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Maintenance of apartment buildings and their measurable deterioration

Utrzymanie budynków mieszkalnych a ich mierzalna degradacja

Abstract

Apartment buildings constructed prior to the First World War are important examples of Polish buildings with regard to their historical significance – the technical maintenance of such buildings remains challenging. The results of the work refer to the general population, estimated for 600 objects, that compose of about 20% of municipal downtown apartment buildings in Wrocław. The purpose of the research was to identify an influence of widely considered maintenance of apartment houses on a degree and intensity of their elements'. The goal of this research has been achieved through the analysis of symptoms reflecting the decline of the inspected elements' exploitation values, that is identification of mechanics of arising their defects. The calculated quantitative data can be used as the basis for identifying the structure of the building companies which are responsible for housing maintenance and repair.

Keywords: apartment buildings, maintenance, deterioration, technical wear

Streszczenie

Prawidłowa, tzn. systematycznie i rzetelnie przeprowadzana, ocena stanu technicznego budynków mieszkalnych stanowi podstawę do szeroko rozumianej organizacji ich obsługi technicznej, a w szczególności do organizacji prowadzenia remontów o ustalonym rodzaju, wielkości i zakresie. Ocena ta, poparta rozpoznaniem wpływu warunków utrzymania budynków mieszkalnych, jest ponadto podstawowym źródłem informacji w racjonalnym zarządzaniu zasobami mieszkaniowymi. Celem badań było rozpoznanie wpływu przebiegu procesów, utożsamianych z szeroko pojętym utrzymaniem starych kamienic czynszowych o konstrukcji tradycyjnej, na wielkość i intensywność zużycia ich elementów. Charakterystyka techniczna i typologiczne uporządkowanie ich uszkodzeń, rozumianych jako wyraz jakości utrzymania budynków mieszkalnych, umożliwiły rozpoznanie warunków eksploatacji rozważanych obiektów. W zdarzeniach losowych, gdzie próbowano opisać stany zaobserwowane (empiryczne) formułami teoretycznymi, rozważono probabilistyczną stronę zagadnienia i jej losowy charakter.

Słowa kluczowe: budynki mieszkalne, utrzymanie, degradacja, zużycie techniczne

1. Introduction

Apartment buildings constructed prior to the First World War are important examples of Polish housing style – these types of buildings account for around 10.1% of the total number of urban apartments. Furthermore, the importance of this type of building is due to the fact that they contribute to the creation of the urban environment. Maintaining the value of the urban environment requires continued effort and is a responsibility that is passed down through the generations. The effort is effective if continuity of the following process is kept: erection, maintenance, repair, maintenance, modernisation, maintenance, etc. until the demolition of the object. Due to the political and economic conditions of the twentieth century developments in many countries have been destroyed over the course of history caused by the events of war. After the Second World War, in plenty of countries in Central Europe, additional devastation factors have appeared as a consequence of a lack of houses, the migration of people and insufficient care and maintenance of buildings – a majority of them as a result of deprivation of a law of property belonged to proprietors of houses. There is currently a need to make efforts to repair and maintain such buildings. Cultural factors doubtlessly motivate such efforts. With regard to the economic and technical justification of such repair and maintenance projects, the degree of technical wear and tear of the buildings in question should be identified [1–9].

This paper is the result of technical research and analyses of old apartment buildings in Wrocław [8]. The aim of the analysis is to provide information which would assist in the planning of maintenance work for the group of the apartment houses in question. A method of scientific research for calculating the technical wear of an apartment house and the detailed results of the technical wear of twenty three considered apartment buildings elements are presented in this paper [8].

2. Research background

The analysis was performed on the apartment buildings erected before the First World War in the city centre of Wrocław [8]. These are apartment houses which were built in the nineteenth and early twentieth centuries. The buildings are situated in the part of the city which was one of very few districts that wasn't completely destroyed by the events of war. The apartment houses are three- or four-storey brick buildings, erected in longitudinal, usually three – row structural systems. With the exception of the solid basement floors, all of the other floors are examples of typical wooden floors. All the buildings are covered with wooden rafter framing, usually of purlin-collar type. The staircases are composed of wooden or steel structural elements with wooden flights of stairs.

