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THE ASSESSMENT OF BUILDING REPAIR NEEDS WITH THE USE OF AN INDICATOR METHOD

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ABSTRACT

The progressive degradation of residential buildings is mainly caused by negligence in their maintenance and repair. In order to maintain the facilities it is necessary to properly prognosticate the repair needs. The article presents a method of repair planning for buildings in use. It also demonstrates the results of its application for planning repair needs for residential buildings, which were erected in the traditional technology, located in Zielona Gora.

KEYWORDS: Degree of Technical Wear, Needs Repair, Repair Planning

INTRODUCTION

Negligence in maintenance and repair is the main reason of the decline of technical value of a building. With the passing years, the repair needs are growing, and the absence of such work results in the loss of the usability value of a building. In order to maintain the existing buildings, it is necessary to solve problems associated with the prognostication of the repair needs (Runkiewicz 1998, Skarzyński 2010).

For a larger collection of buildings (such as municipal buildings within the city of Zielona Góra), it can be stated that buildings and their individual components are damaged in varying degrees. Due to the limited financial resources, it is always a difficult decision to select an element to be repaired. The proposed method of planning repairs of existing residential buildings, which are worn in different degrees, can be helpful in making decisions.

GENERAL CHARACTERISTIC OF THE BUILDINGS

The research included 80 residential buildings located within the municipality of Zielona Góra. The buildings were erected in 1850 – 1915 mainly as classical tenement houses. All the objects are placed on the list of the State Service for the Protection of Monuments. According to the map of Zielona Góra from 1896, most of the buildings are situated along the main streets of the town (e.g. Kupiecka, Jedności, Wandy, Zamkowa).

All of the analysed buildings were erected with the use of similar material and structural solutions. The walls of the examined objects are masonry, solid brick, floors – wooden beam, stairs and roofs performed as wooden structures, purlin-clip roofs, sometimes the collar beam, plain tile roofing. The administrator of all the analysed buildings is the Department of Municipal and Housing Administration in Zielona Góra.

All the buildings of the collected research material have similar material and structural solutions. The differences are only in the spans of floors, numbers of floors and roof truss constructions (usually purlin-Tick, sometimes collar beam). The walls of the tested objects are built of solid brick, floors - wooden beam, stairs and roofs performed as wooden structures, roofing – plain tile.

In the vast majority of buildings included in the analysis, identical defects were found:

- Dampness of the walls due to the lack of horizontal and vertical insulation of basement walls and foundation;
- Dampness of the upper parts of the buildings due to leaks in the roof coverage, lack of cornice coverage, defective roof drainage;
- Biological corrosion of wooden elements such as: floors, stairs, roof trusses, windows, doors and flooring; lack of proper heating in buildings;
- Excessive consumption of the building caused by prolonged lack of maintenance and its improper use.

For all the buildings a periodic assessment of technical condition was carried out by experts. During the evaluation, the consumption rates of individual elements of buildings were established. The data on the average degree of wear of the examined objects are presented in Table 1.

Table 1: Average Values of the Degree of Wear of Buildings Elements

No	Name of the Element	Average Value	Min	Max	Variation Coefficient
1.	Masonry brick walls	46,1	30	70	24,04%
2.	Wooden beam ceilings	46,3	30	80	27,10%
3.	Wooden stairs	45,2	25	90	32,20%
4.	Roof rafter	44,6	25	85	33,30%
5.	Tail caver	48,0	0	75	33,97%
6.	Gutters and drain pipes	53,7	30	80	27,67%
7.	Wooden floor	46,1	30	85	26,10%
8.	Windows	61,8	30	90	20,55%
9.	Doors	49,8	20	80	22,10%
10.	Water supply and sewage pipes	34,1	20	100	35,95%
11.	Water supply and sanitation fittings	35,1	20	100	35,10%
12.	Gas pipes	37,6	20	100	39,65%
13.	Internal plasters	39,1	20	75	25,72%
14.	External plasters	49,7	20	100	32,08%

The obtained mean values of the degree of wear of the buildings indicate a poor technical condition of the analysed buildings. Mean values for all the elements are higher than 60%. The situation is worrying also due to the maximum values of the degree of wear, i.e. 100%, occurring for almost all components of the buildings. However, large values of the variation coefficients indicate significant differences of the technical condition of the examined objects. For five components of the buildings, the variation coefficients are greater than 30.0. The obtained results indicate the heterogeneity of the objects in terms of their degree of wear. The differences in the technical conditions of the examined buildings are due to modernization work carried out in some of the objects in recent years.

