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Research paper

Selection of “white tub” technology using multi-criteria analysis – a case study

Aleksandra Radziejowska[1], Kazimierz Linczowski[2]

Abstract: Currently, more and more investments are carried out in areas with difficult ground conditions, where in addition there may be a high level of groundwater. Therefore, it is necessary to use technologies which ensure the safety of the building in the exploitation phase by, among others, ensuring appropriate leak-tightness of its underground part. The article focuses on presenting the application of watertight concrete system (WCS), also known as "white tub" technology, which is an effective way to protect the underground part of the building against the destructive effects of water. The aim of this paper is to present and analyze selected methods of securing the underground parts of erected buildings using the "white tub" technology. In this paper, the authors analyze and select the solution using a multi-criteria analysis. The presented method will be used on a selected object.

Keywords: monolithic construction, white tub, multi-criteria analysis, underground part of object, watertight concrete system

[1]PhD, Eng., AGH University of Science and Technology in Cracow, Faculty of Civil Engineering and Resource Management, Department of Geomechanics, Civil Engineering and Geotechnics, Av. Mickiewicza 30, 30-059 Cracow, Poland, e-mail: aradziej@agh.edu.pl, ORCID: 0000-0002-3190-7129

[2]M.Sc., Eng., AGH University of Science and Technology in Cracow, Faculty of Civil Engineering and Resource Management, Department of Geomechanics, Civil Engineering and Geotechnics, Av. Mickiewicza 30, 30-059 Cracow, Poland, e-mail: kazlincz@agh.edu.pl, ORCID: 0000-0002-0868-1942

1. Introduction

Nowadays practically all buildings have their foundations, or the entire underground part designed in monolithic technology. In addition, each building, regardless of the technology of its execution and the structure itself, now requires the use of waterproofing or moisture insulation. This is due both to the need to prevent water from entering the building and to protect it from the damaging effects of an often aggressive environment, which can weaken the construction material leading to corrosion of concrete and reinforcement [1, 2]. In addition, due to technical progress, the realization of the component processes of monolithic technology is becoming increasingly complex, mainly due to the use of modern system and material solutions with adapted technology, as well as the need to optimize implementation costs, lead times and other indicators, especially economic and technical. The ability to solve them enables rational allocation of resources over time and allows for their efficient use [3].

For a long time, insulation of underground parts of buildings was either not carried out at all or was carried out in an impermanent or incomplete form, leading to accelerated deterioration of structural elements and consequently to the need for very costly repair work. Most often, if insulation was carried out, various coatings were applied to the foundations of the building - either as one- or two-component slurries or foils. Often, however, especially in the case of difficult ground conditions and high groundwater levels, these solutions were inadequate and required repeated repairs over the years.

Current tendencies in the construction industry influence the execution of investments in more and more difficult ground conditions, which additionally influences the necessity to apply newer and better technologies protecting the underground parts of buildings, especially against the destructive influence of water [4, 5]. For this reason, an increasing number of underground parts of buildings are being built using the watertight concrete system (WCS), also known in construction jargon, as "white tub" – the latter being due to the method of insulation, which in this case is coating-free water insulation systems. WCS is increasingly being chosen for its effectiveness and durability. Thanks to the use of a complex solution in waterproof concrete technology, the facility can serve its users for many years without the need to interfere with its underground, inaccessible part, which in the perspective of long-term use also brings financial savings.

However, WCS also has its disadvantages, primarily the very high technological regime required during implementation. Above all, the requirements during execution are decisive for achieving a tight and durable solution. A range of products can be found among manufacturers to perform comprehensive coating-free insulation. The authors propose to analyse the available solutions by using multi-criteria analysis methods. The set of criteria was established by a group of experts, civil engineers involved in, among other things, the implementation of "white tub" technology. The variants to be assessed, on the other hand, were selected by analyzing the sets of solutions available on the market, excluding specific manufacturers.

2. Research methodology

The problem undertaken for research results from the needs of construction practice. Determination of the aim and scope of research was based on experience in monolithic reinforced concrete works (in particular execution of underground parts of buildings) of site managers cooperating with the authors. Decisions regarding the selection of the most advantageous WCS solution require the consideration of many criteria. In the analysed problem there is a need to perform a multi-criteria analysis. The solution to the problem is proposed by applying the following methodology (Fig. 1).

