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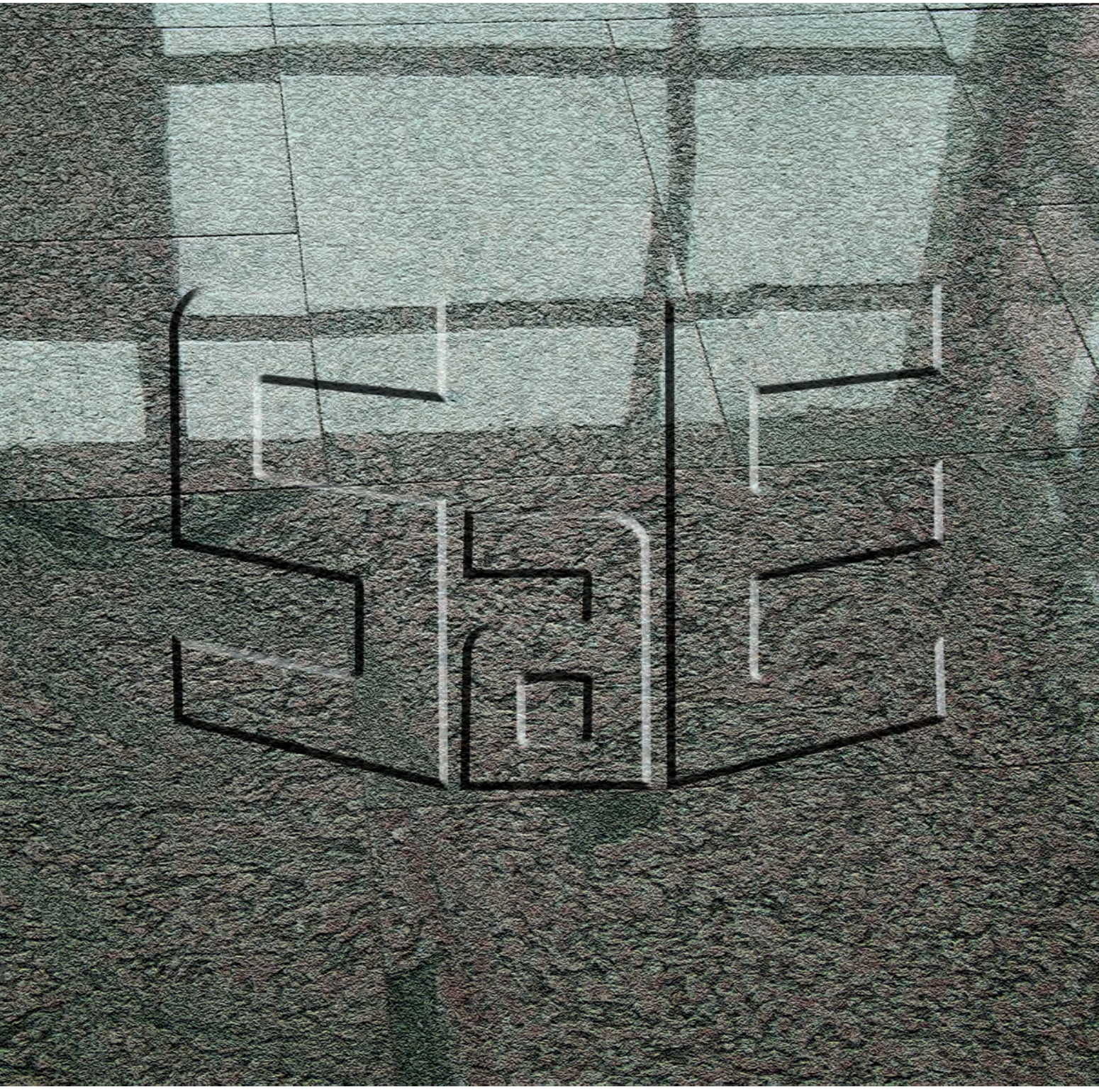

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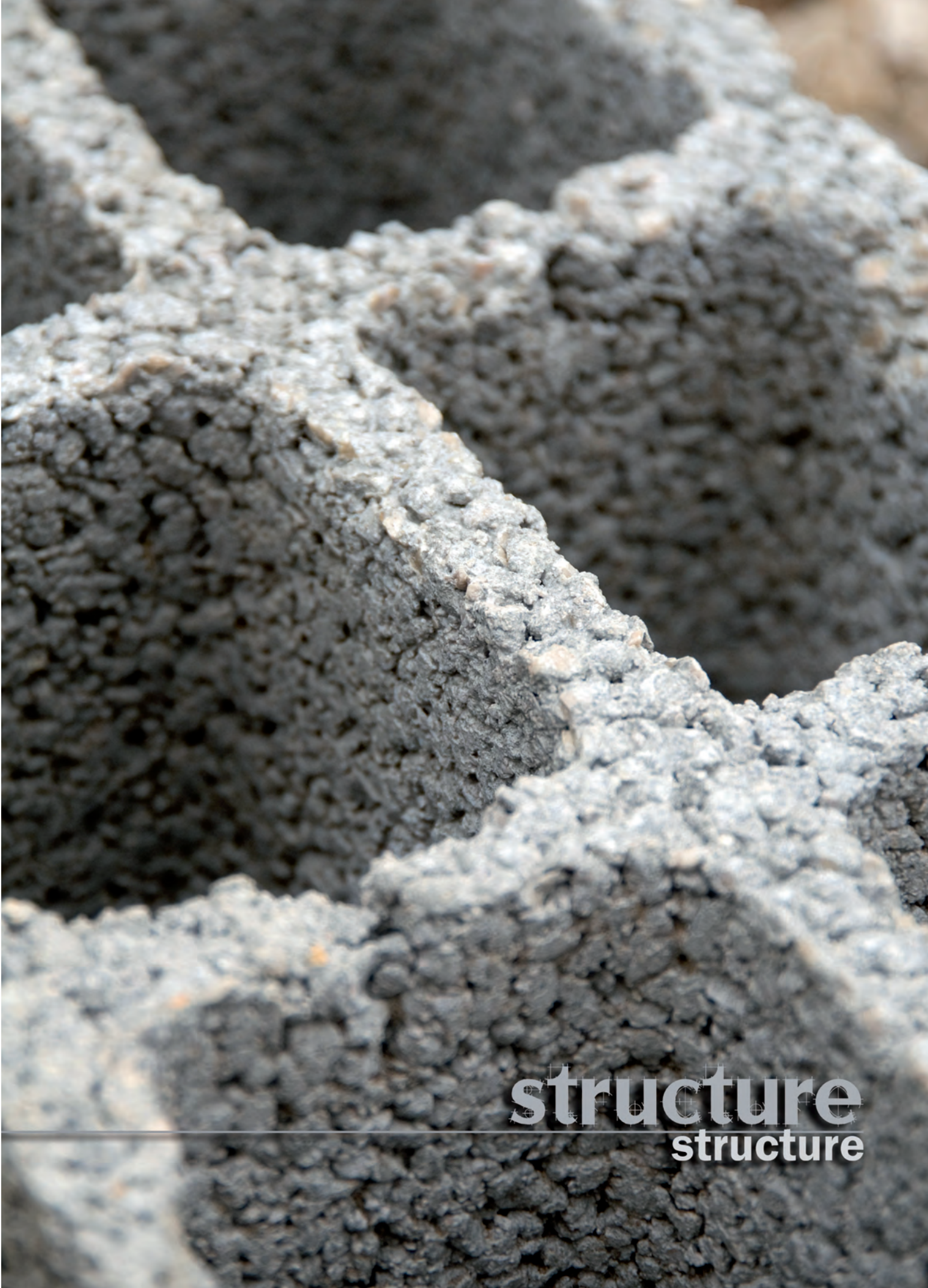

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INFLUENCE OF LIGHTWEIGHT FILLERS ON THE PERFORMANCE OF CEMENT-BASED SKIM COAT

WPŁYW LEKKICH WYPEŁNIACZY NA PARAMETRY UŻYTKOWE GŁADZI CEMENTOWEJ

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Abstract

Lightweight fillers are used in dry-mixed building mortars in order to improve thermal insulation properties, yield, and workability. In the case of thin layer products, used as a finishing layer, reduced thermal conductivity coefficient enables to restrain of water vapor condensation on walls – which inhibits mold growth. The aim of the study was to determine the influence of 4 types of lightweight fillers on the performance of cement-based skim coat – with emphasis on the economic aspect. Formulas reflecting typical commercial products were used. The dosage of different components -such as expanded perlite, glass and polymeric bubbles or expanded glass – was optimized for sufficient yield and workability, keeping the constant price of 1 kg of the final product. Mechanical parameters, capillary absorption coefficient, and thermal conductivity coefficient were determined. Observations by Scanning Electron Microscope revealed poor incorporation of polymer microspheres in the cement matrix, leading to loss of mechanical strength. With the addition of expanded glass, an increase of flexural and compressive strength thanks to the pozzolanic reaction was observed. Glass bubbles were found the most effective additive.

Keywords: lightweight fillers, perlite, microspheres, expanded glass

Streszczenie

Stosowanie lekkich wypełniaczy w suchym mieszankach chemii budowlanej pozwala na poprawę termoizolacyjności, wydajności oraz właściwości roboczych zapraw. W przypadku cienkowarstwowych wyrobów wykończeniowych obniżony współczynnik przewodzenia ciepła hamuje kondensację pary wodnej na ścianach wewnętrznych, redukując powstawanie pleśni. Celem przeprowadzonych badań było określenie wpływu czterech rodzajów lekkich wypełniaczy na właściwości gładzi cementowej, ze szczególnym uwzględnieniem aspektu ekonomicznego. Sporządzono receptury odzwierciedlające skład typowych komercyjnych produktów. Dozowanie poszczególnych dodatków: perlitu ekspandowanego, kulek szklanych i polimerowych oraz spienionego szkła, zoptymalizowano pod kątem odpowiedniej wydajności oraz konsystencji, zachowując przy tym stałą cenę 1 kg ostatecznego wyrobu. Dokonano pomiarów właściwości mechanicznych, absorpcji kapilarnej oraz współczynnika przewodzenia ciepła. Obserwacje pod skaningowym mikroskopem elektronowym pozwoliły wykazać niską przyczepność mikrosfer polimerowych do matrycy cementowej prowadzącą do pogorszenia wytrzymałości. Przy dodatku granulowanego spienionego szkła zaobserwowano wzrost wytrzymałości na zginanie i ściskanie na skutek reakcji pucolanowej. Za najkorzystniejszy uznano dodatek kulek szklanych.

Słowa kluczowe: lekkie wypełniacze, perlit, mikrosfery, ekspandowane szkło

1. INTRODUCTION

The too high humidity of interiors caused by non-efficient ventilation has become an important topic, especially for multi-family housing. Excess of water vapor tends to condense on walls, creating conditions for the growth of fungi, negatively influencing humans' health [1].

Such an effect can be reduced by using of anti-condensation layers – the most popular are paints and coatings. Their action can be based on two different mechanisms: absorption and storage of water vapor and increased thermal insulation properties, where the last one generally plays a bigger role [2].

The addition of lightweight fillers to the material allows for the reduction of the thermal conductivity coefficient [2-4]. Wang et al. [4] confirm also the possibility to improve anti-condensation properties, by showing the correlation between the increase of expanded perlite content and reduction of water vapor condensation for coatings of layer thickness between 1 mm to 2.5 mm. Moreover, the usage of lightweight fillers in mortars introduces a wide range of benefits. Namely: the higher yield (understood as increased covering capacity calculated per square meter) and reduced bulk density. This property enables producers to increase the price for 1 kg of finished product keeping the constant price for one bag – thanks to reduced mass in the packaging. Addition of lightweight fillers often improves application properties of product – such as easiness of application by the craftsmen, coming from reduced density, viscosity and higher aeration [5].

Such as higher yield and improved workability. Lowered bulk density allows for weight reduction in the bag of the final product.

Typically used lightweight fillers can be natural (expanded: perlite, vermiculite), synthetic (polymer or glass microspheres) or waste origin (expanded glass powder or aluminosilicate cenospheres obtained as the lightest fraction of ashes from coal burning). Their mutual feature is low density – below 1200 kg/m^3 [6] – as a result of high internal porosity. However, they can vary in shape, microstructure, and pozzolanic activity [7].

One very common and widely disputed in the literature [8, 9] lightweight fillers is perlite – volcanic rock which, after excavation, was milled and made to expand – at the high-temperature process of swallowing caused by an expansion of water entrapped inside the rock. The obtained material is basically low-density aluminosilicate glass containing small amounts of sodium, potassium, iron, calcium, and magnesium. It is characterized by open pore system. Lanzon et al. [5] proves this could lead to significant increase of water absorptivity of mortars. Absorption of water after 30 min of cement-based render with 1.18% and 3.54% addition of perlite was increased from 3.01% mass to, respectively, 6.11% and 23.65% mass.

Such disadvantage is not the case for synthetic microspheres – glass or polymer based [10]. Polymer microspheres are made in water suspension. The organic phase is a mixture of monomers with a blowing agent. Thanks to the addition of surfactants and stabilizers, the suspension is kept in the form of droplets. Heating up the system initiates the polymerization process inside the droplet with simultaneous expansion of gas coming from the decomposition of the blowing agent. As the polymer formed is insoluble in any of the present phases it precipitates at the border between the organic phase and water, creating the shell of the microsphere [11].

Glass microspheres are most typically produced in a constant process of feeding pre-treated portions of the mixture of glass powder and blowing agent to the flame of a gas burner. In the flame, by the action of high temperature (> 1000°C depending on glass used), the blowing agent decomposes with the creation of expanding gas. At the same time, glass starts to melt and spheroidize spontaneously because of surface tension. After leaving the flame rapid cooling occurs and the hard shell of hollow grain is formed [12].

In both cases, product obtained is characterized by favourable spherical shape with smooth shells and closed porosity [11, 12]. Brooks et al. [13] provides comprehensive comparison of light cement-based mortars with density in the range of 1300-2084 kg/m^3 and W/C = 0.43 with addition of polymer and ceramic microspheres in various dosages. As the authors indicate, the addition of polymer microspheres in the amount of 28.5% by volume, allowed for decreasing thermal conductivity coefficient from 2.23 W/(m·K) to 0.69 W/(m·K) – but the compressive strength was decreased from 49.71 MPa to 12.68 MPa. The addition of the same amount of glass microspheres allowed for achieving similar thermal conductivity coefficient (0.70 W/(m·K)), with conserving the mechanical strength of 48.50 MPa. The authors notice the importance of quality of incorporation of fillers into the cement matrix.

Type of porosity (open or closed) as well as chemical reactivity (or lack thereof) of lightweight

fillers relative to the cement matrix, shapes the final properties of the material to a great extent [7]. In the presented study, the influence different lightweight fillers on mechanical parameters, thermal conductivity and water absorptivity of cement-based skim coat, was compared.

2. MATERIALS AND METHODS

4 different types of lightweight fillers of different origin and production processes were examined. Expanded perlite with grains covered by a hydrophobic agent in order to reduce water absorption was used, as well as glass and polymer microspheres, and granulated expanded glass – waste material obtained by recycling of consumer glass (mainly soda-lime). Milled bottles powder was expanded in a similar way as perlite, resulting in low density.

All the lightweight fillers used are commercially available as raw materials to formulate construction mortars. Details of production process are the secrets of manufacturers. Physicochemical characteristics of materials is presented in Table 2. Information regarding composition are based on material datasheets. Grain size distribution of fillers was tested by laser diffractometry with Helos KR apparatus. Measurements were made in the air stream. A comparison of grain size distribution is presented in Figure 1. Bulk density of fillers, as well as of dry mixes obtained was measured according to EN 1097-3:2000.

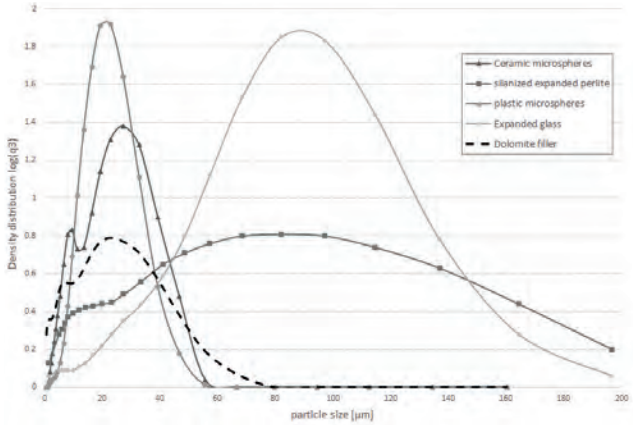

Fig. 1. Grain size distribution of light fillers used

The matrix was the skim coat made of white portland cement CEM I 52.5 R with the addition of hydrated lime and redispersible polymer powder (based on vinyl acetate). Fillers were limestone and dolomite flours with grain sizes between 0-100 µm.

Table 1. Formulas

Composition [%]	Z1	Z2	Z3	Z4	Z5
White CEM I 52.5R	20.0	20.0	20.0	20.0	20.0
Dolomite	38.0	35.0	33.0	37.5	35.0
Calcium Carbonate	39.0	39.0	39.0	39.0	39.0
Hydrated Lime	1.0	1.0	1.0	1.0	1.0
Organic compounds	2.0	2.0	2.0	2.0	2.0
Silanized expanded perlite		3.0			
Expanded glass			5.0		
Glass microspheres				3.0	
Plastic microspheres					0.5
Water demand [%]	39.0	40.0	38.0	40.0	43.0
W/C ratio [-]	1.95	2.00	1.90	2.00	2.15
Bulk density [g/dm^3]	0.89	0.79	0.83	0.80	0.69

Table 2. Properties of lightweight fillers used

Lightfiller	Material	Particle size [µm]			Density [kg/m^3]
		D_{10}	D_{50}	D_{90}	
Silanized expanded perlite	Aluminium-silicate (Silicon coated)	12.07	52.13	117.12	150
Expanded glass	Soda-lime consumer glass	5.59	68.18	119.02	600
Glass microspheres	Soda-lime borosilicate glass	4.81	17.31	33.53	220
Plastic microspheres	Thermoplastic copolymer	9.08	18.96	34.83	25

Lightweight fillers were always added at the expense of dolomite flour – by mass. Amounts of additives were adjusted considering the economic aspect. Always a constant price of 1 kg of final product was kept.

In order to optimize workability parameters, a combination of rheology modifiers based on cellulose and starch ethers were used in constant dosage. Possible differences in the water demand of mortars, caused by addition of lightweight fillers, were not corrected with admixtures. It was assumed it would be too much interference in workability (plasticity, easiness of application); moreover, even small addition of cellulose or starch ether would have far more influence on hydration of cement than small change in W/C ratio [7]. The water amount was adjusted to normative consistency according to PN-EN 1015-3:2003 "Methods of test for mortar for masonry" so that the flow of 16.5 cm was achieved at the flow table. Detailed formulas of mortars are presented in Table 1.

Compressive and flexural strength were determined at 4x4x16 cm prisms according to the norm: PN-EN 1015-11:2001 with a hydraulic press. Remains from the internal part of prisms after strength tests (after 28 days of hydration) were covered with gold and observed by Scanning Electron Microscope SEM FER QUANTA 250 FEG with EDS EDAX microprobe.

Capillary absorption was determined according to PN-EN 1015-18:2003 "Mortar for masonry – determination of water absorption coefficient due to capillary action of hardened mortar". Additionally, according to the same norm, water absorption was measured after 15, 30, 120, 240 min – as the mass gain in grams, caused by capillary absorption. The samples were prepared the same way as for strength tests. The thermal conductivity coefficient was determined by a stationary method with the Bock apparatus: Stiro Lab LM.305 EPS.