3. Comparative analysis of technical wear

During analysis, it was repeatedly noticed that the observed technical wear Ze is greater than the theoretical one Zt during the first stage of building elements use: $Ze = f(t) > Zt = f(t)$. After exceeding some, possible to determine, age t_i the mentioned relation is inversely
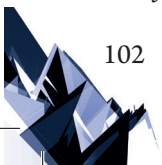
proportional and works until the maximum value of building elements age: t_{max} = 174 years. In the considered example, the age of main walls for which the value for theoretical wear becomes higher than the value for observed wear is 87 years. The difference between theoretical and observed wear increases with the age of the building elements what indicates imperfection in calculating the technical wear according to the theoretical formulas. The mean deviation of the theoretical and the observed technical wear is –3.13. Age seems to be related to the degree to which values relating to theoretical wear and observed wear differ. This relationship seems to exist because all observed elements of the apartment houses show signs of being 'under expected life' during the first stage of building element use and 'over expected life' after exceeding the age t_i There is the only one period, approximately defined as $(t_i - T/10)$ $< t_i < (t_i + T/10)$, where the theoretical and the observed technical wear vary by no more than 10%. The comparative analysis reveals considerable differences between the degree of technical wear calculated according to theoretical formulas and the degree of wear revealed during inspection of the apartment houses – this confirms the existing need to create a model which makes it possible to verify the reliability of the theoretical formulas. The number of gathered observations makes possible to build the model that can be applied to all particular building elements [3, 5, 9].

4. Scope of probabilistic research

The theoretical model of the deterioration of apartment buildings is a function of time t and assumed durability (expected life) T of apartment building elements. Owing to the fact that the purpose of the theoretical simulation solely establishing of a trend of the phenomenon therefore, models of a limited complexity have been chosen [7, 10, 11]. As a result of this basic level of complexity, the scope of the research has been limited to seeking the trend function among linear, power, exponential and hyperbolic dependencies (Table 1).

Table 1. Result of probabilistic research – modelling of new functions $Z_t = f(t)$ and durability T revision

SEEKING OF ALTERNATIVE FUNCTIONS Zt = *f*(t) BY NON-LINEAR REGRESSION METHOD										REIDUUM ANALYSIS
Z9 – STAIRS	NON-LINEAR REGRESSION				VARIANCE ANALYSIS					durability T, for which
	estimators		probability level		model		residuum		determination coef.	average deviation = 0
mathematical formulas	constant A	regression c. B	p(A)	p(B)	df	square sum	df	variance	R*R [%]	and remainder var. = min, for
LINEAR MODEL: Y = A + B X	34.4926	0.1509	0.0000	0.0126	1	1269.919	100	196.666	6.07	804
POWER MODEL: Y = AX^B	3.1387	0.1552	0.0000	0.0004	1	1.206	100	0.090	4.78	6894494
EXPONENTIAL MODEL: Y = exp (A + BX)	3.4810	0.0038	0.0000	0.0038	1	0.083	100	0.094	8.06	519
HYPERBOLIC MODEL: 1/Y = A + B X	0.0323	–0.0001	0.0000	0.0021	1	0.001	100	0.000	9.04	301
RESEARCH OF RELATION SIGNIFICANCE BETWEEN Ze and t BY RANKS OF SPEARMAN'S C.										Ross & Unger formulas
observed significance level	*p*(S) = 0.0264 < 0.05 – CORRELATION Ze/t SIGNIFICANT									(III class of maintenance)
ASSESSMENT OF SIGNIFICANCE DIFFERENCE BETWEEN Ze and Zt DISTRIBUTIONS										Y=X(X+T**)/2T**T**
non-parametrical tests	WU I – V	WU II	WU III	WU IV	EXPLAINATION:					T = 160 lat
"WILCOXON'S TEST"	R	R	R	R	R – distributions are significantly different					literature durability
"TEST ZNAKÓW"	R	I	R	R	I – distributions are identical					for stairs Z9: T = 120 years
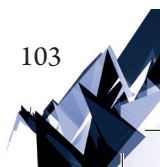
The parameter values of the testing models were selected according to the non-linear regression method [7, 10, 11]. With Z as a dependent variable representing the degree of technical wear of the building element and t as its age (independent variable), a zero-hypothesis based on the rules of non-linear regression was stated. According to the hypothesis H_0, such created model does not explain a systematic alternation the variable Z to the variable t, described by a regression coefficient γ and enlarged by a constant random addend ξ. It appeared that the most influential factor on the random addend ξ was the condition of the considered apartment houses' maintenance. The whole of the model, equation (1), is divided into the section explained by the sought model (dependent on regression γ and the part, which is not explained by the model, defined as a remainder addend (residuum) ξ. Numerical values of parameters γ and ξ have been calculated by the method of least squares. This enabled to determine the estimators referred to the constant A $(= ξ)$ and to the regression coefficient B $(= γ)$. All of these principles are contained in the following rule:

