SCIENTIFIC

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Wear and selected defects in precast large panel buildings

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ABSTRACT:

The article presents the precast large panel construction technology used in Poland from the second half of the 20th century to contemporary times. In addition, it discusses the origins of precast large panel construction, its share among the various building construction methods over a two-decade period, as well as its nature, with consideration given to different large panel systems. It also contains a detailed percentage share of individual precast large panel technologies employed in building construction in the 1970-1985 period, as well as the typical defects occurring in such structures along with a description of the underlying reasons.
Further on, the article describes four methods used to, among others, assess the wear of precast large panel buildings depending on the use and maintenance quality. A table and diagram show the differences in technical wear over the 125 years of expected life of a precast large panel building.

Zużycie techniczne i wybrane wady w budynkach wielkopłytowych

Słowa kluczowe: budownictwo, obiekt budowlany, systemy wielkopłytowe, wady budynków, zużycie

STRESZCZENIE:

W artykule przedstawiono zagadnienie technologii budownictwa wielkopłytowego w Polsce od drugiej połowy XX. wieku do czasów współczesnych. Dodatkowo w artykule zawarto genezę budownictwa wielkopłytowego, jego udział w poszczególnych metodach wznoszenia obiektów budowlanych na przestrzeni dwóch dekad, jak również jego charakterystykę przy uwzględnieniu odmiennych systemów wielkopłytowych. Artykuł zawiera także szczegółowy wykaz procentowy poszczególnych systemów w technologii wielkopłytowej, użytych do wznoszenia obiektów budowlanych w latach 1970-1985 oraz typowe wady występujące w tego rodzaju konstrukcjach, uzupełnione o opis przyczyn ich powstawania. W dalszej części artykułu zawarto opis czterech metod, służących m.in. do oceny stopnia zużycia budynków wielkopłytowych w zależności od jakości prowadzonej eksploatacji i konserwacji. Różnice w stopniu zużycia technicznego na przestrzeni 125 lat spodziewanej trwałości obiektu budowlanego wielkopłytowego zobrazowane zostały w tabeli oraz na wykresie.

1. INTRODUCTION

Industrial scale prefabrication of construction elements began in Poland in 1897, when the plant in Białe Błota, still operating to this day, was opened [1]. In the following decades, until the outbreak of World War II, the development of prefabrication could be observed mainly within the scope of road and technical infrastructure. The 1950s saw dynamic development of construction due to the need to rebuild housing stock destroyed as a result of the war in 1939-1945 The construction of residential buildings using traditional technologies, including wide-scale bricklaying works, was not, unfortunately, enough to satisfy housing needs throughout the country. The implementation of large block technology allowed the construction cycles for residential buildings to be slightly shortened, but only the implementation of precast large-panel technology lead to a breakthrough in this respect.

The development of mechanisation in the 1960s and 1970s led to innovations in technological and organisational solutions for production lines of prefabricated construction elements. Lower labour intensity, shorter transport time, increase the range of offered precast large-panel construction systems and shorter building erection time all followed, among others.

Starting from the 1960s, a significantly greater use of precast large-panel technology in residential construction could be observed (Fig. 1). Its share in the overall rooms planned for construction in the 1965-1970 period increased by as much as 27.6% [2, 3].

2. TECHNOLOGY OF PRECAST LARGE-PANEL CONSTRUCTION IN POLAND

After 1959, residential building in Poland were designed on the basis of the Technical Standard for Designing Apartments and Residential Buildings (NTP), NTP-59 [4] and NTP-74 [5] respectively. These stipulated, among other factors, the apartment's maximum usable floor area depending on its category. In 1967, the OWT-67 system was developed, which also allowed for the construction of auxiliary facilities on housing estates, such as schools, kindergartens, as well as commercial and service structures [6].

Two systems could be distinguished within this precast large-panel construction technology, i.e. the closed and open system. In the closed system, large-panel elements were assembled in one certain way, with their types narrowed down to a repeatable solution: a type of building, its segment or even a single apartment [3]. Construction performed using the, so-called, closed system often meant each wall in the apartment was structural, i.e. load-bearing [7]. Unlike the closed system, the open system allowed various configurations to be developed in a limited number of building types, comprising any urban layout. There were no load-bearing walls inside the apartments [7].