3. RESULTS AND DISCUSSION

3.1. Silanized Perlite

Silanized expanded perlite shows the widest grain size distribution besides all tested fillers (Fig. 1). The volume share of an individual fraction is homogenous in all particle size range (0-200 µm). Single grains show significant open porosity which can be observed by Scanning Electron Microscope (Fig. 2). Despite this fact, the addition of 3% of expanded perlite to mortar Z2 did not result in significant water demand increase comparing to the control (Z1) (Table 1). This is thanks to effective silanization, which decreased water absorptivity of perlite and allowed for limiting the negative impact of open porosity on the consistency and workability of the skim coat.

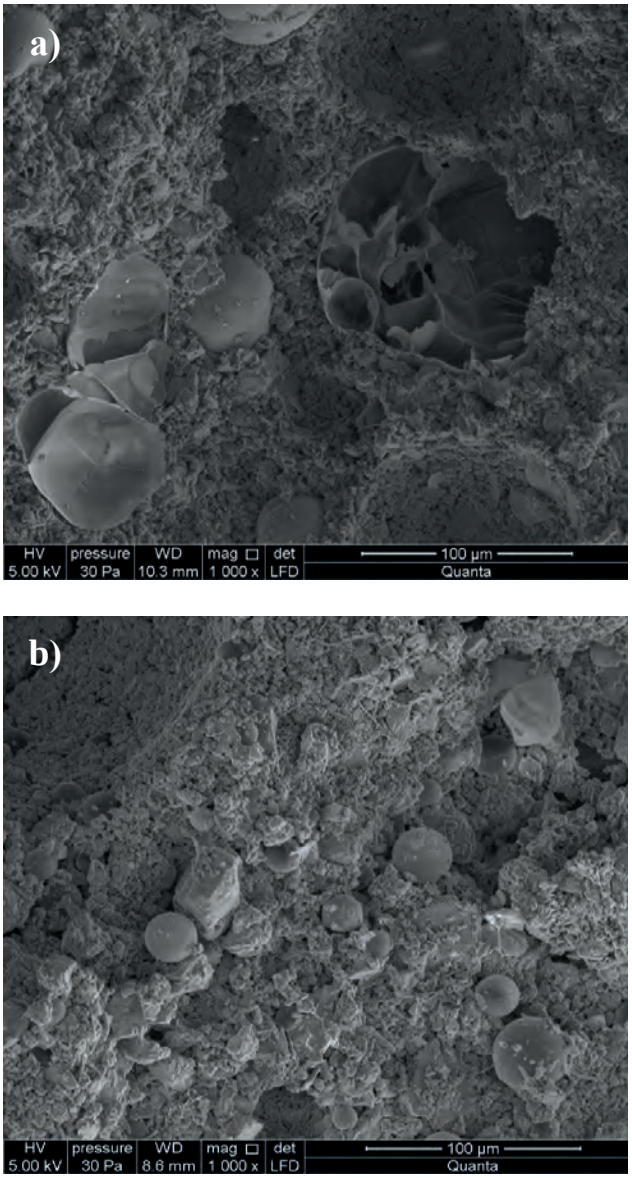

Fig. 2. Microstructure of chosen samples after 28 days of hydration: a) Z2 – cracked perlite grains well incorporated into cement matrix; b) Z5 – bad incorporation of polymer microspheres into mineral matrix

With the addition of perlite, the decrease of compressive strength (-8.6%) and an increase of flexural strength (+7.7%) was observed, which is consistent with results presented in [14]. Thermal insulating properties and capillary absorption of mortar Z2 were not significantly changed when compared to control (Z1). Details are presented in Figure 4. Although slight decrease in thermal conductivity coefficient and also

slight increase in capillary absorption were observed – which may suggest increase in porosity of sample, however, this effect can be equally attributed to the presence of lightweight filler as well as to increase of water/cement ratio – from 1.95 for control sample Z1 to 2.0 for Z2.

Scanning electron microscope observations were conducted after 28 days of hydration. As showed in Figure 2a, single particles of perlite are well incorporated into the cement matrix. Calcium Silicate Hydrates (C-S-H phase) built around the filler densely packed outer layer, with no interface border visible, created as a result of pozzolanic reaction [15, 16].

3.2. Expanded glass

The grain size distribution of expanded glass is comparable to silanized perlite but in a slightly narrower range of particle size – between 0.4 µm to 125 µm. Singular grains have irregular shapes and characteristic microporosity as a result of the production process by foaming and milling. An addition of 5% (the highest of all tested materials) gave water demand a decrease of mortar Z3 from 39% to 38%. The reason is that lightweight filler, in this case, has coarser particles than dolomite flour which was replaced. It also proves low water absorption of expanded glass (in comparison with expanded perlite).

The compressive strength of mortar Z3 is over 30% higher than the control. At the same time, capillary absorption coefficient decrease – from 0.87 $kg/m^2 \cdot min^{0.5}$ to 0.66 $kg/m^2 \cdot min^{0.5}$ and thermal conductivity coefficient increase – from 0.33 W/mK to 0.36 W/mK were observed. All obtained results indicate a decrease in porosity of hardened mortar comparing to the control sample, the most probably as a result of a pozzolanic reaction of expanded glass with calcium hydroxide formed during binder setting and hardening [17].

Some papers on alkali activation of milled waste from packaging glass can be found in the literature [18, 19]. Such material shows high pozzolanic activity because of 100% of reactive glass phase content. Moreover, consumer glass can be characterized with a high content of alkaline oxides od sodium and potassium, acting as activators of reaction with portlandite – a product of cement hydration [20]. In this case also the reaction with hydrated lime added to the skim coat in the amount of 1% may occur.

The presented study shows that granulated expanded glass is lightweight filler with unique properties. Despite decreasing the bulk density of final product (6.7% – Table 1), after 28 days of hydration, more densely packed microstructure was obtained – as the effect of pozzolanic reaction. The improvement of mechanical parameters occurred, and capillary absorption coefficient was decreased. However, thermal conductivity coefficient was increased which negatively impacts anti-condensation properties.

3.3. Glass microspheres

The addition of glass microspheres in the amount of 3% caused a slight increase in water demand of skim coat (from 39.5% to 40%), an increase in flexural strength of 7.7% and a decrease of compressive strength of 9.9%. Obtained results are almost identical as in case of silanized perlite. Considering chemical composition, also in this case, the pozzolanic reaction of filler and cement matrix can be expected, which results in an increase of flexural strength.

The main difference between these two lightweight fillers is particle size. Glass microspheres have significantly lower grains, in the range of 0-60 µm with two clearly visible maximal values at 10 µm and 30 µm (Fig. 1). Further differences can be observed with a scanning electron microscope – contrary to perlite, singular microspheres have very regular shapes and show no visible porosity. This may result in lower water absorption, which could explain a lack of differences in water demand of the final formula with the same addition of perlite and glass microspheres, despite much finer grains of glass microspheres.

Air bubbles entrained to the mortar inside the hollow glass microspheres allowed for decreasing the thermal conductivity coefficient of mortar Z4 of as much as 15% when compared with the control sample, and almost 10% in comparison to the mortar with perlite. At the same time, the mortar was aerated with the air kept inside glassy shells, which prevented an increase of capillary porosity and a decrease of capillary absorption coefficient was observed – in comparison to control mortar. This is the only case from all tested lightweight fillers which by addition improved both: thermal insulation properties and resistance water uptake driven by capillary forces.

3.4. Polymer microspheres

Polymer microspheres were of the finest grain size from all fillers tested. They also have the highest impact on the consistency of the skim coat. With the addition of only 0.5%, the increase in water demand from 38% to 43% was observed. For the sample Z5

containing this filler, there was also found the highest mechanical strength decrease (of about 30%). Finally, the highest capillary absorption was observed (Fig. 3). This is the result of higher water to cement ratio – 2.15 in comparison to 1.9 for control. Moreover, because of chemical composition (thermoplastic copolymer), there is no pozzolanic activity of the filler. Therefore, no reaction with the cement matrix occurs and there is no possibility to compensate for increased porosity of hardened mortar, as it was in the case of other tested fillers.

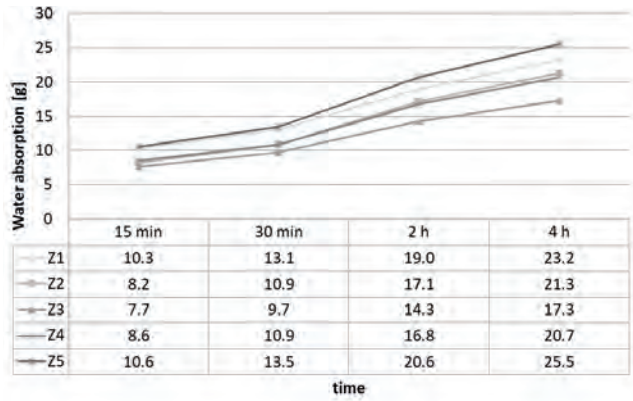

Fig. 3. Water uptake over time and capilary absorption coefficient (C) vs Thermal conductivity coefficient (λ)

Microstructure observations by SEM confirm the poor incorporation of this filler into the mineral matrix. Singular microspheres are not tightly surrounded with the C-S-H phase and the contact zone is not as tightly packed as in the case of glass microspheres. With magnification of 1000x, the border between the matrix and the filler can be easily observed (Fig. 2b).

The addition of polymer microspheres gave a significant improvement in thermal insulative properties. A 23% decrease in the thermal conductivity coefficient was observed. This indicates such filler can be used as a component to formulate mortars with anti-condensation properties. Unfortunately, because of chemical incompatibility with the cement matrix, a significant decrease of other parameters was found. Better effect can be achieved by adding polymer microspheres to products based on organic binders [21].

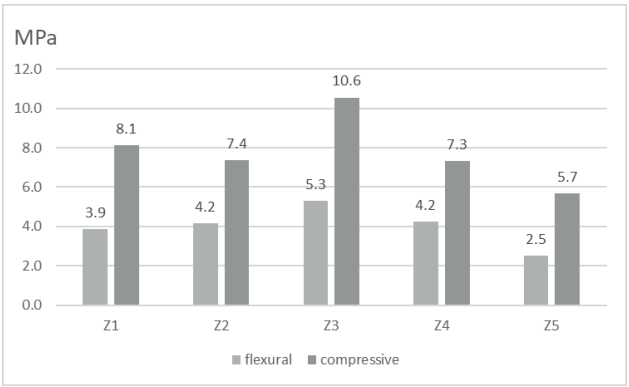

Fig. 4. Mechanical strength of the samples

4. CONCLUSIONS

In the present study, the impact of 4 different types of lightweight fillers on the performance of the cement-based skim coat was determined. The economical aspect was considered. The strong link between microstructure together with the composition of additive and mechanical strength was shown. Final products of different profiles were obtained.

The addition of expanded perlite and glass microspheres in the amount of 3% gives a similar effect. In both cases, flexural strength is increased. Glass microspheres have a more favorable impact on thermal insulative properties and allow for the reduction of capillary absorption. Factor influencing negatively on final properties of mortars containing perlite is its open porosity resulting in relatively high water absorptivity – despite the silanization.

Granulated expanded glass is very attractive filler from the point of view of construction mortars producer. Addition of 5% allowed for decreasing of bulk density of mortar with no increase of water demand. Better application properties and increased coverage capacity can be expected. At the same time, after 28 days of hydration (as the result of pozzolanic reaction), mechanical strength and resistance to capillary water absorption was improved. It is common that addition of lightweight fillers causes reduction of mechanical parameters. Disadvantages of granulated expanded glass is: relatively high bulk density (in relation to other lightweight fillers used in this study) and increase of thermal conductivity of final product.

This is not the material suitable to formulate anti-condensation coatings based on Portland cement.

The lowest thermal conductivity coefficient and bulk density was achieved by the addition of polymeric microspheres. However, because of the increase of water demand and poor incorporation of filler into the cement matrix, a significant decrease in mechanical parameters of the skim coat was observed. Nevertheless, the big potential of this filler as an additive supporting anti-condensation properties was observed – but further optimization of formula is necessary in order to improve mechanical parameters.

REFERENCES

[1] Yu B.F., Hu Z.B., Liu M., Yang H.L., Kong Q.X., Liu Y.H.: *Review of research on air-conditioning systems and indoor air quality control for human health*, International Journal of Refrigeration, 32 (2009), pp. 3-20.
[2] Ruckebusch J.M.: *The use of 3M™ Glass Bubbles to increase time until condensation forms on painted surfaces*; Supplier technical report (2011).
[3] Rashad A.M.: *A synopsis about perlite as building material – a best practice guide for civil engineer*. Constr. Build. Mat. 121 (2016), pp. 338-353,
[4] Wang G., Chen D., Lu L. et al.: *A novel anti-condensation coating*. Journal of Coatings Technology (1998) 70: 55.
[5] Lanzón M., Garcia-Ruiz P.A.: *Lightweight cement mortars: Advantages and inconveniences of expanded perlite and its influence on fresh and hardened state and durability*. Construction and Building Materials 22 (2008), pp. 1798-1780.
[6] EN 13055-1:2002, *Lightweight aggregates — Part 1: Lightweight aggregates for concrete, mortar and grout.*
[7] Li Z. (2011): *Advanced concrete technology*, New York, NY:Wiley.
[8] Demirboga R., Orung I., Gul R.: *Effects of expanded perlite aggregate and mineral admixtures on the compressive strength of low-density concretes*. Cement and Concrete Research, 31(11), pp. 1627-1632. doi: 10.1016/S0008-8846(01)00615-9.
[9] Kramar D., Bindiganavile V.: *Mechanical properties and size effects in lightweight mortars containing expanded perlite aggregate*. Materials and Structures, 44(4), pp. 735-748, doi:10.1617/s11527-010-9662-0.
[10] Asad H., Zeyu L., Yu Ch., Su D., Zongjin L.: *Effects of Different Lightweight Functional Fillers for Use in Cementitious Composites*. International Journal of Concrete Structures and Materials, Vol. 11, No. 1, March 2017.
[11] Gardfors T.: *Synthesis and Evaluation of Expancel® Microspheres*. Degree Project in Engineering Chemistry, Umeå University (2013).
[12] May Yan Lee et al.: *A Comparative Study of Production of Glass Microspheres by using Thermal Process*, IOP Conf. Ser.: Mater. Sci. Eng. 205 (2017) 012022.
[13] Brooks A.L.: *Comparative study of the mechanical and thermal properties of lightweight cementitious composites* et al.: Construction and Building Materials 159 (2018), pp. 316-328.
[14] Nocuń-Wczelik W., Nowak M., Trybalska B.: *Transport wody w zaprawach z dodatkiem perlitu ekspandowanego modyfikowanych domieszkami* (Transport of water in the mortars with perlite addition modified by admixtures). PTcer (Ceramic Materials), IX Konferencja i Zjazd Polskiego Towarzystwa Ceramicznego, Zakopane, 19-22 IX 2013.
[15] Nocuń-Wczelik W., Nowak M., Kapeluszna E.: *Lightweight Mortars with expanded perlite modified by admixtures*. Structures & Environment 31/2 (2017), pp. 102-111.
[16] Kotwica Ł., Pichór W., Nocuń-Wczelik W.: *Study of pozzolanic action of ground waste expanded perlite by means of thermal methods.* Jour. Therm. Anal. Calor. 123/1 (2016), pp. 607-613, doi: 10.1007/s10973-015-4910-8.
[17] Lanzón Torres M., García-Ruiz P.A.: *Lightweight pozzolanic materials used in mortars: Evaluation of their influence on density, mechanical strength and water absorption*. Cem. & Concr. Comp. 31 (2009), pp. 114-119,
[18] Deja J., Gołek Ł., Kołodziej Ł.: *Application of glass cullet in binder production*. Cement, Wapno, Beton 16/6 (2011), pp. 349-354.
[19] Shao Y., Lefort T., Moras S., Rodriguez D.: *2000 Studies on concrete containing ground waste glass*. Cem. Conc. Res.; 30(1), pp. 91-100; 2000.
[20] Gołek Ł.: *Wpływ składu chemicznego szkieł glinokrzemianowych na proces ich alkalicznej aktywacji* – praca doktorska, AGH University of Science and Technology (2007).
[21] Wypych G.: *Handbook of fillers*, ChemTec Publishing (2016).

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EVALUATION OF SELECTED TECHNICAL PROPERTIES OF BITUMEN BINDERS MODIFIED WITH SBS COPOLYMER AND CRUMB RUBBER

OCENA WYBRANYCH WŁAŚCIWOŚCI TECHNICZNYCH LEPISZCZY ASFALTOWYCH MODYFIKOWANYCH KOPOLIMEREM SBS I MIAŁEM GUMOWYM

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Abstract

Good quality bitumen used in the production of bitumen-aggregate mixtures is a binder with high stiffness and elasticity at high operating temperatures occurring in summer and adequate flexibility during exposure to sub-zero temperatures. Currently, one of the best technological solutions to improve the viscoelasticity of bitumen and the resistance to ageing is their modification with various types of additives. The paper presents the results of penetration tests as a function of temperature, softening point (ring and ball method) and strain energy at various temperatures of road bitumen modified with SBS (styrene-butadiene-styrene) copolymer, crumb rubber and simultaneous bitumen modification with SBS copolymer and crumb rubber. The obtained results allowed to assess temperature sensitivity, resistance to changes in selected technical properties of the tested binders as a result of technological ageing process with RTFOT (Roler Thin Film Oven Tester) method and to evaluate changes in their technical properties in relation to the 50/70 base bitumen. Multivariate analysis of variance (MANOVA) was used to analyse the impact of the modification type on the test results of technical properties (significance of the impact of the considered factors on the level of technical properties).

Keywords: road bitumen, modified binders, viscoelasticity of bitumen, technological ageing process

Streszczenie

Dobrej jakości asfalty stosowane do produkcji mieszanek mineralno-asfaltowych to lepiszcza o dużej sztywności, a zarazem sprężystości w wysokich temperaturach eksploatacyjnych występujących latem oraz odpowiedniej elastyczności podczas oddziaływania temperatur ujemnych. Obecnie jednym z najlepszych rozwiązań technologicznych polepszającym właściwości lepkosprężyste asfaltów oraz polepszającym odporność na starzenie jest ich modyfikacja różnego rodzaju dodatkami. W artykule przedstawiono wyniki badań penetracji w funkcji temperatury, temperatury mięknienia PiK oraz energii odkształcenia w różnych temperaturach badania asfaltów drogowych modyfikowanych kopolimerem SBS (styren-butadien-styren), miałem gumowym i jednoczesnej modyfikacji asfaltu kopolimerem SBS i miałem gumowym. Uzyskane wyniki badań pozwoliły na ocenę wrażliwości temperaturowej, odporności na zmiany wybranych właściwości technicznych badanych lepiszczy w wyniku procesu starzenia technologicznego metodą RTFOT (Roler Thin Film Oven Tester) oraz na ocenę zmian ich cech technicznych w odniesieniu do asfaltu bazowego 50/70. Do analizy wpływu rodzaju modyfikacji na wyniki badań cech technicznych (istotność wpływu rozważanych czynników na poziom cech technicznych) wykorzystano analizę wariancji wieloczynnikowej ANOVA.