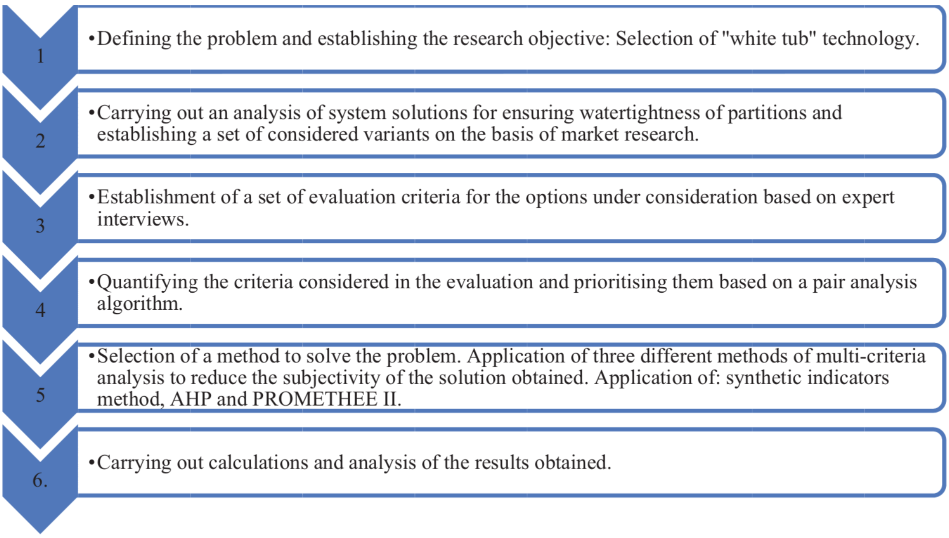

Fig. 1. Methodology for selecting the watertight concrete system (WCS), own elaboration

Applying the right WCS solution to a construction site depends on many factors that have a significant impact on the performance of the works. Multi-criteria analysis is helpful in this. Currently, there are many proposals for the analysis and synthesis of mostly discrete multi-criteria problems, which enable the solution of difficult and complex problems [6].

In order to solve the problem of optimal selection of the WCS technology system, a multi-criteria comparative analysis was carried out using three different calculation methods: the synthetic index method, the AHP method and the PROMETHEE II method. The selected methods belong to different schools of multi-criteria decision-making. Furthermore, the analysis carried out was enriched by expert research including consultations and interviews with experts. The research was carried out between 2019 and 2021 on more than a dozen construction sites mostly in the Małopolska region, finally collecting 16 opinions from engineers and site managers, in particular those dealing with shell works. The variants considered in the analysis were sealing systems in "white tub" technology used in the construction of monolithic parts of structures exposed to the destructive effects of water.

Based on market research sets were established to formulate variants subject to analysis. However, the selection of criteria was established based on conducted expert interviews.

The first method consists in constructing a synthetic indicator [7]. A single-number indicator is obtained by coding the denominated values of the options assessed against the selected criteria and then aggregating the sub-rating. Both the choice of the synthetic indicator and the coding method do not have much influence on the outcome of the assessment. The authors decided to use one of the most popular coding methods – the normalization method.

The second method proposed by the authors is the analytical hierarchical process (AHP) method, developed by Thomas L. Saaty [7]. This method involves decomposing the decision problem into smaller problems and comparing them against the subsequent levels. During the comparison of these levels there is a gradual aggregation of partial evaluations, which ultimately leads to the obtaining of evaluations in the form of scalars for each of the options.

The last method proposed is PROMETHEE II (Preference Ranking Organization Method for Enrichment Evaluations), which has its roots in the European school of decision making. This method examines the extent to which a given alternative is preferred over the rest of the alternatives (positive preference flow) and the extent to which the rest of the alternatives are preferred over a given one (negative reference flow). Finally, the aggregation process also produces a ranking of evaluations in the form of scalar values (the so-called net flow) for each variant.

The problem shown in this paper has been presented in a possibly generalized way, so that the proposed solution could be helpful to the contractors during the execution of structures in watertight concrete technology. The subjectivity of the obtained solution is mainly related to the determination of the weighting of the considered criteria. In the article the selection of weights was made for a specific investment supervised by the authors. However, the assessment of individual variants was performed in accordance with the analysis of solutions available on the market and experience during the implementation of the WCS. The authors believe that the presented methodology can be successfully applied to various objects, however, it is recommended to select each time the weights of considered evaluation criteria.

