. Actions of this type are primarily aimed at reducing energy consumption of buildings and improving living conditions of the inhabitants by eliminating thermal bridges and, consequently, improving thermal comfort.

Even basic thermomodernisation, which consists of installing 5 cm of additional insulation, allows for the reduction of thermal bridges due to the creation of a continuous insulation layer. Correctly performed thermomodernisation makes it possible to reduce heat escaping by 80%. This makes it possible to reduce or even eliminate the basic problem of thermal comfort, i.e., low temperatures in the building envelope. Along with thermomodernisation, inadequate ventilation and lack of control by residents over the amount of heat supplied to rooms can lead to overheating. Excess heat is removed in a natural way (gravitational ventilation) or in a controlled way (ventilating the rooms). The way to rationalize energy consumption for space heating is to install thermostatic valves and heat cost allocators on each radiator.

According to the recommendations of the Building Research Institute, manufacturers of thermal insulation systems and associations, buildings should be insulated with a complete thermal insulation system, installed on the external side of the external partition. The intended effect of increasing the thermal insulation of the partition is sometimes worsened by the application of a thinner insulation layer on window frames or by the lack of insulation of the loggia structure in the area of its contact with the building wall. This results in an increased heat flux through the partition where the uninsulated element meets the insulated one. In addition, it is necessary to replace windows and doors with energy-efficient ones with a low heat transfer coefficient.
A lot of heat loss occurs through the roof surface. Usually made as ventilated, flat roofs are re-insulated in two ways: by blowing mineral wool or impregnated cellulose granulate into the inter-roof space or by insulating the roofing from the outside with hard thermal insulation panels. External walls of basements are rarely insulated, due to the small share of heat loss in the overall energy balance of the building.

[37] Szulc, "Możliwości techniczne napraw lub wzmocnienia budynków z wielkiej płyty".

V. RESULTS

Is it worth it?

Plattenbau buildings are undoubtedly part of Poland's historical and architectural heritage. Their creation is the result of a very specific political and economic situation without which they could not have come into existence. From the very beginning they have been present in culture and through their prism artists have shown both individual tragedies and groundbreaking changes. The political transformation made them something that most of society preferred not to think about. It was a forgotten architecture, a breeding ground for pathologies, which, following the example of Western European countries, should be demolished and replaced with something new, better suited to the capitalist vision of success.

Plattenbau was and still is, to some extent, perceived as ugly architecture devoid of any values. It is described as inhuman, overwhelming and monotonous. However, underneath the garish layer of successive, motley modernisations, there are buildings with value not only from the point of view of architectural history, but also architecture and urban planning in general. They are a large-scale implementation of the modernist idea of industrial construction. They are also an important legacy of almost 50 years of development of Polish architecture and technology. They show that even in difficult circumstances you can try to create good architecture that will make people's lives a little better.

However, their preservation is also necessary for a very pragmatic reason. Given the housing situation in Poland, it is not possible to get rid of such a large number of flats, especially in a short period of time. Contrary to some opinions, the Plattenbau housing estates are not depopulated, nor are they home to the margins of society. They are well functioning neighbourhood units, with developed infrastructure, services and connections to other parts of the cities. Currently, in most cases, the inhabitants do not want to move out and live there of their own free will. In addition Plattenbau housing estates, with a bit of investment, offers something that contemporary estates are not able to offer – greenery and space. Currently, it is not always in good condition, but it has a great potential for revitalisation.

An additional argument for the preservation of the Plattenbau buildings is the enormous savings in CO_2 emissions due to the large amount of embedded emissions which would be lost if the buildings were torn down. Demolition of the buildings would additionally generate further emissions and a very large amount of waste. The challenge is to reduce operational emissions, but it is not an impossible task.

What to do and how to do it?

The analysis shows that Plattenbau buildings are in good technical condition. They are correctly designed buildings with good structural properties. Their biggest problem is quite frequent manufacturing and assembly errors. However they are harmless enough not to threaten stability of the structure. Its life span may even reach another 100 years. Plattenbau buildings obviously require renovation and maintenance as many elements, such as installations or finishing elements, have deteriorated. Generally satisfactory structural condition allows for longer term measures to be taken. If the buildings are to be used for another 100 years, it is necessary to make them resistant to the coming climate changes. This should be achieved by improving the user comfort as well as energy efficiency.

Under current climate conditions, there are already many problems with indoor comfort. Paradoxically, the least problematic issue is thermal comfort in winter. Even in non-upgraded buildings, it is possible to maintain a sufficiently high temperature, but at the cost of very high energy consumption. In such buildings, the big difference between the air temperature and the temperature of the envelope is problematic. This is due to their poor insulation and, in particular, the presence of thermal bridges. The solution to these problems is thermal modernisation.

Even basic thermomodernisation measures, consisting only of wall insulation and window replacement, allow for a significant reduction of thermal bridges, as well as energy savings of up to 20%. Such action, seemingly correct, may at the same time cause a lot of damage. First of all, it is not efficient enough in terms of energy savings. Comprehensive modernisation can reduce energy consumption by up to 50%. By comprehensive modernisation I mean: replacing windows and doors, insulating building walls with a minimum of 12 cm of insulation, insulating cellars and roofs, and sealing joints. An additional desirable measure would be a simultaneous renovation of the heating system, which would allow for more efficient management of thermal energy consumption in the building. After these measures, the Plattenbau building would be at least as energy efficient as a contemporary residential building. However, focusing only on thermal upgrading and lowering energy consumption leads to a deterioration of comfort for the users, so a holistic approach and comprehensive action is needed, taking into account the interplay of individual decisions. This is an approach that does not exist today.