Słowa kluczowe: asfalty drogowe, lepiszcza modyfikowane, właściwości lepkosprężyste asfaltów, starzenie technologiczne

1. INTRODUCTION

The operating properties of bitumen-aggregate mixtures (BAM) are mainly determined by the bitumen used in their production. The binders used to produce BAM should have an appropriate viscoelasticity range. Good quality bitumen is a binder with high stiffness and elasticity at high operating temperatures occurring in summer and adequate flexibility during exposure to sub-zero temperatures. Currently, one of the best technological solutions to improve the viscoelasticity of bitumen and the resistance to ageing is bitumen modification with various types of additives. The technical literature describes many modification methods of bitumen binders, among others: polymers, plastomers, rock asphalt, fly ash, compounds of metallic and organo-metallic salts, latex, rubber, synthetic wax, natural rubber latex, sulphur, lime or nanoparticles [1-5]. However, the most effective improvement results of bitumen technical properties were achieved using polymer additives (especially SBS copolymer) [6, 7] and crumb rubber [8-10].

The dynamically progressing increase in the number of motor vehicles, both in Poland and the world, has caused that, from the point of view of environmental protection, the disposal of worn automotive components, including tyres, has risen to the rank of a very important ecological issue. It has been established that there are about 240 thousand tons of worn car tyres every year in Poland and this number is constantly growing [11]. The need for rapid disposal of stored automotive rubber waste has initiated the development of many technologies leading to their effective recycling. Materials obtained from the processing of worn car tyres are widely used in road construction. Many technologies using rubber waste to build roads are known. One of the ways to reuse rubber waste from worn car tyres is to modify bitumen with crumb rubber. Crumb rubber is a material obtained by grinding worn tyres into particles of less than 1 mm.

The research conducted in Poland and abroad [12-14] have shown that this additive improves the rheological properties of the binder and particularly extends its temperature range of viscoelasticity [15]. The bitumen-rubber-aggregate mixtures are characterized by improved properties in road operating temperature range: higher fatigue life, improved water resistance and high rutting resistance. The improvement of technical properties of bitumen-aggregate mixtures depends on the amount and quality of the rubber additive used in their production and the type of bitumen-aggregate mixture [16]. Bitumen-rubber-aggregate mixtures applied to structural layers of roads are characterized by good ability to dampen vibrations caused by vehicle traffic and to reduce traffic noise [17].

The purpose of the conducted tests and analyses was to assess the temperature sensitivity of modified bitumen binders, to analyse changes in selected technical properties of the binder as a result of the ageing process with the RTFOT method and the impact assessment of the type of modifying additive on the technical properties of the binders modified in relation to the 50/70 base bitumen. Multivariate analysis of variance (MANOVA) was used to analyse the impact of the modification type on technical properties of the analysed bitumen binders.

2. TESTED BITUMEN BINDERS

The following bitumen binders were used for laboratory tests:

- 50/70 bitumen,
- elastomer bitumen: 50/70 bitumen modified with 5% SBS copolymer (5%) (mark: S-5),
- bitumen-rubber binder: 50/70 bitumen modified with crumb rubber (10%) (mark: G-10),
- rubber-elastomer bitumen binder, obtained by simultaneous modification of 50/70 bitumen with crumb rubber (10%) and SBS (2%) (mark: S-2+G-10).

Bitumen binder samples were prepared in accordance with PN-EN 58 and PN-EN 12594 standards. The bitumen binder modification process involved heating the 50/70 bitumen to 180°C (±5°C), then adding the appropriate amount of modifiers. To distribute the additives evenly in the bitumen, the components were mixed in the dryer at a constant velocity of 300 rpm. The effective mixing time was 1 hour for each modification type.

3. TEST METHODOLOGY

For the assessment of the technical properties of modified binders the following laboratory tests were performed before and after the technological ageing process:

- penetration at test temperatures of 5°C, 15°C and 25°C according to EN 1426,
- softening point with ring and ball method, according to EN 1427,
- strain energy at test temperatures of 5°C, 15°C and 25°C according to EN 13703,

The technological ageing process simulation on bitumen binders in laboratory conditions was

performed with the RTFOT method according to the PN-EN 12607-1 standard.

4. TEST RESULTS AND ANALYSIS

4.1. Penetration

The modified bitumen and 50/70 bitumen penetration mark results at test temperatures of 5°C, 15°C and 25°C, before and after the technological ageing process, are shown in Figures 1 and 2.

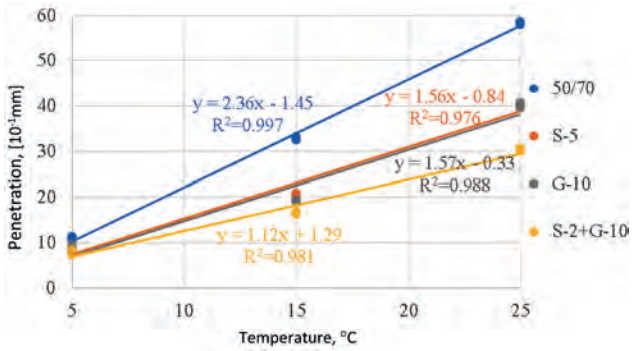

Fig. 1. Penetration test results

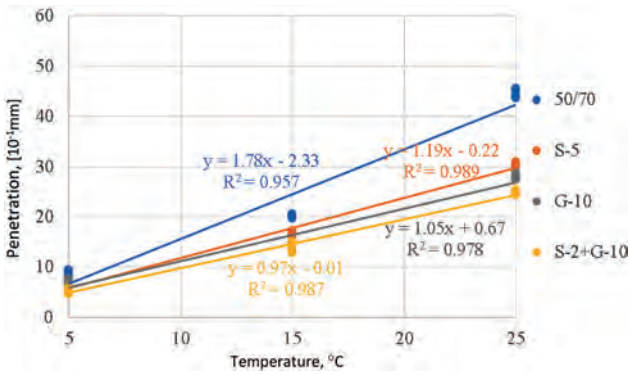

Fig. 2. The penetration test results of binders subjected to RTFOT technological ageing process

On the basis of the obtained results of the 50/70 bitumen, elastomer bitumen (S-5), rubber-bitumen binder (G-10) and rubber-elastomer bitumen binder (S-2+G-10) penetration tests before and after RTFOT technological ageing process at various temperatures, it was found that the modifying additives in the form of SBS copolymer and crumb rubber reduce the bitumen penetration in the entire range of analysed temperatures. It proves that the modifying additives affect the stiffening of the modified binders. The modified binders are much less sensitive to temperature variations in relation to the 50/70 bitumen, which is confirmed by the lower slope value "a" in the given linear functions. It was found that the lowest temperature sensitivity among the analysed bitumen binders is characterized by rubber-elastomer bitumen binder (S-2+G-10) (trend line slope factor value a = 1.12), followed by elastomer bitumen (S 5) (a = 1.56), rubber-bitumen binder (G 10) (a = 1.57) and 50/70 bitumen (a = 2.37). The penetration results of the tested bitumen binders after RTFOT technological ageing process (Fig. 2) indicated that the process of short-term ageing process reduced their temperature sensitivity.

Table 1 presents an impact assessment of the modification method on the results of the bitumen binder penetration tests. The analysis of MANOVA multivariate analysis of variance was used for the impact assessment. The sum of the effect squares (SS), the mean sum of the error squares (MS), the result of the analysis of variance (F) and the probability level (p-value) were determined. The groups of the same number characterized by a set of values with a standard distribution of their values were compared.

The results of multivariate analysis of variance prove that the modifier type has a significant impact on penetration (significance level $p < 0.05$). The interaction between temperature and the modifier on the penetration value also proved important. It was found that the best solution is the simultaneous modification with SBS copolymer and crumb rubber (MS = 2697.61), followed by: modification with crumb (MS = 1366.86), modification with SBS copolymer (MS = 1279.32). Based on the test results after RTFOT technological ageing process, it appears that the best solution is a modification with crumb rubber (MS = 1686.48), followed by a modification with a SBS copolymer (MS = 1490.29), and a simultaneous modification with a SBS copolymer and crumb rubber (MS = 1014.31).

4.2. Softening point (ring and ball method)

Figure 3 shows the mean softening point (ring and ball method) values of modified bitumen and 50/70 bitumen before and after technological ageing process.

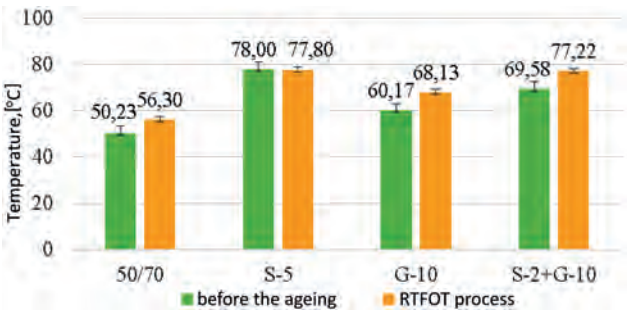

Fig. 3. Results of softening point test of bitumen binders before and after RTFOT technological ageing process

Table 1. Multivariate analysis of variance of modifier type impact on penetration

Modifier type	Ageing	Factor	Sums of Squares	Mean Squares	F-ratio	p-value
SBS	before RTFOT	Temperature	10827.91	5413.95	45659.9	<0.05
		Amount of SBS	1279.32	1279.32	10789.4	<0.05
		Temperature* Amount of SBS	430.94	215.47	1817.2	<0.05
		Error	4.27	0.12		
	after RTFOT	Temperature	6415.05	3207.52	47602.8	<0.05
		Amount of SBS	1490.29	1490.29	7276.4	<0.05
		Temperature* Amount of SBS	290.67	145.33	2156.9	<0.05
		Error	2.43	0.07		
Crumb rubber	before RTFOT	Temperature	10813.79	5406.89	40004.0	<0.05
		Amount of crumb rubber	1366.86	1366.86	10113.0	<0.05
		Temperature* Amount of crumb rubber	447.94	223.97	1657.1	<0.05
		Error	4.87	0.14		
	after RTFOT	Temperature	5868.62	2934.31	38836.4	<0.05
		Amount of crumb rubber	1686.48	1686.48	9085.7	<0.05
		Temperature* Amount of crumb rubber	407.01	203.51	2693.5	<0.05
		Error	2.72	0.08		
SBS + Crumb rubber	before RTFOT	Temperature	8602.07	4301.04	31691.8	<0.05
		Amount of SBS+crumb rubber	2697.61	2697.61	19877.1	<0.05
		Temperature* Amount of SBS+crumb rubber	1012.29	506.15	3729.5	<0.05
		Error	4.89	0.14		
	after RTFOT	Temperature	5455.60	2727.80	39965.4	<0.05
		Amount of SBS+crumb rubber	1014.31	1014.31	14860.8	<0.05
		Temperature* Amount of SBS+crumb rubber	528.52	264.26	3871.7	<0.05
		Error	2.46	0.07		

Table 2. Multivariate analysis of variance of modifier type influence on bitumen binder softening point

Modifier type	Ageing	Factor	Sums of Squares	Mean Squares	F-ratio	p-value
SBS	before RTFOT	Amount of SBS	7502.42	3751.24	10116.75	<0.05
		Error	6.73	0.46		
	after RTFOT	Amount of SBS	5447.95	2724.06	14217.89	<0.05
		Error	3.44	0.26		
Crumb rubber	before RTFOT	Amount of crumb rubber	2141.84	1070.92	8518.73	<0.05
		Error	2.26	0.13		
	after RTFOT	Amount of crumb rubber	1327.34	663.67	3850.01	<0.05
		Error	3.10	0.17		
SBS+crumb rubber	before RTFOT	Amount of SBS+crumb rubber	1328.93	1328.93	6452.62	<0.05
		Error	2.47	0.21		
	after RTFOT	Amount of SBS+crumb rubber	1615.73	1615.73	6500.05	<0.05
		Error	2.98	0.25		

On the basis of the test results of the softening point of 50/70 bitumen, elastomer bitumen (S-5), rubber-bitumen binder (G-10) and rubber-elastomer bitumen binder (S-2+G-10) before and after RTFOT technological ageing process, it was found that the modifying additives in the form of SBS copolymer and crumb rubber significantly increase the softening point temperature in relation to the reference 50/70 bitumen. This is a very positive effect as it can be expected that bitumen-aggregate mixtures with these binders will have a much higher rutting resistance than 50/70 bitumen mixtures. It was found that elastomer bitumen (S-5) (increase by 27.7°C) shows the highest increase in softening point in relation to the 50/70 bitumen, followed by rubber-elastomer bitumen binder (S-2+G-10) (increase by 20°C) and rubber-bitumen binder (G-10) (increase by 9.8°C). The results of the softening point of the tested bitumen binders after RTFOT technological ageing process indicated that the short-term ageing process increases the softening point of rubber-elastomer bitumen binder, rubber-bitumen binder and 50/70 bitumen, but practically does not affect the softening point change of elastomer bitumen (a slight decrease in ring and ball method by 0.2°C).

Table 2 presents an impact assessment of the modification method on the results of the bitumen binder softening point tests.

The results of multivariate analysis of variance prove that the modifier type has a significant impact on softening point (significance level $p < 0.05$). It was found that the best solution is the modification with SBS copolymer (MS = 3751.24), followed by: simultaneous modification with SBS copolymer and crumb rubber (MS = 1328.93), modification with crumb rubber (MS = 1070.92). The same conclusions can be formulated on the basis of the test results after RTFOT technological ageing process: modification with SBS copolymer (MS = 2724.06), simultaneous bitumen modification with SBS copolymer and crumb rubber (1615.73) and crumb rubber (MS = 663.67).

4.3. Strain energy

The modified bitumen and 50/70 bitumen strain energy mark results at test temperatures of 5°C, 15°C and 25°C, before and after the technological ageing process, are shown in Figures 4 and 5. The strain energy is a very good parameter for the quality assessment of bitumen binders [18]. Bitumen with high strain energy is considered to be structurally

more consolidated binders. This test also reflects the proper polymer cross-linking in elastomer bitumen. Bitumen-aggregate mixtures with binders of high strain energy are characterized by higher resistance to the fatigue crackage under road operation conditions.

The test strain energy testing process provides for the sample elongation to 400 mm. It should be noted that the rubber-bitumen binders (G-10) and 50/70 bitumen at test temperatures of 5°C and 15°C have not reached this length both before and after the technological ageing process. The value of the integral (surface area) was adopted for the analysis in the force-elongation constant until the samples break.

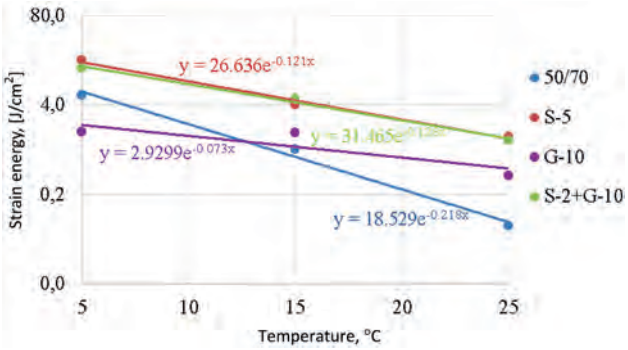

Fig. 4. Strain energy test results

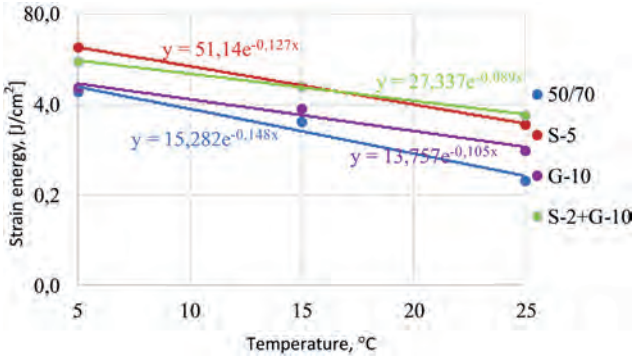

Fig. 5. The strain energy test results of binders subjected to RTFOT technological ageing process

On the basis of the obtained strain energy test results of the 50/70 bitumen, elastomer bitumen (S-5), rubber-bitumen binder (G-10) and rubber-elastomer bitumen binder (S-2+G-10) before and after RTFOT technological ageing process at various temperatures, it was found that the modifying additives in the form of SBS copolymer and crumb rubber increase the bitumen strain energy in the entire range of analysed temperatures. The modifying additives improve structural consolidation of the modified binders. Elastomer bitumen and rubber-elastomer bitumen binder, followed by a rubber-bitumen binder (except for the marks at 5°C) and 50/70 bitumen are characterised by the highest marked strain energy. The strain energy test results of the bitumen binders after RTFOT technological ageing process (Fig. 5) proved that the process of short-term ageing process increases their strain energy.

The strain energy test results indicate that the modified binders are much less sensitive to temperature variations in relation to the 50/70 reference bitumen. It was found that rubber-bitumen binders, followed by rubber-elastomer bitumen binders and elastomer bitumen are characterised by the lowest temperature sensitivity among the analysed bitumen. The 50/70 bitumen showed the highest temperature sensitivity. The test results after RTFOT technological ageing process slightly change the order of temperature sensitivity: Rubber-elastomer bitumen and rubber-bitumen binders, followed by elastomer bitumen are characterised by the lowest temperature sensitivity. As before the ageing process, the 50/70 bitumen showed the highest temperature sensitivity.

Table 3 presents an impact assessment of the modification method on the results of the bitumen binder strain energy tests.

The results of multivariate analysis of variance prove that the modifier type has a significant impact on energy strain (significance level $p < 0.05$). The interaction between temperature and modifier on the energy strain value also proved important. It was found that the modification with SBS copolymer (MS = 287.65) showed the greatest impact, followed by: simultaneous modification with SBS copolymer and crumb rubber (MS = 1328.93) and modification with crumb rubber (MS = 3.67). The same conclusions can be formulated on the basis of the test results after RTFOT technological ageing process: modification with SBS copolymer (MS = 662.37), simultaneous bitumen modification with SBS copolymer and crumb rubber (289.80) and crumb rubber (MS = 6.97).

5. CONCLUSIONS

On the basis of the penetration tests, softening points (ring and ball method) and the strain energy of bitumen modified with SBS copolymer, crumb rubber and the simultaneous modification of bitumen with SBS copolymer and crumb rubber at different temperatures, the following conclusions were formulated:

1. Modified binders subjected to penetration test showed much lower sensitivity to temperature variations compared to 50/70 bitumen, both before and after the technological ageing process.

Table 3. Multivariate analysis of variance of modifier type influence on strain energy

Modifier type	Ageing	Factor	Sums of Squares	Mean Squares	F-ratio	p-value
SBS	before RTFOT	Temperature	799.04	399.52	4464.83	<0.05
		Amount of SBS	287.65	287.65	3214.62	<0.05
		Temperature* Amount of SBS	221.54	110.77	1237.92	<0.05
		Error	2.14	0.08		
	after RTFOT	Temperature	1311.18	655.59	3996.95	<0.05
		Amount of SBS	662.37	662.37	4038.26	<0.05
		Temperature* Amount of SBS	532.41	266.20	1622.98	<0.05
		Error	3.93	0.16		
Crumb rubber	before RTFOT	Temperature	164.07	82.03	1818.09	<0.05
		Amount of crumb rubber	3.67	3.67	81.49	<0.05
		Temperature* Amount of crumb rubber	1.96	0.98	22.21	<0.05
		Error	1.08	0.04		
	after RTFOT	Temperature	189.59	94.79	4916.89	<0.05
		Amount of crumb rubber	6.97	6.97	361.55	<0.05
		Temperature* Amount of crumb rubber	1.24	0.62	16.26	<0.05
		Error	0.46	0.02		
SBS + Crumb rubber	before RTFOT	Temperature	434.01	217.00	2489.78	<0.05
		Amount of SBS+crumb rubber	144.77	144.77	1660.99	<0.05
		Temperature* Amount of SBS+crumb rubber	58.62	29.3	336.29	<0.05
		Error	2.09	0.08		
	after RTFOT	Temperature	532.11	266.05	6069.32	<0.05
		Amount of SBS+crumb rubber	289.80	289.80	6611.09	<0.05
		Temperature* Amount of SBS+crumb rubber	96.12	48.06	1096.41	<0.05
		Error	1.05	0.04		

The most favourable values were obtained in case of simultaneous modification of 50/70 bitumen with crumb rubber and SBS copolymer.