PROPOSED METHOD OF REPAIR PLANNING

For a larger group of buildings, destroyed in varied degrees, there is a problem of a rational selection of the sequence of repair to be carried out, i.e. considering a series of questions:

- Which building should be subject to the repair in the first place and which later?
- Which element (e.g., ceiling, roof) requires immediate intervention, and which elements can be repaired later?

- Or weather to wait with the renovation of the damaged building element until another, interdependent element will be replaced?

The proposed method, called the method of application of indicators [2], useful in planning the repairs of buildings damaged in varying degrees, should provide an answer to these questions.

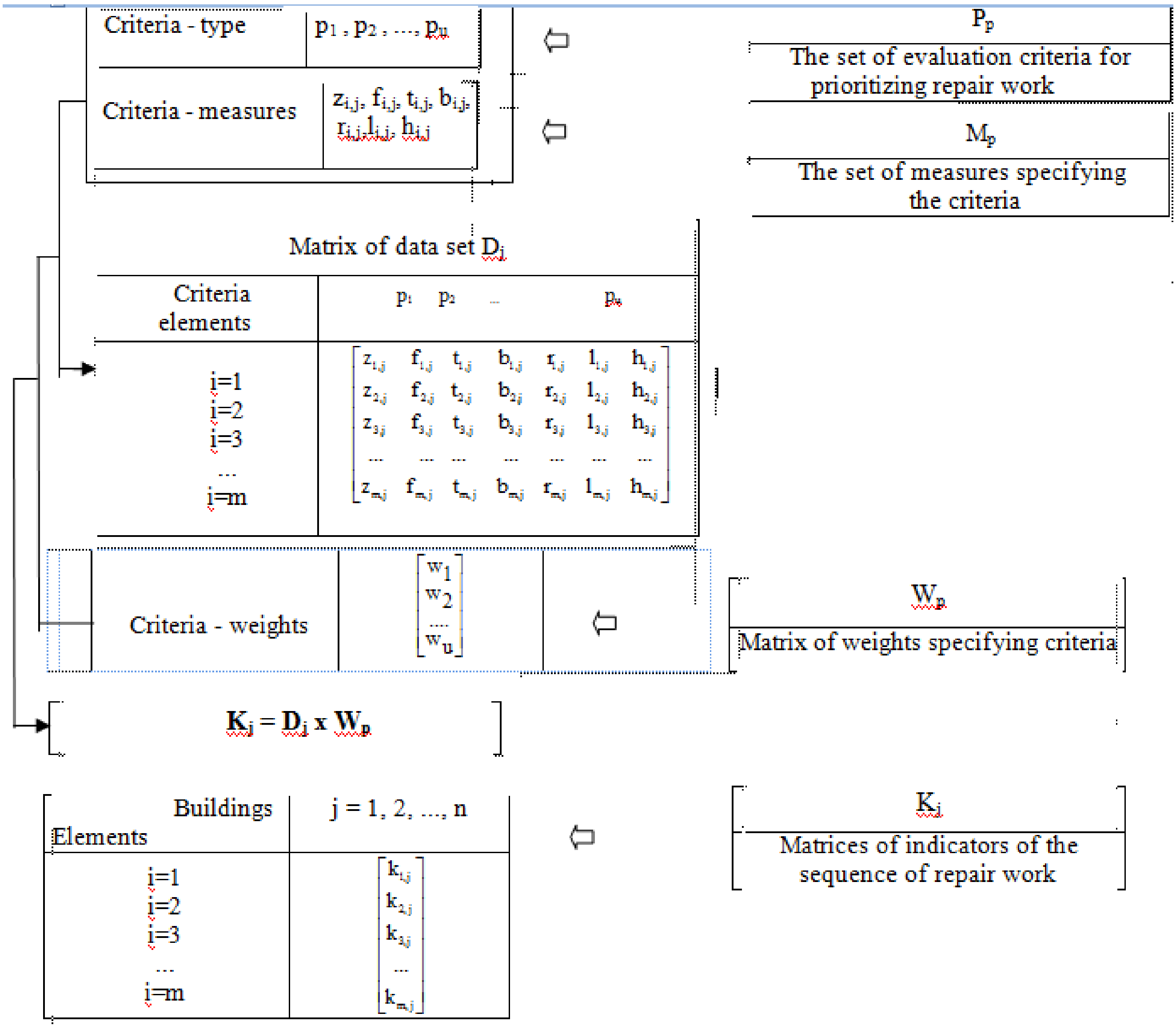

Figure 1: Sketch of Repair Planning According to the Method of the Application of Indicators