3. Description of watertight concrete system

A "white tub" is a reinforced concrete monolithic structure for which waterproof concrete of class W8 or higher is used. This technology is partially described in standards, among others [8], or in the standard updated in 2016 [9]. Some of the most recent guidelines can also be found in the Building Research Institute manual [10].

The WCS technology consists in obtaining an airtight reinforced concrete barrier without additional coating insulation of the reinforced concrete elements. The structure of reinforced concrete elements made in WCS allows for partial migration of moisture and water, but only to a certain depth. In construction practice it is generally accepted that the minimum thickness of a reinforced concrete barrier which makes it possible to achieve airtightness is 25 cm.

Initially, waterproof concrete technology was dedicated to elements placed in the ground. For foundation locations below the groundwater level, WCS was applied to the foundation slab and the foundation walls. The result was a watertight structure whose shape and properties were reminiscent of a bathtub and hence this technology came to be known as “white tub”. Today, the “white tub” technology is recognized, in particular by structural designers and structural engineers. WCS has proved to be such a universal technology that it is now being applied to other reinforced concrete elements which were previously insulated with coatings. The most commonly used reinforced concrete elements in WCS technology, apart from the floor slab and the foundation walls, are the floors above the underground section (mainly outside the building contour), terraces and the roofs of the buildings. The use of WCS enables the abandonment of previously used coating insulations, leading to an acceleration of the pace of works and financial savings. The real benefits of using WCS are the relatively small price increase when adapting the structural concrete to achieve airtightness levels of e.g., W8.

Tightness in WCS technology for a reinforced concrete partition is achieved by demanding guidelines such as:

– Design maximum value of cracks in the concrete structure (mainly shrinkage cracks related to the initial period of setting and largely dependent on care) – not exceeding 2 mm.
– The use of additives and admixtures for concrete, which can be applied in the batching plant or on site directly to the concrete mixer, giving the possibility of creating the so-called setting curve for the concrete mix.
– The ingredients of the concrete mixture, mainly the water-cement ratio and thus the consistency of the concrete mixture.
– Determination of embedding time of the concrete mixture from the moment of mixing the components.
– Specifying the method of placing the concrete mixture, e.g., the height of the drop of the concrete mixture into the formwork, together with the method of density of the mixture in the formwork using vibrators.
– The use of additional reinforcement introduced into the construction in order to reduce the formation of cracks in stress concentration areas, e.g., concave, and convex corners.
– Specifying the minimum and maximum cover for reinforcement in individual reinforced concrete elements.
– Use of compensating spacers (e.g., EPS polystyrene or mineral wool) in elements located below the foundation slab, e.g., lift shaft, oil separator chamber or linear recesses for installations carried out in the thickness of the foundation slab.
– Use of elements generating tightness at joints of technological breaks and dilatations, e.g., “rubber” tapes, sheet metal tapes, injection hoses, systems of sealing of openings after assembly systems of formwork etc.
– Adequate care for 72 hours, depending on the weather conditions, consisting mainly of keeping the formwork in place for up to 72 hours and maintaining the right humidity [10].

In particular, the WCS emphasizes the need to maintain the integrity of the envelope, so a variety of additional elements are used, both in the process breaks and expansion joints (Fig. 2), among which we can distinguish three systems that differ primarily in the way in which the vertical and horizontal elements are connected (slab to wall, wall to floor), these are:

1) system based on "rubber" joints,
2) system based on "metal sheets",
3) system based on injection hose (Fig. 3).