2. The softening point tests proved that modified binders are characterized by a much higher softening point in relation to the reference 50/70 bitumen (before and after RTFOT ageing process). In this test, the most favourable results were obtained using the 50/70 bitumen modification with SBS copolymer.
3. On the basis of the strain energy tests, it was found that the highest determined strain energy is characterized by elastomer bitumen and rubber-elastomer bitumen binders. The modified binders showed less sensitivity to temperature variations in relation to the 50/70 bitumen. The rubber-bitumen binder is characterised by the lowest temperature sensitivity among the analysed bitumen before the technological ageing process, after ageing: rubber-elastomer bitumen and rubber-bitumen binders.

REFERENCES

[1] Liang M., Xin X., Fan W., Wang H., Ren S., Shi J: *Effects of polymerized sulfur on rheological properties, morphology and stability of SBS modified asphalt*, Construction and Building Materials, 150, 2017, pp. 860-871. Doi: https://doi.org/10.1016/j.conbuildmat.2017.06.069.

[2] Wen Y., Wang Y., Zhao K., Sumalee A: *The use of natural rubber latex as a renewable and sustainable modifier of asphalt binder*, International Journal of Pavement Engineering, 18(6), 2017, pp. 547-559. Doi: https://doi.org/10.1080/10298436.2015.1095913.

[3] Iwański M., Mazurek G: *Wpływ dodatku wosku syntetycznego Fischera-Tropscha na właściwości funkcjonalne asfaltu*, Polimery, T. 60, nr 4, 2015, pp. 272-278. Doi: https://doi.org/10.14314/polimery.2015.272.

[4] Cholewińska M., Iwański M., Mazurek G: *Viscoelastic properties of polymer modified bitumen in warm mix asphalt technology in terms of ageing*, Procedia Engineering, 72, 2017, pp. 401-408. Doi: http://doi.org/10.1016/j.proeng.2017.02.007.

[5] Plewa A., Belyaev P.S., Andrianov K.A., Zubkov A.F., Frolov V.A.: *The effect of modifying additives on the consistency and properties of bitumen binders*. Advanced Materials & Technologies, 2016, (4), pp. 35-39. Doi: https://doi.org/10.17277/amt.2016.04. pp.035-40.

[6] Veranko V.A., Ladyshau A.V., Hatalski R.K.: *Investigation of fatigue life for asphalt concrete modified by polymer additives of various types*, Science and Technique, V. 17, No 6, 2018, pp. 451-457. Doi: https://doi.org/10.21122/2227-1031-2018-17-6-451-457.

[7] Veranko V.A.: *The experience of using modified bitumen and asphaltic macadam in the Republic of Belarus*, Bulletin of the Kharkiv National Automobile and Road University, V. 79, 2017, pp. 80-88.

[8] Wang H., You Z., Mills-Beale J., Hao P.: *Laboratory evaluation on high temperature viscosity and low temperature stiffness of asphalt binder with high percent scrap tire rubber*, Constr. Build. Mater., 2012, 26 (1), pp. 583-590. Doi: https://doi.org/10.1016/j.conbuildmat.2011.06.061.

[9] Mashaan N.S., Ali A.H., Karim M.R., Abdelaziz M: *An overview of crumb rubber modified asphalt. International Journal of Physical Sciences*, 2012, 7(2), pp. 166-170. Doi: https://doi.org/10.5897/IJPSX11.007.

[10] Bressi S., Fiorentini N., Huang J., Losa M.: *Crumb Rubber Modifier in Road Asphalt Pavements: State of the Art and Statistics*. Coatings, 2019, 9(6), 384. Doi: https://doi.org/10.3390/coatings9060384.

[11] Duda A: *Wybrane sposoby wykorzystania zużytych opon samochodowych w budownictwie komunikacyjnym*, Czasopismo Inżynierii Lądowej, Środowiska i Architektury, 2017, z. 64, nr 4/I, pp. 379-394.

[12] Koba H., Skotnicki Ł., Szydło A: *Właściwości asfaltu modyfikowanego gumą-praktyczne wykorzystanie*. Drogownictwo, 2010, pp. 378-382.

[13] Abdelmagid A.A., Pei Feng C: *Evaluating the Effect of Rice-Husk Ash and Crumb-Rubber Powder on the High-Temperature Performance of Asphalt Binder*. Journal of Materials in Civil Engineering, 2019, 31(12), 04019296.

[14] Dhoska K., Markja I., Pramono A: *Analysis of recycled tire rubber modified bitumen in Albania for quality of the road construction.* In IOP Conference Series: Materials Science and Engineering, 2019, Vol. 673, No. 1, p. 012126. IOP Publishing.

[15] Pszczoła M., Ryś D., Jaskuła P.: *Analysis of climatic zones in Poland with regard to asphalt performance grading*, Roads and Bridges – Drogi i Mosty 16, 2017, pp. 245-264. Doi: https://doi.org/10.7409/rabdim.017.016.

[16] Shirini B., Imaninasab R: *Performance evaluation of rubberized and SBS modified porous asphalt mixtures*. Construction and Building Materials, 2016, 107, pp. 165-171. Doi: https://doi.org/10.1016/j.conbuildmat.2016.01.006.

[17] Paje S.E., Luong J., Vázquez V.F., Bueno M., Miro R: *Road pavement rehabilitation using a binder with a high content of crumb rubber: Influence on noise reduction*. Construction and building materials, 2013, 47, pp. 789-798. Doi: https://doi.org/10.1016/j.conbuildmat.2013.05.008.

[18] Pakholak R., Plewa A: *Ocena zmiany energii odkształcenia modyfikowanych lepiszczy asfaltowych w funkcji temperatury*. Materiały Budowlane, 2019, (6), pp. 61-62. Doi: http://doi.org/10.15199/33.2019.06.08.

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NON-FORMAL EDUCATION INSTITUTIONS IN THE SYSTEM OF CIVIC BUILDINGS IN UKRAINE

POZAFORMALNE INSTYTUCJE EDUKACYJNE W SYSTEMIE BUDYNKÓW OBYWATELSKICH NA UKRAINIE

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Abstract

The article presents individual positions of the author's research on the integration of non-formal education institutions in the system of civil buildings of Ukraine. The following scientific views on the phenomenon of non-formal education from related industries are analyzed: pedagogy, sociology, psychology, economics and a systematic approach to education as a phenomenon. The prognostic positions of the development of a typological network of non-formal education institutions in connection with the system of public buildings are described. The links are revealed – system objects of a combination of non-formal education institutions with other public buildings. The stages of the study of this problem are briefly described. The proposal on the creation of a universal educational cluster, as a characteristic of non-formal education institutions, is presented, and an example of the formation of the educational block of the center of scientific and technical creativity based on such a cluster is given.

Keywords: non-formal education, institutions of non-formal education, a system of civil buildings, typological identity

Streszczenie

W artykule przedstawiono indywidualne stanowiska badań autora nad integracją pozaformalnych instytucji edukacyjnych z systemem budynków cywilnych Ukrainy. Analizowane są następujące poglądy naukowe na temat zjawiska edukacji pozaformalnej w powiązanych branżach: pedagogika, socjologia, psychologia, ekonomia i systematyczne podejście do edukacji jako zjawiska.

Opisano stanowiska prognostyczne rozwoju typologicznej sieci pozaformalnych placówek oświatowych w powiązaniu z systemem budynków publicznych. Ujawniono powiązania – obiekty systemowe połączenia pozaformalnych instytucji edukacyjnych z innymi budynkami użyteczności publicznej. Etapy badania tego problemu zostały krótko opisane. Przedstawiono propozycję utworzenia uniwersalnego klastra edukacyjnegocharakterystycznego dla instytucji edukacji pozaformalnej, oraz podano przykład utworzenia bloku edukacyjnego centrum kreatywności naukowej i technicznej opartej na takim klastrze.

Słowa kluczowe: edukacja pozaformalna, instytucje edukacji pozaformalnej, system budynków cywilnych, tożsamość typologiczna

1. INTRODUCTION

According to International Standard Classification of Education, non-formal education is education that is institutionalised, intentional and planned by an education provider. The defining characteristic of non-formal education is that it is an addition, alternative and/or complement to formal education within the process of lifelong learning of individuals. It is often provided in order to guarantee the right of access to education for all. It caters to people of all ages but does not necessarily apply a continuous pathway structure; it may be short in duration and/or low-intensity; and it is typically provided in the form of short courses, workshops or seminars. Non-formal education mostly leads to qualifications that are not recognised as formal or equivalent to formal qualifications by the relevant national or sub-national education authorities or to no qualifications at all. Nevertheless,

formal, recognised qualifications may be obtained through exclusive participation in specific non-formal education programmes; this often happens when the non-formal programme completes the competencies obtained in another context. Depending on the national context, non-formal education can cover programmes contributing to adult and youth literacy and education for out-of-school children, as well as programmes on life skills, work skills, and social or cultural development. It can include training in a workplace to improve or adapt existing qualifications and skills, training for unemployed or inactive persons, as well as alternative educational pathways to formal education and training in some cases. It can also include learning activities pursued for self-development and, thus, is not necessarily job related [1].

A systematic approach is the direction of the research methodology, which consists of examining the object as an integral set of elements in the totality of relations and relations between them, that is, considering the object as a system. If you look at the history of the development of definitions of the concept of «system», you can see that each of them reveals a new aspect of the content of this concept. In this case, two main groups of definitions are distinguished. One gravitates to a philosophical understanding of the concept of «system». V.N. Sadovsky gives about 40 definitions of the concept of «system», which are most widely used in literature / System (from the Greek. Systema – a whole made up of parts; connection) – this is a set of elements that are in relation and connection with each other, form certain integrity, unity. Another group of definitions is based on the practical use of systemic methodology and tends to develop a general scientific concept of a system. It is widely represented in the international systemic movement (V.G. Ashby, J. Clear, and others). By the definition of L. Bertalanffy: a system is a complex of interacting elements. A Russian researcher O. Averyanov provides the following definition of this concept: "a system is a limited set of interacting elements" [2]. The system of non-formal education institutions is a subsystem of the educational system, which provides the opportunity to conduct educational programs.

Prikhodko V.V. defines the education system as one of the main social institutions, the most important sphere of personality formation, the historically formed nationwide system of educational institutions and governing bodies, which acts in the interests of educating the younger generation, preparing it for independent life and professional activity, as well as satisfying the individual educational needs. It covers pupils of pre-school educational institutions, general educational institutions, professional institutions and students of higher educational establishments; various forms of vocational training, retraining and advanced training of pedagogical workers, extracurricular and educational and cultural and educational institutions [3]. Bykovskaya O.V. notes that the study of educational problems, including extracurricular ones, has in recent years significantly increased the application of system guidelines to the significant changes that are taking place in it. This was facilitated by two factors: the methodological impact of other sciences and the need for practice. The scholar distinguishes the following components of leisure education, which are related both to it and to each other: activity, institutional, organizational, content, methodological, procedural, functional. The author substantiates the claim that extracurricular education (as a powerful component of non-formal education) develops as a dynamic system in the unity of all components, and its development is determined by socio-economic factors and the hierarchy of values of society. At the same time, the relationship of the extracurricular education system with the social environment is open and manifests itself in changes in both the environment and the system as a whole [4].

Pavlik N.P. notes that from the standpoint of the systematic approach as a methodology of cognition, education is seen as an open system that provides the external environment for people who are needed for the functioning of other social systems. The education system is formed by a complex set of pedagogical systems (pre-school system, system of general \ secondary education, system of vocational education, system of special secondary and higher education) and subsystems (kindergartens, kindergartens, secondary schools, vocational schools, universities), which in their own queues are composed of lower order subsystems (faculties, departments, academic groups, classes, etc.) [5]. In the context of the current research, the author considers it appropriate to determine the place of non-formal education in the system of scientific pedagogical approaches described by Pavlik N.P. Namely, non-formal education is an open educational subsystem – a source for the formation and implementation of the concept of lifelong learning; process, result, system of institutions and institutions aimed at social integration of its subjects, assimilation of systematic knowledge, formation of outlook, development of cognitive capabilities, acquisition of skills (Fig. 1).

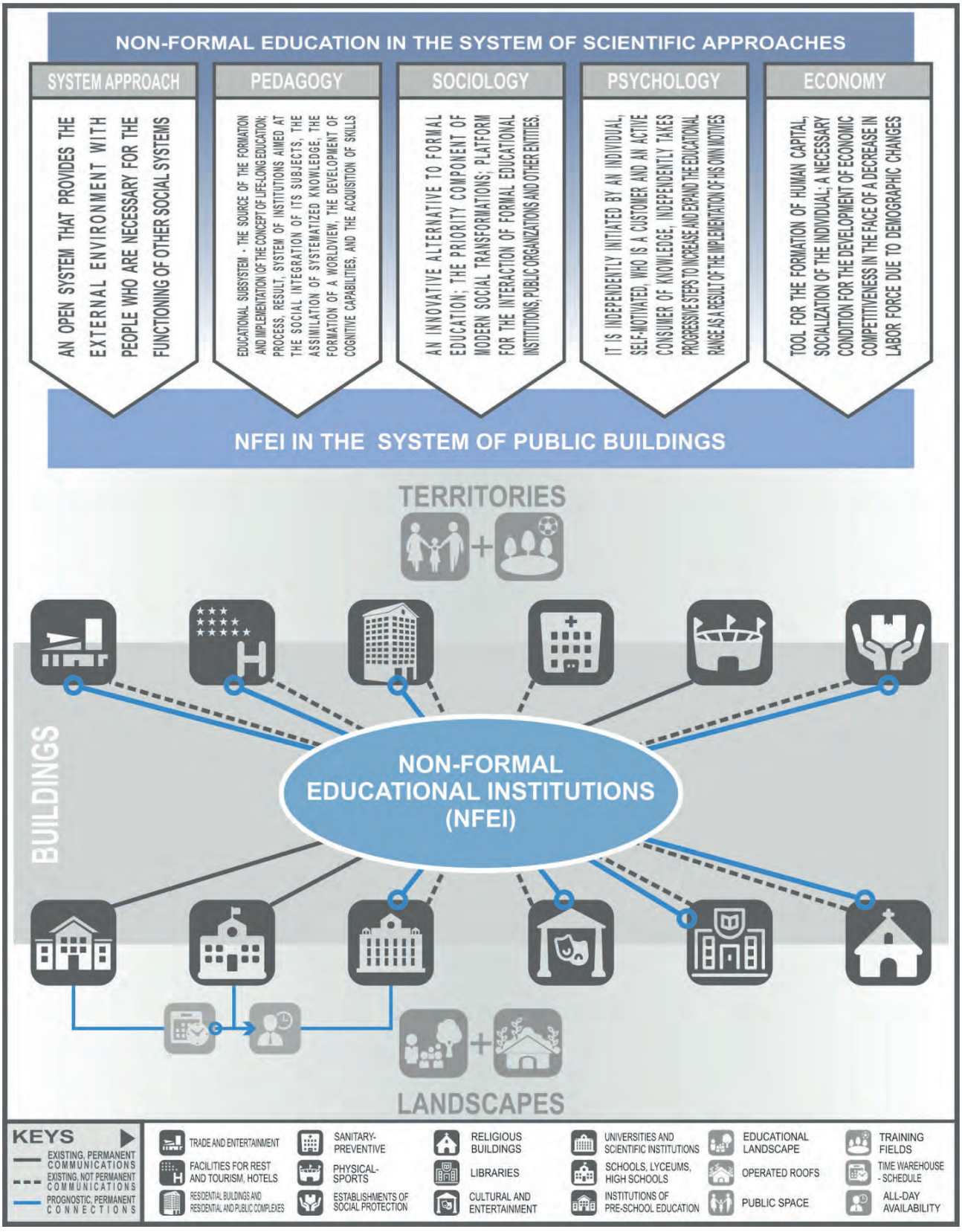

Fig. 1. Non-formal education institutions (NFEI) in the system of civic buildings in Ukraine
Source: author's own research results, research in the related industries [2-10], icons [18].

Elagin V.P. and Blagovestov M.O. note that in the sociological field, non-formal education is developing as an innovative alternative to formal education. It is often additional in the form of a grassroots initiative that is decentralized, focused on the needs of the subject and characterized by personality and self-motivation. Non-formal education is a priority component of modern social transformations due to its flexibility to engage in educational activities of various social and age groups (from young people to the age of three). It is a platform for the interaction of formal educational institutions, public organizations and other entities (Fig. 1). Scientists have identified the following trends in the development of non-formal education in Ukraine: the need for legislative recognition of this form of education; increasing the number of state support areas; development of the system of non-formal education on public initiatives. However, it has been found that the change in the methods of providing educational services is connected with the development of information, multimedia technologies, distance learning and so on. In particular, non-formal education, through the use of electronic means, responds most flexibly to the demands of the modern market and naturally fits into the innovative model of development of modern society [6].

Moskalenko L.M., in particular, notes that in the conditions of economic and social mobility of society, as well as its technological growth, it becomes obvious that formal education can no longer meet the diverse educational needs of modern man. It is non-formal education that is further evolving in the face of the global crisis and the need to adapt in an ever-changing environment. Today, the development of non-formal education is relevant for many developed countries, in which it is considered as a source of competence of modern man [7].

Tkach T.V. sets out the vision of the phenomenon of non-formal education in terms of psychology. Namely, non-formal education does not provide participants with special certificates, but holds a special place in human life, because it is an activity aimed at gaining practical experience. Therefore, it is referred to as "learning by doing". It is open and accessible to people of all ages, social status and personal development. This principle of education gives a person the opportunity to access education, not by age, but in need. The psychological aspect in organizing non-formal education is that it is independently initiated by the individual who is the customer and the active consumer of knowledge. The motivation behind this activity is that the individual tries not only to become aware of changes that have taken place in a particular environment (professional, social, etc.), but also to become the source of these changes. This suggests that the psychological aspect of involving and joining a person in the system of non-formal education is that the individual is not involuntarily involved in the learning process, but motivated by their own will. They independently take progressive steps to increase and expand the educational range as a result of realizing their own motives, needs, interests, which determines the development of their personality [8].

Economists say that the development of a continuing education system as a prerequisite for the development of competitiveness of the economy in the context of labor force decline due to demographic changes has become the main engine for the formation of a strategy for technical and vocational education and retraining in the leading countries of the world [9]. Economists also draw attention to the growing role of human capital as one of the driving forces for the development of various levels of supplementary education [10].

Lucjan W. Kamionka, notes that in the modern world, architecture has become a discipline that covers a wide range of issues that go beyond the traditionally accepted ability to organize and shape space in realistic and accessible forms for a particular era. Architects of the future must have in-depth interdisciplinary knowledge [11]. That is why this architectural study analyzed various approaches to the concept of "non-formal education" as a system, before starting to create a theoretical model of a building system for non-formal education institutions.

2. BASIC THEORY

The basic theory of the functioning of non-formal education institutions (NFEI) in the system of civic buildings is as follows. The author has identified a typological series of civic buildings that are capable of functionally incorporating non-formal education centres into their premises. Such links are indicated in Figure 1. These are shopping and entertainment complexes and multifunctional buildings, residential buildings and housing and public complexes, sanatorium-and-prophylactic institutions, sports and sports facilities, social welfare institutions, places of worship, libraries, buildings of cultural and leisure facilities, and, of course, educational institutions. Predictive theory is based on a powerful trend towards the cooperation of resources and functions.