The method of the application of indicators is illustrated by diagram presented in figure 5. The established evaluation criteria for planning the subsequent repair works p_1, p_2,..,p_7, determined by measures of the evaluation criteria $z_{i,j}$, $f_{i,j}$, $t_{i,j}$, $b_{i,j}$, $r_{i,j}$, $l_{i,j}$, $h_{i,j}$ and weights of these criteria w_1, w_2,...,w_7 constitute the output data to determine the matrix of indicators of the order of executing the repair works $k_{i,j}$.

The proposed method of the selection of the order of execution of the repair works in residential buildings consists of the following sequence of actions:

- establishing criteria affecting the order of the repairs;
- determination of the weight factors for each criterion;
- establishing the set of the analysed buildings;
- establishing the numerical measures of the criteria;
- determination of a mathematical equation which will lead to the order of repairs;
- providing indicators determining the selection of the sequence of elements.

In the method the following criteria have been adopted:

- The degree of the building wear;
- The structure of the building;
- The durability period of the element;
- The impact of the element wear on the condition of other elements;
- Interdependence between the repair of one element and the repair of another one;
- The locality of the building;
- Cultural and historical value of the object.

The criterion of the degree of wear of individual elements in buildings is based on the percentage values of wear of elements established during the evaluation of the technical condition of buildings.

The structure criterion connotes the division of the building into the following components: structural, shielding, equipment and finishing.

Durability criterion includes the diverse processes of wear and tear of the building elements due to their different durability periods.

The effect of their destruction on the condition of other elements was determined on the bases of the impact of the wasted element on the destruction of other elements in the building.

It should be noted, however, that these criteria are just selected major indications for prioritization, i.e. the sequence determination, of the repair work. There are also many other criteria for overhaul planning, for example, the interdependence while performing repair works in complexes of buildings, the kind of used materials and technologies as well as criteria related to the modernization of buildings.

The weights of the evaluation criteria were established on the basis of consultation with those associated with the issue of the maintenance of residential buildings: building administrators, university academics, appraisers, historic buildings restorers, designers, and contractors performing the repair works. However, it is estimated that the evaluation of criteria weighting is an extremely complex problem and the adopted weights should be verified in the future. For example, a nation-wide extensive survey into planning the overhauls and the determination of evaluation criteria could be conducted among the interested parties.

Matrix of data set D_j is determined by the following measures $m_{i,j}$:

- $z_{i,j}$ – measure of the wear of an i-th element in the j-th building;
- $f_{i,j}$ - measure of the building structure;
- $t_{i,j}$ - measure of the durability of an i-th element in a j-th building;
- $b_{i,j}$ - measure of the impact of the devastation of an i-th element on other elements in a j-th building;
- $r_{i,j}$ - measure of interdependence between the repair of an i-th element and the repair of other elements in a j-th building;
- $l_{i,j}$ - measure of localisation of a j-th building;
- $h_{i,j}$ - measure of culture and historical values of a j-th building;
- where i – denotes an ordinal number of an element in a building, i = 1, 2, 3, ..., m;
  - j – denotes an ordinal number of the object; j = 1, 2, 3, ..., n.

The temporal arrangement of the execution of the repair works may be determined after the indicators $k_{i,j}$ have been sequenced. The sequentiality indicators for n elements in a j-th object may be obtained by solving matrix equation (1).

$$K_j = D_j * W_p \tag{1a}$$

$$[k_{ip,j}]_{mx1} = [d_{ip,j}]_{mxu} * [w_p]_{ux1} \tag{1b}$$

where:

K_j , $[k_{ip,j}]_{mx1}$ - matrix of indicators determining the order of the repair works in a j-th building;

D_j, $[d_{ip,j}]_{mxu}$ - matrix of measures of criteria for elements in a j-th building;

W_p, $[w_p]_{ux1}$ - matrix of criteria weights;

i - ordinal number of the element in the object, i = 1, 2, 3, ...,m

j - ordinal number of the object, j = 1, 2, 3, ..., n

p - ordinal number of the criterion, p = 1, 2, 3, ..., u

Matrix of measures of criteria D_j (for a j-th building), determined by equation (2), is a rectangular matrix of finite m x u.