Among numerous other precast large-panel systems in Poland, the most common included: W-70, Wk-70, OWT (all types), WUF-T, the Szczecin system, as well as a number of regional systems (Fig. 2) [6, 7].

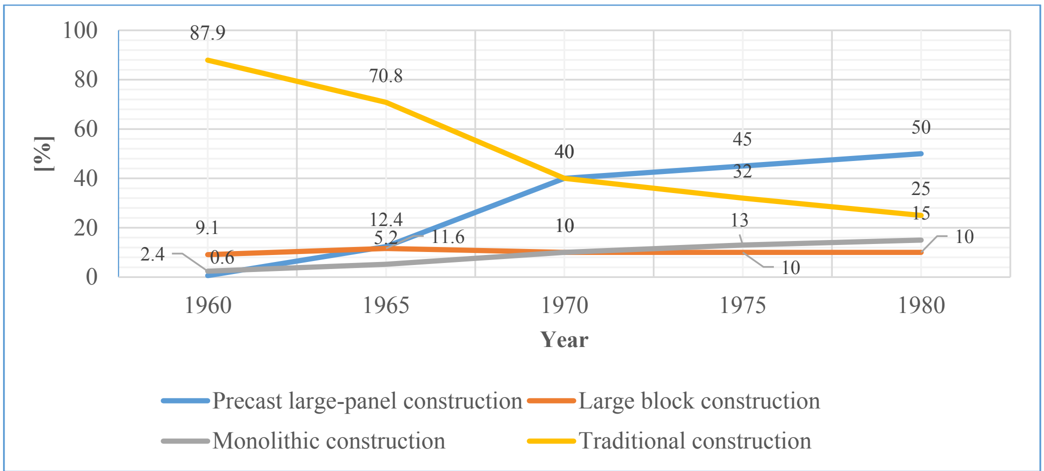

Figure 1 Summary of rooms planned to be constructed with a breakdown into individual construction methods in the 1960-1980 period [2, 3]

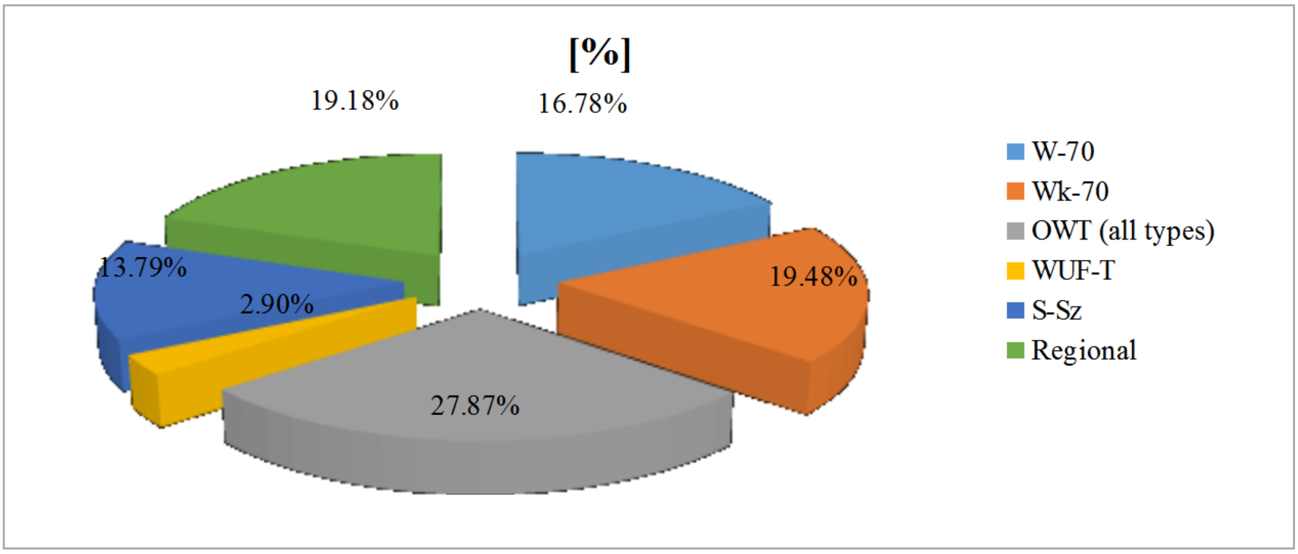

Figure 2 Graph showing the percentage share of individual precast large-panel systems in Poland in the 1970-1985 period [3, 8]