Z – random variable (dependent = Y) ⟺ technical wear of building element Z = $\{z_1, z_2, ..., z_n\}$;

t – age of building element (independent variable = X), t = $\{t_1, t_2, ..., t_n\}$;

$$Z = ξ + f(t, γ) = ξ + γt \tag{1}$$

where:

γ – directional coefficient of regression – part dependent on regression;

ξ – remainder addend (residuum), with values $ξ_1, ξ_2, ... ξ_k$ – not explained by model.

A variance analysis was applied to test the extent to which the theoretical model fits to the empirical data. This analysis resulted in the calculation of determination coefficient R^2. The value of coefficient R^2 provided information how big part of the observed in the sample building element's technical wear diversification was explained by its regression as to the apartment buildings age – the results of the variance analysis are shown in Table 1.

Correlation coefficients of SPEARMAN'S ranks allowed comparisons between ranks of the two variables which are present in the model – dependent variable Z and independent variable t. If an observed significance level $p(S)$ was lower than the assumed level of α = 0.05, then the null hypothesis was rejected and the alternative hypothesis H_1 was accepted; therefore, the existing correlation between the technical wear and age of apartment house elements can be treated as significant (Table 1).

An assessment of the significance difference between the theoretical Zt and the observed Ze value distributions of the technical wear of building elements was undertaken through the use of two non-parametrical tests – the WILCOXON test and the 'Znaków' test. A result of the testing was the calculation of the level of probability that the sample output statistics would support the zero-hypothesis regarding the identity of variable distributions (Table 1).

The last stage of the non-linear regression method is based on a residuum analysis. It revealed a priceless piece of information about durability of the building elements considered as a posterior data [6]. The actual durability T^{**} of the apartment buildings chosen elements belongs to the period of 153–177 years and is greater than the well-known referred durability T^* – the average deviation should cross the '0' point (Fig. 1), the remainder variation should be minimum (Fig. 2).
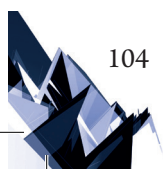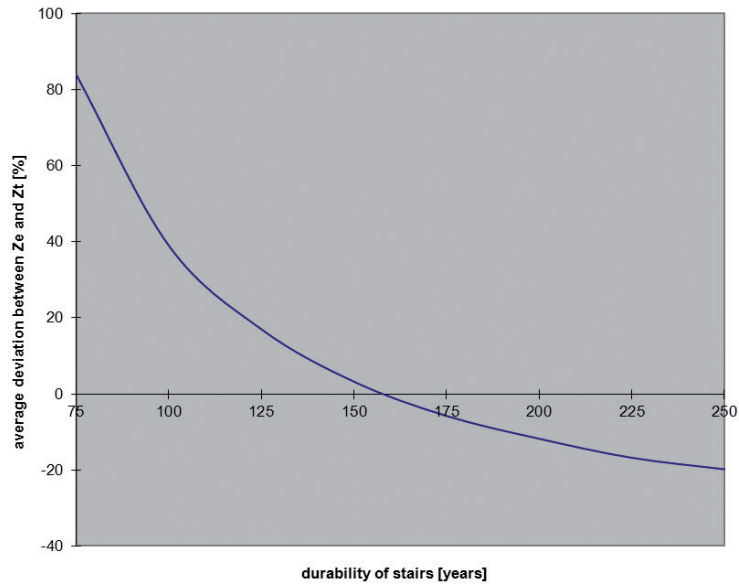
Fig. 1. Deviation between observed technical wear and estimated theoretical
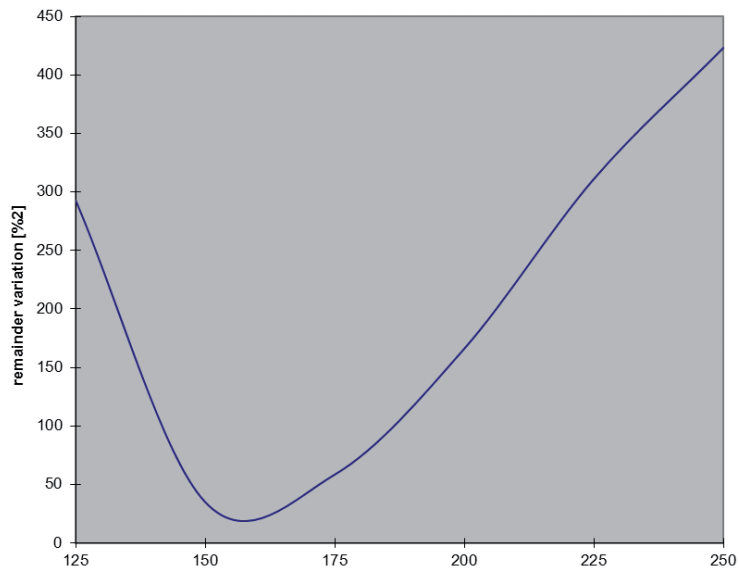wear as a function of stair durability