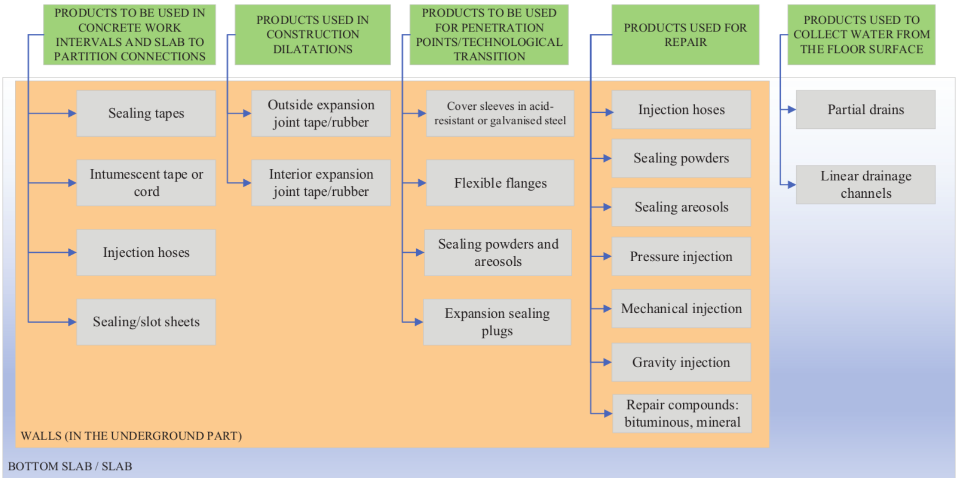

Fig. 2. Elements used in the WCS, own elaboration

a) b) c)

Fig. 3. Systems based on: a) "rubber" joints, b) "metal sheets", c) injection hoses (authors' archives)

There is no objective distinction, especially in the case of systems 1 and 2, as to which of them is more advantageous, in what type of ground conditions, or for what type of investment they will perform their functions better. The use of a particular system usually results from the experience of designers and companies installing the elements in question. The company supervising the realization of the design assumptions related to white water technology during the execution of the investment is also responsible for the tightness during the guarantee and warranty period and is able to determine, based on empirical knowledge, which of the systems is more beneficial to it and under which conditions. Designers, on the other hand, are most often guided by their own experience or loyalty agreements with manufacturers of WCS elements. The latter fact often translates into the possibility of obtaining a more favourable price for the proposed solutions and, at the tender stage, may also influence the presentation of a competitive price by a given contractor.

4. Difficulties in using watertight concrete technology

The WCS is a difficult technology to implement. The design of the shell-less insulation itself is rarely problematic for an experienced builder. However, even for an experienced contractor the realization of an investment in WCS technology can cause many problems. The technological regime required during the execution of structural elements in white tub technology is often difficult or impossible to achieve and significantly affects the effectiveness of the designed solutions.

Knowledge and experience show that in practice it is difficult to avoid design and execution errors. Thus, the main risks that may occur at the stage of preparing the design of white tub technology include:

1) lack of adequate familiarization with the original design of the structure,
2) routine and habits of the designer,
3) lobbying by companies supplying sealing elements for the WCS and not having a full range of solutions,
4) lack of preparation of details of all solutions envisaged in the design,
5) unreadable summary design showing layout of all WCS solutions,
6) concrete mix formulation not adapted to weather conditions and/or season,
7) no consultation of the WCS design with the chief structural designer,
8) failure to issue additional reinforcement resulting from the WCS, or issue incomplete reinforcement,
9) release for execution of incomplete detailed design intended e.g., for interprofessional consultation,
10) lack of solutions for sealing of entrances, exits and passages of sub-floor installations.

Whereas the main threats which may occur at the stage of executing the investment include:

1) incorrect formulation of concrete mix delivered to site,
2) substitution of concrete mix recipe ingredients without consultation with WCS designer,
3) inappropriate consistency of the concrete mix e.g., by adding water before the concrete mix is embedded,
4) excessive delivery time of the concrete mix to the site,
5) incorrect application of additives and admixtures applied at the construction site
6) inappropriate placing of the concrete mixture in the formwork, e.g., too high discharge height of the concrete mixture into the formwork,
7) inadequate compaction of the concrete mixture (too long period of holding the vibrator in the concrete mixture).

8) inadequate preparation of reinforcement and formwork, e.g., lack of reinforcement elements issued in the additional detailed design for WCS,
9) inadequate cover for the main reinforcement (too small or too large),
10) inadequately installed WCS elements issued in WCS design,
11) replacement of sealing elements issued in WCS design by other ones without knowledge of WCS designer,
12) lack of sealing elements, which are included in the WCS design,
13) inadequate care of reinforced concrete elements made in WCS failure to maintain sufficient surface moisture in the reinforced concrete element),
14) removing the formwork too quickly (failure to keep the period of keeping the concreted element in the formwork specified in the WCS design),
15) unfamiliarisation with WCS design and performing construction works based on experience from other construction sites,
16) inadequate storage of sealing elements specified in the WCS design as weather or moisture sensitive,
17) premature installation of sealing elements which are sensitive to weather and moisture.