$$D_j = \begin{bmatrix} z_{1,j} & f_{1,j} & t_{1,j} & b_{1,j} & r_{1,j} & l_{1,j} & h_{1,j} \\ z_{2,j} & f_{2,j} & t_{2,j} & b_{2,j} & r_{2,j} & l_{2,j} & h_{2,j} \\ z_{3,j} & f_{3,j} & t_{3,j} & b_{3,j} & r_{3,j} & l_{3,j} & h_{3,j} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ z_{m,j} & f_{m,j} & t_{m,j} & b_{m,j} & r_{m,j} & l_{m,j} & h_{m,j} \end{bmatrix} \tag{2}$$

The expressions in matrix W_p are weights of u-criteria (3).

$$W_p = \begin{bmatrix} w_z \\ w_f \\ w_t \\ w_b \\ w_r \\ w_l \\ w_h \end{bmatrix} \tag{3}$$

Indicators determining the order of the repair works of m-elements in the j-th building are comprised in matrix K_j (4) which is the solution to equation (1).

$$K_j = \begin{bmatrix} k_{1,j} \\ k_{2,j} \\ k_{3,j} \\ \ldots \\ k_{m,j} \end{bmatrix} \tag{4}$$

The task involves solving matrix equation (1). Multiplying numerical measures of criteria by their weights we obtain numerical values assigned to each of the examined element in the building, which was included in the study. Numerical values resulting from the study, are indicators of the order of execution of repairs - $k_{i,j}$. The higher the rate is, the more urgent renovation of the i-th element in the j-th object. The indicator does not mean, however, any physical size of the repaired components, it only serves to rank the elements of the building due to the proposed order of repairs.

Using the principles of elementary matrix operations, a mathematical picture of an i-th element in the j-th building can be obtained:

$$\mathbf{k_{i,j} = z_{i,j}*w_z + f_{i,j}*w_f + t_{i,j}*w_t + b_{i,j}*w_b + r_{i,j}*w_r + l_{i,j}*w_l + h_{i,j}*w_h} \tag{5}$$

The result of equation (5) is the indicator of the order for a particular element in a particular object. An interesting sequence of repairs may be obtained by comparing the indicators of the order of elements which were qualified to repair in the pre-selection process.

For a larger complex of buildings, the result will be presented in a form of a set of matrices in the number equal to the number of buildings. For an arbitrary number of buildings, the specific expressions of the matrix provide the possibility to prioritize the analysed objects and their components as well as to determine the sequence of any two objects and their components.

In the planning of repair work, the method of indicators may be used to elaborate a schedule of tasks to be performed. The method does not help in the determination of the date of the repair of any of the examined object or its components, as the term depends on the funds that the buildings administrators may spend on the repair and also on the costs of the overhauls of particular building components.

Prediction of the Repair needs for Buildings in Zielona Góra

According to the proposed rules and assumptions of the method of indicators, the research included data collected for 50 sample buildings, which were further analysed on the bases of the carried out calculations. The obtained results, which are the indicators of the order of the execution of the repair work for individual elements of all the examined buildings, were ordered from the highest to the lowest values thus indicating the order in which the repairs of all components of buildings should be performed.

Table 2: Mean Values of Sequence Indicators for Building Elements

No.	Name of the Element	Mean Value	Min	Max	Standard Deviation	Variability Coefficient
1.	Masonry brick walls	0,067	0,063	0,072	0,003	4,48%
2.	Wooden beam ceilings	0,071	0,067	0,079	0,003	4,23%
3.	Wooden stairs	0,066	0,063	0,074	0,003	4,55%
4.	Roof rafter	0,076	0,072	0,084	0,003	3,95%
5.	Tail caver	0,073	0,067	0,081	0,004	5,48%
6.	Gutters and drain pipes	0,067	0,059	0,073	0,005	7,46%
7.	Wooden floor	0,043	0,038	0,049	0,003	6,98%
8.	Windows	0,058	0,053	0,065	0,004	6,90%
9.	Doors	0,052	0,047	0,059	0,004	7,69%
10.	Water supply and sewage pipes	0,058	0,053	0,066	0,005	8,62%
11.	Water supply and sanitation fittings	0,058	0,053	0,066	0,005	8,62%
12.	Gas pipes	0,059	0,054	0,067	0,005	8,47%
13.	Internal plasters	0,037	0,032	0,045	0,004	10,81%
14.	External plasters	0,060	0,053	0,067	0,004	6,67%

The obtained results, presented in Table 2, allow conclusion that among all elements of a building, floors, roof trusses and roof coverings demonstrated the highest average values of the sequence indicators, which amounted more than 0.07. These elements should be repaired in the first place. The largest differences of the obtained values of the sequence indicators occurred for water supply, sewerage, heating systems as well as for gutters and downpipes. The standard deviation for these elements is the largest.