As can be observed, in the 1970-1985 period over half of all construction technologies based on precast large-panels used in residential buildings were the OWT, W-70 and Wk-70 systems. Meanwhile, from the beginning of the 1990s and over the next two decades, a clear decline in the number of buildings erected using precast large-panel technology could be observed. Monolithic construction of residential buildings has increasingly taken its place, which is a process continuing to this day. However, this does not mean that prefabrication in construction has been completely abandoned. For example, large prefabricated concrete elements, which are used not only in infrastructure development, but also in housing construction, are still popular [9]. In addition, increasingly demanding deadlines for completion of residential facilities, combined with rising labour costs in construction increasingly encourage investors to consider a technology based on assembling prefabricated elements.

3. WEAR OF PRECAST LARGE-PANEL RESIDENTIAL BUILDINGS

3.1 Introduction

Between the 1950's and 1970's residential construction in Poland focused mainly on erecting new housing within the shortest possible investment cycles. This meant, for example, little attention was paid to potential design and manufacturing errors or flaws possible in later periods. Already after 1970, the initial period of use of precast large-panel buildings, defects began to appear, mainly related to the workmanship. They significantly reduced the apartments' usability and functionality. Starting in the 1980s, negative phenomena classified as, so-called, technological defects, could be observed in precast large-panel buildings. These included, among others, leaks, freezing over of external walls, which caused thermal comfort to be low, and incorrect apartment use conditions when compared to the original design goals and requirements of standards [6]. This problem, despite years passing and various expenditure incurred by property managers and building cooperatives, including, for example, the introduction of thermal insulation in buildings or the replacement of windows and doors, was partially solved only in the first two decades of the 21st century.

3.2 Technological and technical defects in precast large-panel buildings

The most common defects occurring in the walls of three-layer precast large-panel buildings along with a description of their causes can be found in the table below (Tab. 1).

Table 1 List of the most common defects in three-layer walls of precast large-panel buildings [6]

LN.	Defect description	Reasons for occurrence
1	❖ leaks and walls freezing over	• bad quality of the prefabricated part, • inaccurate assembly at the construction stage (missing thermal insulation layers at tie beams and joints), • incorrect installation of the thermal insulation layer at the manufacturing stage (excessive gaps in the thermal insulation material joints), • use of an excessively compressible thermal insulation material, • excessive number of hangers, • unfavourable influence of weather conditions.
2	❖ deformation and cracks on the outer texture layer	• significant differences in the thickness of the texture and load-bearing layers, as well as uneven shrinkage, • ineffective circumferential rib mounting.
3	❖ separation of the texture layer from the insulation	• no or insufficient number of thin connectors (pins), • wind pressure.
4	❖ micro-fractures on the textured wall surface	• uneven thermal loads on individual wall layer thicknesses, • atmospheric phenomena, including concrete carbonation, the effects of CO_2 causing the loss of passive protection of the textured concrete layer, • non-elastic, rigid connection of hangers – relates to cracks within these elements.
5	❖ cracks, chipping and moisture penetration into texture layers	• incorrect demoulding of the prefabricated element at the manufacturing stage, resulting in damage to its texture layer, • bad lubricant quality, improper use of lubricants.
6	❖ discolouration on the façade	• condensation in areas where ribs and connectors are present, • inadequate cover of reinforcing bars - concerns rusty staining.

In the case of many defects, their occurrence was sometimes the result of several phenomena described in the cause column happening simultaneously.