The above shows how many situations can lead to improper execution of coating-free insulation. It is therefore worth taking care to select the right components for the WCS in accordance with the designed properties. This will be carried out by analyzing the feasible sealing solutions in each case, using the presented technology. The authors propose the use of multi-criteria analysis in selecting appropriate elements to ensure the tightness of structural elements of the building. Thanks to the multi-criteria analysis method, it will be possible to select the optimum solution during the realization of the investment in which the watertight concrete technology is designed.

5. The set of analyzed variants and criteria

5.1. Description of the object under analysis

The analysed building is a single-family building situated on a plot with a significant slope towards the south, located near Krakow. Due to the planned basement, the owner decided to use WCS in the underground part of the building. Regarding the planned construction of the "white tub" technology, the client decided to analyse possible variants by means of a multi-criteria analysis in order to optimize the choice of solution. Through market research, possible products were identified, and variants of complex, applicable solutions were determined. For the criteria previously established through the expert interview, the investor together with the site manager determined their validity. Calculations were carried out using a pairwise analysis algorithm. The results of the calculations are presented in Table 1.

The executive design of the WCS in the facility as implemented is shown in Fig. 4.

Table 1. Set of evaluation criteria and their weightings

	Criteria	W1	W2	W3	Weight	Ch.
K1	Cost of execution	1	2	4	0.15	D
K2	Assembly time	3	1	5	0.06	D
K3	Supply logistics	2	1	4	0.06	D
K4	Complexity of assembly	4	2	5	0.09	D
K5	Availability of system components	3	3	4	0.13	S
K6	Requirement of assembly time of elements before concreting	2	2	1	0.03	D
K7	Possibility of using recycled materials for the production of components	4	4	1	0.04	S
K8	Requirement for qualifications of workers during assembly of the system	3	2	4	0.07	D
K9	Reactivity of the component	3	4	1	0.09	D
K10	Environmental impact during production of the product	3	2	3	0.04	D
K11	Necessity of using specialist equipment during assembly	3	1	5	0.09	D
K12	Positive experiences from previous projects	4	3	1	0.13	S

∗ the individual variants are rated on a scale of 1–5 (min 1; max 5) taking into account the character of the criterion. Ch. – character of criterion (D – destimulant, S – stimulant).

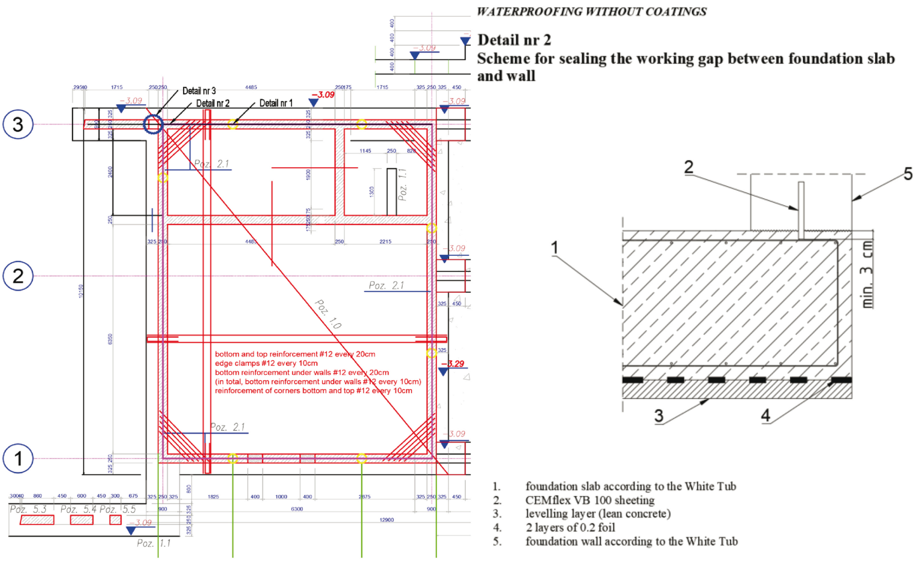

Fig. 4. Plan of foundation slab with location of WCS sealing products and detail of executed joint between slab and wall, own elaboration

5.2. Variants of solutions for WCS

Due to the differences in the applied solutions resulting mainly from the use of elements in the WCS at the slab-wall junction, the following variants were adopted for analysis.