The first issue that is directly linked to thermal upgrading measures is the deterioration of air comfort. In the Plattenbau buildings, there are large leaks in the envelope compensating for inefficient ventilation. Sealing of partition walls, including windows replacement, leads to reduction of air exchange, which reduces its quality. In extreme cases, this may result in the growth of mould in the rooms. The same danger occurs also in buildings before thermomodernisation, but it has a different cause – freezing and dampness of partitions. During renovation activities, attention should also be paid to the remains of harmful substances used during construction – including asbestos.

Increasing the insulation of the envelope also affects thermal comfort in the summer. Even before modernisation, temperatures in buildings can be dangerous to health and even life, especially for the elderly. Once the building envelope has been sealed and the number of air changes reduced, the situation becomes even worse. This is due to the high heat gain through glazing, which is combined with the issue of light comfort. Plattenbau housing estates are characterised by large distances between buildings, relatively large glass surfaces and lack of any shading elements. This results in the aforementioned heat gains as well as the threat of glare in summer.

There are also problems with acoustic comfort. Despite correct design assumptions, frequent construction errors resulted, in some buildings, in a significant reduction of acoustic comfort. This is also often the result of faulty renovations carried out by residents. The issue of acoustic comfort is much less related to other aspects of occupant comfort and more to the technical condition of the building.

In summary, preserving Plattenbaus through adaptive reuse while keeping energy usage to a minimum is possible. Coherent design measures are necessary, taking into account overlapping factors. A key action is to address overheating in buildings by introducing shading systems. This will allow thermal modernisation to be carried out without compromising thermal comfort in summer. Such actions, combined with the replacement of installations, would ensure a significant reduction in energy consumption while providing comfort to users in both summer and winter. It would also solve the problem of too high intensity of light in summer. During a complete renovation, which is necessary due to the building's age, it would be possible both to improve the acoustic properties and to install more efficient ventilation, which would compensate for the increased tightness of the partition walls. Such measures are difficult, time-consuming and expensive, but Plattenbau is worth it, and we have no other choice anyway.

VI. DISCUSSION

The analysis conducted on the base of collected materials was limited in some respects because the number of available data was not large. There is a lack of comprehensive studies of the topic of comfort in Plattenbau construction. Individual topics are developed in isolation from each other, mostly within rather short academic articles published in the trade press. The issues of the technical condition of buildings, energy consumption and individual aspects of user comfort are not addressed as often and to not the same extent. By far the most common are studies on thermal modernisation of buildings. However, this topic is addressed quite superficially without paying attention to the consequences of the proposed actions. Popularity of this topic results in economic conditions. From this point of view, it seems to be the most urgent problem and its solution brings both the authorities and inhabitants very clear benefits in the form of savings.

Some topics are not addressed at all – there is a lack of studies related to light and visual comfort, both those based on simulations and real measurements. The topic of overheating of buildings in summer is also addressed to a very limited extent and is not present in the wider awareness of designers. Acoustics and ventilation issues are more widely known, but more detailed data on them is lacking. Even the nationwide research on the technical condition of the Plattenbau buildings conducted by the Building Research Institute included only 300 buildings in comparison to about 60 000 existing buildings constructed in several different prefabrication systems. For these reasons, conclusions presented in the paper are drawn on the basis of a relatively small sample. This may make them less universal.

In case of further work, it would be necessary to elaborate more cross-sectional analyses, which on the one hand would be based on a larger sample of buildings and at the same time would take into account interdependencies between particular issues. It would probably be necessary to limit oneself to studying one construction system at a time. Obviously, such activities are far beyond the scope of a study possible a within the Enonce Theorique, or other work carried out at the university. They should be done as part of system-wide programs. The last comprehensive treatment of the subject of the Plattenbau was 12 booklets with basic instructions and recommendations for operation and repair. They were published in 2002-2003 by the Building Research Institute. They did not directly address the problems of comfort of users and some of the information contained in them has already become outdated.

In order to adapt buildings to contemporary and future needs, other actions are also necessary, which are not directly related to the topics of user comfort and energy efficiency. The most fundamental problem is adapting buildings to the needs of people with disabilities. It is necessary to add storage spaces for bicycles and strollers, which were abandoned at the design stage in favor of additional apartments. Buildings require replacement of installations, general overhauls of common parts and the apartments themselves. Quite a significant problem is the aesthetic layer of the facades of buildings, especially those that underwent thermal modernization. Most of them lost their elevation tectonics and were additionally painted in geometrical patterns in various pastel colors. In the Polish architectural community, there is even a term to describe this phenomenon – „*pastelosis*". Decisions about the facade's appearance are not made by architects but by residents' administrators, which probably contributes to the final effect. Green areas, which have not always been well maintained, need to be revitalized. Some services are missing or are located in places poorly suited for their function.

VII. BIBLIOGRAPHY

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