3.3 Definition and methods for determining the degree of technical wear of precast large-panel buildings

Technical wear (ZT) is defined as a percentage. It stems from, among other factors: the age of the structure, the durability of the materials used, the quality of the construction workmanship, design defects and renovation management. Therefore, the technical condition of a building depends on the durability of three main groups of elements, i.e.:
• structure;
• finishing;
• furnishing [10].
In determining the degree of wear, it has to be remembered that the actual condition of the precast large-panel building and related fittings need to be considered. The degree of wear should be determined on the day of visual inspection and evaluation of the structure [10].
The following methods are used to determine technical wear [10]:
• assessing the wear of individual elements of the structure;
• assessing the weighted average technical wear of a structure;
• assessing the average technical wear of a structure on the basis of time methods.
The weighted average technical wear of a precast large-panel building is calculated on the basis of the degree of wear of individual components (Sw_ze_i):

$$Sw_ze_i = \frac{Ue_i \cdot S_ze_i}{100\%}[\%] \quad (1)$$

where:
S_ze_i – component technical wear as a percentage [%];

Ue_i – percentage share of the costs of the i-th component in the total costs of the structure's replacement, expressed as a percentage [%].

In the next stage, the weighted average wear is calculated (S_z) for the entire precast large-panel building based on the following formula:

$$S_z = \sum_{i=1}^{n} \frac{Ue_i \cdot S_z e_i}{100\%} [\%] \qquad (2)$$

where:

S_z – weighted average of technical wear for the entire structure, expressed as a percentage [%];

n – number of assessed elements in the structure;

i – another element.

When calculating the technical wear of precast large-panel buildings based on time methods, the following should be considered:

- age of the structure, expressed in years;
- expected lifetime of the structure expressed in years.

An example of the estimated lifetime for large residential buildings is 100-150 years [10].

An assessment of the degree of wear of precast large-panel buildings needs to be performed on the assumption that their technical wear increases over time and depends on the quality of care, ongoing maintenance, periodic renovations, as well as repairs and replacements of individual elements. The methods allowing such an assessment are as follows [11]:

- Ross method (linear, proportional);
- Ross and Unger method (Eytelwein, nonlinear);
- Romsterfen method;
- Ross and Eytelwein method (parabolic).

A detailed description of the individual methods is presented in the table below (Tab. 2).

Based on the above formulas and the assumed lifetime of precast large-panel buildings, which is 125 years on average, a table containing the percentage of precast large-panel building wear depending on the quality of operations and maintenance can be prepared. Detailed results are presented in the table below (Tab. 3).

Table 2 Description of time methods used to determine the wear of precast large-panel buildings

LN.	Description of the method and formula	Conditions of use
1	**Ross method:** $S_z = \frac{t}{T} \cdot 100\%$	Badly conducted operations and maintenance of a precast large-panel building.
2	**Ross and Unger method:** $S_z = \frac{t \cdot (t+T)}{2 \cdot T^2} \cdot 100\%$	Acceptable or average level of conducted operations and maintenance of a precast large-panel building.
3	**Romsterfen method:** $S_z = \frac{t \cdot (2 \cdot t + T)}{3 \cdot T^2} \cdot 100\%$	Well conducted operations and maintenance of a precast large-panel building.
4	**Ross and Eytelwein method:** $S_z = \frac{t^2}{T^2} \cdot 100\%$	Very well conducted operations and maintenance of a precast large-panel building.
t – age of the precast large-panel building in years; T – expected lifetime of a precast large-panel building.		

Table 3 Percentage of technical wear of a precast large-panel building according to the quality of operations and maintenance

Type of time method used:	Technical wear percentage of a precast large-panel building at the end of subsequent 25-year periods [%]:				
	1	2	3	4	5
Ross method	20.0	40.0	60.0	80.0	100.0 75.0 87.5 100.0
Ross and Unger method	12.0	28.0	48.0	72.0	100.0 65.6 82.0 100.0
Romsterfen method	9.3	24.0	44.0	69.3	100.0 62.4 80.1 100.0
Ross and Eytelwein method	4.0	16.0	36.0	64.0	100.0 56.3 76.6 100.0