The system based on “rubber” connections is burdened with high labour-intensity of assembly of elements at the slab-wall connection because the required depth of assembly of the rubber tape in the concrete is larger than the cover on the upper reinforcement mesh of the foundation slab. This results in the need for a so-called “lift” to achieve the required level of anchorage of the rubber strip in the concrete. Lifting is achieved by installing supporting materials, e.g. perforated trapezoidal sheeting or flexible steel wire mesh as shown in Fig. 5, Fig. 6, which are used as lost elements. These elements are installed between the reinforcement grids of the vertical elements and filled with concrete mix. A rubber strip is installed into the resulting linear element and stabilised with clips to the reinforcement bars of the vertical element. The variety of rubber bands depends on the offer of a given manufacturer, and its selection is often determined by the predicted hydrostatic pressure at the site of the project. This system requires face welding of the rubber tapes to continue the assembly.

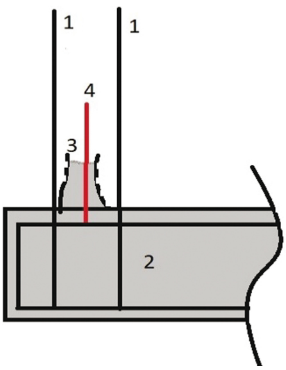

Fig. 5. Scheme of the lifting assembly for the rubber strip. 1 – reinforcement bars, 2 – reinforced concrete slab, 3 – mounting lift obtained with flexible steel mesh and filled with concrete, 4 – rubber tape (WCS sealing element), own elaboration

Fig. 6. System based on “rubber” joints (authors’ archive)

The “metal sheet” system is characterized by the small level of anchorage required in the concrete. In most cases the basic cover provided in the foundation slab is sufficient. There are extreme opinions on the effectiveness of such sheet anchoring among contractors, with opponents questioning the anchoring of the sheet to a depth of only 2 cm or 3 cm. On the other hand, the proponents confirm the effectiveness of the solution by, among other things, presenting successfully secured realizations carried out in this way. Depending on the type of sheet metal sheets, the assembly consists in placing the sheet on the upper reinforcement of the foundation slab and stabilizing it with clips to the reinforcement of the vertical element. There is no need to weld sheet metal strips, the connection of subsequent pieces of sheet is realized through a sufficiently large overlap additionally fastened with clips and clamps depending on the manufacturer. It should also be mentioned that the sheets may be raw or covered with various coatings, e.g., bentonite.

The system based on injection hoses is mainly associated with repair works where it is necessary to obtain tightness in the absence of rubber or sheet metal elements in the working breaks or as an additional protection to systems 1 and 2 in sensitive areas where there is a danger of leakage despite the use of other solutions. However, it is a system of elements that can be used as a stand-alone solution to achieve airtightness of technological breaks. Ensuring the watertightness of partitions with injection hoses consists in performing the sealing after the concrete has reached full strength. The injection hoses are installed mechanically by using brackets at the point of the planned technological break. Once the individual elements have been completed and have reached the design strength, injecting substances (e.g., epoxy resin, etc.) are injected under pressure into the hoses to seal any gaps, discontinuities and defects inside the technological break.

5.3. Selection of assessment criteria

Due to the necessary very high technological regime during the execution of the WCS technology, the authors propose that the criteria should be selected based on possible execution errors, which in the case of this technology occur very often. Therefore, from own experience and conducted expert interviews (among cooperating contractors) the criteria resulting directly from the execution of WCS have been indicated.

The following criteria have been identified as important during implementation Table 1.

The above-mentioned criteria were evaluated for significance using a pair-wise algorithm. The most important criterion was the cost of execution (K1) with a weight of 0.15, closely followed by criteria K5 (availability of system components) and K12 (positive experience of using the solution in previous projects) with a weight of 0.13. The least important criterion was K6, which is related to the requirement of time of assembly before concreting.