The study found that for the uniform provision of educational and enlightenment services to different

age groups of users, it is necessary to provide for appropriate means, which, according to the author, are, first of all, the creation of universal multifunctional educational facilities and methods for combining them with other typological links. Predictably, these can be the following system elements (see Fig. 1):

- NFEI + comprehensive school;
- NFEI + higher education institution;
- NFEI + multifunctional complex;
- NFEI + health and recreation homes and facilities;
- NFEI + fitness, health and sports facilities;
- NFEI + cultural and entertainment, permission of the left and religious institutions;
- NFEI + social welfare institutions;
- NFEI + research institutions;
- NFEI + residential buildings;
- NFEI + institutions of public organizations.

When working on the creation of a three-dimensional component, it is necessary to provide for the involvement in the functional scenario and the landscape component by creating educational and recreational landscapes.

3. RESULTS AND DISCUSSION

The study of the place of non-formal education institutions (NFEI) in the system of public buildings was divided into several stages:

1. The first step was to determine the development of the historical premises of the formation of institutions similar in function to the object of study.
2. The second stage is the analysis of modern world experience in the design, construction and operation of such establishments.
3. The third stage is a generalization of the current regulatory requirements for the creation of architectural objects having educational and/or enlightening functions.
4. The fourth stage is the analysis of the ability of existing typological links of public buildings in cooperation with non-formal educational institutions of various types.

The first stage found that in their formation the buildings for the implementation of non-formal education did not go through an easy, but interesting development path. From the spontaneous emergence of summer colonies, to the formation of a summer camp system, the design, construction and further operation of which were regulated by the state (USSR experience). Also interesting is the experience of the emergence and development of the architecture of the so-called people's houses, which later developed into the houses of pioneers and schoolchildren, trade unions and workers, which later became centers for the development of children and youth, various clubs and the like. The defining link for the formation of a typological network of non-formal education institutions in Ukraine was the periods of 1917-1930. 1918 is the year of the birth of extracurricular education in Ukraine as a system; in the 20-30s of the 20th century, the system of extracurricular institutions rapidly formed and by 1940 their interaction with the school was established [12].

At the second stage of the study, an analysis was made of the modern experience in the formation of the architecture of non-formal educational institutions, which really strikes with examples. In addition to the formation of monofunctional institutions of additional education, there are very successful objects that combine not only various functions, but also different age categories of users, various methods of forming a three-dimensional component and demonstrate the architecturally sound use of historical buildings and structures that no longer function by appointment for one reason or another. In addition, when considering modern examples of public buildings of foreign experience, a powerful tendency was found to combine the various typological links of public buildings with institutions that provide educational and/or educational services. The author of the article already wrote about some such examples [13-15].

The third stage of the study showed a certain lack of flexibility in the existing regulatory documents on the creation of NFEI in the modern sense. First of all, this concerns the mode of functioning of educational facilities. It is clear that with the rapid growth of public demand for new educational scenarios, including new architectural objects, it is necessary to determine a new algorithm for the formation of NFEI. The author suggested, among other things, to study the formation of universal educational clusters of various capacities and purposes, for the integration of educational centers in public buildings, which are typologically related to other links. Smirnova A.V., for example, was engaged in the typological foundations of the formation of innovative buildings in the urban environment. Among other things, the scientist notes that the modular method of shaping in architecture is one of the most common in foreign practice, often determines the appearance and constructive solution of buildings. The main reason for the growing interest in modular architectural forms is the spread of environmental ideas, the desire for economically viable construction, costs and environmental damage. These qualities (environmental

friendliness and economy) should be observed not only in the external form of the building but mainly in structural, functional relationships that facilitate the integration of individual modules of an architectural object into the system. The module (from the Latin: Modulus – measure) – the initial value, taken as the basis for calculating the size of buildings or structures, their parts, components and elements, and serves to express multiple ratios of sizes of an architectural object and its parts. As a module, measures are taken of the length of one of the elements of an object; an element of a structure (determined independently of the absolute dimensions) is a size related to the dimensions of the human body. The module can be a complete element or be an integral part of the building. Also, Smirnova A.V. notes that modular design should be applied in all types of buildings: industrial, residential, civic. Currently, it is especially advisable to use them in multifunctional complexes and innovative research and production facilities [16].

In the study of NFEI architecture, it is necessary to investigate the formation of complex and specialized institutions of additional education at the present stage in order to summarize approaches to the design of NFIE. A major aspect of such developments should be the combination of requirements for a new educational process for different age groups of users.

Along with the global trend of combining different functional training zones in a single space, there is a need to create separate educational modules that should organize and isolate the group for the duration of the lesson in accordance with the type of activity. The author suggested the capacity of this cluster – 20 people, as optimal (see Fig. 2). The structural step of the supporting elements is 7.5 m x 9 m. According to the optimal natural light exposure of the training room at 6 m, there are places for classes in this area. The structure can be implemented in a monolithic reinforced concrete framework, a metal framework with overlapping of various types (beams, trusses, structures), etc. Creating places for individual lessons, along with group classes and/or putting them into a common communication space, is also one of the trends in the formation of educational centers. The module is designed for different age groups. During the study, the author also proposed a scientific and technical educational module, which is also formed on the basis of a universal educational module (see Figs. 2, 3) [17].

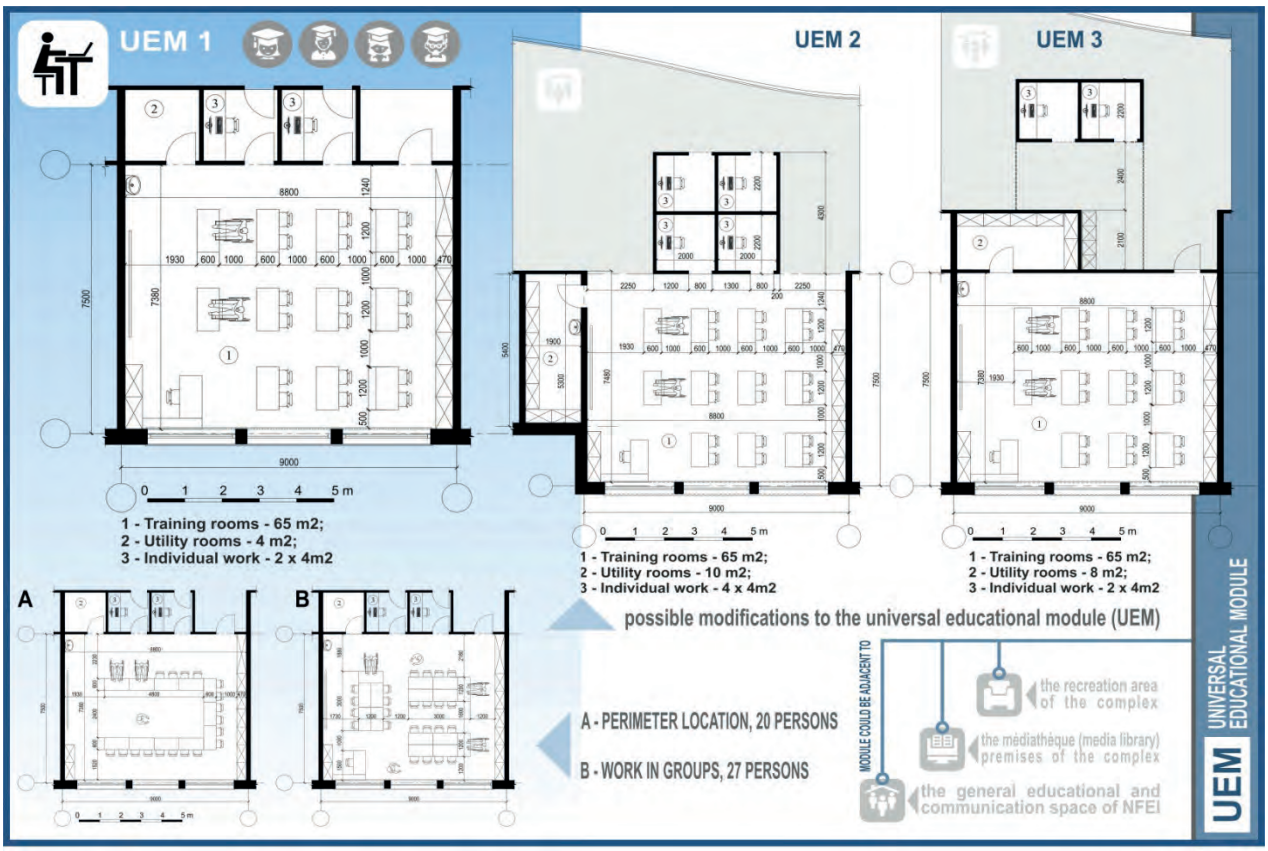

Fig. 2. The proposal for the creation of a universal educational module of NFIE
Source: author's own research results, icons [18].

The result of the fourth stage of the study was the following positions. The traditional combination of school buildings with supplementary education institutions in Ukraine takes place in the system of educational buildings to this day. But the problem lies in the fact that for the full functioning of the NFIE, the structural and functional component should be reviewed in order to provide all-day access to the services of additional education to everyone.

Figure 3 presents the proposal of creating a scientific and educational cluster based on a universal educational module (see Fig. 2).

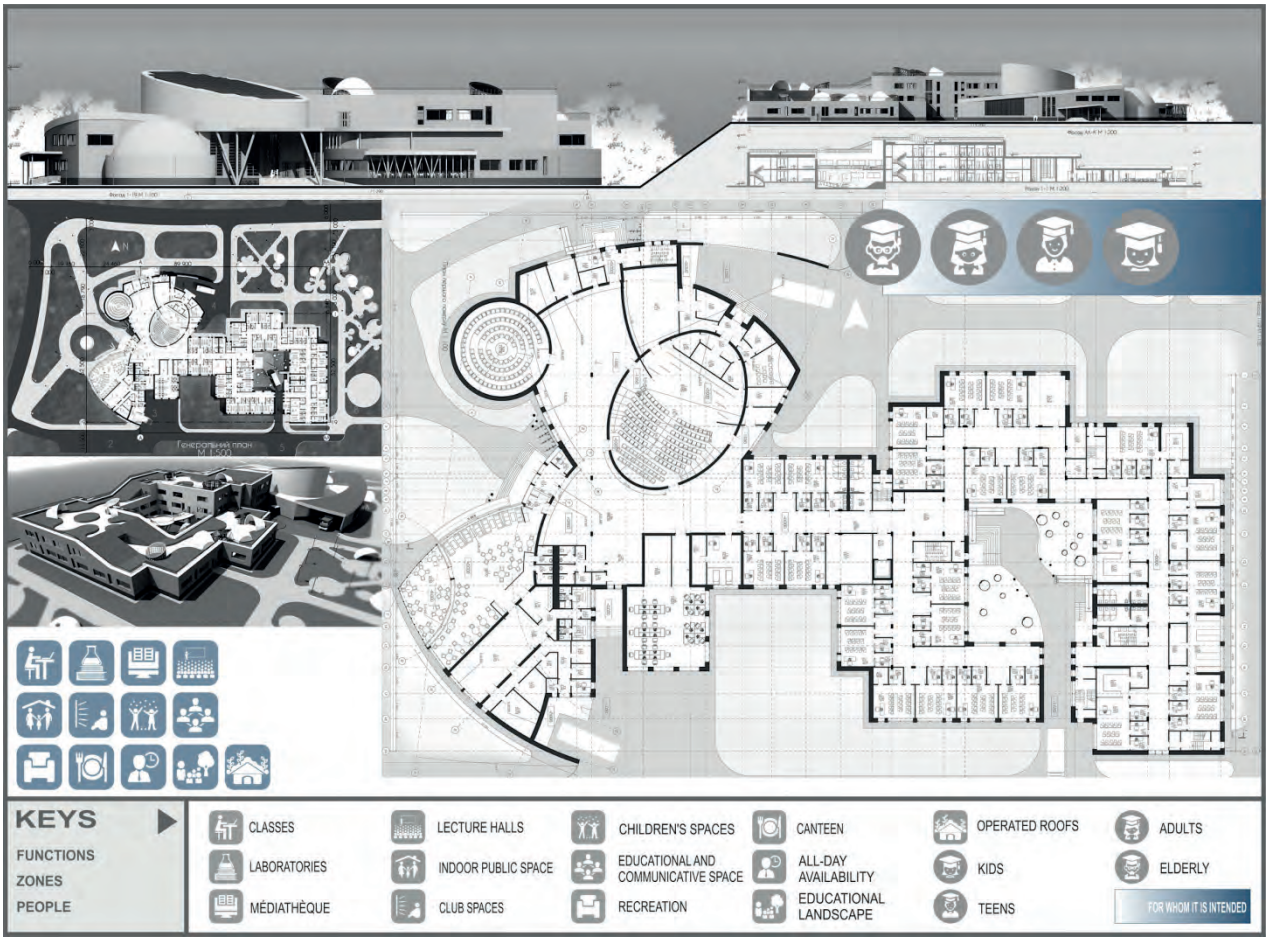

Fig. 3. An example of application of scientific-educational modules in diploma design. Fragment of the diploma diploma project qualification level "master": Features of formation of the center of scientific development of the child. Complied with student ABS-63 Zagorodnya E.A. The Department of Theory of Architecture of KNUCA, Kyiv, 2015. Leader: architect, Ph.D., associate prof. Kravchenko I.L.
Source: the scheme developed by Iryna L. Kravchenko according to master degree project of Zagorodnya E.A., icons [18].

The aim of the graduation project of the qualification level "Master" was an attempt to generalize the requirements for creating a scientific and educational environment, to make it recognizable and comfortable for potential users of different age categories. Thanks to the use of a modular-cluster approach in the design of educational centers of a new generation, it was possible to create an environment that can respond qualitatively to social demand in the field of non-formal education. In the project, such a scientific and educational cluster is connected with a public zone (an act-lecture hall, planetarium premises, a café block) by a common communicative public space of the building. The project is aimed at the practical application of a modular-cluster concept for the development of the architecture of non-formal educational institutions of a research direction. Also, among the main advantages of the project is the improvement of the educational and communicative zone of the educational group of premises by forming recreation centers in a modular architectural and planning component and using the exploited roof for scientific experiments that require outdoor research. Thanks to this decision, the landscape of the center for scientific development performs not only a recreational function, but turns into an educational one, which is also a powerful global trend in the development of architecture of the ZNFO.

4. CONCLUSION

The place of the concept of "non-formal education" in the system of scientific approaches in various branches related to research has been determined. The problem of the formation and development of non-formal education is widely studied in pedagogy, sociology, psychology, economics, and is also the subject of research from the point of view of a systematic approach. Research in the related branches of the phenomenon of "non-formal education" has led to the formation of a view on the creation of the architecture of non-formal education institutions. It was found that an important element in the implementation of non-formal education is, among other things, the creation of an architectural educational space. For the cooperation of other institutions with NFEI, which is the tendency to include such institutions in the system of public buildings, it is proposed to develop a number of universal modules and clusters that can be built-in or attached, and separate institutions of non-formal education of combined functions can be formed from such clusters. The author's suggestions for improving and optimizing the architectural environment for non-formal education institutions are the result of the analysis of numerous scientific works, the historical development of the NFEI architecture, modern experience in the formation of educational institutions of the new time and modern requirements of society for new educational scenarios. So, it is proposed to block the premises of artistic and aesthetic, scientific, technical and other types, in a single group (cluster) with its own entrance group to meet the needs of users throughout the day. In school buildings, the communicative component is also being revised. The space that previously performed the function of connecting groups of rooms now takes on a new meaning and acts as a public educational and recreational space. A tendency towards floor zoning may also be viable.

The idea of creating modules and clusters in architectural practice is not new; many practicing architects and scientists have developed it for various purposes. The purpose of this study is an attempt to generalize the world experience of such exercises and direct it to the improvement of educational institutions, which should provide additional educational services. Based on the fact that the typological identity of public buildings is undergoing significant changes, a universal educational module was proposed – an architectural and planning element that can integrate into the structure of any public building at the design stage, either independently or be an integral part of the educational cluster, which can be recruited from similar elements. The modular-cluster system proposed by the author of the article is only one of the ways that can help create typological links of various capacities and purposes for the integration of non-formal education institutions in the system of civic buildings in Ukraine.

The author sees the following research paths in this context in the search for solutions to architectural and planning schemes of such buildings, different in capacity, location and direction, in the development of proposals for optimizing the educational and recreational space and in the search for methods for incorporating the scientific and educational landscape into the functional structure of the building.

REFERENCES

[1] *Non-formal education. Definition.* Source definition ISCED 2011, p. 11-12, items 39, 40. URL: http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf (in Engl.).

[2] Shabanova Y.O.: *Systematic Approach in the Higher School*, A Textbook for Master's Students in the Higher Education Pedagogy [Systemnyy pidkhid u vyshchyy shkoli: pidruchnyk dlya studentiv mahistratury za spetsial′nistyu «Pedahohika vyshchoyi shkoly»]. Dnipropetrovsk, NMU, 2014, 120 p. (in Ukr.).

[3] Prikhodko V.V, Maliy V.V., Galatska V.L, Mironenko M.A.: *Dictionary of Terms and Concepts in Higher Education Pedagogy*, A Handbook [Slovnyk terminiv i ponyat′ z pedahohiky vyshchoyi shkoly]. Dnepropetrovsk, 2005, 181 p. (in Ukr.).

[4] Bykovskaya O.V.: *Out-of-school education: theoretical and methodological foundations*, monogr. [Pozashkil′na osvita: teoretychni ta metodychni osnovy]. Kiev, EPC ALCON, 2008, 336 pp. (in Ukr.).

[5] Pavlik N.P.: *Non-formal education in the education system of Ukraine* [Neformal′na osvita u systemi osvity Ukrayiny]. ISSN Online: 2312-5829. Educational discourse. 2016, No. 2 (14), pp. 27-37 (in Ukr.).

[6] Yelagin V.P., Blagovestov M.O.: *Development specifics and trends in the system of non-formal education in Ukraine* [Osoblyvosti ta tendentsiyi rozvytku systemy neformal′noyi osvity v Ukrayini.]. State building - № 1/2019. An electronic scientific publication of the Kharkiv Regional Institute of Public Administration of the National Academy of Public Administration under the President of Ukraine. ISSN 1992-2337. doi: 10.342 / db.19.01.12 (in Ukr.).

[7] Moskalenko L.M.: *Trends in the development of non-formal education in Ukraine (based on a survey)* [Tendentsiyi rozvytku neformal′noyi osvity v Ukrayini (za rezul′tatamy sotsiolohichnoho doslidzhennya)]. VISNYK LVIV. UNIV. Sociology Series. 2018. Issue 12, pp. 212-220, DOI: http://dx.doi.org/10.30970/vso.2018.12.12 (in Ukr.).