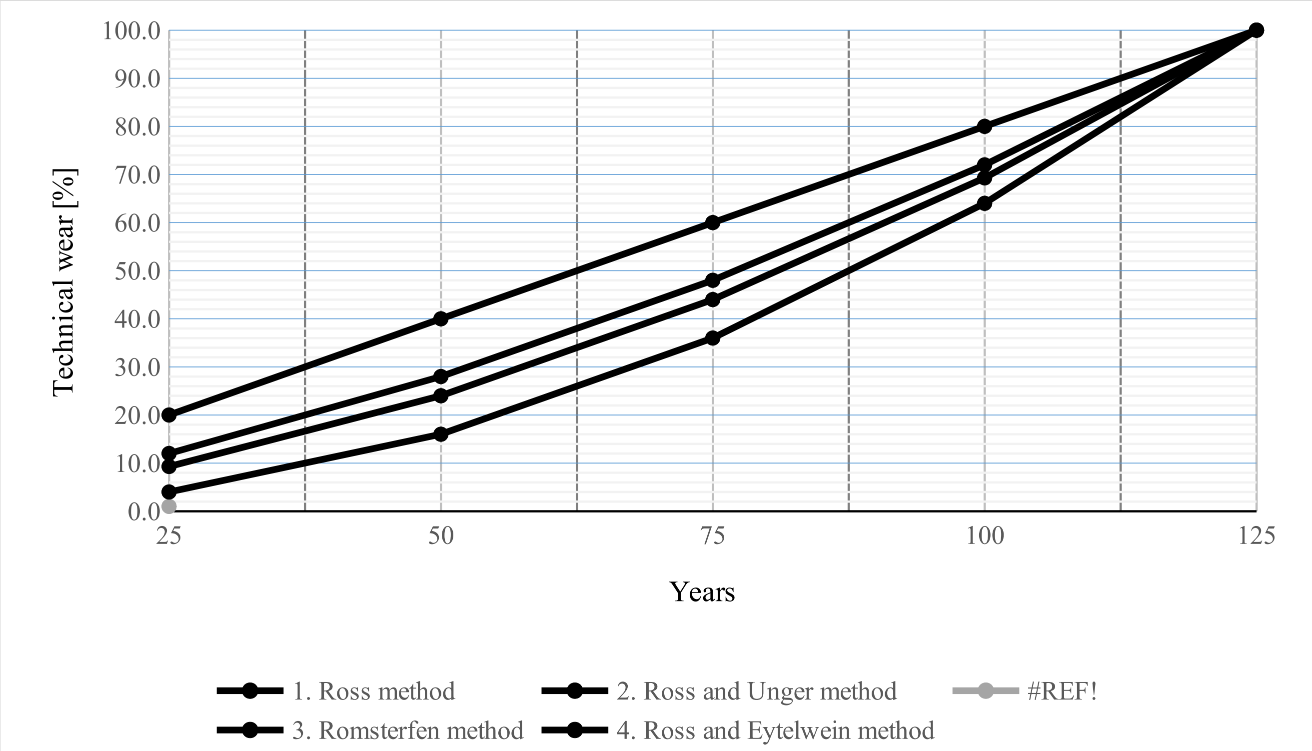

Figure 3 Percentage of technical wear of a precast large-panel building according to the quality of operations and maintenance

The greatest differences in the wear of a precast large-panel building occur between 50 and 75 years. The maximum value is 25.0%. The obtained results relate to two extreme time methods, i.e. the Ross and Eytelwein, and the Ross methods. The differences for the remaining time methods are smaller and do not exceed the extreme value of 25.0%. In the initial period of use of a structure, i.e. between year zero and 25, the extreme difference in technical wear arising due to the quality of the maintenance performed is smaller than in the period between the 50th and 75th year of use. A similar occurrence can be observed in the expected end life of a building, i.e. between year 100 and 125, in which the extreme difference in technical wear calculated using time methods decreases. This situation is shown in detail in Figure 3.

4. SUMMARY

Despite monolithic technology being extensively used in the construction of residential buildings, precast large-panel buildings will constitute a significant part of Poland's housing stock for many years. Some of these buildings are over 50 years old, which means their technical wear exceeds 16.0%, if operations and maintenance are conducted very well. Maintenance and operational procedures conducted incorrectly or without due diligence may, in extreme cases, cause over 40% technical wear of the building.

The subject matter discussed and the calculations performed here are helpful in assessing the technical condition of a building, its value and its correct use in previous periods - this stems from the fact they show the importance of their proper maintenance in correct use of the buildings, including precast large-panel structures. Incorrect maintenance by building managers may lead to excessive costs of ongoing property maintenance.

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