6. Calculation results and their discussion

Partial calculations and results obtained in the multi-criteria analysis carried out with the following methods: synthetic indicators, AHP and PROMETHEE II are presented below.

In the synthetic indicator method, the first step is to encode the titled values to the unchanged values, which are summarized in the following Table 2.

Second method used in proposal analysis was AHP. Calculations for the second level is shown in Table 3.

And the third level (Table 4).

Finally, we obtain the overall priority (Table 5).

Table 2. Values coded by using the method of normalization and the adjusted indexes

	System based on "rubber" joints	System based on "metal sheets"	System based on injection hose
K1	4.00	2.00	1.00
K2	1.67	5.00	1.00
K3	2.00	4.00	1.00
K4	1.25	2.50	1.00
K5	0.75	0.75	1.00
K6	1.00	1.00	2.00
K7	1.00	1.00	0.25
K8	1.33	2.00	1.00
K9	1.33	1.00	4.00
K10	1.00	1.50	1.00
K11	1.67	5.00	1.00
K12	1.00	0.75	0.25
Adjusted summation index	1.6505	**2.0896**	1.1642
Adjusted multiplicative index	0.000001140	**0.000025979**	0.000000015
Adjusted additive index	0.1834	**0.2322**	0.1294
Weighted harmonic mean	1.2750	**1.3427**	0.6872
Weighted geometric mean	1.4235	**1.6505**	0.9017

In the PROMETHEE II for each pair of decision variants x and y is calculated aggregated indexes of preferences:

(6.1)
$$\Pi(x,y) = \sum_{j=1}^{k} w_j P_j(x,y)$$

(6.2)
$$\Pi(y,x) = \sum_{j=1}^{k} w_j P_j(y,x)$$

Next, for each variant of the decision-making are calculated positive and negative flow preferences (6.1) and (6.2).

(6.3)
$$\Phi^{+}(x) = \frac{1}{n-1} \sum_{y \in A} \Pi(x,y)$$

(6.4)
$$\Phi^{-}(x) = \frac{1}{n-1} \sum_{y \in A} \Pi(y,x)$$

The final stage is to calculate net flows for each of the considered variants by using equations (6.3) and (6.4) (Table 6).

Table 3. Calculation of eigenvectors for second level in AHP method

No.	Criterion	Vector w_i
K1	Cost of execution	0.15
K2	Assembly time	0.10
K3	Supply logistics	0.07
K4	Complexity of assembly	0.08
K5	Availability of system components	0.12
K6	Requirement of assembly time of elements before concreting	0.04
K7	Possibility of using recycled materials for the production of components	0.04
K8	Requirement for qualifications of workers during assembly of the system	0.06
K9	Reactivity of the component	0.11
K10	Environmental impact during production of the product	0.04
K11	Necessity of using specialist equipment during assembly	0.07
K12	Positive experiences from previous projects	0.11
	λ_{max}	13.68
	C.I.	0.15
	C.R.	**0.10**

Table 4. Calculation of eigenvectors for second level in AHP method

No.	W1	W2	W3	λ_{max}	C.I.	C.R.
K1	0.56	0.32024	0.123	3 1/43	0.01	0.02
K2	0.28	0.61935	0.096	3 5/41	0.06	0.11
K3	0.28	0.60258	0.114	3 1/18	0.03	0.05
K4	0.19	0.72351	0.083	3 1/9	0.06	0.10
K5	0.2	0.2	0.6	3	0.00	0.00
K6	0.2	0.2	0.6	3	0.00	0.00
K7	0.13	0.125	0.75	3	0.00	0.00
K8	0.26	0.63335	0.106	3 1/18	0.03	0.05
K9	0.17	0.10333	0.723	3 4/81	0.02	0.04
K10	0.2	0.6	0.2	3	0.00	0.00
K11	0.23	0.69653	0.072	3 3/31	0.05	0.08
K12	0.7	0.23161	0.072	3 7/89	0.04	0.07

Table 5. Overall priority for AHP method

No.	Variant	
1	system based on "rubber" joints	0.32
2	system based on "metal sheets"	0.40
3	system based on injection hose	0.28

Table 6. Positive and negative flow preferences and net flows for each variants

Variant	System based on "rubber" joints	System based on "metal sheets"	System based on injection hose
Positive flow	0.19	0.28	0.08
Negative flow	0.10	0.10	0.40
NET FLOW	0.09	0.20	–0.30