[8] Tkach T.V.: *Personality development by means of non-formal education. Actual problems of psychology* [Rozvytok osobystosti zasoby neformal′noyi osvity. Aktual′ni problemy psykholohiyi]. Collection of scientific works of the Institute of Psychology named after G.S. Kostyuk of the National Academy of Pedagogical Sciences of Ukraine. T.7, Issue 15, 2008. ISSN 2072-4772, pp. 287-291 (in Ukr.).
[9] Polushkina E.A., Krasnova G.A.: *The development of the continuing education system of the Netherlands: status and prospects* [Razvitiye sistemy nepreryvnogo obrazovaniya Niderlandov: sostoyaniye i perspektivy]. Bulletin of the Peoples' Friendship University of Russia, Informatization of Education series, 2014, No. 4, pp. 92-99 (in Rus.).
[10] Smirnov V.: *Lifelong learning: from the 1920s to the present* [Navchannya protyahom zhyttya: vid 1920-kh do s′ohodennya]. Psychological and pedagogical problems of rural school. 2012, No. 43 (2), pp. 342-348. URL: http: // nbuv.gov.ua/UJRN/ (in Ukr.).
[11] Kamionka L.: *Creative and coordination attributes in architectural education and in the way of profession for the future*. Nacionalnowo Uniwesitetu Lwiwska Politechnika Seria: Architektura. ISSN 2523-4757, Nr 895.2018. Lwów, pp. 49-53 (in Ukr.).
[12] Rusova S.F.: *Selected Pedagogical Works* [Vybrani pedahohichni tvory], preface Editor O.B. Proskura. Kyiv: Osvita, 1996, 303 p. (in Ukr.).
[13] Kravchenko I.L., Khmel M.: *Ways of integration of scientific and technical profile specialized premises into the structure of a comprehensive school*. SPACE&FORM, Szczecin 2019, No 38, pp. 47-58, e-ISSN 2391-7725, ISSN 1895-3247, DOI: 10.21005/pif.2019.38.B-04 (in Engl.).
[14] Kravchenko I.L.: *External and internal factors of influence on development of architecture of non-formal education establishments*. STRUCTURE AND ENVIRONMENT, Kielce 2019, No. 3/2019, Vol. 11, pp. 177-190, PL ISSN 2081-1500, DOI: 10.30540/sae-2019-013.
[15] Kravchenko I.L.: *Ways of formation of architecture of education`s non-formal institutions in modern conditions in Ukraine*. STRUCTURE AND ENVIRONMENT, Kielce 2019, No. 2/2019, Vol. 11, pp. 119-125, PL ISSN 2081-1500. DOI: 10.30540/sae-2019-009 (in Engl.).
[16] Smirnova O.V.: *Typological foundations of the formation of innovative buildings in the urban environment*, monograph [Tipologicheskiye osnovy formirovaniya innovatsionnykh zdaniy v gorodskoy srede, monografiya]. O.M. Beketov National University of Urban Economy in Kharkiv, Kharkov: KNUUE them. A.N. Beketova, 2018, 189 p., ISBN 978-966-695-438-4 (in Rus.).
[17] Kravchenko I.L., Zagorodnaya E.A.: *Modular design of classes and laboratories of an out-of-school educational institution of a scientific direction* [Modul′ne proektuvannya klasiv ta laboratoriy pozashkil′noho navchal′noho zakladu naukovoho spryamuvannya]. Modern problems of architecture and urban planning. Scientific and technical collection. Issue No. 42. Kyiv KNUCA 2016, pp. 289-294 (in Ukr.).
[18] Icons. URL: https://www.svgrepo.com/.

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ARCHITECTURAL PERIODS OF THE UKRAINIAN NON-FORMAL EDUCATION

OKRESY ARCHITEKTONICZNE UKRAIŃSKIEJ EDUKACJI POZAFORMALNEJ

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Abstract

The article considers three conditional formation periods of the extracurricular education in Ukraine (before the revolution of 1917, the Soviet era, the period of independent Ukraine). The features of extracurricular institutions of each period, the formation purposes, the main tasks of the periods, the implementation forms of extracurricular education are studied. The description of Ukrainian landmark buildings of each period is given. The modern problems such as the problem of moral and physical obsolescence of educational spaces, private establishments control system, the lack of regulatory documents for extracurricular institutions design, difficulties related to functioning of extracurricular education system in the structure of united territorial communities and the fate of abandoned cultural centres are reviewed. Development trends of extracurricular institutions of Ukraine are revealed. The question of the extracurricular educational system formation in foreign countries is touched upon and the specifics of foreign extracurricular educational systems are revealed.

Keywords: extracurricular institution, non-formal education, community house, architectural periods, "Settlement", care concept, development concept

Streszczenie

Artykuł dotyczy trzech okresów tworzenia edukacji pozaszkolnej na Ukrainie (przed rewolucją 1917 roku, erą Sowiecką, okresem niepodległej Ukrainy). Badane są cechy instytucji pozaszkolnych każdego okresu, cele formacyjne, główne zadania okresów, formy realizacji edukacji pozaszkolnej. Podano dokonano opisu ukraińskich zabytków każdego okresu. Artykuł rozpatruje współczesne problemy, takie jak problem moralnej i fizycznej dezaktualizacji przestrzeni edukacyjnych, system kontroli placówek prywatnych, brak dokumentów regulacyjnych dotyczących projektowania instytucji pozaszkolnych, trudności związane z funkcjonowaniem systemu edukacji pozaszkolnej w strukturze zjednoczonych wspólnot terytorialnych oraz losy opuszczonych centrów kultury. Ujawnia trendy rozwojowe pozaszkolnych instytucji Ukrainy. Porusza kwestię tworzenia pozaszkolnego systemu edukacji w obcych krajach i ujawnia specyfikę zagranicznych programów edukacji pozaszkolnej.

Słowa kluczowe: instytucja pozaszkolna, edukacja pozaformalna, dom kultury, okresy architektoniczne, „Osada", koncepcja opieki, koncepcja rozwoju

1. INTRODUCTION

Cultural and educational activities accompany a person throughout life. We born and live in the cultural environment of a particular country, region, from the beginning to the end of our lives, we are surrounded by a set of cultural values: family values, social environment values, national and human values. Education, in particular the extracurricular section, participates in the human values formation. One of the main extracurricular education (EE) tasks is to facilitate the maximum personal fulfilment of each child, that is enshrined in the legal acts of Ukraine, another one task is to promote socialization.

This study is based on the works of Badavi A.A., Molokov D.S. and Merilova I.O., Ignatovich O.V. who researched the experience of foreign countries in the field of extracurricular activities; on the researches made by Boyko O.M., Ignatovich O.V., Kravchenko

I.L., Shirochin S. and Gutsol A.V. who investigated the EE formation particularities.

The study of EE centres in Ukraine at different times will allow to determine the ways of their actualization in the modern architectural environment and educational context. Studying the experience of different countries in the field of education makes it possible to choose the best world examples and to follow the leading tendencies in reforming the national educational system.

The purpose of this article is to analyse the main forms of extracurricular activities that existed on the modern Ukraine territory since the end of the XIX century and to identify the main development challenges of modern EE.

2. HISTORICAL REVIEW

The formation of extracurricular education can be conditionally divided into three stages: the pre-revolutionary period, the EE formation in the Soviet era (which also includes the 1917-1922 time span), EE development during the independent Ukraine's lifetime. The research is structured according to the aforementioned periods.

Stage I.
Pre-revolutionary Extracurricular Education (till 1917)

The term "extracurricular education" was introduced in the second half of the XIX century to identify the cultural and educational activities of public organizations and individuals [1]. Historically, a part of the present-day Ukraine lands was ruled by the Russian Empire, "in the territory of Ukraine at the close of the 1800s – in the early 1900s the general population literacy was low due to the government policy pursued by the Russian Empire. General illiteracy hindered the economic and cultural development of the whole country" [2].

According to the research of Ignatovich O.V., the development of education began in the eighteenth century, the main task of that period was the illiteracy elimination across the population, the formation of public cultural consciousness. The first forms of EE were of social and pedagogical nature, and the teachers of evening and Sunday schools taught voluntarily and unpaid [1].

There was a movement of populism in the Russian Empire of 1860-1880-ies, the form of its realization was so called "going to the people" by noblemen and intellectuals. On the territory of Ukraine, the movement of populism had a cultural nature and was aimed at the advancement of learning among peasants and workers, while in the rest of the territory it had more political nature (propaganda of socialist ideas and democratic change of regime) [3].

The main forms of extracurricular education in the pre-revolutionary period were: community readings, public lectures, community houses, libraries, re-classes, community theatres, people's universities, professional courses for adults, etc. The peculiarity of this period is that EE was opposed to school education, the adult population was an usual educational seeker, as well as children and adolescents who had no other access to education [1]. According to Kravchenko I.L. study, the typological units of extracurricular educational establishments such as art, sport and music schools were already established in the world at the close of the 1800s – in the early 1900s, but the formation of compensatory-type establishments (for children from low-income families, homeless people) was only begun. At first, such establishments were recreational, but subsequently the educational function became their integral part [4].

Public libraries and reading rooms were free educational institutions of EE in pre-revolutionary Russia, which were organized at schools (including Sunday ones). In 1885 the Odessa Public Library was founded. After the 1917 revolution, public libraries were transformed into mass libraries. Similar institutions were founded by district councils, city councils, cooperatives, cultural and educational unions, patrons and peasant communities [5, p. 41-42].

Community House – an extracurricular cultural and educational institution in pre-revolutionary Russia, which usually contained: a library, a reading room, a theatre-lecture hall with a stage, a choir, a Sunday school, a tea-room, a book-shop, sometimes museum, "evening classes with literacy, mathematics and literature studies; training groups, separate for men and women" [6, p. 159]. In community houses lectures, systematic classes, exhibitions, readings, interviews, concerts, craft courses were held, later they were started to use for advocacy and propaganda activities, also as reception rooms for specialists and for the activities of societies (the first Russian community houses appeared in the latter half of the 1880s). Rural community houses were no different from pubs, but only "sophisticated public" visited the community houses in cities. After the revolution, the rural community houses were replaced by reading-houses, peasants' houses, later – by communal farm clubs and state-owned clubs, houses of culture. City

Fig. 1. Architecture of extracurricular establishments
Source: the scheme is developed by Daria Vasylchenko according to [7, 8, 13, 23, 24, 27-29].

community houses were transformed into palaces and houses of culture, working clubs. The construction of community houses was financed by the local self-government authorities, patrons, district councils, cooperatives [5, p. 42-44].

Up to the present time, the Lukianiv community House (architect Artynov M.G., construction of 1902-1905 years) and the Trinity community House (architect Antonovsky, construction of 1901-1902) – today the National Opera Academy of Operetta – have been preserved and functions as centres of Kyiv cultural life [7].

The Lukyaniv community House (Fig. 1) was founded in 1897 by the Society of Temperance, since 1902 it began to occupy a two-storey building with a basement, designed by Mikhail Grigorovich Artynov in the old Russian style of the XVIII century. The house is made of brick, the roof has a complex structure, the semicircular attic windows are framed by corbel arches, the ventilation pipes are also decorated. The main façade is three-sectioned, the central risalite stands out with wide windows and door slots, previously there was a faceted-in-plan balcony with a parapet and high spires on the horn ends – but, unfortunately, they were lost. The side windows on the first floor are completed with arrow arches, the spaces between them are decorated with three-quarter columns and pilasters. The courtyard facade is distinguished by the conciseness of the solution, the central triangular risalite is accentuated by a window on the ground floor and by a balcony on the first floor. The three-dimensional structure of the house is symmetrical, the ground floor contained a lobby, the second – an auditorium, originally designed for 550 people; around these large rooms were all others: a library, classrooms for evening classes, the building also contained tea and dining rooms, a night shelter, outpatient clinic [8].

After the abolition of the autocracy, the building of the community house was handed over to the Ukrainian Workers' Club; in 1919 the club's cultural and educational section established a working theatre on the basis of the club; in the late 1920s – early 1930s, the building was donated to the trade union organization of the Lenin Tram Park, thus it was given the name of the Trammer Club; after the WWII the building became Kiev tram and trolleybus management House of Culture [9]. In 1972-1974 architectural replanning of the building and repairs and redevelopment of internal premises were carried out [8]. The modern address of the former Community House is Degtyarivska Street, 5: now it serves as the Kyiv Small Opera House. This example is very interesting because, firstly, it has survived during so many social upheavals, and secondly, it has always served for a cultural function, and thirdly, the old day's architecture is the decoration of the modern city.

One of the significant steps in the formation of children's EE is the "Settlement" movement. The purpose of this organization was the cultural and educational activities for low-income children and adolescents. In 1905 a children's colony was organized, later the "Day shelter for children" appeared in Moscow, which contained a children's club and a kindergarten, workshops. Experimental work and handicraft courses, educational process of children, adolescents, kindergartens and hobby groups for children were conducted, in 1907, a primary school began to work on the basis of club, cultural and educational activities were also conducted among adults [5, p. 839-840]. The activists of the first club in Moscow were teacher Shatsky S.T. and architect Zelenko O.V. (during his trip abroad he became acquainted with the activities of Western children's clubs and had the aim of introducing a similar one to his country), Louise Schleger, Azarevich and others [5, 4].

Stage II.
Extracurricular education of the Soviet era

In the early days of the USSR, extracurricular education was a complex of activities aimed not only at the education of children and adolescents, but also of adults, as the general level of population culture was low. The extracurricular education of the Soviet era had socially pedagogical character and was aimed at educating Soviet identity.

The foundation of the extracurricular education unit of Ukraine dates back to 1918 [10]. The following documents: "Regulations on Uniform Labour Schools" (1918), "Declaration on Uniform Labour Schools" (1918) [1] were among first to adopt, the campaign against illiteracy took place. The Decree of 1919 "On the Elimination of Illiteracy among the Population of the Soviet Union" obliged all residents in ages between 8 and 50 who were unable to read and write, to study their native or Russian language [2]. On the territory of Ukraine from 1923 till 1936 the association named after V. Lenin's "Downright Illiteracy" worked, hobby groups and schools were created, individual work was also carried out; the teaching was conducted simply by educated people, by upperclassmen, students and teachers. The termination of the company in 1936 is

linked to the statement on the complete elimination of population illiteracy [11].

One of the main achievements of the extracurricular education of the Soviet pre-war period is the network construction of extracurricular institutions (EI) as methodical centres for the development of this education sector, also the organization of a scientific and pedagogical institute of extracurricular methods in 1925 should be mentioned. After the decision of the Central Committee of the CPSU (b) "On measures for the deployment of extracurricular work among children" profile extracurricular establishments were created. In the period from 1934 to 1941, extracurricular networks in almost all regional centres and major cities of Ukraine were developed [10]. The wartime caused great harm to the country's EI and their material and technical facilities.

Formation of extracurricular education in the Soviet post-war era is considered in Gutsol A.V. dissertation [12] (Table 1). The author identifies the study period (1946-1991) into four stages.

Table 1. Extracurricular education development stages in the post-war Soviet times

Stage	Legal basis	The main tasks	Features of the period	Impact on EEI
1946-1958	Law "On the 5-year plan for the reconstruction and development of the economy of the USSR for 1946-1950"	Network development after WWII	– Applied nature of training; – focus on physical and health rehabilitation of children; – reducing child crime and neglection; – the need to restore the logistics base	– Network expansion of pioneering and children's wellness camps, sports clubs
1958-1973	Law "On Strengthening the School's Relationship with Life and Further Developing of Public Education"	Polytechnic education to increase the number of skilled workers	– Modernization and innovation activities of the hobby groups; – strengthening of the profiling process; – improvement of financing; – low level of logistical support	– Diversification of EI work areas; – emphasis on the development of technical direction
1973-1984	"Statutory framework of the USSR and the Union Republics for Public Education"	Regulation of the legal framework of EE	– Continuation of the introduction of polytechnic education policy; – strengthening of extra-curricular technical, excursion-tourist, naturalistic work	– Legally approved material and technical base for each type of software; – the typical provisions of the EI functioning are accepted
1984-1991	"Main directions of reform for secondary and vocational school"	Reforming the EE institution system based on the national pedagogy traditions	– Underestimation of national, regional peculiarities of state development; – Democratization of social and political life; – strengthening the centralization of education management	– Increasing the number of complex software; – further branching of the software network; – clearly defined material and technical base

The author identifies four main tendencies in the formation of the EI system of the Soviet post-war period:

1. Dependence of features of EI development stages on social tasks facing the state and society.
2. Profiling of EE.
3. Professionalization of the EI staff.
4. Improvement of the mechanism of financing of extracurricular institutions.

Extracurricular educational institutions in 1946-1991 had four sources of funding: state, local, chief and self-financing [12].

The modern researcher of the Soviet building of Kiev Semyon Shirochin notes that the main tendency of the Soviet period was socialization, including leisure. Soviet clubs have borrowed the idea of creating a publicly accessible cultural institution from community houses [7]. At first, institutions were transformed from community houses into clubs and later – into the houses of culture (after the 1917 revolution) and then – into palaces of culture (in 1930s). The author also notes that large enterprises were often the source of financing for houses of culture and clubs (Fig. 2).

According to Ignatovich's research, the pre-revolutionary extracurricular education system was transformed in the Soviet era in four directions:

1. The function of adult education, which is gradually adopted by formal education: workers' faculties, schools at industrial plants, schools of working youth, evening schools, etc. were formed.
2. Extracurricular education, which was aimed specifically at the child population and youth, and

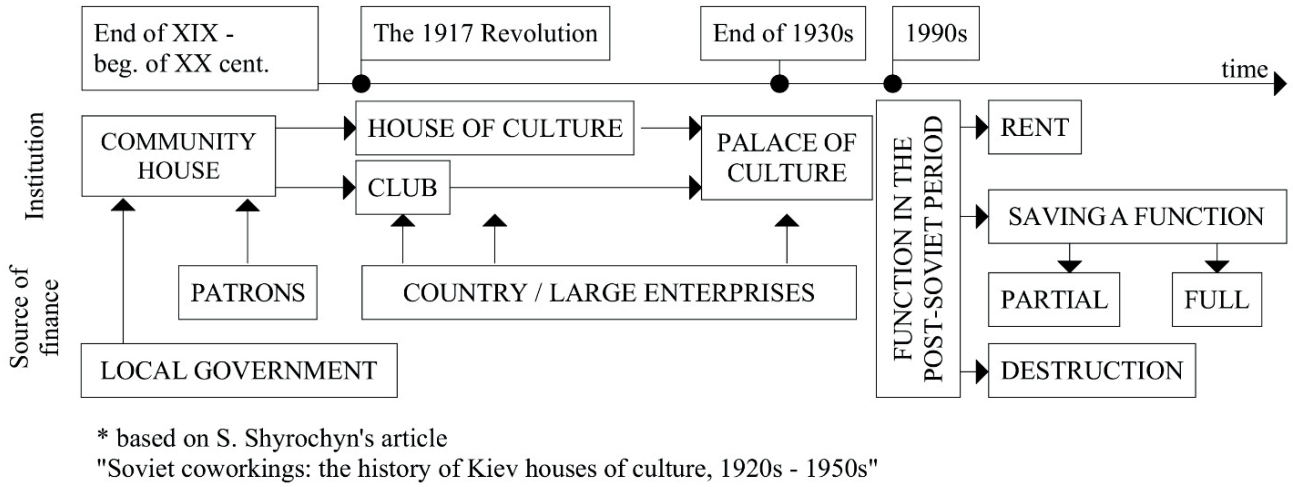

Fig. 2. Key points of S. Shirochin's study [7]
Source: the scheme is developed by Daria Vasylchenko according to [7].

was presented in the following forms: palaces and houses of pioneers and pupils, children and youth libraries, palaces and houses of culture, sport palaces, houses of techniques of vocational school students, young technicians (naturalists, tourists) stations and clubs, children railways, sport schools, pioneer camps, labour and recreation camps, teens' interest clubs, technical and artistic clubs, sport sections; music and art schools.

3. Professional improvement system that was implemented in the form of internships and training courses.
4. The system of evening and extramural education aimed at raising the cultural level of the working population [1].