Four groups of elements were adopted in terms of the repair sequence:

- elements for which repair is absolutely necessary, the values of sequence indicator index are greater than 0.068,
- elements, for which the repair is required, the values of sequence indicator index range from 0.051 to 0.068,
- elements for which repair is recommended, the values of sequence indicator index range from 0,031 to 0,051,
- elements for which the repair is currently not required, the values of sequence indicator index are lower than 0.031.

The first two groups include buildings elements which wear rate is greater than 50%. Additionally, the repair is absolute recommended for them due to the cultural and historical values of the buildings themselves or their location.

The “recommended repair” group contains elements with the degree of wear lower than 50%, but due to their location and cultural conditions, their (or their elements) repair must be performed earlier than the repair for the elements of the fourth group.

Assuming the division of the buildings into the four groups, it is possible to assess the size of the repair needs for the analysed group of buildings.

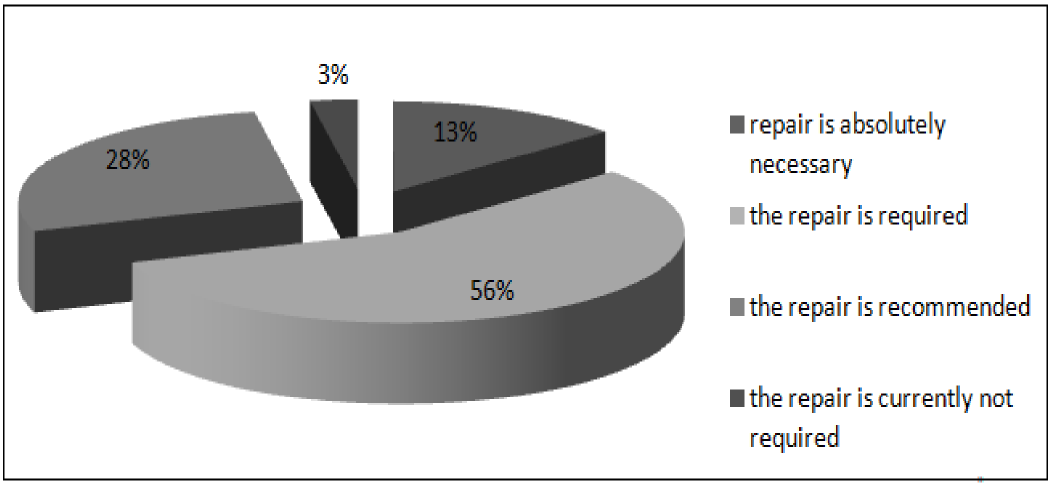

Figure 2: Sizes of the Repair Needs of the Analysed Buildings

The results presented in figure 6 prove the validity of a negative assessment of the current housing situation in Poland. Among the elements included in the analysis, i.e. 14 components of 80 buildings (total number – 1120 elements), only 3% elements did not require repair at that time (these are usually plasters), and for the remaining 97%, repairs should be performed. For 13% of the elements, the renovation is absolutely necessary, for 56% - required, for 28% of elements – recommended.

The proposed method for planning repairs of buildings, erected in a traditional manner, enables sequencing the examined objects in terms of the necessity of their overhauls as well as the determination of the ordering relationship between two arbitrary buildings. The method may be applied to the process of repair planning for both a single building and a larger group of buildings.

CONCLUSIONS

- Due to the limited financial resources, selecting a building or its component to be repaired is always a problem of particular importance for a decision-maker. The proposed method of planning repairs of existing manor-palace buildings, worn in different degrees, may prove to be helpful in making decisions.
- Renovation work in existing buildings which are performed according to the plans prepared with the use of the method of indicators will result in the inhibition of progressive degradation of buildings.
- The proposed method of repair planning for an arbitrary group of buildings erected in the traditional technology allows ranking the studied objects in terms of the repair needs and to determine the ordering relation between two arbitrary objects. It may be used for repair planning for both a single building and a larger group of buildings.
- The indicator method may also be used in planning complex repairs for all quarters of a town. The result of such applied method will be one matrix of sequence for all the buildings, which can be obtained after determining the weighted average wear for all the buildings.

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