The ranking obtained for each method was the same, classifying W2, the sheet metal system, in first place, W1, the system based on rubber joints, in second place, thus placing W3, the system based on injection hoses, in last place. The high score obtained by the W2 system was influenced by the fact that as many as seven out of twelve criteria were evaluated in the highest score, i.e. (*K2 – Assembly time, K3 – Supply logistics, K4 – Complexity of assembly, K7 – Possibility of using recycled materials for production of components, K8 – Requirement for employees' qualifications, K10 – Environmental impact during production of the product, K11 – Necessity of using specialist equipment during assembly*). It is interesting to note that W2 – system based on "metal sheets" did not rank first in the assessment due to the criteria of highest weight. However, due to a number of criteria related to the simplicity of its implementation, and thus an easier possibility to maintain the technological regime, it finally took the first place among the considered variants.

The presented analysis has shown that it is worth conducting a comparative analysis of systems for the implementation of WCS technology at the design stage. The contractor executing the selected construction project could, thanks to a small outlay at the planning stage, schedule the WCS implementation with higher security of its appropriate execution, and thus in the long-term achieve savings. In the object presented in the article, the proposed methodology was used and finally a "white tub" was decided and executed using the products presented in the system based on "metal sheets".

7. Conclusions

The building market offers a wide range of products for the waterproofing of building structures. Ultimately, however, the standard of the individual products offered for sealing the building envelope is basically the same. However, three systems can be distinguished among the proposed solutions, the differences of which are mainly due to the use of elements in the WCS at the slab-wall junction, among which the system based on rubbers, on metal sheets and on injection hoses. These are the options that have been analysed.

The criteria considered in the assessment and analysed variants provide a universal set that can be successfully applied to most buildings during the decision-making process for the selection of appropriate solutions to ensure the watertightness in difficult ground conditions. Carrying out the calculations using the proposed methodology can be a practical tool to assist both the investor and the contractor in selecting the sealing system during the implementation of the WCS in the facility. The criteria proposed in the methodology and, in relation to the specific conditions of the project, the choice of their weights can help in making the right decision concerning the selection of appropriate products for the implementation of the WCS. This will enable better consideration to be given to the specific realization conditions of the building and will reduce the risk of errors associated with the difficulty of fulfilling the technological regime required during the execution of elements in watertight concrete technology.

This paper evaluates multi-criteria selection of a "white tub" technology system in a basement building where waterproofing was required. The criteria related to the implementation aspect of the watertight concrete technology that were considered in the assessment were established based on expert questionnaires, while the weights themselves are proposed to be determined each time taking into account the opinions of the participants of the investment process, in the case study presented: the site manager and the investor. By establishing the importance of each criterion with people directly involved in the project, it is possible to find the most advantageous solution under the given conditions, which will have an impact on the quality of the works carried out and the satisfaction of the investor.

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Dobór technologii „białej wanny" do zabezpieczenia części podziemnych konstrukcji z wykorzystaniem analizy wielokryterialnej – studium przypadku

Słowa kluczowe: budynki, „biała wanna", analiza wielokryterialna, część podziemna obiektu, technologia betonu wodoszczelnego

Streszczenie:

Obecnie coraz więcej inwestycji realizowanych jest na obszarach o trudnych warunkach gruntowych, na których dodatkowo może występować wysoki poziom wód gruntowych. W związku z tym niezbędnym jest stosowanie technologii zapewniających bezpieczeństwo budynku w fazie jego eksploatacji poprzez m.in. zapewnienie odpowiedniej szczelności jego podziemnej części. W artykule skoncentrowano się na przedstawieniu zastosowania technologii betonu wodoszczelnego (TBW) zwanego również technologią „białej wanny", która stanowi skuteczny sposób zabezpieczenia części podziemnej budynku przed niszczącym w skutkach działaniem wody. Celem artykułu jest zestawienie i analiza wybranych sposobów zabezpieczania części podziemnych budowanych budynków stosując technologię „białej wanny". W artykule autorzy dokonują analizy i wyboru właściwych rozwiązań z wykorzystaniem analizy wielokryterialnej. Prezentowana metoda zostanie przedstawiona na wybranym przykładzie.

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