The design and construction of cultural buildings in the USSR were conducted mainly with the use of typical projects. A landmark building of Soviet times in Kyiv is the modern Kyiv Palace of Children and Youth (Fig. 1), which was built in 1965 according to design of A. Miletsky and E. Bilsky in the style of Soviet modernism and firstly was called the Palace of Pioneers and Schoolchildren. Monumentalists Rybachuk A. and Melnichenko V. worked on the project, and developed mosaics for the interiors and the decorative pool near the building. The composition of the institution is emphasized by the highest flagpole in Kiev – 50 meters high. The three-storey palace has an area of 12,000 m^2 and contains halls, offices, laboratories and workshops, as well as an observatory, cinema and concert halls. In its foundation year there were 400 educational groups and 8000 children were engaged, today there are about 600 educational groups in the palace and 10000 children attend them [13].

Stage III.
Extracurricular education in independent Ukraine

Cultural and educational activities in the modern world begin with the family, then other people communities flow into our lives, the interconnections between us and society increase as time goes on. The goal of modern Ukraine, as well as other humanistic countries, is to implement laws to support and develop the education sector, including extracurricular ones (in particular, the law on extracurricular education that enshrines the right of each child to develop his or her abilities according to his or her own desire [14]). In connection with the decentralization reform launched in 2014 [15], the question about the quality and equal accessibility of EE for all children comes up, how to organize it in the best possible way locally in the context of the united territorial communities (UTC) existence.

Children EI should be attractive and interesting to its users. The competent use of architectural and design techniques can help to improve the exterior of the building and its interior spaces, it's necessary to focus on the harmonious combination of the building and the environment, the ergonomics of the context, the evolving nature etc. These techniques are aimed at creating a space that encourages the child to act or to react emotionally, helps him/her to develop [16].

The issue of reforms in the field of EE is relevant today, the reform continues, among the latest achievements we should note the concept of reforming the system of providing the population with cultural services approved in 2019, which contains the decision to develop a system for monitoring and assessing the quality of cultural services, creating conditions for

the cultural services formation and highly qualified personnel, infrastructure modernization policy implementation, reform of financial system support, approval of minimum standards of citizens providing with cultural services [17].

On December 23, 2019 there was an event-presentation of the last year achievements of extracurricular education: speakers paid special attention to legislative support of extracurricular education, state-public partnership in the field, improving the quality of extracurricular education, successful projects (expansion of media space), the development of extracurricular activities in communities, teacher training and development of software and methodological support for extracurricular education [18].

On January 13, 2020, a "Guidebook for managers" was published, stating that planning a viable education network should be the most important task that local governments should fulfil [19, p. 250] by analysing the UTC own situation, developing their vision and action plan on that basis. So, now, with the help of partners and enthusiasts, Ukraine is improving its legislative and public support for the field of EE, but there are still enough challenges, as some time is passing between the enactment and its successful implementation.

Studying the experience of foreign countries and introducing the best models into the practice of Ukrainian EE is one of the nowadays tasks.

The experience of Russia: Badawi's research on the experience of modern Russia emphasizes the need to develop standards for the design of all-types extracurricular institutions. In his study, Badawi cites the classification of children educational centres by the spatial model type that is used (small – designed for a residential group or quarter, medium – calculated for a building estate, large – for a district, integrated – as a unit of the complex "school – kindergarten – children educational centre"), and also compares them by location, funding source, most commonly used scheduling etc. It is also noted that in modern Russia, the most widespread and most required is the multifunctional children educational centre, which places in close proximity to housing and is often built-in [20]. The author also notes that such centres do not have uniform standards for design.

The experience of Europe: According to Molokov, EU residents refer to non-formal (extracurricular, supplementary) education as to a component of lifelong learning, which should be first of all accessible [21]. The author notes that all existing concepts in the field of non-formal education can be divided into two groups: the care concept and the development concept. In her work, Merilova notes that Ukraine is currently in a state of uncertainty about one of the concepts domination of, in her opinion, the "development concept" is a more economical-costly option for Ukraine, since it requires a significant modernization of the existing institutions, material and technical base, as well as expanding the existing extracurricular network. Alternatively, the "care concept" provides much more state−attention only for problem children, and the rest of the children population should be served by private EI. The problem of the second variant is the complexity of controlling the actions of private EI [22].

There is a problem of moral and physical obsolescence of educational spaces in Ukraine: educational reforms require certain solutions, in particular the architectural environment of educational spaces, but during the independence, very few buildings were designed and constructed specifically for cultural purposes.

The contemporary Ukrainian example of cultural space is the five-storey building of the Metropolitan Andrey Sheptytsky Centre in Lviv (Fig. 1), built on the territory of the Ukrainian Catholic University specifically for the library. The area of the Centre is 6027 m^2. The main premises are a library, an exhibition hall, coworkings, training rooms, a conference room, administrative rooms, a coffee shop, a children room and a souvenir shop. The project was designed by the German company Behnisch Architekten and AVR Development, and the main architect of the project was Stefan Benisch. The library is a training and cultural centre. The environment was designed with a view to create a barrier-free environment, that also should be accessibly for visually impaired people. The peculiarities of the building are equipped terraces and green roofs [23, 24]. This library is an example of modern solution of the cultural, educational space that is accessible not only for students of the institution, but also for everyone interested (for a small fee) [23].

Due to the decentralization reform (which includes, in particular, the hub school establishment and their branches and the organization of students' transportation from areas where it is not economically justified to maintain their own institution or branch), some educational buildings remain abandoned and require either renovation, rehabilitation or total

elimination. UTC are now free to decide the fate of such institutions at their discretion. It is necessary to highlight the idea of creating coworking as one of the possible ways to use the old building of a Community House or club among contemporary decisions about the public cultural space renovation. This decision was initiated by the residents of the village of Krasiv (Lviv region), developed by A. Space and approved by UTC. In the reconstructed space it is planned to hold hobby group classes, to arrange a library centre, places for convenient communication and work. It is planned that further renting of coworking in the picturesque village should generate some income for UTC [25]. This example is a good variant of renovating an outdated space, but many cultural and educational facilities are still waiting for some solution and are just empty. The architects task will be to create spaces guided by the deep interdisciplinary knowledge and to persuade the population to implement such solutions [26]. The study of world analogues of the abandoned cultural centres use is an under-researched topic and has to be refined.

3. CONCLUSIONS

The pre-revolutionary stage of the extracurricular education formation was aimed at cultural and educational activities among the underprivileged: the "Settlement" movement, whose main audience was children and adolescents, should be noted; as well as the activities of Community Houses, reading rooms, public libraries, etc. aimed at eliminating illiteracy mainly among adults and adolescents and forming the cultural consciousness of the population.

The main achievement of extracurricular education during the existence of the Soviet system was the formation of an extensive network of institutions almost all over the country. In today's Ukraine, the achievements are a significant branching of the extracurricular education system, the existence of not only public but also private institutions. However, there remain unresolved issues regarding the control of private establishments, design rules for different spatial models institutions, and the existence of extracurricular education system in the structure of UTCs and the fate of abandoned cultural centres.

REFERENCES

[1] Ignatovich E.V.: *From 'out-of-school education' to 'supplementary education' in Russia: a comparative historical-linguistic analysis of the concepts (the 18th - 21st centuries)*. Continuous education: XXI century. №3 (23), 2018, 2-26. Retrieved [04/02/2020] from – https://cyberleninka.ru/article/n/ot-vneshkolnogo-obrazovaniya-k-dopolnitelnomu-sravnitelnyy-istoriko-lingvisticheskiy-analiz-kontseptov.

[2] Boyko O.M.: *Organizational stage of illiteracy elimination (1919-1922 years of the XX century)*. Psychological and pedagogical problems of rural school, 45, 2013, pp. 202-208.

[3] Baran S.A., Barabash T.M., Kokotko N.V., Polishchuk T.S., Tarnavsky R.B.: *An online history guide for distance learning*. History section. Lviv, 2010, 101. Retrieved [01/02/2020] from – http://oman.lviv.ua/pages/library/history_I_oz.pdf.

[4] Kravchenko I.L.: *Development of the architecture of the informal education institution in the period between the end of the 19th and the beginning of the 20th century*. SPACE & FORM: Scientific Journal of the Polish Academy of Sciences and West Pomeranian University of Technology. Szczecin, 2019, No. 37, pp. 197-206, ISSN 2391-7725, ISSN 1895-3247 (Index CopernicusValue), DOI: 10.21005 / pif.2019.37.E-01.

[5] *Pedagogical Encyclopedia* / Chief. ed. Kairov I.A. and Petrov F.N., vol. 3, Moscow, Soviet Encyclopedia, 1966, 880 p. with illus.

[6] Bim-Bad B.M.: *Pedagogical Encyclopedic Dictionary*. Moscow. The Great Russian Encyclopedia, 2008, 528.

[7] Shirochin S.: *Soviet coworkings: The History of Kiev houses of culture of the 1920s - 1950s*. Skyscraper: Environment. 2018. Retrieved [01/02/2020] - https://hmarochos.kiev.ua/2018/01/24/sovetskie-kovorkingi-istoriya-kievskih-domov-kulturyi-1920-h-1950-h/.

[8] *Summary of Historical and Cultural Monuments of Ukraine: Kiev*: encyclopedic edition. Book. 1, Part 1. A-L / editorial board: executive editor Tronko P. and others: Compiled by: Gorbik V., Kiporenko M., Fedorova L. Kiev, 1999, 608, with illus, ISBN 966-95478-1-4.

[9] *Kiev. Encyclopedic Reference Book*. Chief Editor Kudritsky A.V. Kiev, 1985, pp. 363-364.

[10] *Historical stages of formation and development of the extracurricular education system*. Kharkiv National Highway University Training Site Retrieved [06/02/2020] from – http://dl.khadi.kharkov.ua/mod/book/view.php?id=35319&chapterid=5387.

[11] Tkachova L.I.: Association "Downright Illiteracy" named after V. Lenin. Encyclopedia of Contemporary Ukraine: Society. 2006. Retrieved [05/02/2020] from – http://esu.com.ua/search_articles.php?id=29405.

[12] Gutsol A.V.: *Development of the system of extracurricular educational institutions in Lugansk and Donetsk regions (1946-1991)*: Cand. of ped. sciences diss. abstract.: Special. 13.00.01 "General Pedagogy and History of Pedagogy". Lugansk national university named after Taras Shevchenko. Lugansk, 2010, 20 p.
[13] Beba Y.: *Where you work: I work at the Kyiv Palace of Children and Youth*. The Village Kiev, 2017. Retrieved [26/02/2020] from – https://www.the-village.com.ua/village/business/wherework/265333-ya-pratsyuyu-v-kiyivskomu-palatsi-ditey-ta-yunatstva.
[14] *On Extracurricular Education*: Law of Ukraine No. 1841-III of 16 January. 2020 Database "Legislation of Ukraine". Verkhovna Rada of Ukraine. Retrieved [30/01/2020] from – https://zakon.rada.gov.ua/laws/show/1841-14.
[15] *The concept of reforming local self-government and governmental territorial organization in Ukraine*: approved. By order of the Cabinet of Ministers of Ukraine dated April 01, 2014 №333-p. Database "Legislation of Ukraine". Verkhovna Rada of Ukraine. Retrieved [30/01/2020] from – https://zakon.rada.gov.ua/laws/show/333-2014-%D1%80.
[16] Kravchenko I.L., Vasylchenko D.K.: *Image in the architecture of children's out-of-school establishments.* Modern problems of architecture and urban planning: scientific and technical anthology №49, Kiev National University of Construction and Architecture, Kyiv, 2017, pp. 165-169.
[17] *The concept of reforming the system of providing the population with cultural services*: approved. By order of the Cabinet of Ministers of Ukraine dated January 23, 2019, No. 27. Database "Legislation of Ukraine". Verkhovna Rada of Ukraine. Retrieved [30/01/2020] from - https://zakon.rada.gov.ua/laws/show/27-2019-%D1%80.
[18] *Extracurricular education – 2019: ten wins.* Presentation of achievements. Ukrinform. Multimedia platform of foreign language of Ukraine. Retrieved [30/01/2020] from – https://www.ukrinform.ua/rubric-presshall/2842251-pozaskilna-osvita2019-desat-peremog-prezentacia-dosagnen.html.
[19] *U-LEAD with Europe Program Guide Guide. Successful community: providing quality services to citizens and promoting sustainable development*. Retrieved [30/01/2020] from – https://decentralization.gov.ua/uploads/library/file/527/RFL-UA-Web.pdf.
[20] Badavi A.A.: *Architectural typology of children leisure and educational centres*. Electronic scientific journal. Engineering Herald of Don, №4 (47), 2017. Retrieved [31/01/2020] from – https://cyberleninka.ru/article/n/arhitekturnaya-tipologiya-detskih-dosugovo-obrazovatelnyh-tsentrov.
[21] Molokov D.S.: *Foreign Experience on Service in the Sphere of Children's Further Education*. Yaroslavl Pedagogical Bulletin. Psychological and Pedagogical Sciences, №1, 2013, pp. 225-231.
[22] Merilova I.A.: *Variant variants of extracuricular educational network's development in Ukraine on the base of world concepts' analysing*. Bulletin of the Pridneprovsk State Academy of Civil Engineering and Architecture, № 2 (203), 2015, pp. 52-63. Retrieved [04/02/2020] from – https://cyberleninka.ru/article/n/varianty-razvitiya-seti-vneshkolnogo-obrazovaniya-v-ukraine-na-osnove-analiza-mirovyh-kontseptsiy.
[23] Perehrest O.: *Library with dignity*. The Sheptytsky Center was officially opened in Lviv // ZAXID.NET, 2017 Retrieved [26/02/2020] from – https://zaxid.net/biblioteka_z_gidnistyu_n1435960.
[24] Eismunt V.: *Sheptytskyi Center was nominated for EU Architectural Prize*. Your City, 2018. Retrieved [26/02/2020] from – http://tvoemisto.tv/news/tsent_sheptytskogo_nominuvaly_na_arhitekturnu_premiyu_yes_97378.html.
[25] Troschuk S.: *From Rural People's House to Coworking: Where They Seek Money and How They Persuaded Officials*. Channel 24. 2019. Retrieved [01/02/2020] from – https://24tv.ua/ru/iz_selskogo_narodnogo_doma_v_kovorking_gde_ishhut_dengi_i_kak_ubezhdali_chinovnikov_n1221919.
[26] Kamionka L.: *Creative and coordination attributes in architectural education nad in the way of profession for the future*. Nacionalnowo Uniwesitetu Lwiwska Politechnika Seria: Architektura. ISSN 2523-4757, Nr 895.2018. Lwów.
[27] Image.URL: https://upload.wikimedia.org/wikipedia/commons/8/8b/Kiev-Lukianovskiy-public-house.png.
[28] Images.URL: http://www.avr-development.com/portfolio/sheptytsky/.
[29] Image.URL: https://photos.wikimapia.org/p/00/01/47/02/90_big.jpg.

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APPLICATION OF THE PHREEQC PROGRAM TO ASSESS THE CHEMICAL STABILITY OF TAP WATER IN KIELCE

ZASTOSOWANIE PROGRAMU PHREEQC DO OCENY STABILNOŚCI CHEMICZNEJ WODY WODOCIĄGOWEJ W KIELCACH

DOI: 10.30540/sae-2020-005

Abstract

The research was conducted on samples of water in Kielce from two intakes: Białogon and Zagnańsk. The results of selected indicators for these waters were presented, among others, the most important ones influencing its chemical stability i.e. calcium or magnesium. Then, using the PHREEQC program, stability indices were calculated for water in Kielce from the two shots in question. In the next stage, the correctness of the water test method was checked by means of a program through the ionic balance of the water and comparison of pH of the water determined with the value determined by calculation. For the above mentioned activities, tables and calculations were prepared on the basis of which appropriate conclusions were made.

Keywords: PHREEQC, water chemical stability, stability index.

Streszczenie

Badania przeprowadzono na próbkach wody w Kielcach pochodzące z dwóch ujęć: Białogon i Zagnańsk. Przedstawiono wyniki wybranych wskaźników dla tych wód, m.in. najważniejszych wpływających na ich stabilność chemiczną, tj. wapnia lub magnezu. Następnie, za pomocą programu PHREEQC, obliczono wskaźniki stabilności dla wód w Kielcach z dwóch ujęć, o których mowa. W kolejnym etapie sprawdzono poprawność metody badania wody za pomocą programu poprzez bilans jonowy wody i porównanie pH wyznaczonej wody z wartością wyznaczoną w wyniku obliczeń. Dla wyżej wymienionych czynności przygotowano tabele i obliczenia, na podstawie których wyciągnięto odpowiednie wnioski.

Słowa kluczowe: PHREEQC, stabilność chemiczna wody, wskaźnik stabilności.

1. INTRODUCTION

The chemical stability of water is one of the main problems associated with tap water quality. The chemical stability of water is usually determined by based on its carbonate-calcium balance. Water with a tendency to precipitate large amounts of $CaCO_3$ tends to accumulate deposits of significant amounts of sediment on pipeline walls. On the other hand, water with the ability to dissolve $CaCO_3$ is described as aggressive, which proves its corrosive properties [1].

Water, which is chemically stable, prevents the formation of deposits on the inner surfaces of pipes and their destruction. Substance appearing in water, they often react with the plastic of the water pipes,

which negatively affects the chemical stability of the water. The most important factors for this stability are, among others, aggressive carbon dioxide, various types of sulphates, as well as chlorides, dissolved oxygen and detergents used for disinfection, and the carbonate-calcium balance is also of great importance for maintaining stability [2].

When water, which is not chemically stable, is introduced into the water supply system, electrochemical corrosion of the pipes can be caused, as well as the penetration of substances resulting from it into the water, especially metal compounds of released materials used for their construction [3, 4]. As a result, water becomes cloudy and has a visible colour. In water characterized by its corrosivity, deposits inside the pipes may be released, and with them further microbiological as well as chemical impurities develop [5].

PHREEQC is a program that originates from FORTRAN PHREEQE. This program is used to perform various calculations of water quality indicators. Its wide possibilities allow to predict the state of water in water supply systems under certain conditions, which may increase its chemical stability [6].

2. THE PHREEQC PROGRAMME AND ITS CAPABILITIES

The PHREEQC geochemical model has the ability to simulate the equilibrium reaction between water and minerals, ionic substitutes, solid and gaseous solutions. The kinetic formula used in the program allows to model unbalanced dissolution and precipitation of minerals, microbiological reactions, decomposition of organic compounds and other kinetic reactions [7]. The PHREEQC program includes the possibility of reactive transport, including multi-component diffusion and transport of surface compound species.

Currently, computer programs can be used to simulate the ionic composition of water. The calculation takes into account the degree of dissociation of a given compound depending on the ionic strength of the water. For the calculation, the PHREEQC program was used, which is applicable in the temperature range from 0°C to 50°C and the ionic strength of water below 0.1 mol/dm^3. The calculations are based on the Debye-Huckle rule and ion association theory in aqueous solutions [8]. The program can be used for:

- calculation of saturation indices of inorganic compounds that may precipitate from or be dissolved by water;
- determination of the forms of occurrence of chemical compounds in water, i.e. the ionic composition of water and the concentrations of compounds remaining in the non-ionic form;
- calculation of reversible and irreversible equilibriums at the water-solid, water-gas interface, including ion exchange;
- determination of stability of inorganic compounds during water mixing with different water quality or temperature changes;
- searching for groups of inorganic compounds or gases responsible for changes in the composition of water during its flow through an aquifer or technological equipment;
- distribution of redox elements in speculative calculations, when they are in the valencian states;
- estimate the correct mass of water in the aqueous phase during the reaction and transport calculations;
- analysis of complex reactions;
- of mixing solutions, reverse calculations for modelling that may have an acceptable uncertainty in the analytical data [9, 10].

3. TEST METHODOLOGY

On the basis of the values of water indices listed in Table 1, using the PHREEQC programme, stability indices have been calculated for selected minerals that may precipitate from water. The results of these tests are presented in the Table 2.