Fig. 2. Remainder variation as a function of stair durability with average maintenance
of building element

Owing to the unsatisfying results of the observed states' modelling by the theoretical formulas a second attempt was made to measure the buildings deterioration. This attempt was based on looking for quantitative relationships between the defects of the elements of the apartment buildings (as an indication of state of maintenance) and the intensity of the deterioration of the considered elements [1, 2, 10, 11].
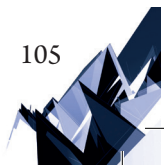
5. Conclusions drawn from research

5.1. Conclusions relating to methods of measuring the deterioration of the apartment buildings

The widely applied theoretical methods of measuring the extent of technical wear to apartment buildings and their elements insufficiently describe the state of reality. What is doubtful it is as the way of attribution these methods to maintenance conditions as the choice of too general mathematical formulas with the only two variables: t and T.

Theoretical formulas for determining the technical wear of building elements take into account their age t and durability T as the only parameters and do not include the influence of the state of the apartment buildings maintenance. The assessment of the measurable difference between the theoretical and the observed values of the technical wear of the building elements conducted using the Wilcoxon and 'Znaków' tests shows significant differences between these distributions in the majority of cases.

None of parabolic functions represent the character of the determined technical wear over time (that means a very small determination coefficient R^2 and unnaturally high quantity of parametric durability T^{**}). The exponential and hyperbolic mathematical models better represent the theoretical tendency of the apartment buildings elements' deterioration.

5.2. Conclusions regarding the influence of the maintenance of apartment houses on their deterioration

Considered apartment houses are in such period of their using when the time of a proper work up to a defect shows the character of exponential trend – an average rest of their using time is at each moment unchangeable.

Less than 30% of the technical wear of the apartment house elements is explained by their age – the maximum value of the determination coefficient is $R2 = 30.89\%$.

Two types of the building element defects play a major role in the rapid deterioration of an apartment house:

- ▸ calculated as a result of probabilistic analysis the defects caused by water penetration and humidity migration; the rule is particularly relevant in the case of poorly maintained objects;
- ▸ determined as a result of the random calculation of the mechanical defects of the structure and the surface of the elements (which result in considerable frequency and cumulating effect and lead to permanent increase in the apartment buildings elements' deterioration); the regularity is characteristic for well and average maintained objects.

6. Summary

The research (the methodological assumption, the mathematical application and the conclusions) should be treated as a piece of exploratory work. Thus, it is an attempt of the recognition of the mechanism of the reasons and effects phenomena, which an engineer
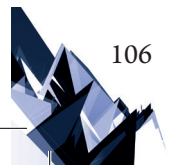
expert meets while technically inspecting a building object. This assessment, however, is naturally gifted with an immeasurable aspect (partly subjective). Creating a new model of the technical inspection of apartment buildings, based on procedures and conclusions drawn from this work, would make possible to transfer the weight of technical assessment from being qualitative to quantitative in nature. The author's intention is to direct further research connected with the widely considered measurable diagnoses of technical objects in the direction described above.

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