The possibilities of the programme were presented using the composition of water supply water in Kielce from the intake in Białogon and Zagnańsk. Table 1 presents the values of selected indicators for water intakes in Kielce.

The values of selected indicators of tested water at the temperature of 10°C for two of the discussed intakes in Kielce are higher for most substances for the Kielce – Białogon intake. This is particularly visible on the example of calcium, which in the Zagnańsk intake is over 30g/m^3 less than in Białogon. The calcium content in water affects its hardness.

4. RESULTS

The water stability index can be most simply determined on 3 levels:

a) solubility – the mineral has a negative index;
b) stability – the mineral has an index close to or equal to zero;
c) precipitation – the mineral has an index with a positive value.

Table 1. Values of selected water indicators supplied to the city of Kielce from the intake in Zagnańsk and Białogon

Index name	Symbol	Kielce – Białogon	Zagnańsk	Unit
Calcium	Ca^{+2}	90.19	62.2	g/m^3
Magazine	Mg^{+}	8.53	12.2	g/m^3
Sodium	Na^{+}	10	5	g/m^3
Potassium	K^{+}	1.2	2	g/m^3
General Iron	Fe	0.01	0.04	g/m^3
Sulphates	SO_4^{-2}	41.6	45.3	g/m^3
Chlorides	Cl^{-}	27.9	15.4	g/m^3
Nitrates	NO_3^{-}	22	17.3	g/m^3
Fluoride	F	<0.10	<0.10	g/m^3
pH	–	7.78	7.42	–
Temperature	–	10	10	°C
pe	–	4	4	–

Table 2. Value of stability indices for precipitated minerals

Mineral	Chemistry formula	Zagnańsk	Białogon
Anhydride	$CaSO_4$	-2.3	-2.39
Argonit	$CaCO_3$	0.19	-0.32
Kalcyt	$CaCO_3$	0.34	-0.18
Dolomite	$CaMg(CO_3)_2$	-0.22	-0.91
Hydrated iron (III) Hydroxide	$Fe(OH)_3$	1.58	1.49
Geothyt	FeOOH	6.90	6,82
Gypsum	$CaSO_4 \cdot 2H_2O$	-1.83	-1.92
Hausmannit	Mn_3O_4	-19.94	-21.64
Hematite	Fe_2O_3	15.74	15.57
Manganite	MnOOH	-6.08	-7.10
Melatrit	$FeSO_4 \cdot 7H_2O$	-8.66	7.57
Hydixyapatyk	$Ca_5(PO_4)_3OH$	-7.70	-10.00
Pirochroit	$Fe(OH)_3$	-7.72	-8.38
Pyroluzite	MnO_2	-12.87	-14.25
Rhodochrosyt	$MnCO_3$	-2.25	-2.54
Syderite	$FeCO_3$	-1.93	-1.28

The Table 2 summarises the stability indices calculated for water in the water supply network in Kielce from a shot in Zagnańsk and Białogon. In the analysed waters, calcium carbonate, which may precipitate in the form of aragonite or calcite, indicates stability. In case of water contact with anhydrite, dolomite (in case of water from Zagnańsk), gypsum, melaniterite, hausmannite, manganite, pyrochroite, pyrolysite, rhodochrosite and syderite will dissolve these minerals. Geothite, hematite and hydrated iron(III) hydroxide can be precipitated. It is noteworthy that the corrosion products (geothite and hydrated iron(III) hydroxide) were not dissolved by flowing water.

5. CHECKING THE CORRECTNESS OF THE METHOD

The correctness of the water analysis by the programme can be assessed on the basis of:

a) ionic balance of the water – the analysis is correct when the condition is met:

$$\frac{|Kt - An|}{Kt + An} \cdot 100 \leq 10\% \qquad (1)$$

here:

$$Kt = \sum_{i=1}^{n} m_i^{Kt} z_i^{Kt} \qquad (2)$$

$$An = \sum_{j=1}^{n} m_j^{An} z_j^{An} \qquad (3)$$

where:

m_i^{Kt} – concentration of cations, mol/dm^3,

m_j^{An} – anion concentration, mol/dm^3,

z_i^{Kt} – the value of cations,

z_j^{An} – the value of anions.

If this condition is not met, the analysis is highly flawed and absolutely cannot be used for further calculations of the ionic composition of the water, the most common reason being the lack of determination of sodium and potassium content.

b) comparison of the water pH (pH_{ozn}) with the value determined by calculation (pH_{obl}). The water analysis is correct when there is inequality:

$$|pH_{ozn} - pH_{obl}| \leq 0.2 \qquad (4)$$

When the condition I_S^M>0 is met, the compound precipitates. If I_S^M c (-0.5;0.5) then we are talking about chemical balance between water, and the substance precipitated from it. Knowing the concentration values of ions present in water we can determine the stability indices of the compounds precipitated or dissolved in water [11].

6. SUMMARY

Computer programs enable simulation of ionic composition of water and calculation of stability indices of the compounds contained in it. Analyses carried out by means of the PHREEQC programme have the possibility to take into account a considerable number of different factors influencing chemical balance, which results in much more precise forecasts and can therefore be used for diagnostic purposes for water supply plants. Maintaining chemical stability in water supply systems will allow for a long service life of their pipes.

For two examined water intakes in Kielce – Zagnańsk and Białogon, the tests of selected indicators showed slightly higher values for water intake from Białogon, which may influence its hardness. In these waters, however, calcium carbonate showed stability. The substances tested whose stability index presented in Table 2 has a positive result will precipitate out of the water, while those whose values are negative will dissolve in it.

REFERENCES

[1] Wolska M., Mołczan M.: *Assessment of stability of water entering the water supply system*.
[2] Palomo A., Blanco-Varea M.T., Granizo M.L., Puertas F., Vazqez T., Grutzeck M.W.: *Chemical stability of cementitious materials based on methacaolin*. Cement and Concrete Research (1999), Vol. 29, No. 7, pp. 997-1004.
[3] Tartara M.: *Secondary pollution of tap water during its distribution in terms of deterioration of the physico-chemical quality of water*. Gas, Water and Sanitary Technology (2001), No. 6, pp. 201-205.
[4] Sarin P., Snoeyink V.L., Lytle D.A., Kriven W.M.: *Iron corrosion scales: Model for scale growth, iron release, and colored water formation*. Journal of Environmental Engineering (2004), Vol. 130, No. 4, pp. 364-373.
[5] Volk C., Dundore E., Schiermann J., Le-Chevallier M.W.: *Practical evaluation of iron corrosion control in a drinking water distribution system.* Water Research (2000), Vol. 34, No. 6, pp. 1967-1974.
[6] Wingender J., Flaming H.C.: *Potencjał zanieczyszczeniowy biofilmów sieci dystrybucji wody pitnej*. Water Science and Technology (2004), Vol. 49, No. 11-12, pp. 277-286.
[7] Adrien R., Ellway M., Lin J.: *Study of corrosion material accumulated on the inner wall of steel water pipe*. Corrosion Science (2001), Vol. 43, No. 11, pp. 2065-2081.

[8] Balcerzak W., Knapik K., Kubała K.: *Changes in water quality in the distribution system*. Mat. Conf. "Water supply and water quality". PZITS, Gdańsk (2002), pp. 615-823.
[9] Łomotowski J., Siwoń Z.: *Utilization of programs stimulating ionic composition of water for evaluation of chemical stability of tap water*. "Ochrona Środowiska" (2004).
[10] Smith A. L.: *Causes and prevention of quality changes in water supply systems*. "Ochrona Środowiska" (2003), No. 4, pp. 3-6.
[11] Łomotowski J., Radosz M.: *Stabilność wody w systemach wodociągowych*. Matthew Conf. „Wspomaganie komputerowe w projektowania i eksploatacji systemów wodociągowych", Świnoujście-Copenhagen 2002.

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INFLUENCE OF LIGHTWEIGHT FILLERS ON THE PERFORMANCE OF CEMENT-BASED SKIM COAT

WPŁYW LEKKICH WYPEŁNIACZY NA PARAMETRY UŻYTKOWE GŁADZI CEMENTOWEJ

Structure and Environment No. 1/2020, vol. 12, p. 5 DOI: 10.30540/sae-2020-001

Abstract

Lightweight fillers are used in dry-mixed building mortars in order to improve thermal insulation properties, yield, and workability. In the case of thin layer products, used as a finishing layer, reduced thermal conductivity coefficient enables to restrain of water vapor condensation on walls – which inhibits mold growth. The aim of the study was to determine the influence of 4 types of lightweight fillers on the performance of cement-based skim coat – with emphasis on the economic aspect. Formulas reflecting typical commercial products were used. The dosage of different components -such as expanded perlite, glass and polymeric bubbles or expanded glass – was optimized for sufficient yield and workability, keeping the constant price of 1 kg of the final product. Mechanical parameters, capillary absorption coefficient, and thermal conductivity coefficient were determined. Observations by Scanning Electron Microscope revealed poor incorporation of polymer microspheres in the cement matrix, leading to loss of mechanical strength. With the addition of expanded glass, an increase of flexural and compressive strength thanks to the pozzolanic reaction was observed. Glass bubbles were found the most effective additive.

Streszczenie

Stosowanie lekkich wypełniaczy w suchym mieszankach chemii budowlanej pozwala na poprawę termoizolacyjności, wydajności oraz właściwości roboczych zapraw. W przypadku cienkowarstwowych wyrobów wykończeniowych obniżony współczynnik przewodzenia ciepła hamuje kondensację pary wodnej na ścianach wewnętrznych, redukując powstawanie pleśni. Celem przeprowadzonych badań było określenie wpływu czterech rodzajów lekkich wypełniaczy na właściwości gładzi cementowej, ze szczególnym uwzględnieniem aspektu ekonomicznego. Sporządzono receptury odzwierciedlające skład typowych komercyjnych produktów. Dozowanie poszczególnych dodatków: perlitu ekspandowanego, kulek szklanych i polimerowych oraz spienionego szkła, zoptymalizowano pod kątem odpowiedniej wydajności oraz konsystencji, zachowując przy tym stałą cenę 1 kg ostatecznego wyrobu. Dokonano pomiarów właściwości mechanicznych, absorpcji kapilarnej oraz współczynnika przewodzenia ciepła. Obserwacje pod skaningowym mikroskopem elektronowym pozwoliły wykazać niską przyczepność mikrosfer polimerowych do matrycy cementowej prowadzącą do pogorszenia wytrzymałości. Przy dodatku granulowanego spienionego szkła zaobserwowano wzrost wytrzymałości na zginanie i ściskanie na skutek reakcji pucolanowej. Za najkorzystniejszy uznano dodatek kulek szklanych.

RAMAN PAKHOLAK
ANDRZEJ PLEWA
RAMAN HATALSKI

EVALUATION OF SELECTED TECHNICAL PROPERTIES OF BITUMEN BINDERS MODIFIED WITH SBS COPOLYMER AND CRUMB RUBBER

OCENA WYBRANYCH WŁAŚCIWOŚCI TECHNICZNYCH LEPISZCZY ASFALTOWYCH MODYFIKOWANYCH KOPOLIMEREM SBS I MIAŁEM GUMOWYM

Structure and Environment No. 1/2020, vol. 12, p. 12 DOI: 10.30540/sae-2020-002

Abstract

Good quality bitumen used in the production of bitumen-aggregate mixtures is a binder with high stiffness and elasticity at high operating temperatures occurring in summer and adequate flexibility during exposure to sub-zero temperatures. Currently, one of the best technological solutions to improve the viscoelasticity of bitumen and the resistance to ageing is their modification with various types of additives. The paper presents the results of penetration tests as a function of temperature, softening point (ring and ball method) and strain energy at various temperatures of road bitumen modified with SBS (styrene-butadiene-styrene) copolymer, crumb rubber and simultaneous bitumen modification with SBS copolymer and crumb rubber. The obtained results allowed to assess temperature sensitivity, resistance to changes in selected technical properties of the tested binders as a result of technological ageing process with RTFOT (Roler Thin Film Oven Tester) method and to evaluate changes in their technical properties in relation to the 50/70 base bitumen. Multivariate analysis of variance (MANOVA) was used to analyse the impact of the modification type on the test results of technical properties (significance of the impact of the considered factors on the level of technical properties).

Streszczenie

Dobrej jakości asfalty stosowane do produkcji mieszanek mineralno-asfaltowych to lepiszcza o dużej sztywności, a zarazem sprężystości w wysokich temperaturach eksploatacyjnych występujących latem oraz odpowiedniej elastyczności podczas oddziaływania temperatur ujemnych. Obecnie jednym z najlepszych rozwiązań technologicznych polepszającym właściwości lepkosprężyste asfaltów oraz polepszającym odporność na starzenie jest ich modyfikacja różnego rodzaju dodatkami. W artykule przedstawiono wyniki badań penetracji w funkcji temperatury, temperatury mięknienia PiK oraz energii odkształcenia w różnych temperaturach badania asfaltów drogowych modyfikowanych kopolimerem SBS (styren-butadien-styren), miałem gumowym i jednoczesnej modyfikacji asfaltu kopolimerem SBS i miałem gumowym. Uzyskane wyniki badań pozwoliły na ocenę wrażliwości temperaturowej, odporności na zmiany wybranych właściwości technicznych badanych lepiszczy w wyniku procesu starzenia technologicznego metodą RTFOT (Roler Thin Film Oven Tester) oraz na ocenę zmian ich cech technicznych w odniesieniu do asfaltu bazowego 50/70. Do analizy wpływu rodzaju modyfikacji na wyniki badań cech technicznych (istotność wpływu rozważanych czynników na poziom cech technicznych) wykorzystano analizę wariancji wieloczynnikowej ANOVA.

IRYNA L. KRAVCHENKO

NON-FORMAL EDUCATION INSTITUTIONS IN THE SYSTEM OF CIVIC BUILDINGS IN UKRAINE

POZAFORMALNE INSTYTUCJE EDUKACYJNE W SYSTEMIE BUDYNKÓW OBYWATELSKICH NA UKRAINIE

Structure and Environment No. 1/2020, vol. 12, p. 20 DOI: 10.30540/sae-2020-003

Abstract

The article presents individual positions of the author's research on the integration of non-formal education institutions in the system of civil buildings of Ukraine. The following scientific views on the phenomenon of non-formal education from related industries are analyzed: pedagogy, sociology, psychology, economics and a systematic approach to education as a phenomenon. The prognostic positions of the development of a typological network of non-formal education institutions in connection with the system of public buildings are described. The links are revealed – system objects of a combination of non-formal education institutions with other public buildings. The stages of the study of this problem are briefly described. The proposal on the creation of a universal educational cluster, as a characteristic of non-formal education institutions, is presented, and an example of the formation of the educational block of the center of scientific and technical creativity based on such a cluster is given.

Streszczenie

W artykule przedstawiono indywidualne stanowiska badań autora nad integracją pozaformalnych instytucji edukacyjnych z systemem budynków cywilnych Ukrainy. Analizowane są następujące poglądy naukowe na temat zjawiska edukacji pozaformalnej w powiązanych branżach: pedagogika, socjologia, psychologia, ekonomia i systematyczne podejście do edukacji jako zjawiska.

Opisano stanowiska prognostyczne rozwoju typologicznej sieci pozaformalnych placówek oświatowych w powiązaniu z systemem budynków publicznych. Ujawniono powiązania – obiekty systemowe połączenia pozaformalnych instytucji edukacyjnych z innymi budynkami użyteczności publicznej. Etapy badania tego problemu zostały krótko opisane. Przedstawiono propozycję utworzenia uniwersalnego klastra edukacyjnegocharakterystycznego dla instytucji edukacji pozaformalnej, oraz podano przykład utworzenia bloku edukacyjnego centrum kreatywności naukowej i technicznej opartej na takim klastrze.

DARIA VASYLCHENKO

ARCHITECTURAL PERIODS OF THE UKRAINIAN NON-FORMAL EDUCATION

OKRESY ARCHITEKTONICZNE UKRAIŃSKIEJ EDUKACJI POZAFORMALNEJ

Structure and Environment No. 1/2020, vol. 12, p. 29 DOI: 10.30540/sae-2020-004

Abstract

The article considers three conditional formation periods of the extracurricular education in Ukraine (before the revolution of 1917, the Soviet era, the period of independent Ukraine). The features of extracurricular institutions of each period, the formation purposes, the main tasks of the periods, the implementation forms of extracurricular education are studied. The description of Ukrainian landmark buildings of each period is given. The modern problems such as the problem of moral and physical obsolescence of educational spaces, private establishments control system, the lack of regulatory documents for extracurricular institutions design, difficulties related to functioning of extracurricular education system in the structure of united territorial communities and the fate of abandoned cultural centres are reviewed. Development trends of extracurricular institutions of Ukraine are revealed. The question of the extracurricular educational system formation in foreign countries is touched upon and the specifics of foreign extracurricular educational systems are revealed.

Streszczenie

Artykuł dotyczy trzech okresów tworzenia edukacji pozaszkolnej na Ukrainie (przed rewolucją 1917 roku, erą Sowiecką, okresem niepodległej Ukrainy). Badane są cechy instytucji pozaszkolnych każdego okresu, cele formacyjne, główne zadania okresów, formy realizacji edukacji pozaszkolnej. Podano dokonano opisu ukraińskich zabytków każdego okresu. Artykuł rozpatruje współczesne problemy, takie jak problem moralnej i fizycznej dezaktualizacji przestrzeni edukacyjnych, system kontroli placówek prywatnych, brak dokumentów regulacyjnych dotyczących projektowania instytucji pozaszkolnych, trudności związane z funkcjonowaniem systemu edukacji pozaszkolnej w strukturze zjednoczonych wspólnot terytorialnych oraz losy opuszczonych centrów kultury. Ujawnia trendy rozwojowe pozaszkolnych instytucji Ukrainy. Porusza kwestię tworzenia pozaszkolnego systemu edukacji w obcych krajach i ujawnia specyfikę zagranicznych programów edukacji pozaszkolnej.

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APPLICATION OF THE PHREEQC PROGRAM TO ASSESS THE CHEMICAL STABILITY OF TAP WATER IN KIELCE

ZASTOSOWANIE PROGRAMU PHREEQC DO OCENY STABILNOŚCI CHEMICZNEJ WODY WODOCIĄGOWEJ W KIELCACH

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Abstract

The research was conducted on samples of water in Kielce from two intakes: Białogon and Zagnańsk. The results of selected indicators for these waters were presented, among others, the most important ones influencing its chemical stability i.e. calcium or magnesium. Then, using the PHREEQC program, stability indices were calculated for water in Kielce from the two shots in question. In the next stage, the correctness of the water test method was checked by means of a program through the ionic balance of the water and comparison of pH of the water determined with the value determined by calculation. For the above mentioned activities, tables and calculations were prepared on the basis of which appropriate conclusions were made.

Streszczenie

Badania przeprowadzono na próbkach wody w Kielcach pochodzące z dwóch ujęć: Białogon i Zagnańsk. Przedstawiono wyniki wybranych wskaźników dla tych wód, m.in. najważniejszych wpływających na ich stabilność chemiczną, tj. wapnia lub magnezu. Następnie, za pomocą programu PHREEQC, obliczono wskaźniki stabilności dla wód w Kielcach z dwóch ujęć, o których mowa. W kolejnym etapie sprawdzono poprawność metody badania wody za pomocą programu poprzez bilans jonowy wody i porównanie pH wyznaczonej wody z wartością wyznaczoną w wyniku obliczeń. Dla wyżej wymienionych czynności przygotowano tabele i obliczenia, na podstawie których wyciągnięto odpowiednie wnioski.

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